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Plant species composition in relation to green cover configuration and function of urban parks in Beijing, China

Abstract Parks, as one specific type of urban open space, play important roles in the conservation of urban biodiversity and provision of recreational services for local residents. As there is a lack of specific insight into park plant species composition in relation to park features, 24 sample parks within the inner city of Beijing, the capital of China, were studied by stratified random plot sampling of their tree, shrub, and herbaceous communities, respectively, in order to investigate how human activities have influenced park green cover configuration and floristic characteristics. The quantitative correlation of species richness and the park green cover indices (patch size, shape, etc.) were studied. The importance value index for plant species (trees, shrubs, and herbaceous species) of each park was calculated. The two-way indicator species analysis approach (TWINSPAN) was applied to classify the 24 parks into different groups based on their species assemblages. Two-hundred and eighty-eight species were recorded within the 24 study parks, belonging to 184 genera and 72 families dominated by Gramineae, Compositae, and Leguminosae. Among all the recorded species, 41% are exotic. The species occurrence, abundance and diversity vary significantly among different parks. Besides the positive correlation ($R=0.505$, $P<0.05$) between herbaceous species abundance and the park green cover size, no other significant relations were found between the species abundance and other indices of park green cover configuration. Remarkably, the TWINSPAN classification resulted in a good discrimination between park functional types and the variation in their species assemblage. For the parks of similar age (development history) or landscape design, their species assemblages show more similarity. The methodology adopted and results can be employed to improve baseline information on urban plant ecology and support the setting of priorities for future park management and vegetation protection.

Keywords Urban ecology · Urban park · Biomass structure · Species abundance · Species diversity

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Introduction

Fast urbanization and large-scale human activity have greatly affected urban landscapes. Thus, rapidly growing cities are unique ecosystems with distinctive species compositions and unique collections of habitats (Sukopp and Werner 1983; Gilbert 1989; Bastin and Thomas 1999; Olff and Ritchie 2002; Zerbe et al. 2003; Miyawaki 2004). Consequently, conservation and enhancement of the biodiversity within urbanized area have grown in importance as two of the major objectives in regional or worldwide conservation strategies. Urban biogeography and urban ecology are now clearly defined subdisciplines of ecology (Trepl 1995; Konijnendijk 2003).

Urban parks, as relatively isolated open spaces, are important natural, semi-natural, or managed habitats, and are important sources of increasing species diversity, with many native plant species and an increasing number of introduced plants imported by landscape managers and horticulturists at different moments in their history to satisfy multiple recreational requirements (Kent et al. 1999; Rivard et al. 2000; Konijnendijk 2003; Stenhouse 2004). Regarding the major factors determining the plant species distribution within parks, these valuable habitats are worthy of special phytosociological study in terms of their plant species composition and

succession in the context of urban ecology (Jiang 1993; Greller et al. 2000). Fast urbanization increases the fragmentation of these urban habitats. These landscape changes dominated by anthropogenic activities are the major driving factors resulting in plant community variation. One of the major questions facing researchers and managers is what are the exact effects of these human activities on urban biodiversity through changing landscape characteristics (Saunders et al. 1991; Jacqumyn et al. 2003). Previous research on biodiversity specifically in city parks or forests is very limited (Cornelis and Hermy 2004). Lawesson et al. (1998) concluded it is hard to find significant relationships between species composition and habitat size in fragmented Danish forests. However, other workers observed that urban habitat diversity and patch age were important variables explaining the biodiversity of urban fragmented forests. Moreover, Hermy and Cornelis (2000) demonstrated from their study of urban parks in Belgium, that park area had a positive relationship with species richness and proposed some habitat–species related indicators for measuring urban biodiversity. Many researchers have explored the impacts of fragmentation on biodiversity. However, it is difficult to derive conclusions on the relations of plant species composition and habitat characteristics, which depend to a great extent on the purposes and extent of human disturbance. Thus, more research is necessary in order to explore the plant species composition in relation various degrees of human disturbance which different parks have been subjected to, in order to provide information on the range and distribution of urban species and assist with the process of park planning and management.

Beijing, the capital of China, one of the largest and oldest cities in the world, covers approximately 16,800 km^2 with a population of 13 million people. In recent decades the city has developed very rapidly. The inner city which is densely built has grown about eightfold compared with 50 years ago at the early stage of the foundation of the People's Republic of China, i.e. from 84 to 670 km^2. Accordingly, the city population has grown almost 2.6-fold from 4 million to >13 million during the past half century. The inner city is congested with a large and dense human population, which results in fewer and smaller natural and semi-natural open spaces. Various parks in the inner city are valuable open spaces, not only for recreational, ornamental functions and historic protection, but also for their open habitats. Thus, these parks represent the last refuge for a diversity of organisms in a highly developed city environment. Although there have been a number of studies of urban habitat according to specific species (Lu et al. 2000a, 2000b; Yang et al. 2002; Zhao et al. 2002; Meng et al. 2004), there is a lack of specific insights into park plant species composition and how species assemblages are related to different park features in Beijing. Considering the green cover configuration indices (e.g. habitat size, shape, and connectivity) as well as the function-determined factors (e.g. history, development purposes, and landscape fashions) we would expect parks to differ in relation to plant species composition. Therefore, in this study, we combine the comprehensive field surveys, landscape index analysis and two-way indicator species analysis approach (TWINSPAN) cluster analysis to identify the plant species composition in 24 sample parks within the inner city of Beijing and explore the important factors that determine this.

Materials and methods

Study sites

The study was carried out within the inner city of Beijing. The city is 3,000 years old and has been a capital city for 850 years covering four dynasties since 1153 AD. The city grew very quickly from 1949, after the foundation of the People's Republic of China. The development pattern of Beijing is a typical concentric expansion, which forms an obvious ring-shaped expansion pattern from the inner centre to the outskirts. The inner city lies on flat ground with an average elevation of < 50 m, and has a temperate humid monsoon continental climate. The annual average temperature and precipitation are around 11–12°C and 400–500 mm, respectively. The lowest temperatures usually occur in January, with an average temperature for the month ranging between −7 and 4°C. The highest temperatures, usually in July and August, are approximately 25–26°C and most rainfall occurs between June and September. To summarise, the geophysical conditions within the inner city are relatively similar, and thus should not cause differences in the plant species assemblage within this area.

Most urban parks are state properties managed by Beijing's Administrative Bureau of Gardens or public institutions. The municipal Bureau of Gardens is the authority responsible for all urban registered parks.

Sampling

The species survey covered 670 km^2 of the inner city, mainly within the fifth ring motorway (see Fig. 1). There are in total 56 public owned parks registered by the municipal Bureau of Gardens, ranging in area from 1.6 to 408.5 ha with varied physical features (Beijing Bureau of Garden 2000). With respect to the development history and functions of these urban parks, the typology of most Chinese parks could be explicitly defined according to park age and landscape design, which are the most important factors determining park functions. These parks can be divided into two groups: old parks, developed before 1949, and new (young) parks, developed after 1950. Both old and new parks can also be sub-divided into green space-dominant parks and architecture-dominant parks. The old green space-dominant parks are usually imperial gardens, while most of the old architecture-dominant parks are protected as

historic, cultural or heritage sites, such as sites of old imperial temples or palaces. Similarly, the new green space-dominant parks are often composed of large green spaces, while most of the new architecture-dominant parks are designed with some specific architectural landscapes simulating traditional architecture or world famous garden styles. All the new parks were developed mainly for recreation. These 56 public parks are distributed relatively evenly within the inner city, and include 23 old parks, ranging from 1.6 to 320 ha, and 33 new parks, ranging from 4.7 to 408.5 ha. Based on the comprehensive study on the 56 public parks, 24 sample parks were selected for this study and met the following requirements (Table 1, Fig. 1): (1) they covered the whole range from small parks to the biggest park, i.e. 7.3–408.5 ha, and to be included in the study, the smallest sample park had to be > 4 ha; (2) they represented all the types of parks as described above; (3) their distribution was relatively even within the inner city.

Field survey

The species surveys on urban parks were carried out as part of a comprehensive biodiversity investigation in Beijing during the summer of 2003. During early reconnaissance visits to the study parks, the differences in floristic types were well observed. As a consequence, the stratified random sampling method was used to sample plots within each park in relation to the known distribution of different plant communities. The plots were randomly selected within tree, shrub and herbaceous species communities, respectively, in each park, with the number of plots per communities being proportional to the area. The optimum size of the quadrat for a particular plant community was estimated using the concepts of minimal area and species-area curves (Kent and Coker 1992). The sampling quadrats used were 10 m×10m, 2 m×2 m, and 1 m×1 m for tree, shrub and herbaceous communities, respectively. In total, 200 tree plots, 36 shrub plots and 728 herbaceous plots were sampled for the 24 parks. Within different tree community plots, we measured the number, height, diameter breast height, and canopy of each individual tree species. Within different shrub and herbaceous community plots, the number, average height, and cover for each individual shrub and herbaceous species were also measured and recorded.

Data analysis

The plant species composition for each park was studied using the summarized analysis on all the sample plots of tree, shrub, and herbaceous communities, respectively. It is necessary to point out that with the stratified random samples, a complete inventory of all species was impossible. There were a number of sparsely distributed

Table 1 General characteristic of the 24 study parks, Beijing

No.	Name	Park functional features	Location	
			Ring	District
1	Bei Hai park	Green space-dominant, old imperial park	2	West City
2	Chao Yang park	Green space- and modern architecture-dominant, new park	3–4	Chao Yang
3	Da Guan Yuan park	Specific architecture-dominant, new park designed to simulate old architectural style	2	Xuan Wu
4	Di Tan park	Specific architecture-dominant park, old temple site	2–3	Dong Cheng
5	Hong Ling Jin park	Green space- and modern architecture-dominant, new park	4–5	Chao Yang
6	Jing Shan park	Old park on composite green space and old architecture	2	West City
7	Lian Hua Chi park	Old lake-dominant park	2–3	Feng Tai
8	Liu Yin park	Green space-dominant, new park	2–3	Dong Cheng
9	Long Tan Hu park	Old artificial lake- and modern architecture-dominant, new park	2	Cong Wen
10	Qing Nian Hu park	Artificial lake- and modern architecture-dominant, new park	2–3	Dong Cheng
11	Ren Ding Hu park	Specific architecture-dominant, new park to simulate European architectural style	2–3	West City
12	Shi Jie park	Specific architecture-dominant, new park to simulate world-famous architectural styles	4–5	Feng Tai
13	Shuang Xiu park	Specific architecture-dominant, new park to simulate Japanese garden style	2–3	West City
14	Tao Ran Ting park	Specific architecture-dominant park, old historic construction site	2	Xuan Wu
15	Tian Tan park	Specific architecture-dominant park, old historic temple site	2	Cong Wen
16	Tuan Jie Hu park	Artificial lake-dominant, new park	3–4	Chao Yang
17	Wan Fang Ting park	Specific architecture-dominant park, old historic construction site	2–3	Feng Tai
18	Xuan Wu park	New park on composite green space and historic construction site	2	Xuan Wu
19	Yi He Yuan park	Green space-dominant, old imperial park	4–5	Hai Dian
20	Yu Yuan Tan park	Old artificial lake-, green space- dominant park	2–3	Hai Dian
21	Yuan Ming Yuan park	Green space-dominant park, old imperial garden	4–5	Hai Dian
22	Yue Tan park	Specific architecture-dominant, old historic temple site	2–3	West City
23	Zhong Shan park	Specific architecture-dominant, old historic temple sites	2	Dong Cheng
24	Zi Zhu Yuan park	Green space-dominant, new park	2–3	Hai Dian

Fig. 1 Location of the study parks in the inner city of Beijing
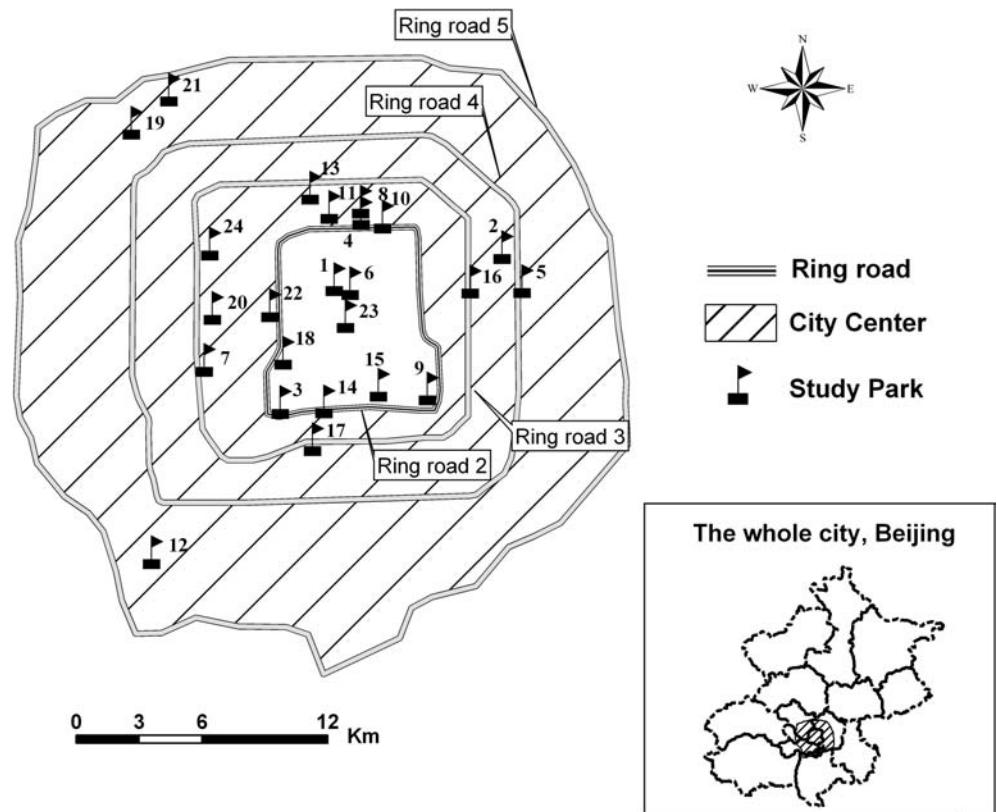
species, which were not included in regular sample plots. All the dominant species in parks were covered within our sample plots. The Simpson index (D) was used to calculate species diversity of each park:

$$D = 1 - \sum_{i=1}^{s} \left(\frac{N_i}{N}\right)_i^2 \tag{1}$$

where N_i is the total number of organisms of a particular species i and N is the total number of organisms of all species.

The importance value index (IVi) (Kent and Coker 1992) of each park was computed as follows:

$$IVi = DRi + FRi + CRi \tag{2}$$

Where DRi, FRi, CRi are the relative density, the relative frequency, and the relative cover rate of species i, respectively.

The green cover of investigated parks was determined from the city green space map at a scale of 1:10,000 and used to calculate the important landscape indices. Here, "green cover" refers to plant cover. In order to explore the relationship between green cover configuration and species communities, we selected several major landscape indices, including habitat size, edge and shape index, to calculate the plant cover pattern of each park. All the spatial related analyses were completed with ArcView 3.0 and Arc Patch Analyst extension in ArcView 3.0.

Spearman's rank correlation coefficients were calculated between plant species abundance, diversity, and habitat structural factors to explore the relationship and factors affecting the species communities. In order to determine the impacts of park-related factors on the variation of species assemblage, we applied the TWINSPAN cluster approach, a very popular procedure that classifies the objects by hierarchical division (Kent and Coker 1992; Woolley and Kirkpatrick 1999; Godefroid and Koedam 2003; Zhang 2004; Baruch 2005), to classify the parks into different groups based on the importance value matrix of tree, shrub, and herbaceous species, respectively. The correlation analysis was calculated with SPSS software. The TWINSPAN cluster analysis was performed using Canoco for Windows 4.5.

Results

Park patterns

The surveyed 24 parks varied in area from 7.3 to 408.5 ha and exhibited different amounts of green cover. The average green cover was 71%, with a minimum of 22% and a maximum of almost 98% (note: most parks include some areas of water that were excluded from the calculation of the proportion of park green cover). The total area of green cover per park varied between 4.3 and

Table 2 Major landscape indices of the 24 study parks, including total park area, green cover area, mean patch edge index (*MPE*), mean shape index (*MSS*), and mean patch fractional dimension (*MPFD*)

No.	Name	Total area (ha)	Green area (ha)	MPE	MSS	MPFD
1	Bei Hai park	68.2	18.3	1,667.09	2.31	0.82
2	Chao Yang park	320.0	117.6	1,921.20	2.00	1.53
3	Da Guan Yuan park	12.6	8.1	2,976.59	2.25	1.35
4	Di Tan park	43.0	26.9	1,570.42	1.24	1.25
5	Hong Ling Jin park	39.0	17.5	2,240.78	2.15	1.35
6	Jing Shan park	23.0	16.6	1,949.16	1.21	1.24
7	Lian Hua Chi park	44.6	17.7	1,327.28	2.51	1.83
8	Liu Yin park	17.1	9.7	2,120.64	2.42	1.42
9	Long Tan Hu park	49.2	12.9	1,449.24	1.60	1.41
10	Qing Nian Hu park	17.0	7.6	4,330.24	3.78	1.45
11	Ren Ding Hu park	9.2	5.7	2,500.76	2.81	1.42
12	Shi Jie park	46.7	26.7	2,067.23	1.50	1.31
3	Shuang Xiu park	7.3	5.5	1,121.06	1.38	1.29
14	Tao Ran Ting park	59.1	32.9	3,606.82	2.33	1.53
15	Tian Tan park	210.2	173.0	2,380.03	1.83	1.32
16	Tuan Jie Hu park	12.3	4.3	1,184.01	2.60	1.63
17	Wan Fang Ting park	10.6	8.3	2,428.98	1.87	1.32
18	Xuan Wu park	7.4	5.8	1,414.27	1.71	1.33
19	Yi He Yuan park	290.1	55.0	2,993.39	3.38	1.49
20	Yu Yuan Tan park	136.7	56.4	943.63	2.70	1.56
21	Yuan Ming Yuan park	408.5	219.1	1,407.00	1.97	1.43
22	Yue Tan park	8.0	5.3	940.98	1.31	1.29
23	Zhong Shan park	23.8	12.0	3,065.80	2.58	1.41
24	Zi Zhu Yuan park	47.4	36.0	2,230.30	2.37	1.41

Table 3 The abundance and diversity of tree, shrub and herbaceous species, respectively, within the 24 study parks

No.	Park name	Species abundance			Species diversity		
		Tree	Shrub	Herbaceous	Tree	Shrub	Herbaceous
1	Bei Hai park	14	7	12	0.86	0.79	0.70
2	Chao Yang park	18	6	22	0.87	0.78	0.39
3	Da Guan Yuan park	21	9	29	0.89	0.88	0.90
4	Di Tan park	15	8	35	0.43	0.66	0.80
5	Hong Ling Jin park	11	4	12	0.71	0.67	0.60
6	Jing Shan park	8	7	30	0.70	0.76	0.74
7	Lian Hua Chi park	9	7	36	0.75	0.81	0.85
8	Liu Yin park	25	14	57	0.91	0.79	0.93
9	Long Tan Hu park	16	6	34	0.91	0.53	0.80
10	Qing Nian Hu park	16	10	36	0.86	0.88	0.91
11	Ren Ding Hu park	9	4	10	0.84	0.67	0.05
12	Shi Jie park	6	0	9	0.71	0.00	0.31
13	Shuang Xiu park	9	7	26	0.76	0.80	0.82
14	Tao Ran Ting park	22	12	44	0.87	0.89	0.86
15	Tian Tan park	11	4	58	0.84	0.77	0.89
16	Tuan Jie Hu park	11	6	11	0.88	0.61	0.50
17	Wan Fang Ting park	10	2	16	0.81	0.60	0.60
18	Xuan Wu park	22	12	33	0.85	0.89	0.85
19	Yi He Yuan park	20	14	60	0.79	0.81	0.89
20	Yu Yuan Tan park	11	8	40	0.84	0.65	0.86
21	Yuan Ming Yuan park	23	8	40	0.91	0.83	0.87
22	Yue Tan park	17	4	10	0.84	0.77	0.57
23	Zhong Shan park	9	6	16	0.59	0.53	0.72
24	Zi Zhu Yuan park	14	11	30	0.75	0.73	0.88

219.1 ha. The smallest area of green cover patch is about 0.7 ha, and the average of all parks is about 9.4 ha. The mean patch edge index (MPE), the mean shape index (MSS), and the mean patch fractional dimension (MPFD) per park varied between 940.98 and 4,330.24, between 1.21 and 3.78, and between 0.82 and 1.83, respectively (Table 2).

Plant species composition

In total there are 288 vascular plant taxa, belonging to 72 families, and 184 genera found within sample plots in the 24 parks. These species comprised 78 tree species, 57 shrub species, and 153 herbaceous species. The three dominant families are Gramineae, Compositae, and

Leguminosae, including 58 genera and 84 species (29% of all the species). Spearman correlation analysis between the tree, shrub, and herbaceous species abundance showed significant relationships between all three ($r_{\text{tree—shrub}} = 0.720$, $r_{\text{tree—herbaceous}} = 0.518$, $r_{\text{shrub—herbaceous}} = 0.677$; all $P < 0.01$) (Table 3).

Non-native species represented a large proportion of the total, and accounted for 62.3% of the tree, 63.8% of the shrub, and 21.5% of the herbaceous species for all the 24 parks. Among each park, the proportion of non-native species varied, i.e. 27.27–77.78% for trees, 25–100% for shrubs, and 1.69–11.11% for herbaceous species. The Spearman correlation analysis showed significant relationships between the richness of native and non-native species for trees and herbaceous plants, respectively ($r_{\text{tree}} = 0.647$, $r_{\text{herbaceous}} = 0.811$, $P < 0.01$).

Most tree and shrub species are planted by urban planners and managers. Among the 78 tree species, only two, *Betula papyrifera* (L.) Vent. and *Diospyros lotus* L., grew spontaneously. Among 57 shrub species, only eight, *Lycium chinensis* Miller, *Ginkgo biloba* var. *parviflora*, *Lespedeza bicolor* Turcz., *Caragana sinica* (Buc'hoz) Rehd., var. *heterophylla* (Franch.) Rehd., *L. chinensis* var. *spinosa* (Bunge) Hu ex H. F. Chow, and *Rhamnus parvifolia* Bunge, grew spontaneously. In contrast, 114 herbaceous species of 153 grew spontaneously.

Across all the 24 sample parks, few frequently occurring tree and shrub species were found. The most frequently occurring tree species was *Sabina chinensis* (L.) Ant., a non-native species found in 21 parks. In addition, another 11 species, including four non-native ones, were relatively frequently in more than ten parks. For shrub species, *Forsythis suspensa* (Thunb.) Vahl., a native species, was the most frequently occurring in 14 parks. Another three shrub species, *Lonicera maackii* (native species), *Parthenocisus quinquefolia* (exotic species), and *Berberis thunbergii* cv. Atropurpurea (exotic species), were found relatively frequent in more than ten parks. Noticeably, compared with tree and shrub species, a larger number of herbaceous species were found more frequently. *Setaria viridis* (L.) Beauv. and *Chenopodium album* (L.) (both native species) were the

Table 4 Spearman's rank correlation coefficients between species richness and indices of park green cover configuration of the 24 study parks. For abbreviations, see Table 2

Landscape index	Number of tree species	Number of shrub species	Number of herbaceous species
Area (ha)	0.181	0.142	0.505*
Mean patch size	0.139	0.038	0.429*
MPE	0.201	0.273	0.189
MSS	0.189	0.401*	0.187
MPFD	0.251	0.389*	0.393*

*$P < 0.05$ (two-tailed)

Table 5 Two-way indicator species analysis approach (TWINSPAN) used to classify groups, derived from data of 24 parks, based on species importance value index matrix for trees, shrub and herbaceous species, respectively

Group no.	Park no.	Cluster hierarchy no.	General functional features for cluster group
General functional features of parks based on tree species cluster groups			
1	4, 14, 17	11	Old architecture-dominant parks with long history
2	6, 15, 16, 22, 23	101	Old park comprising composite architecture and green space
3	10, 11, 13, 18	1001	New architecture-dominant parks
4	2, 5	1000	New green space-dominant parks
5	3, 9, 12	0111	New architecture-dominant parks
6	19, 21	0110	Old green space-dominant, imperial gardens
7	1, 8, 20, 24	010	New green space-dominant parks
8	7	00	Old lake-dominant park
General functional features of parks based on shrub species cluster groups			
1	2, 22, 23	11	Composite features
2	3, 5, 14, 15, 18, 21, 24	1011	Composite features
3	1, 4, 6, 8, 13, 16, 19, 20	1010	Composite features
4	7, 9, 10	100	Lake-dominant parks
5	11, 17	0	Composite features
General functional features of parks based on herbaceous species cluster groups			
1	6, 19, 20, 21	11	Green space-dominant parks (most are old parks)
2	3, 4, 18, 10, 14	10	Architecture-dominant parks (most are old parks)
3	1, 8	011	Green space-dominant parks (including both old and new parks)
4	9, 15, 16, 17	0100	Architecture-dominant parks (most are old parks)
5	2, 5, 11, 12, 23	0101	Composite landscape fashions (most are new parks)
6	13, 22, 24	001	Composite features
7	7	000	Old lake-dominant park

most frequent species in 23 parks. Another 24 herbaceous species, including 21 native species, were found in more than ten parks.

Correlations between species assemblage and park features

Relationship between species richness and indices of park green cover configuration

The correlation coefficients between species abundance and indices of park green cover configuration (area, MPS, MPE, MSS, and MPFD) are shown in Table 4. The correlation between green cover area and herbaceous species abundance was the most significant, but no correlations between the former and the number of tree species and shrub species were found. The correlations between the MPE and the number of tree, shrub, and herbaceous species were not significant either. The MSS and the number of shrub species showed a significant relationship, but no correlations were found between the MSS and the number of tree and herbaceous species. MPFD and a number of shrub and herbaceous species had a positive correlation, but no similar tendency was found between MPFD and tree species.

Relationship between plant species assemblage and park functional features

For tree species assemblage, the 24 parks were clustered into eight groups with the distance between them ranging from 0.311 to 0.43 among four divisive hierarchy levels (Table 5). Integrating the functional features of each park within groups showed that park age and dominant landscape design are the significant functional factors which impact the plant species composition among different park groups. The park functional features within each group were relatively similar. According to the hierarchy level, the tree species assemblage within groups of new parks (groups 3–5) and old green space-dominant parks (group 6) was found to be more similar. Groups of old parks often contain more unique trees than groups of new parks. For instance, the old parks, groups 1 and 2, include seven unique tree species (Table 6). In contrast, most groups of new parks contain frequently occurring species. For example, groups 3–5 only contain two or three unique tree species. The tree species clustering results demonstrate that old parks are more important sites in terms of harbouring unique species than most new parks. Relatively intensive management meant that most new parks grew frequently occurring species. Moreover, various tree species represented a large percentage of total tree species ($>45\%$) for all these park groups (Table 6). Thus trees of most urban parks are planted. Hence, many non-native trees were introduced into various parks as ornamentals, irrespective of the age or landscape design of the park.

For the shrub species assemblage, the 24 parks were clustered into five groups with the distance between them ranging from 0.413 to 0.588 among four divisive hierarchy levels (Table 5). However, when analysing the functional features of parks within each cluster group, no specific characteristics were found for different groups. Park functional features were not the main factors explaining shrub species assemblage pattern.

For herbaceous species assemblage, the 24 parks were clustered into seven groups with the distance varying between 0.282 and 0.467 among four divisive hierarchy levels (Table 5). This also showed that park age and landscape design are important factors affecting herbaceous species assemblage. For the groups mostly composed of old parks, such as groups 1, 2, and 4, the number of total species was >70, and included a high number of unique species (more than ten) (Table 6). In contrast, for the groups mostly composed of new parks, such as groups 3, 5, and 6, the number of total species was <50, and included few unique species (less than five). This obvious difference among old and new park groups illustrates that herbaceous species composition is quite sensitive to park age in relation to different human disturbance. For the new parks, the designers and

Table 6 The floristic characteristics of the park groups classified by TWINSPAN based on tree and herbaceous species assemblage

Trees assemblage group	1	2	3	4	5	6	7	8
No. of parks	3	5	4	2	3	2	4	1
Total species	32	33	30	20	27	28	36	9
Unique species	7	7	3	2	2	3	9	1
Mean richness	16	11	14	16	14	22	16	9
Exotic species (%)	46.9	57.6	53.3	55	51.9	46.4	47.2	66.7

Herbaceous species assemblage group	1	2	3	4	5	6	7
No. of parks	4	5	2	4	5	3	1
Total species	82	74	51	71	39	40	36
Unique species	19	10	5	10	2	2	6
Mean richness	43	35	35	30	14	22	36
Exotic species (%)	18.3	17.1	17.3	19.4	21.1	15	16.7

managers clearly intended the removal of ruderal species and development of uniform or mowed lawns for decoration or outdoor activities, which make their herbaceous species composition more homogeneous than that of the tree or shrub communities. In contrast, old parks have a long history and diverse landscapes, which provide opportunities for the more spontaneous growth of herbaceous species. Moreover, the percentage of non-native herbs for all park groups varied between 15 and 21.1% (Table 6), much lower than that of non-native trees for different parks. This means that urban parks provide great potential for herbaceous biodiversity conservation, especially for that of native herbaceous species.

Discussion

A high plant diversity, i.e. 288 species belonging to 184 genera, and 72 families, was found in Beijing's urban parks within the city centre; this was especially high compared with the number of plant species grown in other types of land use. For instance, Meng (2004) carried out a comprehensive investigation of flora of different types of urban land use within the inner city of Beijing, and recorded 188 and 133 species, respectively, for typical residential blocks and along major roads. This finding is also consistent with some related studies of western countries that, thanks to the diversity and heterogeneity of habitat types, urban parks, private gardens or backyards are important sites for maintaining urban diversity (Hobbs 1988; Loeb 1989; Hermy and Cornelis 2000; Jim and Liu 2001; Cornelis and Hermy 2004; DeCandido 2004). The main reasons for the relatively high species richness of parks within the inner city could be interpreted as due to the richness of park habitats, which usually include various types of artificial, semi-natural, or natural vegetation, such as recreational sites, forest, lawn, meadow, hedges, wetlands, and places suitable for ruderals, etc. These diverse habitats lead to high plant habitat heterogeneity and high species diversity (Planty-Tabacchi et al. 1996; Lonsdale 1999). In Chinese cities, such as Beijing, the inner centre is densely congested due to all kinds of urban land use, and there are few front gardens or backyards like those popularly developed within urban residential areas, or other types of land use, in western countries. Notably, most Chinese urban parks are owned and managed by municipal governments as closed sites, extensively including various public grounds for recreation, culture and heritage (Liang 1999; Jia 2001; Kang 2005), and contain heterogeneous habitats due to their historical landscape features. Therefore, parks of Chinese cities are unique and extremely important sites contributing to urban biodiversity. However, the inventory of the regional flora (Beijing Normal University 1992), recorded 1,482 vascular species for the entire metropolitan region of Beijing, so compared with the surrounding geographical zone, the species richness of the inner city is quite low.

Table 7 Infrequently occurring native species found in only one or two of the 24 study parks

Growth form	Native species occurring in less than three parks
Tree species	*T. chinensis* Lour., *T. hopeiensis* Hu et Chow, *Q. aliena* Bl., *Q. liaotungensis* Koidz, *T. mongolica* Maxim., *Q. variabilis* Bl., *P. meyeri* Rehd et Wils., *Diospyros lotus* L., *A. mono* Maxim.
Shrub species	*Cornus alba*, *S. caprea* L., *M. australis* Poir., *V. farreri*, *W. florida* (Bunge) A. DC., *C. sinica* (Buc' hoz) Rehd., *A. humulifolia* Bunge., *L. chinensis* Bung, *C. multiflorus* Bge., *R. parvifolia* Bunge, *G. biloba* var. *parviflora*, *L. bicolor* Turcz., *S. kirilowii* (Regel) Maxim.
Herbaceous species	*A. argyi* Levl. et Van., *A. lividus* L., *I. cylindrica* (L.) Beauv., *V. variegata* Fisch. ex Link, *B. chinense* Bge., *R. dentatus* L., *D. grandiflorum* L., *L. anandria* (L.) Nakai, *T. giganteum* Engl., *M. aquaticum* (L.) Fries, *T. erythropodium* Kitag, *C. virgata* Swartz, *C. glaucum* L., *A. splendens* (Trin.) Nevski, *S. oleraceus* L., *S. bryoniaefolius* Maxim., *A. debilis* Sieb. et Zucc., *P. hieracioides* L. ssp. *japonica* Krylv., *D. chrysoblephara* Flig. et De Not, *L. tatarica*, *S. gracilis* (Bess.) K. Pol, *lyrata* (Bunge) Bunge, *S. septemlobum* Bunge, *V. collina* Bess., *Kochia scoparia* (L.) Schrad. f. *trichophlla*, *C. urbicum* L., *N. tetragona* Georgi, *L. tenuissimum* (*Nakai*) Kitag, *A. cochinchinensis* (Lour.) Merr., var. *mitis* (Pursh.) Peterm. Fl., *P. sibirica* Roshev., *longifolia* Willd. ex Schlecht, *D. chanetii* (Levl.) Shih, *P. tenuiflora* (Turcz.) Scribn. Merr., *G. soja* Sieb. et Zucc., *V. sepium* L., *C. heterostachya* Bge., *C. hancei* Keng, *A. adsurgens* Pall., *W. sinensis* Sweet., *T. repens* L., *M. suaveolens* Ledeb., *C. caespitosa* Keng, *S. sibiricus* Trin., *C. thesioides* (Freyn.) K. Schum., *E. pilosa* (L.) Beauv., *Z. japonica* Steud., *U. cannabina*, *O. undulatifolius* (*Arduino*) Beauv., var. *australe* (Maxim.) Tsiang et P. T. Li, *D. indica* (Andr.) Focke, *C. chinensis* Lam., *C. rotundus* L., *T. angustifolia* Bory et Chaub., var. *seticuspe* (Maxim.) Shih, *A. capillaris* Thunb.

In comparison, urban parks and gardens for most western countries contribute a relatively high number of species to their surrounding area, with regard to their regional geographical situation and the variety of land use patterns (Loeb 1989; Cornelis and Hermy 2004; DeCandido 2004). This clear difference may have two explanations. The first is that the definition of the extension of the urban park is different for China and most western countries. In western countries, various front gardens and backyards of residential areas are widely developed and effectively extend urban parks, and enhance the contribution of park biodiversity to the surrounding area. The second is that the park design of China and western countries is quite different. Compared with in western countries, Chinese urban park planners and managers usually give more emphasis to artificial landscape architecture for aesthetic reasons and recreational value rather than the intrinsic ecological value of parks. For example, the proportions of green cover of 24 of the sample parks varied from 22 to 98%, among which 14 parks had < 60% green cover. Thus, a number of Chinese parks are dominated by various architectural landscapes, while the areas of green cover are designed to fit in with and decorate these artificial landscapes.

Moreover, a large number of non-native plants, i.e. 62.3% of tree, 63.8% of shrub and 21.5% of herbaceous species, were determined by the park floristic composition. This did not agree with our original expectation that urban parks, as relatively isolated habitats, should contribute more to native species protection, as reported by some findings in western countries (Florgård 2000; DeCandido 2004). This finding implied that the Chinese parks, especially those located in densely urbanized area, are more intensively influenced by frequent management activities than those of cities in western countries. The management of these parks is mainly designed to ornament the environment by constructing new landscape sites or introduce ornamental plants in order to attract more visitors. These very high human disturbances caused the clear increase in non-native species; as concluded by some researchers, successful invasion by alien species is more common in strongly human-modified habitats than in natural habitats (Rebele 1994). Furthermore, significant positive correlations between the number of native species and non-native species were found for park tree and herbaceous species. This revealed that the native and alien species richness of Beijing parks are favoured by similar landscape conditions, and agreed with a number of studies that the high habitat diversity supports species richness of alien as well as native plant species (Duhme and Pauleit 1998; Deutschewitz et al. 2003). Moreover, many native species only occurred in a few parks and with a low number of individuals. For instance, 79 native species, including ten tree, 23 shrub, and 56 herbaceous species, were only found in one or two. Table 7 gives these infrequent native species, which should be given more attention by park managers and need to be planted more. Many

studies have documented the same trend, i.e. that high anthropogenic disturbance and a large departure from the natural disturbance regime favour more invasive species (Daehler 2003; DeCandido 2004; Sukopp 2004).

It is expected that some relationship might exist between park species richness and habitat size as predicted by the species–area relationship hypothesis (Arrhenius 1921; Wu and Vankat 1991; Cornelis 2004). Our correlation between species abundance and green cover only showed a positive correlation for herbaceous species; neither tree nor shrub species abundance were related to the area of green cover. For park herbaceous species, various wild species represented a large proportion (78.5%), and grew widely within parks as an understorey to trees and shrubs. Therefore, our findings supported the species—area relationship when less anthropogenic or natural disturbance was involved in highly heterogeneous habitats. In comparison, most park tree and shrub species were planted or cultivated by the managers, with a simple species composition and biomass structure, in isolated configurations with little consideration for ecological value. Thus, no species—area relations were found for park trees and shrubs. This corresponds with some similar findings, which stressed that intensive human-induced disturbance would change the natural succession processes and patterns (Helliwell 1976; Lawesson et al. 1998). It illustrates that in highly human-disturbed areas, the area of green cover might be an indicator only for the amount of urban green space, and would be a biased indicator if used to evaluate biodiversity. The so-called important indicators for measuring city sustainability, like amount of public green spaces, public park area, recreation areas, etc. could be of real worth when the intrinsic ecological values are taken well into account or assessed. All urban planners, who usually focus on increasing the amount of green cover, can be reminded that more ecological knowledge needs to be incorporated into urban green space planning and management. Besides the species–area relationship, there were no significant relationships between tree species and other park landscape indices (MPS, MPE, MSS, and MPFD). Once again, this is due to the fact that most of the trees were planted by managers, who designed their habitat patterns with a specific structure and species composition in mind, such as forest patches of cherry blossom, white yulan and peach blossom, where no relation between the tree biodiversity and physical landscape indices could be concluded. Positive relationships were found between shrub species abundance and MSS and MPFD, but not for tree and herbaceous species. This apparently shows that most park shrubs are planted as ornamental, isolated or defended fences, mainly designed as diverse line segments, so the human-made features of a habitats' shape would significantly affect shrub species composition and distribution pattern. Furthermore, there were significant correlations between herbaceous species abundance and MPS and MPFD. This indicates that herbaceous species, both wild and non-native, are more

likely to disperse and grow spontaneously within various habitat types, such as diverse lawns, meadows, tree-or shrub-dominant sites, so regular relationships between species richness and patch shape and habitat structure could be induced.

It is remarkable that park age and landscape design were found to be the important factors influencing park tree and herbaceous species assemblage rather than features of park green cover. The parks of similar age and landscape design have relatively similar species assemblage. Most old parks contained more species or harboured more unique tree and herbaceous species than new parks (Table 6). This reflected the public's viewpoint on park design strategies at a different period of the urbanization process. In China, "to come into nature as it is" was the starting point for the design of parks at a former time (Jin 1990; Zhang 2003; Jin and Hua 2004). On the one hand, the old parks, irrespective of whether they were green space or architecture landscape dominant, contained more diverse habitats for vegetation than new parks. On the other hand, the habitats of old parks represented a more mature successional stage than those of new parks, which is extremely significant for tree species. This historical uniqueness and the overwhelming external control of succession are the important features distinguishing urban habitats (Trepl 1995). In contrast, modern park planners may put more efforts into designing artificial green cover or architecture landscapes in order to beautify human-made environments and satisfy local residents' increasing recreational requirements, so most of the habitats are at the early successional stage with dense and frequent human disturbance. Particularly for herbaceous species, frequently occurring or planted species (e.g. mown lawns) are more popular in new parks than old parks, where herbaceous species which grow more spontaneously are harboured. Therefore, these species assemblages are linked to a certain period of park design, and can be the indicators for this from different historic phases. This finding agrees with some research conclusions that urban floristic variation might be strongly impacted by urban development history and city structure that results in different human disturbance of vegetation (Kent et al. 1999; Maurer 2000; Dana 2002; Zerbe et al. 2004).

Conclusion

This is the first study of the plant species composition of urban parks in the inner city zone of Beijing (for a complete list of species see Appendix; Tables 8, 9). Urban parks with relatively high species abundance are the "hotspots" of biodiversity in this intensely urbanized zone. However, this study revealed that a lot of non-native species contribute to the biodiversity of these parks, especially for tree and shrub species, while many native species have been neglected and rarely occur. This means that the parks of the inner city are weak or restrictive in protecting native biodiversity. There is a significant relationship between herbaceous species and park green cover area, but this relationship does not hold true for trees and shrubs. Thus, the amount of green spaces or area of green cover are not the main indicators for evaluating urban park biodiversity. In contrast, park age and landscape design are the important factors which can be used to explain the difference in the plant species assemblages of parks for trees and herbaceous species. Both the tree and herbaceous species assemblages of parks of similar age or landscape design appear to be more similar. These findings are useful for municipal planning authorities, with respect to recognizing the importance of maintaining urban biodiversity, assessing urban biodiversity and designing park management schemes for maintaining urban diversity. Park management in the future should not only consider the aesthetic value, but also strengthen the intrinsic ecological value of these areas. Based on ecological knowledge, habitat-specific management strategies need to be proposed for urban park design. This approach would enhance the richness of habitat types and high species diversity of urban parks and help maintain them, through leaving certain sites unmanaged, some sites managed lightly, and more intensively managing others. The variety of such site-specific management strategies would be highly beneficial to the maintenance of park biodiversity. For old parks, more efforts are needed to increase the "wildness" of their natural habitats with quite limited human disturbance for diverse species conservation, as well as maintaining their historic value as cultural or heritage sites. For new parks, the planning authorities needs to pay greater attention to the maintenance of urban biodiversity based on the comprehensive understanding of the floristic variation and ecological process in relation to the land use patterns and evolution of city development.

The methodology adopted and findings of this research can be employed to improve basic information on urban plant ecology and support the setting of priorities for urban vegetation management and protection. However, given the large number of species and diversity of park designs, the necessity to establish a database of urban floras is emerging through a future continuous and regular monitoring programme in order to understand more of the ecological processes in urban environments. The recognition of this by the planning authority will ensure that re-surveying occurs at regular intervals, in order to provide up-to-date and accurate data for planning.

Appendix

Table 8 List of the total 288 plant species investigated within the 24 study parks

Family name	Genera	Species	Growth form
Liliaceae	*Liriope* Lour.	*L. spicata* (Thunb.) Lour.	Perennial herb
	Asparagus L.	*A. cochinchinensis* (Lour.) *Merr.*	Perennial herb
	Hemerocallis L.	*H. fulva* (L.) L.	Perennial herb
Cupressaceae	*Platycladus* Spach	*P. orientalis* (L.) Franco	Evergreen tree
	Juniperus L.	*J. formosana* Hayata	Evergreen tree
	Sabina Mill.	*S. chinensis* (L.) Ant. (*Sabina chinensis* cv. Kaizuca)	Evergreen tree
		S. chinensis (L.) Ant.	Evergreen tree
		S. procumbens (Endl.) Iwata et Kusaka	Evergreen creeping shrub
		cv. Globosa	Evergreen shrub
		S. vulgaris Ant.	Evergreen creeping shrub
Plantaginaceae	*Plantago* L.	*P. asiatica* L.	Perennial herb
		P. major L.	Perennial herb
Tamaricaceae	*Tamarix* L.	*T. chinensis* Lour	Deciduous shrub or small tree
Labiatae	*Amenthystea* L.	*A. caerulea* L.	Annual herb
	Leonurus L.	*L. artemisis* (Lour.) S. Y. Hu	Biennial herb
Oxalidaceae	*Oxalis* L.	*O. corniculata* L.	Perennial herb
Euphorbiaceae	*Euphorbia* L.	*E. humifusa* Willd.	Annual herb
		V. philippica Cav.	Perennial herb
	Leptopus Decne.	*L. chinensis* Bunge	Deciduous shrub
Leguminosae	*Glycine* Willd.	*G. soja* Sieb. et Zucc.	Annual herb
	Astragalus L.	*A. adsurgens* Pall.	Perennial herb
	Arachis L.	*A. hypogaea* L.	Annual herb
	Gueldenstaedtia Fisch.	*G. multiflora* Bunge	Perennial herb
		G. stenophylla Bunge	Perennial herb
	Acacia Mill.	*A. farnesiana* (L.) Willd.	Deciduous shrub or small tree
	Dolichos L.	*D. lablab* L.	Annual twining herb
	Melilotus	*M. albus* Desr.	Annual or biennial herb
		M. officinalis (L.) Desr.	Annual or biennial herb
		M. suaveolens Ledeb.	Annual or biennial herb
	Trifolium L.	*T. repens* L.	Perennial creeping herb
	Albizia Durazz.	*A. julibrissin* Durazz	Deciduous tree
	Lespedeza Michx.	*L. floribunda* Bunge.	Deciduous shrub
		L. bicolor Turcz.	Deciduous shrub
	Sophora L.	*S. japonica* L.	Deciduous tree
		f. *pendula* hort.	Deciduous tree
		f. *oligophylla*	Deciduous tree
	Caragana Fabr.	*C. rosea* Turcz.	Deciduous shrub
		C. sinica (Buc' hoz) Rehd.	Deciduous shrub
	Robinia L.	*R. pseudoacacia* L.	Deciduous tree
	Vicia L.	*V. sepium* L.	Perennial herb
	Gleditsia L.	*G. sinensis* Lam.	Deciduous tree
	Cercis L.	*C. chinensis* Bunge	Deciduous tree or shrub
	Amorpha L.	*A. fruticosa* L.	Deciduous shrub
	Wisteria Nutt	*W. sinensis* Sweet.	Perennial deciduous climbing shrub
Eucommiaceae	*Eucommia* Oliver	*E. ulmoides* Oliver.	Deciduous tree
Tiliaceae	*Grewia* L.	*G. biloba* var. *parviflora*	Deciduous shrub
	Tilia L.	*T. mongolica* Maxim.	Deciduous tree
Lemnaceae	*Spirodela* Schleid.	*S. polyrrhiza* (L.) Schleid.	Perennial aquatic floating herb
Gramineae	*Eleusine coracana* (L.) Gaertn.	*E. indica* (L.) Gaertn.	Annual herb
	Phyllostachys Sieb. et Zucc.	*P. propinqua* McClure	Evergreen tree
	Imperata Cyr.	*I. cylindrica* (L.) Beauv.	Perennial herb
	Echinochloa Beauv.	*E. crusgali* (L.) Beauv.	Annual herb
		var. *mitis* (Pursh.) Peterm. Fl.	Annual herb
	Melica L.	*M. scabrosa* Trin.	Perennial herb
	Spodiopogon Trin.	*S. sibiricus* Trin.	Perennial herb
	Lolium L.	*L. temulentum* L.	Annual herb
		L. perenne L.	Perennial herb
	Roegneria C. Koch.	*R. kamoji* Ohwi	Perennial herb
	Setaria Beauv.	*S. viridis* (L.) Beauv.	Annual herb
	Cynodon Rich.	*C. dactylon* (L.) Pers.	Perennial herb
	Secale L.	*S. cereale* L.	Annual or perennial cultivated herb
	Chloris Swartz	*C. virgata* Swartz	Annual herb

Table 8 (Contd.)

Family name	Genera	Species	Growth form
	Eragrostis Beauv.	*E. cilianensis* (All.) Link ex Vignolo-Lutati	Annual herb
		E. pilosa (L.) Beauv.	Annual herb
	Achnatherum Beauv.	*A. splendens* (Trin.) Nevski	Perennial herb
	Puccinellia Parl.	*P. tenuiflora* (Turcz.) Scribn. Merr.	Perennial herb
	Zoysia Willd.	*Z. japonica Steud.*	Perennial herb
	Phragmites Adans.	*P. communis* Trin.	Perennial herb
	Digitaria Haller	*D. sanguinalis* (L.) Scop.	Annual herb
		D. chrysoblephara Flig. et De Not	Annual herb
	Oplismenus Beauv.	*O. undulatifolius* (Arduino) Beauv.	Annual herb
	Festuca L.	*F. elata* Keng	Perennial herb
	Buchloe Engelm.	*B. dactyloides* (Nutt.) Engelm	Perennial herb
	Cleistogenes Keng	*C. hancei* Keng	Perennial herb
		C. chinensis (Maxim.) Keng	Perennial herb
		C. caespitosa Keng	Perennial herb
	Poa L.	*P. pratensis* L.	Perennial herb
		P. sibirica Roshev.	Perennial herb
Juglandaceae	*Pterocarya* Kunth.	*P. stenoptera* C. DC.	Deciduous tree
	Juglans L.	*J. regia* L.	Deciduous tree
Cucurbitaceae	*Schizopepon* Maxim.	*S. bryoniaefolius* Maxim.	Annual herb
	Citrullus Neck.	*C. lanatus* (Thunb.)	Annual contagious herb
Saxifragaceae	*Philadelphus* L.	*P. pekinensis* Rupr.	Deciduous shrub
Buxaceae	*Buxus* L.	*B. sinica* var. *parvifolia*	Evergreen shrub or tree
Zygophyllaceae	*Tribulus* L.	*T. terrestris* L.	Annual herb
	Acalypha L.	*A. australis* L.	Annual herb
Violaceae	*Viola* L.	*V. variegata* Fisch. ex Link	Perennial herb
		V. pekinensis (Regel) W. Beck.	Perennial herb
		V. collina Bess.	Perennial herb
Malvaceae	*Hibiscus* L.	*H. syriacus* L.	Deciduous shrub or small tree
	Abutilon Miller	*A. theophrasti* Medicus.	Annual herb
	Althaea L.	*A. rosea* (L.) Cavan.	Perennial herb
Compositae	*Conyza* Less.	*C. canadensis*. (L.) Cronq.	Annual herb
	Leibnitzia Cass.	*L. anandria* (L.) Nakai	Perennial herb
	Erigeron L.	*E. acer* L.	Biennial herb
	Heteropappus Less.	*H. altaicus* (Willd.) Novopokr.	Perennial herb
	Bidens L.	*B. pilosa* L.	Annual herb
	Artemisia L.	*A. argyi* Levl. et Van.	Perennial herb
		A. annua L.	Annual herb
		A. mongolica (Fisch. ex Bess.) Nakai	Perennial herb
		A. igniaria Maxim	Perennial herb
		A. capillaris Thunb.	Perennial herb
	Cirsium Mill.	*C. setosum* (Willd.) MB.	Perennial herb
	Dendranthema (DC.) Des Moul.	var. *seticuspe* (Maxim.) Shih	Perennial herb
		D. morifolium (Ramat.) Tzvel.	Perennial herb
		D. chanetii (Levl.) Shih	Perennial herb
		var. *seticuspe* (Maxim.) Shih	Perennial herb
	Sonchus L.	*S. oleraceus* L.	Perennial herb
		I. sonchifolia Hance.	Perennial herb
	Ixeris Cass.	*I. chinensis* (Thunb.) Nakai	Perennial herb
		I. sonchifolia Hance.	Perennial herb
		I. denticulata (Houtt.) Stebb.	Perennial herb
	Picris L.	*P. hieracioides* L. ssp. *japonica* Krylv.	Biennial herb
	Hemistepta Bunge	*H. lyrata* (Bunge) Bunge	Biennial herb
	Galinsoga Ruiz et Cav.	*G. parviflora* Cav.	Annual herb
	Taraxacum L.	*T. erythropodium* Kitag	Perennial herb
		T. monogolicum Hand. Mazz.	Perennial herb
	Lactuca L.	*L. tatarica* (L.) O. C. A. Mey.	Perennial herb
		L. indica L.	Biennial or annual herb
	Helianthus L.	*H. tuberosus* L.	Perennial herb
	Inula L.	*I. japonica* Thunb.	Perennial herb
Fagaceae	*Quercus* L.	*Q. aliena* Bl.	Deciduous tree
		Q. liaotungensis Koidz	Deciduous tree
		Q. variabilis Bl.	Deciduous tree
Simaroubaceae	*Ailanthus* Desf.	*A. altissima* (Mill.) Swingle	Deciduous tree
Calycanthaceae	*Chimonanthus* Lindl.	*C. praecox* (L.) Link	Deciduous shrub
Chenopodiaceae	*Chenopodium* L.	*C. glaucum* L.	Annual herb
		C. album L.	Annual herb
		C. urbicum L.	Annual herb

Table 8 (Contd.)

Family name	Genera	Species	Growth form
	Kochia Roth	*Kochia scoparia* (L.) Schrad.	Annual herb
		Kochia scoparia (L.) Schrad. f. trichophlla	Annual herb
Polygonaceae	*Polygonum* L.	*P. aviculare* L.	Annual herb
		P. hydropiper L.	Annual herb
	Rumex L.	*R. dentatus* L.	Perennial herb
Asclepiadaceae	*Cynanchum* L.	*C. thesioides* (Freyn.) K. Schum.	Perennial herb
		var. *australe* (Maxim.) Tsiang et P. T. Li	Perennial herb
	Metaplexis R. Br.	*M. japonica* (Thunb.) Makino	Perennial herbaceous climbing shrub
Verbenaceae	*Clerodendrum* L.	*C. trichotomum* Thunb.	Deciduous shrub or small tree
	Vitex L.	var. *heterophylla* (Franch.) Rehd.	Deciduous shrub
Portulacaceae	*Portulaca* L.	*P. oleracea* L.	Annual herb
Aristolochiaceae	*Aristolochia* L.	*A. debilis* Sieb. et Zucc.	Perennial twining herb
Ranunculaceae	*Delphinium* L.	*D. grandiflorum* L.	Perennial herb
	Paeonia L.	*P. suffruticosa* Andr.	Deciduous shrub
		P. lactiflora Pall.	Perennial herb
Magnoliaceae	*Magnolia* L.	*M. liliflora*	Deciduous shrub
		*M. soulangeana*Soul.	Deciduous shrub or small tree
		M. biondii	Deciduous tree
		M. denudata Desr.	Deciduous tree
Oleaceae	*Fontanesia* Labill	*F. fortunei*	Deciduous shrub
	Ligustrum L.	*L.* x *vicaryi* hort. hybrid	Semi-evergreen shrub
		L. lucidum Ait	Evergreen shrub or small tree
		L. quihoui Carr.	Semi-evergreen shrub
	Jasminum L.	*J. nudiflorum* Lindl	Deciduous shrub
	Forsythia Vahl	*F. viridissima* Lindl.	Deciduous shrub
		F. suspensa (Thunb.) Vahl.	Deciduous shrub
	Syringa L.	*S. pekinensis* Rupr.	Deciduous small tree
		S. oblata Lindl	Deciduous shrub
	Fraxinus L.	*F. chinensis* Roxb.	Deciduous tree
		F. pennsylvanica var. *subintegerrima*	Deciduous tree
Vitaceae	*Parthenocissus* Pl.	*P. quinquefolia.*	Deciduous woody climbing shrub
		P. tricuspidata (Sieb. et Zucc.) Planch.	Deciduous woody climbing shrub
	Ampelopsis Michx.	*A. humulifolia* Bunge.	Deciduous woody climbing shrub
		A. aconitifolia Bunge.	Deciduous woody climbing shrub
Aceraceae	*Acer* L.	*A. chinensis* Bunge	Deciduous tree
		A. mono Maxim.	Deciduous tree
		A. truncatum Bunge.	Deciduous tree
Anacardiaceae	*Cotinus* (Tourn.) Mill.	*C. coggygria* Scop.	Deciduous shrub or tree
	Rhus (Tourn.) L. Emend. Moench	*R. typhina* L.	Deciduous shrub or tree
Lythraceae	*Lagerstroemia* L.	*L. indica* var. *alba*	Deciduous shrub or small tree
		L. indica L.	Deciduous shrub or small tree
Urticaceae	*Urtica* L.	*U. cannabina*	Perennial herb
Rubiaceae	*Rubia* L.	*R. cordifolia* L.	Perennial climbing herb
Rosaceae	*Potentilla* L.	*P. supina* L.	Annual or biennial herb
		P. chinensis Ser.	Perennial herb
		P. longifolia Willd. ex Schlecht	Perennial herb
	Duchesnea J. E. Smith	*D. indica* (Andr.) Focke	Deciduous tree
	Kerria DC.	*K. japonica* (L.) DC.	Deciduous tree
	Prunus L.	*P. cerasifera* Ehrh. f. *atropurpurea* (Jacq.) Rehd	Deciduous small tree
		P. persica cv. Duplex	Deciduous tree
		P. davidiana (Carr.) de Vos ex Henry	Deciduous tree
		P. pseudocerasus Lindl	Deciduous tree
		P. japonica	Deciduous shrub
		P. trlloba f. Plena Depp.	Deciduous shrub
		cv. Atropurpurea	Deciduous small tree
	Armeniaca Mill.	*P. armeniaca*	Deciduous tree
	Chaenomeles Lindl.	*C. lagenaria*	Deciduous shrub
	Malus Mill.	*M. spectabilis* (Ait) Borkh.	Deciduous small tree
		M. pumila Mill.	Deciduous tree
		M. micromalus Makino	Deciduous small tree
	Rosa L.	*R. multiflora* Thunb.	Deciduous shrub
		R. xanthina Lindl.	Deciduous shrub
		R. rugosa Thunb.	Deciduous shrub
		R. primula	Deciduous shrub
		R. chinensis Jacq.	Deciduous shrub

Table 8 (Contd.)

Family name	Genera	Species	Growth form
	Rubus L.	*R. crataegifolius* Bge.	Deciduous shrub
	Cotoneaster B. Ehrhart	*C. horizontalis* Dcne.	Deciduous or semi-evergreen shrub
		C. multiflorus Bge.	Deciduous shrub
Sorbaria	*S. kirilowii sorbifolia* (L.) A. Br.	Deciduous shrub	
\(Ser.) A. Br. ex Aschers.	*S. kirilowii* (Regel) Maxim	Deciduous shrub	
Solanaceae	*Lycium* L.	*L. chinense* Miller	Annual herb
	Lycopersicon Mill	*L. esculentum* Mill	Deciduous shrub
	Solanum L.	*S. nigrum*. L.	Annual herb
		S. septemlobum Bunge	Annual herb
Caprifoliaceae	*Viburnum* L.	*V. farreri*	Deciduous shrub
	Weigela Thunb.	*W. coraeensis*	Deciduous shrub
		Lonicera maackii Maxim	Deciduous small tree
		W. florida (Bunge) A. DC.	Deciduous shrub
Umbelliferae	*Sphallerocarpus* Bess. ex DC.	*S. gracilis* (Bess.) K. Pol	Biennial herb
	Ligusticum L.	*L. tenuissimum* (Nakai) Kitag	Perennial herb
Moraceae	*Humulus* L.	*H. scandens* (Lour.) *Merr.*	Deciduous tree
	Broussonetia L'Herit. ex Vent	*B. papyrifera* (L.) Vent.	Deciduous tree
	Morus L.	*Morus alba tortuosa*	Deciduous tree
		M. alba L.	Deciduous tree
		M. australis Poir.	Deciduous shrub or small tree
Cyperaceae	*Cyperus* L.	*C. rotundus* L.	Perennial herb
	Juncellus (Griseb.) C.B. Clarke	*J. serotinus* (Rottb.) C. B. Clarke	Perennial herb
	Carex L.	*C. lanceolata* Boott.	Perennial herb
		C. siderosticta Hance	Perennial herb
		C. rigescens (Fr.) Krecz	Perennial herb
		C. heterostachya Bge.	Perennial herb
Cornaceae	*Cornus* L.	*M. officinalis* Sieb. et Zucc.	Deciduous shrub or tree
	Swida Opiz	*Cornus alba*	Deciduous shrub
Taxodiaceae	*Metasequoia* Miki ex Hu et Cheng	*M. glyptostroboides* Hu et Cheng	Deciduous tree
Cruciferae	*Lepidium* L.	*L. apetalum* Willd.	Annual or biennial herb
	Rorippa Scop.	*R. islandica* (Oed.) Borb.	Biennial or perennial herb
	Capsella Medic.	*C. bursapastoris* (L.) Medic.	Annual or biennial herb
	Erysimum L.	*E. bungei* (Kitag.) Kitag.	Perennial herb
Punicaceae	*Punica* L.	*P. granatum* L.	Deciduous shrub or small tree
Caryophyllaceae	*Malachium* Fries	*M. aquaticum* (L.) Fries	Perennial herb
Ebenaceae	*Diospyros* L.	*Diospyros lotus* L.	Deciduous tree
		D. kaki L.	Deciduous tree
Rhamnaceae	*Rhamnus* L.	*R. parvifolia* Bunge	Perennial aquatic herb
	Ziziphus Mill.	*Z. jujuba* M.	Deciduous tree
		var. *spinosa* (Bunge) Hu ex H. F. Chow	Deciduous shrub or tree
Nymphaeaceae	*Nelumbo* Adans.	*N. nucifera* Gaertn.	*Perennial aquatic herb*
	Nymphaea L.	*N. tetragona*. Georgi	Perennial aquatic herb
Pinaceae	*Pinus* L.	*P. bungeana* Zucc. ex Endl.	Evergreen tree
		P. armandi Franch.	Evergreen tree
		C. deodara (Roxb.) G. Don	Evergreen tree
		P. tabulaeformis Carr.	Evergreen tree
	Picea A. Dietr.	*P. koraiensis* Nakai	Perennial herb
		P. wilsonii Mast.	Perennial herb
		P. meyeri Rehd et Wils.	Evergreen tree
Araceae	*Pinellia tenore*	*P. ternata* (Thunb.) Breit.	Perennial herb
	Typhonium Schott	*T. giganteum* Engl.	Perennial herb
Celastraceae	*Euonymus* L.	*Bungeanus* Maxim.	Deciduous small tree
		E. ya pomicus L.	Evergreen shrub or small tree
		E. fortunei (Turcz.) Hand. Mazz.	Evergreen climbing shrub
Sapindaceae	*Xanthoceras* Bunge	*X. sorbifolia* Bunge	Deciduous shrub or tree
	Koelreuteria Laxm.	*K. paniculata* Laxm.	Deciduous tree
Sterculiaceae	*Firmiana marsili*	*F. platanifolia* (L. f.) Marsili	Deciduous tree
Amaranthaceae	*Amaranthus* L.	*A. lividus* L.	Annual herb
		A. retroflexus L.	Annual herb
		A. viridis L.	Annual herb
Typhaceae	*Typha* L.	*T. angustifolia* Bory et Chaub.	Perennial paludous herb
Berberidaceae	*Berberis* L.	cv. Atropurpurea	Deciduous shrub or small tree
Scrophulariaceae	*Paulownia* Sieb. et Zucc.	*P. tomentosa* (Thunb.) Steud.	Deciduous tree
	Digitalis L.	*D. purpurea* L.	Biennial or perennial herb

Table 8 (Contd.)

Family name	Genera	Species	Growth form
Platanaceae	*Platanus* L.	*P. orientalis* L.	Deciduous tree
		P. occidentalis L.	Deciduous tree
		P. acerifolia	Deciduous tree
Convolvulaceae	*Calystegia* R. Br.	*C. hederacea* Wall. ex Roxb.	Annual twining or creeping herb
	Pharbitis Choisy	*P. hederacea* (L.) Choisy	Annual herb
		P. nil	Annual twining herb
		P. purpurea (L.) Viogt.	Annual herb
	Cuscuta L.	*C. chinensis* Lam.	Annual parasitic climbling shrub
	Convolvulus L.	*C. arvensis* L.	Perennial herb
Commelinaceae	*Commelina* L.	*C. communis* L.	Annual herb
Salicaceae	*Salix* L.	*S. babylonica* L.	Deciduous tree
		S. matsudana Koidz.	Deciduous tree
		S. f. pendula Schneid.	Deciduous tree
		S. caprea L.	Deciduous shrub or small tree
	Populus L.	*P. hopeiensis* Hu et Chow	Deciduous tree
		P. canadensis Moench.	Deciduous tree
		P. tomentosa Carr.	Deciduous tree
		P. alba L. var. *pyramidalis* Bunge.	Deciduous tree
		P. alba L.	Deciduous tree
Ginkgoaceae	*Ginkgo* L.	*G. biloba* L. Mant.	Deciduous tree
Ulmaceae	*Celtis* L.	*C. bungeana* Bl.	Deciduous tree
	Ulmus L.	*U. carpinihlia* cv. Pcendula	Deciduous tree
		U. pumila L.	Deciduous tree
Iridaceae	*Iris* L.	*I. iactea* Pall. var. *chinensis* (Fisch.) Koidz	Perennial herb
Rutaceae	*Zanthoxylum* L.	*Z. bungeanum* Maxim.	Deciduous shrub or tree
Boraginaceae	*Bothriospermum* Bge.	*B. chinense* Bge.	Annual herb
Bignoniaceae	*Catalpa* Scop.	*C. ovata* G. Don	Deciduous tree
		C. bungei C. A. Mey.	Deciduous tree
Crassulaceae	*Sedum*	*S. aizoon* L.	Perennial herb
		S. sarmentosum Bge.	Perennial herb

Table 9 List of the dominant species [importance value index (IV*i*) > 0. 2] within 24 study parks

No.	Name	Dominant species with IV*i* > 0. 2
1	Bei Hai	*P. orientalis* (L.) Franco, *S. chinensis* (L.) Ant., *A. julibrissin* Durazz, *P. tabulaeformis* Carr., *S. babylonica* L.; var. *heterophylla* (Franch.) Rehd., *R. xanthina* Lindl., *Lonicera maackii* Maxim, *B. sinica* var. *parvifolia*, *L. chinensis* Bunge, *S. kirilowii sorbifolia* (L.) A. Br.; *S. viridis* (L.) Beauv, *V. philippica* Cav., *C. album* L., *I. sonchifolia* Hance
2	Chao Yang	*P. tomentosa* Carr., *S. japonica* L., *P. tabulaeformis* Carr., *F. chinensis* Roxb; *W. florida* (Bunge) A. DC., *V. farreri*, *C. chinensis* Bunge, *F. suspensa* (Thunb.) Vahl., *F. viridissima* Lindl., *P. trilloba* f. Plena Depp.; *P. pratensis* L., *F. elata* Keng, *L. perenne* L.
3	Da Guan Yuan	*S. babylonica* L., *ungeana* Zucc. ex Endl., *F. chinensis* Roxb, *F. platanifolia* (L. f.) Marsili, *P. hopeiensis* Hu et Chow, *S. matsudana* Koidz.; *P. trlloba* f. Plena Depp.., *F. suspensa* (Thunb.) Vahl., *E. ya pomicus* L., *S. kirilowii sorbifolia* (L.) A. Br., *H. syriacus* L., *C. chinensis* Bunge, *Lonicera maackii* Maxim; *C. rigescens* (Fr.) Krecz, *V. philippica* Cav., *C. album* L., *I. sonchifolia* Hance.
4	Di Tan	*P. orientalis* (L.) Franco, *P. tomentosa* Carr.,*P. persica* cv. Duplex, *P. propinqua* Mcclure; *E. ya pomicus* L., cv. Atropurpurea, *S. kirilowii sorbifolia* (L.) A. Br., *R. xanthina* Lindl., *Lonicera maackii* Maxim; *P. pratensis* L., *V. philippica* Cav.,*F. elata* Keng, *C. rigescens* (Fr.) Krecz
5	Hong Ling Jin	*P. tomentosa* Carr., *S. japonica* L., *S. babylonica* L., *F. chinensis* Roxb; var. *spinosa* (Bunge). Hu ex H. F. Chow, *F. suspensa* (Thunb.) Vahl., *S. kirilowii sorbifolia* (L.) A. Br., *E. ya pomicus* L.; *L. spicata* (Thunb.) Lour., *P. pratensis* L., *L. perenne* L.
6	Jing Shan	*S. chinensis* (L.) Ant., *ungeana* Zucc. ex Endl., *K. paniculata* Laxm.; var. *heterophylla* (Franch.) Rehd., var. *spinosa* (Bunge). Hu ex H. F. Chow, *B. sinica* var. *parvifolia*, *S. vulgaris* Ant, *R. xanthina* Lindl.; *P. pratensis* L., *C. rigescens* (Fr.) Krecz, *C. lanceolata* Boott., *O. corniculata* Linn

Table 9 (Contd.)

No.	Name	Dominant species with IVi > 0. 2
7	Lian Hua Chi	*S. f. pendula* Schneid., *P. tabulaeformis* Carr., *P. tomentosa* Carr., *R. pseudoacacia*L., *M. micromalus* Makino; *S. procumbens* (Endl.) Iwata et Kusaka, *E. ya pomicus* L., *L. x vicaryi* hort. hybrid, *R. xanthina* Lindl., *F. suspensa* (Thunb.) Vahl., cv. Atropurpurea; *B. dactyloides* (Nutt.) Engelm, *S. viridis* (L.) Beauv
8	Liu Yin	*S. matsudana* Koidz., *S. f. pendula* Schneid., *S. babylonica* L.; *S. procumbens* (Endl.) Iwata et Kusaka, *J. nudiflorum* Lindl, var. *heterophylla* (Franch.) Rehd.; *V. philippica* Cav., *I. japonica* Thunb.
9	Long Tan Hu	*S. babylonica* L., *P. tomentosa* Carr., *P. davidiana* (*Carr.*) de Vos ex Henry, *ungeana*; Zucc. ex Endl., *C. ovata;* G. Don; cv. Atropurpurea; *P. trlloba;* f. Plena Depp., *W. coraeensis*, L. x *vicaryi*; hort. hybrid, *L. chinense;* Miller, *R. xanthina;* Lindl.; *F. elata;* Keng, *L. spicata* (Thunb.) Lour., *B. dactyloides* (Nutt.) Engelm, *O. corniculata*; L.
10	Qing Nian Hu	*S. f. pendula* Schneid., *R. pseudoacacia* L., *P. tomentosa* Carr., *S. chinensis* (L.) Ant., *S. japonica* L., *ungeana* Zucc. ex Endl.; *S. procumbens* (Endl.) Iwata et Kusaka, L. x *vicaryi* hort. hybrid, *P. quinquefolia.*, cv. Atropurpurea, *R. rugosa* Thunb., *E. ya pomicus* L.; *P. pratensis* L., *C. rigescens* (Fr.) Krecz, *V. philippica* Cav., *S. viridis* (L.) Beauv, *F. elata* Keng
11	Ren Ding Hu	*P. tomentosa* Carr., *R. pseudoacacia* L., *S. chinensis* (L.) Ant., *S. japonica* L., *ungeana* Zucc. ex Endl., *S f. pendula* Schneid., *G. biloba* L. Mant., *C. deodara* (Roxb.) G. Don; *C. horizontalis* Dcne., *P. japonica*, *B. sinica* var. *parvifolia*, cv. Globosa; *P. pratensis* L., *S. nigrum* L.
12	Shi Jie park	*S. japonica* L., *P. tomentosa* Carr., *S. babylonica* L., *ungeana* Zucc. ex Endl., *F. chinensis* Roxb; *P. pratensis* L., *O. corniculata* L., *L. spicata* (Thunb.) Lour.
13	Shuang Xiu	*S. chinensis* (L.) Ant., *P. tomentosa* Carr., *S. japonica* L.; *S. oblata* Lindl, *B. sinica* var. *parvifolia*, cv. Atropurpurea, *F. suspensa*(Thunb.) Vahl., *C. trichotomum* Thunb.; *L. spicata* (Thunb.) Lour., *O. corniculata* L., *S. viridis* (L.) Beauv, *V. philippica* Cav.
14	Tao Ran Ting	*S. japonica* L., *G. biloba* L Mant., *S. chinensis* (L.) Ant., *P. tabulaeformis* Carr., *P. propinqua* McClure; *R. xanthina* Lindl., var. *heterophylla* (Franch.) Rehd.; *L. spicata* (Thunb.) Lour., *O. corniculata* L., *C. album* L.
15	Tian Tan	*S. chinensis* (L.) Ant., *P. orientalis* (L.) Franco, *S. japonica* L.; *F. suspensa* (Thunb.) Vahl., *P. pekinensis* Rupr., *R. crataegifolius* Bge., *P. quinquefolia*, *E. ya pomicus* L.; *B. dactyloìdes* (Nutt.) Engelm, *P. pekinensis* Rupr., *P. pratensis* L., *O. corniculata* L., *L. spicata* (Thunb.) Lour.
16	Tuan Jie Hu	*J. formosana* Hayata, *ungeana* Zucc. ex Endl., *S. chinensis* (L.) Ant., *A. truncatum* Bunge., *P. orientalis* (L.) Franco, *J. regia* L., *G. biloba* L. Mant.; *S. vulgaris* Ant, var. *heterophylla* (Franch.) Rehd., cv. Atropurpurea, *K. japonica* (L.) DC., *H. syriacus* L.; *L. spicata* (Thunb.) Lour., *C. rigescens* (Fr.) Krecz, *B. dactyloides* (Nutt.) Engelm
17	Wan Fang Ting	*P. tabulaeformis* Carr., *A. truncatum* Bunge., *X. sorbifolia* Bunge, *S. japonica* L., *A. altissima* (Mill.) Swingle; *B. sinica* var. *parvifolia*, *S. procumbens* (Endl.) Iwata et Kusaka; *P. pratensis* L., *B. dactyloides* (Nutt.) Engelm, *S. viridis* (L.) Beauv, *D. sanguinalis* (L.) Scop.
18	Xuan Wu	*P. tomentosa* Carr., *P. tabulaeformis* Carr., *S. chinensis* (L.) Ant., *G. biloba* L. Mant.; *Lonicera maackii* Maxim, *F. suspensa* (Thunb.) Vahl., *P. suffruticosa* Andr., *S. kirilowii sorbifolia* (L.) A. Br., *R. chinensis* Jacq.; *P. pratensis* L., *V. philippica* Cav., *C. rigescens* (Fr.) Krecz, *C. album* L.
19	Yi He Yuan	*P. orientalis* (L.) Franco, *S. matsudana* Koidz., *P. tomentosa* Carr.; var. *heterophylla* (Franch.) Rehd., *E. ya pomicus* L., *L. floribunda* Bunge., *J. nudiflorum* Lindl, *G. biloba* var. *parviflora*; *P. pratensis* L., *S. viridis* (L.) Beauv, *O. corniculata* L.
20	Yu Yuan Tan	*P. tomentosa* Carr., *P. tabulaeformis* Carr., *R. pseudoacacia* L., *P. stenoptera* C. DC., *U. pumila* L.; var. *heterophylla* (Franch.) Rehd., *F. suspensa* (Thunb.) Vahl., *G. biloba* var. *parviflora*, *S. procumbens* (Endl.) Iwata et Kusaka, *J. nudiflorum* Lindl; *P. pratensis* L., *C. album* L., var. *seticuspe* (Maxim.) Shih
21	Yuan Ming Yuan	*S. matsudana* Koidz., *G. biloba* L Mant., *E. ulmoides* Oliver.; *F. suspensa* (Thunb.) Vahl., var. *heterophylla* (Franch.) Rehd., *H. syriacus* L., *Lonicera maackii* Maxim, *L. bicolor* Turcz.; *P. pratensis* L., *C. album* L., var. *seticuspe* (Maxim.) Shih, *V. philippica* Cav.
22	Yue Tan	*P. tomentosa* (Thunb.) Steud., *S. chinensis* (L.) Ant., *G. biloba* L Mant.; *R. rugosa* Thunb., *C. chinensis*Bunge, *R. crataegifolius* Bge., *L. indica* var. *alba*, *K. japonica* (L.) DC., *F. viridissima* Lindl.; *O. corniculata* L., *P. pratensis* L.
23	Zhong Shan	*S. chinensis* (L.) Ant., *P. orientalis* (L.) Franco; *P. suffruticosa* Andr., *K. japonica* (L.) DC., *Lonicera maackii* Maxim, *F. viridissima* Lindl., *L. quihoui* Carr., *R. xanthina* Lindl.; *L. spicata* (Thunb.) Lour., *P. pratensis* L., *O. corniculata* L.
24	Zi Zhu Yuan	*S. babylonica* L., *P. tabulaeformis* Carr., *S. chinensis* (L.) Ant.; *P. quinquefolia.*, *P. pekinensis* Rupr., *Lonicera maackii* Maxim; *P. pratensis* L., *V. pekinensis* (Regel) W. Beck., *O. corniculata* L., *C. communis* L., *L. spicata* (Thunb.) Lour.

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