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Response of Understory Plant Diversity to Soil Physical and Chemical Properties in Urban Forests in Beijing, China

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Abstract: Understory vegetation affects the richness and stability of urban forest ecosystems. To investigate the influence of soil physicochemical properties on the diversity of understory plants in urban forests, this study used 30 urban forest communities in the Beijing Plain area as the research object and analyzed the correlation between understory plant diversity and soil factors by correlation analysis. Furthermore, pH, soil bulk density (SBD), total soil porosity (TSP), soil water content (SWC), soil organic carbon (SOC), soil organic matter (SOM), total nitrogen (TN), total phosphorus (TP), effective phosphorous (AP), and effective potassium (AK) were determined in this study. The Shannon diversity index (H'), Pielou evenness index (E), Simpson dominance index (C), and Margalef richness index (DMG) of understory plants were calculated. The soil nutrient contents and the understory plant diversity indices of the different community types showed significant differences. There was a strong correlation between soil properties and the diversity index of understory vegetation. SOM and SOC were the main factors affecting the Shannon-Wiener index, Pielou index, Simpson index, and Margalef richness index of the understory plants. We conclude that soil properties were one of the primary drivers of the formation of understory vegetation diversity. The results of the study can provide scientific guidance for the management of urban forests.

Keywords: urban forest; understory diversity; plantation forest; soil physicochemical properties; redundancy

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1. Introduction

Plants are the basic components of urban forests, and rich plant diversity can improve the overall function of urban ecosystems [1]. Furthermore, diversity indices can be used to quantify plant diversity [2], and the plant diversity index values reveal the complex relationships between individual plants and are a unique way to reflect the status of plant use of environmental resources [3] Among diversity indices, the richness index is frequently used to describe the number of species found in a community, and diversity indices are functions that combine species diversity and species abundance, such as Simpson's index and Shannon's index [4] The Pielou index is used to describe the distribution of species within a community [5] These diversity indices are widely employed to measure vegetation diversity.

Understory vegetation is an important protective layer of urban forest biodiversity and is highly sensitive to environmental changes [6,7]. Studies have found that understory plant diversity is influenced by biotic factors such as forest stand age [8], stand density [9,10], soil biological properties [11], and anthropogenic disturbance [12], as well as abiotic factors such as climatic conditions [13], topographic conditions [14], and soil physical and chemical properties [15,16]. However, at the community scale, the diversity of undergrowth plants is more affected by soil physical and chemical properties, microtopography, and forest structure [17–19]. Compared to topographic factors, forest stand structure and soil factors have a greater influence on understory plant diversity at the community scale [20]. Among them, soil physicochemical properties are fundamental factors in maintaining plant species richness and are widely considered to be significantly correlated with plant diversity [15] Competition among individual plants and between plant species for soil resources is an important factor affecting the species composition and succession of plant communities, and the quality of the soil environment at certain spatial and temporal scales influences or even determines the plant diversity of a region [21,22]. Understory vegetation influences soil nutrient availability by altering the input of compounds and organic matter in the form of litter and root exudates [23]. Changes in soil nutrient availability caused by vegetation [24] have an impact on nutrient absorption and assimilation by vegetation [25]. Thus, the relationship between the interaction of soil physicochemical properties and plant diversity is an important issue explored in ecology [26]. However, differences in the soil factors governing understory diversity at the community scale are caused by different study site locations, different stages of urban forest succession, and different stand types [27]. As a result, more research is needed to identify the key drivers influencing understory plant diversity at the community level.

In fact, few studies have examined the effects of soil physicochemical properties on understory plant diversity in different communities. There is no unified conclusion on the mechanisms by which soil physicochemical properties regulate each diversity index. In 2012, Beijing implemented afforestation of plain areas and built a large area of urban forest in the plain areas of Beijing, which had a significant impact on the city's urban forest ecosystem [28], and it is crucial to study the relationship between understory plant diversity and soil physicochemical properties in urban forests. Previous research on understory plants in Beijing urban forests has concentrated on the investigation of diversity and the unilateral study of soil property characteristics [29,30], with few studies on the relationship between understory plant diversity and soil physicochemical properties.

In this study, 30 community types in the urban forest of Beijing were selected as the research objects. We predict that the soil physical and chemical values of different community types will differ, which will have an effect on plant diversity beneath the forest. As a result, the objectives of this study are as follows: (1) quantify the quantitative characteristics and differences in soil physical and chemical properties of different community types of urban forest in Beijing; (2) evaluate the diversity index differences among different community types in spring, summer, and autumn; and (3) investigate the soil factors that affect the diversity of undergrowth plants. It is expected that this research will provide a scientific foundation for urban forest design and management.

2. Materials and Methods

2.1. Study Sites

Beijing (39°54′20″ N, 116°25′29″ E) is located in Northern China, in the Northern part of the North China Plain, and has an area of 16,410 km^2.The climate is a temperate humid monsoon, and the zonal vegetation type is primarily a warm temperate deciduous broad-leaved forest [31], with an annual precipitation total of approximately 450–680 mm. Beijing's vegetation cover will reach 44% by 2022, with the plain areas where the plain afforestation project is being implemented accounting for approximately 38% of the total area of Beijing (Figure 1).

2.1.1. Sampling Site Selection

Sampling was carried out by a combination of systematic sampling and typical sampling methods, and the urban forest sample plots constructed by the project were evenly distributed in the context of the overall planning of the Beijing Plain Afforestation Project, and 42 sample sites were selected from 12 districts (Table 1). All of the sampling sites were treated with reference to the "Beijing New Million Mu Afforestation and Greening Project Construction Technical Guide" and "Beijing Plain Afforestation Engineering Technology Implementation Rules (revised version)".

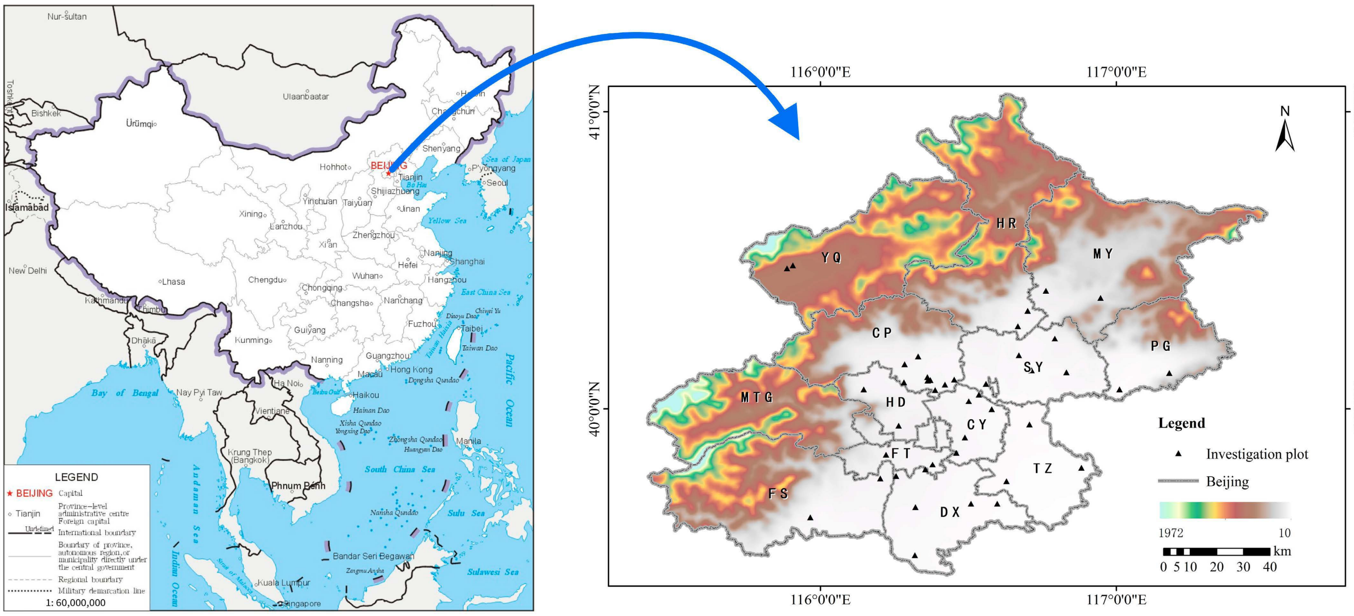


Figure 1. Plain afforestation research plot. HR (Huairou District), YQ (Yanqing District), MY (Miyun District), PG (Pinggu District), CP (Changping District), SY (Shunyi District), HD (Haidian District), CY (Chaoyang District), TZ (Tongzhou District), FS (Fangshan District), FT (Fengtai District), and DX (Daxing District).

Table 1. Basic information about the 42 selected sample sites.

District	Sample Site	Longitude (°N)	Latitude (°W)	District	Sample Site	Longitude (°N)	Latitude (°W)
DX (Daxing)	DX1	39.681165	116.508758	PG (Pinggu)	PG1	40.121068	117.178731
	DX2	39.681206	116.59744		PG2	40.066124	117.010529
	DX3	39.669858	116.321655	MY (Miyun)	MY1	40.397534	116.76196
	DX4	39.507692	116.319536		MY2	40.373566	116.946701
	DX5	39.774158	116.256056	HR (Huairou)	HR1	40.278431	116.667219
FS (Fangshan)	FS1	39.635622	115.966366		HR2	40.330371	116.700131
	FS2	39.76578	116.202661	HD (Haidian)	HD1	40.089601	116.282661
FT (Fengtai)	FT1	39.846551	116.222275		HD2	39.943478	116.264863
	FT2	39.796151	116.355014		HD3	40.06604	116.146538
	FT3	39.852475	116.459305	SY (Shunyi)	SY1	40.129908	116.713629
	FT4	39.812886	116.379154		SY2	40.123078	116.831259
CP (Changping)	CP1	40.095728	116.362866		SY3	40.084625	116.559386
	CP2	40.082261	116.421362		SY4	40.18036	116.670752
	CP3	40.063893	116.388207		SY5	40.23692	116.791866
	CP4	40.098987	116.45221	TZ (Tongzhou)	TZ1	39.801547	116.881987
	CP5	40.097294	116.371731		TZ2	39.756524	116.628646
	CP6	40.176499	116.330578		TZ3	39.947695	116.706227
	CP7	40.150183	116.285046	YQ (Yanqing)	YQ1	40.473383	115.887473
	CP8	40.107098	116.36192		YQ2	40.48354	115.907326
CY (Chaoyang)	CY1	39.904041	116.488239				
	CY2	39.998927	116.578898				
	CY3	40.048159	116.535358				
	CY4	40.026288	116.501034				

2.1.2. Investigation of Understory Plants

A 50 m × 50 m precision grid was used for a uniform distribution of points in 42 set sampling plots, and some sampling points were added and positioned according to the actual situation. The study was conducted twice a year from 2019–2021, once in spring and summer (March–August) and once in autumn (September–November).

The sampling survey referred to the survey method of Jing-Yun Fang [32]. A total of 30 community types and 1189 sampling points with similar stand depression (Table 2) and microtopography were selected for the study to control a single variable, and each sampling point was set up in a 20 m × 20 m sampling square to research the tree layer (Figure 2). The average distribution method was used to set five 1 m × 1 m small sampling squares in the center and four corners of each sample square for herbaceous plants and understory regeneration seedlings, and no separate sample squares were established due to the small number of shrubs (H1–H5 in Figure 2 are herbaceous plant collection sample points). The observation records included information on the survey site: latitude and longitude, elevation, community type; species names, heights, and quantities of shrubs; and species names, average heights, coverages, and abundances of herbs.

Table 2. Community types of the study sample plots (n = 1189).

Type	Name	Abbreviation	Number of Plots
Pure forests	*Betula platyphylla* forests	BPF	40
	Robinia pseudoacacia forests	RPF	39
	Tufted *Acer truncatum* forests	ATCF	22
	Eucommia ulmoides forests	EUF	19
	Platanus acerifolia forests	PAF	34
	Styphnolobium japonicum forests	SJF	43
	Salix matsudana forests	SMF	23
	Robinia pseudoacacia f. *decaisneana* forests	RPDF	45
	Ulmus pumila 'Jinye' forests	UPJF	22
	Koelreuteria paniculata forests	KPF	25
	Populus tomentosa forests	PTMF	31
	Quercus mongolica forests	QMF	19
	Ailanthus altissima 'Qiantou' forests	AAQF	51
	Catalpa bungei forests	CBF	30
	Populus davidiana forests	PDF	16
	Diospyros kaki forests	DKF	12
	Robinia pseudoacacia 'Idaho' forests	RPIF	45
	Fraxinus pennsylvanica forests	FPF	47
	Ginkgo biloba forests	GBF	30
	Ulmus pumila forests	UPF	33
	Acer truncatum forests	ATF	35
	Catalpa ovata forests	COF	41
	Pinus bungeana forests	PBF	60
	Platycladus orientalis forests	POF	36
	Juniperus chinensis forests	JCF	39
	Pinus tabuliformis forests	PTF	78
	Cedrus deodara forests	CDF	35
Deciduous broadleaf mixed forests	Deciduous broadleaf mixed forests	DDMF	102
Broadleaf and coniferous mixed forests	Broadleaf and coniferous mixed forests	BCF	77
Coniferous mixed forests	Coniferous mixed forests	CMF	60

2.1.3. Soil Sample Collection

To prevent the surrounding environments from influencing the study results, the soil profile points were selected at sites far from roads without vegetation damage, recent collapse, or severe ground erosion [33]. The sample sites were collected as referenced in Section 2.1.2, with a total of 1231 sampling points.

Soil samples were collected according to the national forestry standard "Collection and Preparation of Forest Soil Samples" [34]. The study was conducted from June to October 2020, and soil samples were collected at soil depths of 0–20 cm, 20–40 cm, and 40–60 cm, with three replicates of each sample, for a total of 3693 soil samples. The soil samples from the same soil layer were mixed and brought back to the laboratory in bags for the determination of soil physical and chemical properties. During the collection process, three in situ soil samples were taken in each of the three soil layers with a ring knife (5 cm in diameter, 100 cm^3 in volume) to determine the soil water content.

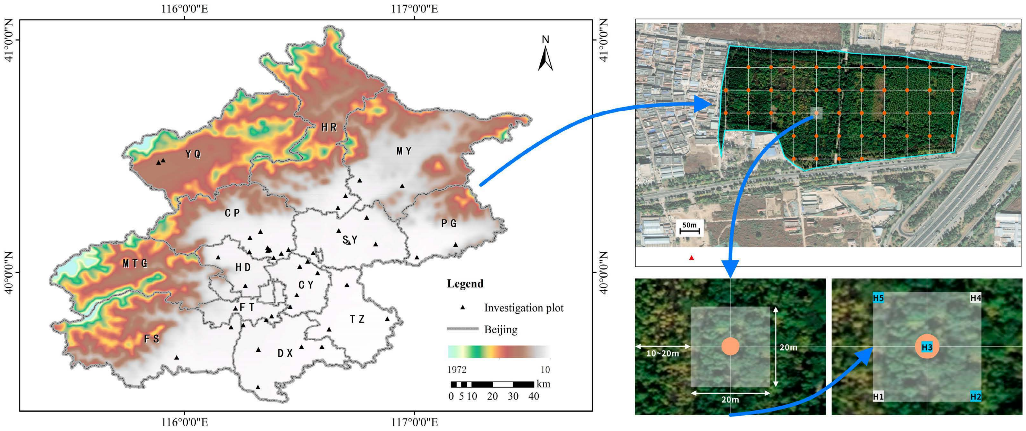


Figure 2. Sample plots for plant and soil collection. Note: In the figure, H1–H5 are the survey sample points for understory plants; H2, H3, and H5 are soil sampling points.

The collected soil samples were transported to the laboratory, debris was removed, and samples were dried naturally. The soil samples were pulverized for 3 min and passed through a nylon sieve. Then, the air-dried soil samples were preserved for analysis.

2.2. Methods for Determining the Physical and Chemical Properties of Soils

Combining the results of previous studies on urban forest soil [35,36], hydrogen ion concentration (pH), soil bulk density (SBD), total soil porosity (TSP), soil water content (SWC), organic carbon (SOC), organic matter (SOM), total nitrogen (TN), total phosphorus (TP), available phosphorous (AP), and available potassium (AK) were selected in this study. The porosity included soil capillary porosity (CP) and noncapillary porosity (NCP).

The pH was determined by a PHSJ-5 laboratory pH meter (Thundermagnetic Instrument Co., Ltd., Shanghai, China). The SBD was determined through the ring knife sampling analysis method [37], and the TSP was determined by a TYC-1 pore pressure measuring instrument. The SWC was determined through the drying method and the neutron deceleration method [38]. The SOC was determined by the potassium dichromate oxidation spectrophotometry method [39]. The SOM was determined by multiplying the SOC result by a conversion factor of 1.724; the TN was determined by the semimicro Kjeldahl method [40]; the TP was determined by the sodium hydroxide fusion-molybdenum antimony anti-colorimetric method [41]; the AP was determined by the Olsen method [42]; and the AK was determined by the 0.5 mol-L^{-1} sodium bicarbonate leaching method [43].

The evaluation criteria for soil physical and chemical properties refer to the classification of the soil census techniques in China [44].

2.3. Calculation Methods of Diversity Correlation Index Data Analysis

Combined with the research data, a statistical analysis of the understory plant species diversity in the Beijing Plain afforestation sample sites was conducted. The calculated indices included the Shannon–Weiner index, Simpson index, Pielou index, and Margalef richness index [45–47].

Shannon–Weiner index (H′):

$$\mathrm{H}' = -\sum_{i=1}^{S} P_i ln p_i (i = 1,\ 2,\ 3,\ \ldots\ldots\ldots,\ S) \tag{1}$$

Simpson index (C):

$$C_{\mathrm{sim}} = 1 - \sum_{i=1}^{s} (p_i)^2 (i = 1, 2, 3, \ldots\ldots\ldots, S) \tag{2}$$

Pielou index (E):

$$E = \frac{H'}{lnS} \tag{3}$$

Maximum richness index (DMG):

$$D_{\mathrm{Ma}} = \frac{S - 1}{lnN} \tag{4}$$

where S is the total number of species, N is the total number of individuals of all species, and P_i is the importance value of species i.

Based on the survey results, the stand types in the current sample plots were classified into 30 community types (Table 2).

2.4. Data Analysis

Correlation analysis was performed after uniformity and normal distribution tests, and the natural logarithm or a trigonometric function was employed for data conversion if the data did not follow a normal distribution. Soil physicochemical parameters and understory plant diversity were compared using one-way analysis of variance (ANOVA) followed by Tukey's HSD ($p < 0.05$) in SPSS 22.0 software (SPSS, Chicago, IL, USA). Mantel test correlation analysis of environmental factors and understory plant diversity was performed in R (v3.2.0). Redundancy analysis (RDA) of the soil physicochemical properties and understory plant diversity was executed using CANOCO 5.0 software (Microcomputer Power, Ithaca, NY, USA). Variance partitioning analysis (VPA) was conducted in R using the "vegan" package to determine the contribution of soil factors to understory plant diversity. The correlation analysis graphs were produced with Origin 2019 (OriginLab Corporation, Northampton, MA, USA).

3. Results

3.1. Soil Physicochemical Property Analysis

The results of the study showed that the pH value of urban forests indicates an alkaline reaction (pH 7.5–8.5). The results showed that the current soil conditions are class 4–5 soils, indicating that the current soils are of poor quality and barren. Some community types have very thin soil layers, with soil-cover depths less than 60 cm.

3.1.1. Soil Physical Property Characteristics

The soil capacitance results of multiple comparative analyses of the physical properties of the soil (Figure 3) showed that the *Robinia pseudoacacia* f. *decaisneana* forest (1.116 ± 0.314 g/cm^3), broadleaf and coniferous forest (1.106 ± 0.245 g/cm^3), and mixed broadleaf forest (1.086 ± 0.237 g/cm^3) had lower soil capacity values and looser soils. In contrast, the *Fraxinus pennsylvanica* forest (2.568 ± 0.593 g/cm^3), *Platycladus orientalis* forest (2.095 ± 0.528 g/cm^3), and *Styphnolobium japonicum* forest (2.034 ± 0.466 g/cm^3) had higher soil capacity values, with compact and poorly structured soils.

In terms of TSP, the mixed broadleaf forests, *Pinus bungeana* forest, and *R. pseudoacacia* f. *decaisneana* forest had higher values of 51.393% ± 3.317%, 50.359% ± 11.516%, and 49.765% ± 9.889%, respectively. The ranking of CP differed from that of TSP but remained the same for all three community types. The comparative analysis of NCP showed that the *Ulmus pumila* 'jinye' forest (3.431% ± 0.602%) had a higher value, but most of the community types did not show significant differences, and the NCP values were lower in the *Salix matsudana* forest (1.390% ± 0.336%), *Populus tomentosa* forest (1.279% ± 0.266%), and *R. pseudoacacia* f. *decaisneana* forest (1.274% ± 0.284%).

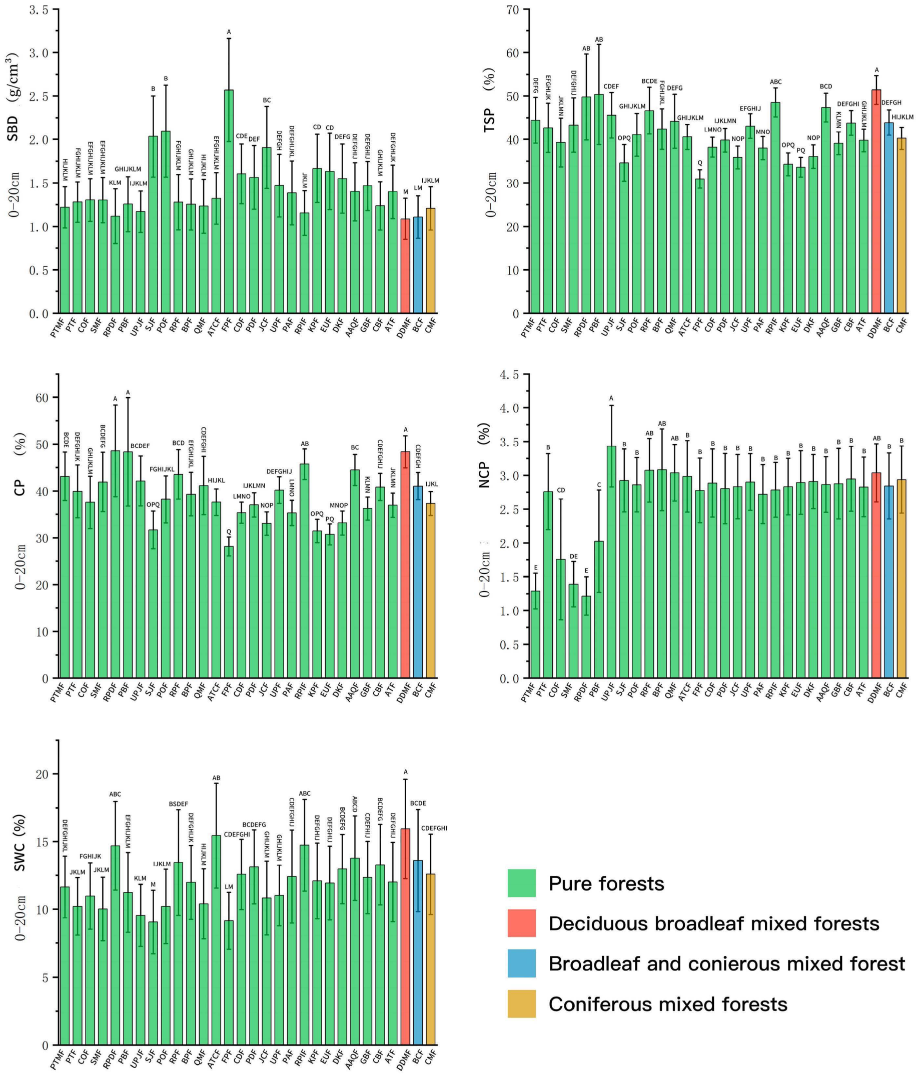


Figure 3. Multiple comparative analyses of the physical properties of soils in different communities. SWC: soil water content; CP: soil capillary porosity; SBD: soil bulk density; TSP: total soil porosity; NCP: noncapillary porosity. Note: Different lowercase letters indicate significant differences in the values of soil chemical properties between different community types ($p < 0.05$). Abbreviations of community names refer to Table 2.

The SWC analysis showed that the broadleaf mixed forest had the highest SWC, which was significantly higher than that of the other community types, with a value of 15.925% ± 3.668%, followed by the tufted *Acer truncatum* forest and the *R. pseudoacacia* 'Idaho' forest, with values of 15.441% ± 3.88% and 14.731% ± 3.39%, respectively. In contrast, the SWC of *Ulmus pumila* 'Jinye' forest (9.547% ± 2.290%), *F. pennsylvanica* forest (9.140% ± 2.107%), and *S. japonicum* forest (9.050% ± 2.347%) was significantly lower than that of the other community types.

3.1.2. SOC and SOM Characteristics

By comparing the SOM and SOC values of different communities, the results (Figure 4) showed that the SOC and SOM contents of the *R. pseudoacacia* f. *decaisneana* forest, mixed broadleaf forest, and *R. pseudoacacia* forest were significantly higher than those of other community types in the 0–20 cm soil layer, with SOC values of 17.163 ± 3.771 $g \cdot kg^{-1}$, 15.479 ± 3.406 $g \cdot kg^{-1}$ and 15.478 ± 1.356 $g \cdot kg^{-1}$, respectively, and SOM values of 29.589 ± 6.50 $g \cdot kg^{-1}$, 26.69 ± 5.87 $g \cdot kg^{-1}$, and 26.68 ± 2.33 $g \cdot kg^{-1}$, respectively. The SOC contents (9.488 ± 0.944 $g \cdot kg^{-1}$, 9.463 ± 2.827 $g \cdot kg^{-1}$, and 9.212 ± 1.359 $g \cdot kg^{-1}$) and

SOM contents (16.358 ± 1.627 g·kg^{-1}, 16.315 ± 4.874 g·kg^{-1}, and 15.880 ± 2.343 g·kg^{-1}) were the lowest among all community types and differed significantly from the numerical contents of other community types (Figure 3).

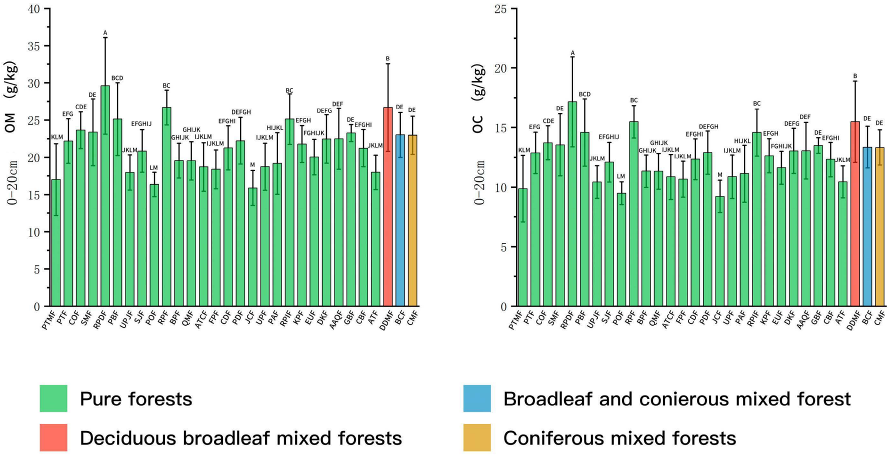


Figure 4. Multiple comparative analyses of soil organic carbon and organic matter in different urban forest communities. OC: organic carbon; OM: organic matter Note: Different lowercase letters indicate significant differences in soil organic matter and organic carbon values between different community types ($p < 0.05$). Abbreviations of community names refer to Table 2.

3.1.3. Soil Chemical Property Characteristics

Significance was correlated and labeled by comparing the soil pH values between community types at different soil depths. The results showed that the pH values of the soils in Beijing urban forests were all alkaline and higher than 7.5. The pH of the *Robinia pseudoacacia* forest (8.825 ± 0.698) was slightly higher than that of the other forest types, while the pH of the *Ulmus pumila* forest (7.275 ± 0.911) was the lowest among all community types.

Broadleaf mixed forests had significantly higher levels of TN (0.884 ± 0.119 g·kg^{-1}), TP (0.908 ± 0.121 g-kg^{-1}), AP (30.634 ± 3.994 mg·kg^{-1}), and AK (115.244 ± 13.053 mg·kg^{-1}) among all communities (Figure 5). The chemical properties of the *R. pseudoacacia* 'Idaho' forest, coniferous mixed forest, and broadleaf and coniferous forest also showed some dominance, while the chemical properties of the *Fraxinus pennsylvanica* forest, *Juniperus chinensis* forest, *Platycladus orientalis* forest, and *Populus tomentosa* forest were significantly lower than those of the other community types and had lower nutrient levels.

3.2. Understory Plant Diversity Characteristics

In the selected urban forest sample sites, a total of 166 species (including varieties/cultivars) in 110 genera belonging to 46 families of understory plants were surveyed and recorded (Appendix A Table A1).

According to the statistical analysis, the Shannon diversity index (H′) of understory plants in most communities was significantly lower in spring and summer than in autumn. For the spring and summer understory plant diversity, H′ was highest (3.13 ± 0.88) in the broadleaf mixed forest, with a significant difference ($p < 0.05$), followed by the *P. bungeana* forest (2.65 ± 0.86) and *R. pseudoacacia* 'Idaho' forest (2.60 ± 0.99) (Figure 6a). The H′ of understory plants in autumn in broadleaf mixed forests (3.63 ± 0.97) was highest ($p < 0.05$), followed by that in *R. pseudoacacia* f. *decaisneana* forest (2.91 ± 0.94), with a fluctuating H′ in autumn, ranking second, and that in *Robinia pseudoacacia* 'Idaho' forest (2.91 ± 0.70), ranking third. The H′ indices of the *Ulmus pumila* 'Jinye' forest and *Platycladus orientalis* forest were higher in spring than in autumn (Figure 6b).

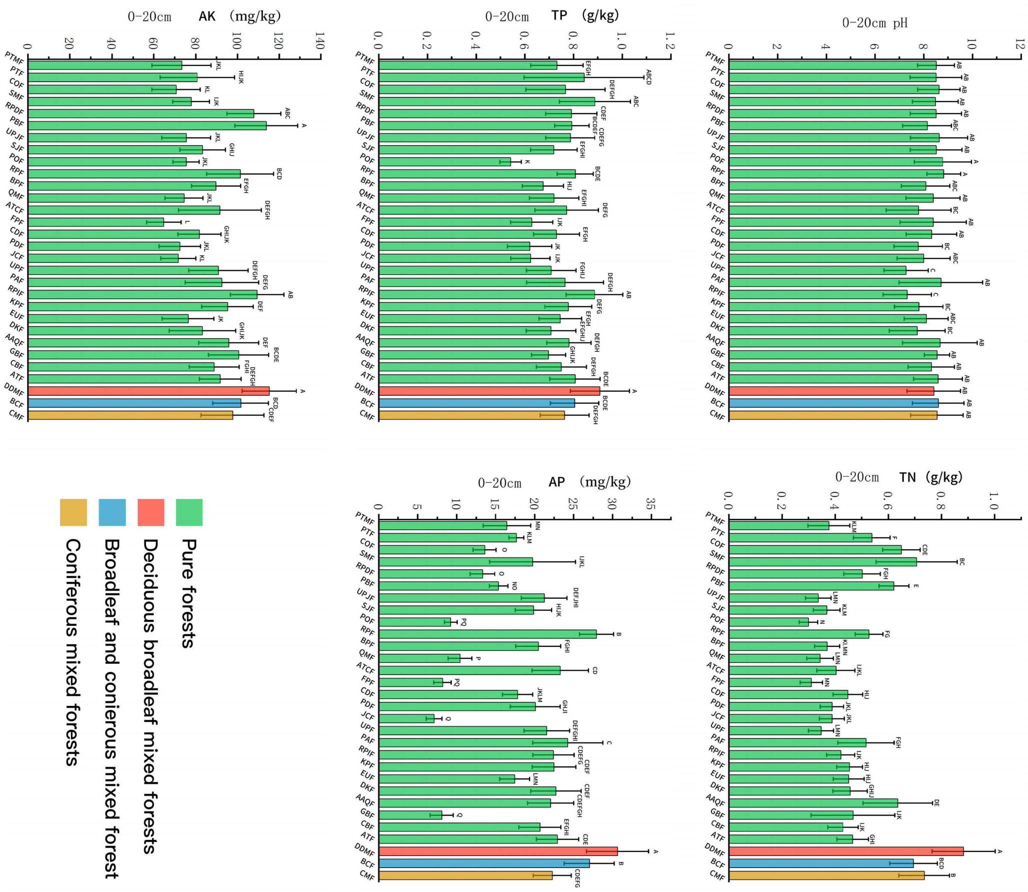
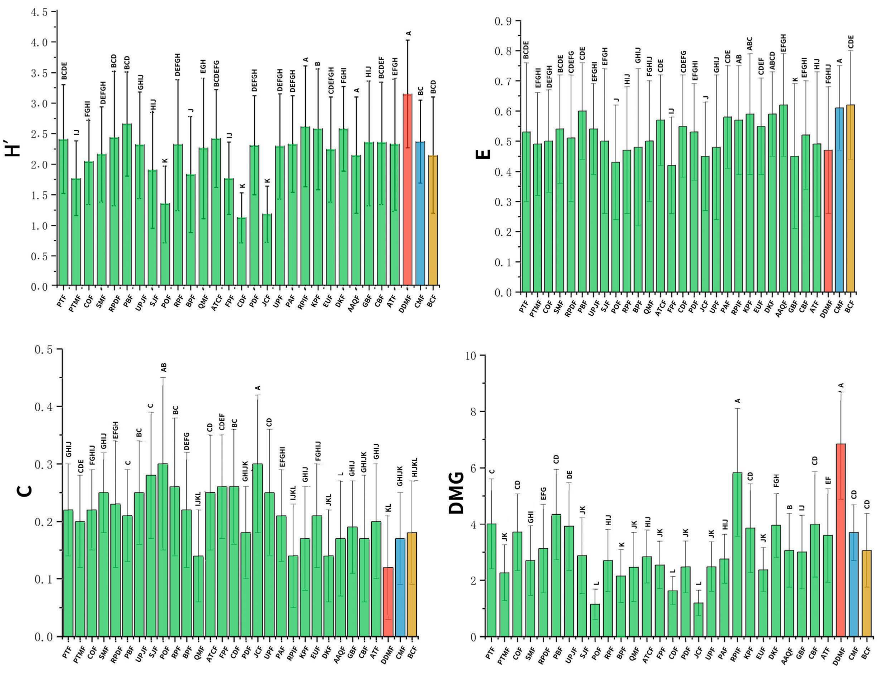


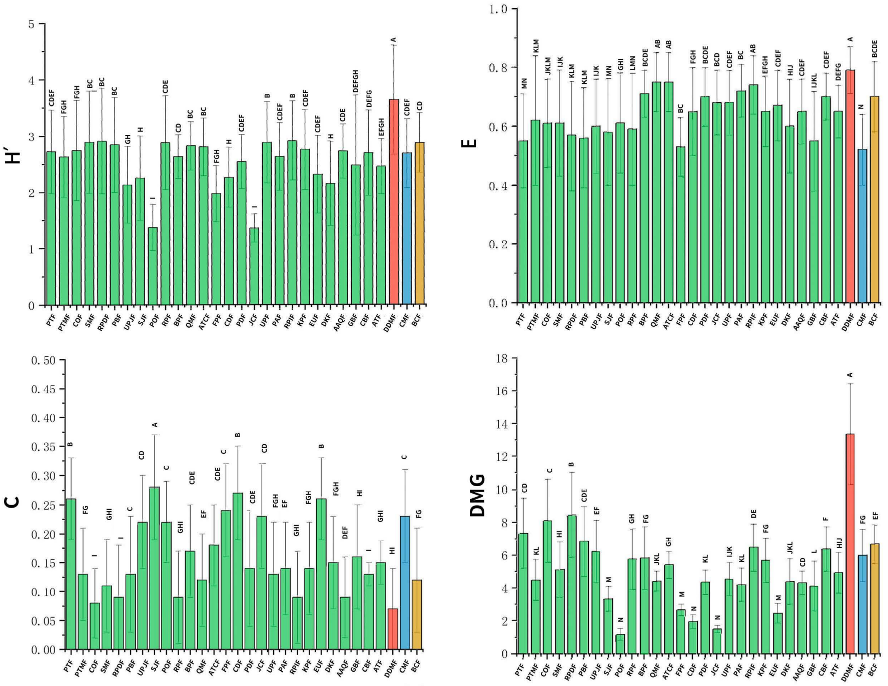
Figure 5. Multiple comparative analyses of soil chemistry in different urban forest communities. pH: hydrogen ion concentration; TN: total nitrogen; TP: total phosphorus; AP: available phosphorous; AK: available potassium. Note: Different lowercase letters indicate significant differences in the values of soil physical properties between different community types ($p < 0.05$). Abbreviations of community names refer to Table 2.

Correlations of the Pielou evenness index (E) of understory plants of different community types showed a high evenness index for understory plants ($p < 0.05$) in spring in broadleaf and coniferous forests (0.62 ± 0.18), followed by the *Ailanthus altissima* 'Qiantou' forest (0.62 ± 0.17), and mixed coniferous forests (0.61 ± 0.14) (Figure 6a). As the number of understory plant species increased, the highest evenness index of the understory plants in autumn was found in the deciduous broadleaf mixed forest (0.79 ± 0.08), *Q. mongolica* forest (0.75 ± 0.10), and tufted *A. truncatum* forest (0.75 ± 0.10) (Figure 6b).

The lowest Simpson dominance index in spring was found in broadleaf mixed forests (0.12 ± 0.09), although the *Diospyros kaki* forest (0.14 ± 0.08) and *Q. mongolica* forest (0.14 ± 0.08) also had low levels, indicating that their understory plants were more evenly distributed and did not have significantly dominant plants (Figure 6a). The plant distribution in the understory of the mixed broadleaf forests (0.07±0.07) remained more uniform in autumn, as did the plant composition of the *R. pseudoacacia* 'Idaho' forest (0.09 ± 0.08), *R. pseudoacacia* forest (0.09 ± 0.08) and *R. pseudoacacia* f. *decaisneana* forest (0.09 ± 0.09) (Figure 6b). The *Cedrus deodara* forest, *Styphnolobium japonicum* forest, *Juniperus chinensis* forest, and *Platycladus orientalis* forest have always had higher Simpson index values due to the small number of plants within these types of tree forests and their uneven distribution. In contrast, the Simpson dominance index was higher in the *P. tabuliformis* forest in autumn due to the absolute dominance of dogwood in the oleander forest in autumn, which resulted in a higher diversity index.



(a) Spring and summer



(b) Autumn

🟩 Pure forests 🟦 Broadleaf and conierous mixed forest

🟥 Deciduous broadleaf mixed forests 🟨 Coniferous mixed forests

Figure 6. Plant diversity characteristics of different community types in Beijing urban forests ((**a**) spring and summer; (**b**) autumn). H′: Shannon–Weiner index; C: Simpson index; E: Pielou index; DMG: Margalef richness index. Note: Different lowercase letters indicate significant differences in the diversity values of different community types ($p < 0.05$). Abbreviations of community names refer to Table 2.

Analysis of the Margalef richness index showed that the understory of the mixed broadleaf forest was the most abundant in both seasons and significantly ($p < 0.05$) higher than that of the other community types, with values of 6.84 ± 1.96 and 13.35 ± 3.08, respectively. This was followed by the *R. pseudoacacia* 'Idaho' forest > *R. pseudoacacia* f. *decaisneana* forest > *P. bungeana* forest > mixed conifer forest, which all had rich understories (Figure 6). The abundances of the community types, such as *Juniperus chinensis* forest, *P. orientalis* forest, *C. deodara* forest, and *Eucommia ulmoides* forest, were all lower and showed a decreasing trend with seasonal changes.

3.3. Correlations of Understory Plant Diversity with Soil

3.3.1. Correlations between Soil and Plant Diversity in Spring and Summer

Based on the correlation analysis of understory plant diversity with soil factors, all soil factors, except pH, had significant effects on understory plant diversity ($p < 0.05$). RDA was employed to determine the relationship between understory plant diversity and soil physicochemical parameters. The results showed that the contribution rates of eigenvalues on the RDA1 and RDA2 axes reached 36.5% and 2.77%, respectively (Figure 7a). Mantel test analysis showed that SOM and SOC were the key drivers of understory plant diversity (Figure 7b). The Shannon—Wiener index (H′) showed significant positive correlations with SOM, SOC, TP, AP, AK, and TSP ($p < 0.05$) and negative correlations with SBD ($p < 0.05$); the Pielou index (E) showed a significant positive correlation with SOM, SOC, TP, AP, and AK ($p < 0.05$); the Simpson index (C) had a significant negative correlation with SOM, SOC, TP, AP, and AK ($p < 0.05$); and the Margalef richness index (DMG) showed significant positive correlations with SOM, SOC, TP, AP, AK, and TSP ($p < 0.05$). SOC and SOM showed a correlation coefficient of 0.72 ** ($p < 0.01$) with the Shannon—Wiener index (H′); 0.48 ** and 0.49 ** ($p < 0.01$) with the Pielou index (E); and −0.53 ** ($p < 0.01$) with the Simpson index (C). The correlation coefficient was −0.53 **; the correlation coefficient for the Margalef richness index (DMG) was 0.73 ** ($p < 0.01$), which was the highest value (Figure 7c).

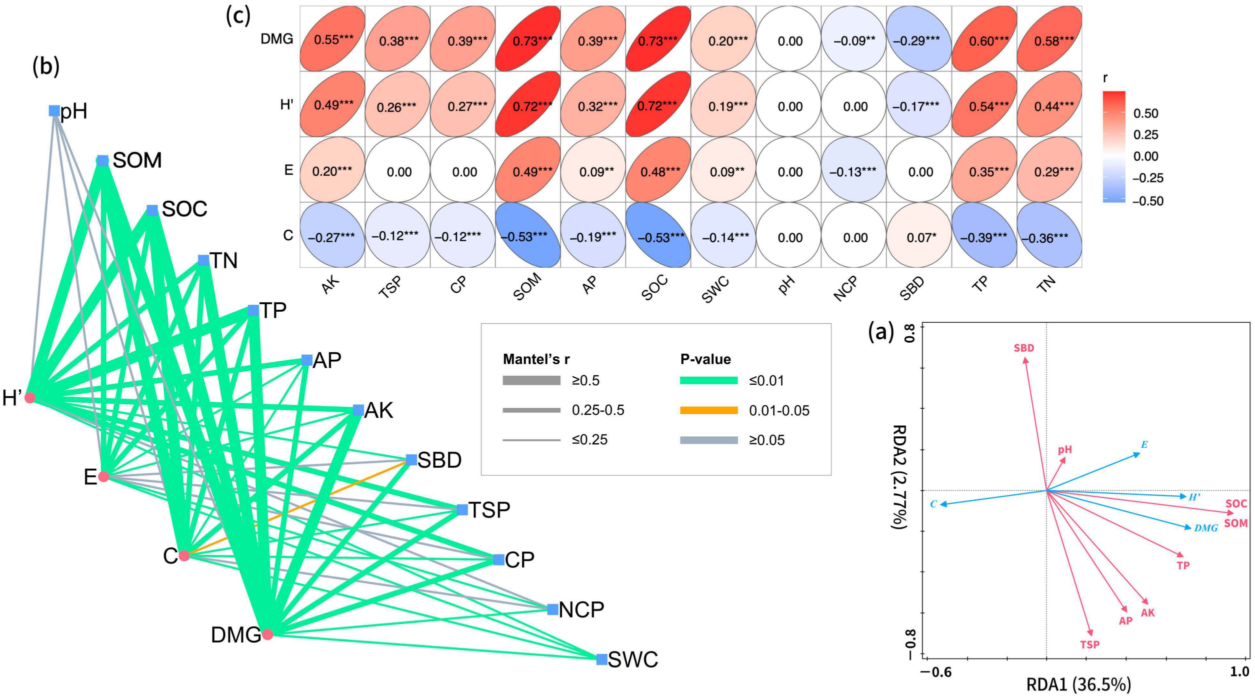


Figure 7. Plant community diversity index (spring and summer) and RDA ordination map of soil environmental factors. (**a**) Redundancy analysis (RDA) on soil factors and understory plant diversity; (**b**) correlation between diversity index of understory plants and soil factors in spring and summer; (**c**) correlation coefficient between understory plant diversity index and soil factors in spring and summer. Note: * correlation significant at 0.01–0.05 level. ** correlation significant at 0.01–0.001 level. *** correlation significant at <0.001 level.

VPA was used to analyze the comprehensive contribution of soil physicochemical parameters to the understory plant diversity (Figure 8). Based on the results, the SOM had a high interpretation rate of 36.6%, while the TP, TSP, AK, SBD, SOC, AP, and pH each explained 10.1%, 6.1%, 3.6%, 2.4%, 1.3%, 0.9%, and 0.6%, respectively.

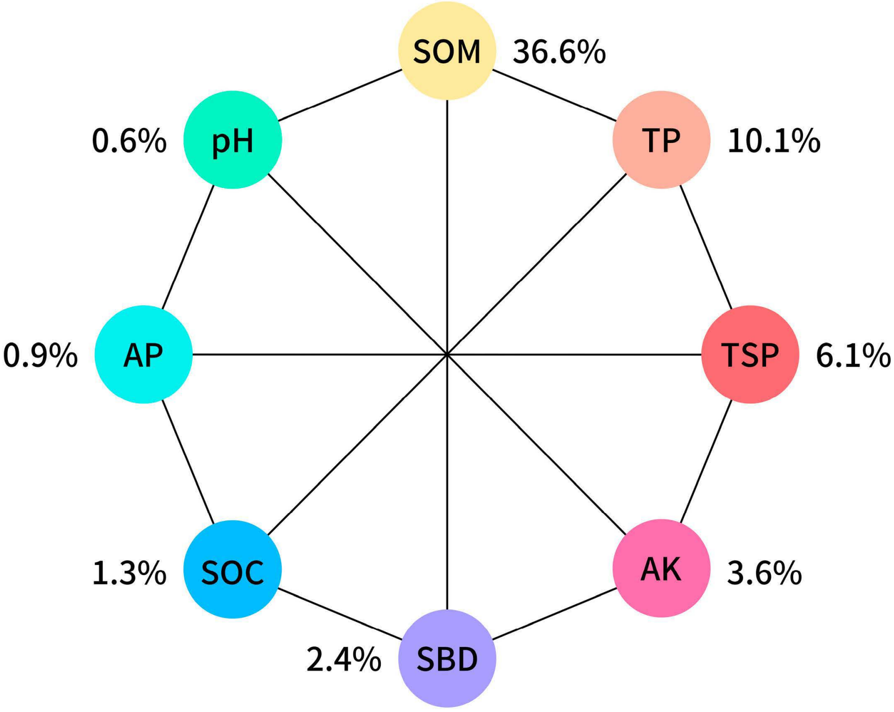


Figure 8. Variance partitioning analysis (VPA) showing the effects of soil factors on understory plant diversity in spring and summer.

3.3.2. Correlations between Soil and Plant Diversity in Autumn

The correlation between understory plant diversity and soil factors in autumn was similar to that in spring. The results of RDA showed that the contribution rate of eigenvalues on the RDA1 and RDA2 axes reached 50.2% and 6.8%, respectively (Figure 9a). Mantel test analysis showed that SOM and SOC were key drivers of the understory plant diversity that remained in autumn (Figure 9b). The Shannon—Wiener index (H′) had significant positive correlations ($p < 0.05$) with SOM, SOC, TN, TP, AP, and CP and negative correlations ($p < 0.01$) with SBD and NCP. The Pielou index (E) had a significant positive correlation ($p < 0.05$) with SOM, SOC, TN, TP, AP, and CP. The Simpson index (C) showed a significant negative correlation ($p < 0.05$) with SOM, SOC, TN, TP, AP, SBD, and CP. The Margalef richness index (DMG) had a significant positive correlation ($p < 0.05$) with SOM, SOC, TN, TP, AP, and CP and a significant negative correlation ($p < 0.05$) with SBD and NCP. The highest correlation coefficients were found for SOC and SOM, where the correlation impact coefficients were 0.74** and 0.75** for the Shannon—Wiener index (H′) ($p < 0.01$); 0.38** and 0.39** for the Pielou index (E) ($p < 0.01$); the correlation coefficient effect on the Simpson index (C) was −0.36**; and the correlation coefficient effect on the Margalef richness index (DMG) was 0.66** ($p < 0.01$) and 0.67** (Figure 9c).

The results of the VPA-based analysis showed that SOM still had the highest explanation rate of 49.9%, and the influence of soil physicochemical parameters on understory plant diversity decreased in the following order: SOM > SBD > TP > CP > AP > NCP > TN > SOC (Figure 10).

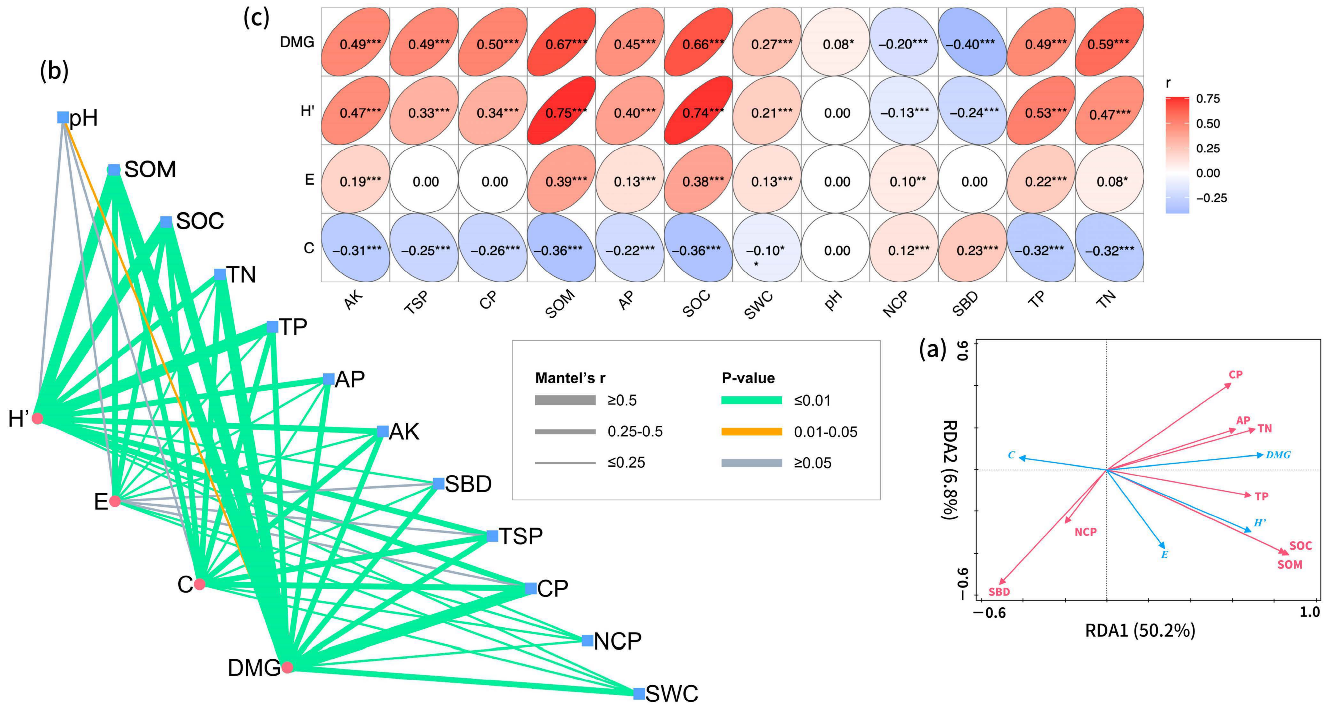


Figure 9. Plant community diversity index (autumn) and RDA ordination map of soil environmental factors. (**a**) Redundancy analysis (RDA) on soil factors and understory plant diversity; (**b**) correlation between diversity index of understory plants and soil factors in autumn; (**c**) correlation coefficient between understory plant diversity index and soil factors in autumn. Note: * correlation significant at 0.01–0.05 level. ** correlation significant at 0.01–0.001 level. *** correlation significant at <0.001 level.

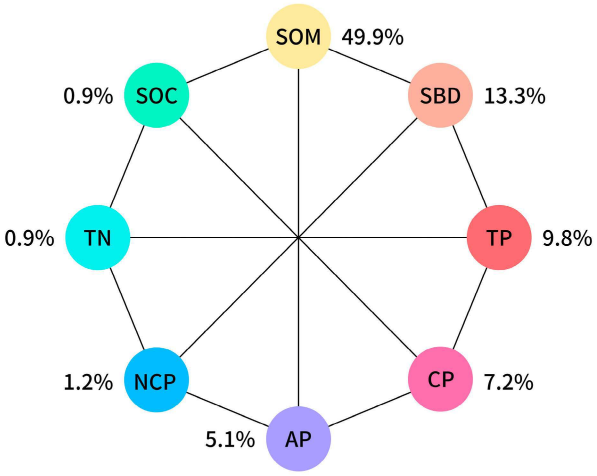


Figure 10. Variance partitioning analysis (VPA) showing the effects of soil factors on understory plant diversity in autumn.

4. Discussion

4.1. Diversity of Understory Plants in Different Communities

The community species diversity index is one of the most direct characteristics of the structure of a community [48]. Studies have shown that the complexity of mixed forests is significantly and positively correlated with the diversity index, and mixed forests are superior to pure forests in improving stand structure and increasing stand habitat heterogeneity and stand stability [3]. Conversely, factors such as plantation type (silvicultural species) and stand composition (pure or mixed forest) may have positive or negative effects on understory species diversity due to the overly subjective selection of tree species in plantations [49]. This may be one of the reasons for the significant variability in understory plant diversity across community types.

The study found that under the same steric conditions, the understory plant diversity indices of both broad-leaved mixed forests and coniferous mixed forests showed higher levels and exhibited some advantages. The mixed forests created different tree levels, which created a suitable environment for the growth of other understory plants and increased the level of understory plant diversity [50]. In this study, the species diversity of understory plants was comprehensively measured using the Shannon–Weiner index (H′), Simpson index (C), Pielou index (E), and Margalef species richness index (DMG) (Figures 7 and 8). Similar to the results of previous studies, the diversity indices of broad-leaved mixed forests showed high levels and exhibited certain advantages [51]. This result indicates that the understory species in mixed broad-leaved forests are more abundant and more evenly distributed than those in other communities. In addition, there are some urban forest groups in which the undergrowth plants have no obvious seasonal changes (such as lateral Berlin and cedar forests). They have a higher Simpson (C) index and a lower Margalef richness index (DMG), which may be related to the canopy density of forest stands, and related studies can be conducted subsequently. Based on the above findings, community creation and maintenance of urban forests should also focus on creating complex mixed communities to maintain a high level of understory plant diversity.

4.2. Effect of Different Community Types on Soil Physicochemical Properties

In this study, except for soil pH, there were significant differences ($p < 0.05$) in soil physicochemical indicators among community types, which indicates that community type differences could have a significant effect on soil physicochemical properties. Differences in the physical and chemical properties of soils are important factors influencing the structure of plant communities, and plants of different types of communities directly or indirectly affect soil physicochemical properties through long-term succession due to growth activities and decomposition of plant litter [52,53]. The soil beneath conifers is more acidic than the soil beneath broad-leaved species under the same environmental conditions, according to previous studies [54]. This difference is due to the high content of organic acids produced by conifer litter during the decomposition process. However, this study differs from previous studies, and the soil nutrient statuses of the broad-leaved plant community were better than those of the coniferous plant community. This difference may be because the litter decomposition of broad-leaved tree species is usually stronger than that of coniferous species, and this attribute is more conducive to soil nutrient accumulation. In addition, the soil bulk density and water content have a large range of numerical fluctuations between different communities, and some communities have serious soil compaction (such as *F. pennsylvanica* forests), which may be related to the allelopathy of some arbor species; these topics require additional consideration in follow-up research.

Although Beijing has continued to carry out afforestation projects since 2012, compared with a previous study [55], the physical and chemical values of the Beijing urban forest had a downward trend with growth each year, which indicates that the soil nutrients of the community have not been supplemented in time, and weed cleaning too frequently may lead to the soil nutrient loss of willows, which may indicate that the management measures taken in the forest area need to be improved. In addition, this study found that the SOM content in the urban forest soil in the Beijing urban forest had a downward trend, which would affect the soil fertility, soil structure, water retention, and nutrient content. This result may be related to the current unreasonable maintenance management mode.

4.3. Relationship between Soil Factors and Understory Plant Diversity

Some research results suggest that soil organic matter (SOM) is positively correlated with plant diversity, and an increase in plant species diversity enhances the function of the soil ecosystem [56]. However, some research results have shown that SOM is negatively correlated with plant diversity [57]. It is believed that high soil nutrient levels lead to increased attacks by plant pathogens, which negatively affect plant survival and then lead to decreased plant diversity [58]. In this study, soil organic matter (SOM) and organic carbon (SOC) were the main soil factors influencing understory plant diversity, which is also consistent with the results of previous studies. SOM (soil organic matter) is a key indicator of soil quality [25]. It affects soil nutrient availability as an energy material for microbial activities [51]. However, according to the classification criteria of China's second soil census, the soils in the current study area are classes III and IV, indicating that the current soil nutrient content is low, which could be due to frequent weed removal.

The N, P, and K counts in the soil were the most important factors influencing species composition in the area, while the nutrient distribution characteristics explained the distribution characteristics of herbaceous plants and shrubs to some extent [58]. Plant diversity and species turnover increased with forest succession, and both altered the availability of soil N and P. High plant diversity can both improve soil N and P availability as a result of increased productivity, altered litter quantity and quality, and changed soil physical and chemical properties (i.e., SOC) [59]. In this study, total nitrogen (TN), total phosphorus (TP), and effective phosphorus (AK) were important soil factors influencing understory plant diversity indirectly by regulating soil properties, which is also consistent with the results of previous studies [60,61]. Furthermore, some environmental variables were not explained in this study, indicating that community distribution was influenced by other factors (such as stand factors, biotic interaction factors, disturbance factors, and stochastic factors) [62], and additional research is needed to investigate the relationship between other environmental variables and understory plant diversity. However, the effects of other soil microorganism-caused factors on understory diversity were not considered in this study. This is a shortcoming of this study, and the influence of these factors on understory diversity should be further studied in the future.

4.4. Implications for Future Urban Forest Design

According to this study, in the process of urban forest conservation, attention should be given to regulating and improving soil nutrients and retaining deadfall within the forest floor to increase SOM content, thereby providing a good supply of nutrients for the growth of understory plants and thus enhancing the diversity level of understory plants. As the diversity level of understory plants increases, deadfall can effectively increase soil nutrient content and improve soil physicochemical properties, thus forming a benign ecological cycle between soil and understory plants.

As a component of urban forest ecosystems, soil not only affects plant diversity at the community scale but also plant growth at the regional scale. Related studies have shown that it is very important to evaluate soil physical and chemical properties, nutrients, SOM loss, pollution, biodiversity, etc., within a certain temporal interval [22]. The dynamic stability of an ecosystem is maintained by the synergistic mechanism between vegetation and soil [63]. For the maintenance and subsequent creation of urban forests in Beijing, it is necessary to coordinate the interrelationship between community species growth and soil fertility, focus on the combination and matching of tree species, and appropriately intervene with anthropogenic measures for timely nutrient replenishment to establish a dynamic and balanced urban forest community.

5. Conclusions

This study revealed the influence of soil physicochemical properties on understory plant diversity in different community types. Our results showed that the Shannon—Wiener index, Pielou index, Simpson index, and Margalef richness index of the mixed deciduous broad-leaved forest were significantly ($p < 0.05$) higher than those of the other community types. Except for soil pH, all other soil physicochemical indicators were significantly different, with mixed deciduous broad-leaved forests having better soil physicochemical properties than the other community types.

The results showed that soil organic matter (SOM) was significantly positively correlated with the diversity of understory plants and was the most important factor affecting the diversity of understory plants. The comprehensive contribution rate of SOM to the diversity of understory plants in spring was 36.3%, and the comprehensive contribution rate to the diversity of understory plants in autumn was 49.9%, according to VPA results. The soil total nitrogen (TN), total phosphorus (TP), and effective phosphorus (AK) also have an impact. To maintain the stability of understory plant diversity in urban forests, designing communities of mixed forest types and forming a good synergistic effect with soils should be the focal points of future urban forest communities.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. List of understory plants.

No.	Family	Genus	Latin Scientific Name	Type
1	Cornaceae	*Cornus*	*Cornus alba*	Shrub
2	Tamaricaceae	*Tamarix*	*Tamarix chinensis*	Shrub
3	Rutaceae	*Zanthoxulum*	*Zanthoxylum simulans*	Shrub
4	Ebnaceae	*Diospyros*	*Diospyros lotus*	Shrub
5	Solanaceae	*Lycium*	*Lycium chinense*	Shrub
6	Oleaceae	*Forsythia*	*Forsythia suspensa*	Shrub
7	Oleaceae	*Syringa*	*Syringa oblata*	Shrub
8	Fabaceae	*Cercis*	*Cercis chinensis*	Shrub
9	Rosaceae	*Amygdalus*	*Amygdalus triloba*	Shrub
10	Rosaceae	*Sorbaria*	*Sorbaria sorbifolia*	Shrub
11	Rosaceae	*Kerria*	*Kerria japonica*	Shrub
12	Rosaceae	*Kerria*	*Kerria japonica* f. *pleniflora*	Shrub
13	Lythraceae	*Lagerstroemia*	*Lagerstroemia indica*	Shrub
14	Cupressaceae	*Juniperus*	*Juniperus sabina*	Evergreen Shrub
15	Buxaceae	*Buxus*	*Buxus megistophylla*	Evergreen Shrub
16	Cupressaceae	*Juniperus*	*Juniperus procumbens*	Evergreen Shrub
17	Asteraceae	*Artemisia*	*Artemisia argyi*	Herb
18	Amaranthaceae	*Amaranthus*	*Amaranthus blitum*	Herb
19	Poaceae	*Imperata*	*Imperata cylindrica*	Herb
20	Poaceae	*Echinochloa*	*Echinochloa crus-galli*	Herb
21	Boraginaceae	*Bothriospermum*	*Bothriospermum chinense*	Herb
22	Polygonaceae	*Polygonum*	*Polygonum aviculare*	Herb
23	Asteraceae	*Xanthium*	*Xanthium strumarium*	Herb
24	Fabaceae	*Melilotus*	*Melilotus officinalis*	Herb
25	Rosaceae	*Potentilla*	*Potentilla supina*	Herb
26	Plantaginaceae	*Plantago*	*Plantago asiatica*	Herb

Table A1. *Cont.*

No.	Family	Genus	Latin Scientific Name	Type
27	Asteraceae	*Lactuca*	*Lactuca indica*	Herb
28	Alismataceae	*Sagittaria*	*Sagittaria trifolia* subsp. *leucopetala*	Herb
29	Convolvulaceae	*Calystegia*	*Calystegia hederacea*	Herb
30	Poaceae	*Setaria*	*Setaria faberi*	Herb
31	Asteraceae	*Cirsium*	*Cirsium japonicum*	Herb
32	Asteraceae	*Artemisia*	*Artemisia sieversiana*	Herb
33	Chenopodiaceae	*Kochia*	*Kochia scoparia*	Herb
34	Orobanchaceae	*Rehmannia*	*Rehmannia glutinosa*	Herb
35	Euphorbiaceae	*Euphorbia*	*Euphorbia humifusa*	Herb
36	Apocynaceae	*Cynanchum*	*Cynanchum thesioides*	Herb
37	Rosaceae	*Sanguisorba*	*Sanguisorba officinalis*	Herb
38	Brassicaceae	*Lepidium*	*Lepidium apetalum*	Herb
39	Apocynaceae	*Cynanchum*	*Cynanchum chinense*	Herb
40	Brassicaceae	*Orychophragmus*	*Orychophragmus violaceus*	Herb
41	Caryophyllaceae	*Stellaria*	*Stellaria media*	Herb
42	Amaranthaceae	*Amaranthus*	*Amaranthus retroflexus*	Herb
43	Araceae	*Lemna*	*Lemna minor*	Herb
44	Boraginaceae	*Trigonotis*	*Trigonotis peduncularis*	Herb
45	Poaceae	*Setaria*	*Setaria viridis*	Herb
46	Poaceae	*Cynodon*	*Cynodon dactylon*	Herb
47	Brassicaceae	*Rorippa*	*Rorippa indica*	Herb
48	Poaceae	*Chloris*	*Chloris virgata*	Herb
49	Asteraceae	*Artemisia*	*Artemisia annua*	Herb
50	Amaranthaceae	*Chenopodium*	*Chenopodium glaucum*	Herb
51	Fabaceae	*Kummerowia*	*Kummerowia striata*	Herb
52	Zygophyllaceae	*Tribulus*	*Tribulus terrestris*	Herb
53	Solanaceae	*Nicandra*	*Nicandra physalodes*	Herb
54	Asteraceae	*Crepidiastrum*	*Crepidiastrum sonchifolium*	Herb
55	Poaceae	*Setaria*	*Setaria pumila*	Herb
56	Asteraceae	*Helianthus*	*Helianthus tuberosus*	Herb
57	Asteraceae	*Sonchus*	*Sonchus brachyotus*	Herb
58	Fabaceae	*Glycine*	*Glycine soja*	Herb
59	Papaveraceae	*Corydalis*	*Corydalis pallida*	Herb
60	Geraniaceae	*Geranium*	*Geranium wilfordii*	Herb
61	Amaranthaceae	*Chenopodium*	*Chenopodium album*	Herb
62	Polygonaceae	*Polygonum*	*Polygonum persicaria*	Herb
63	Convolvulaceae	*Ipomoea*	*Ipomoea nil*	Herb
64	Asteraceae	*Senecio*	*Senecio nemorensis*	Herb
65	Solanaceae	*Solanum*	*Solanum nigrum*	Herb
66	Poaceae	*Phragmites*	*Phragmites australis*	Herb
67	Apocynaceae	*Apocynum*	*Apocynum venetum*	Herb
68	Apocynaceae	*Metaplexis*	*Metaplexis japonica*	Herb
69	Cannabaceae	*Humulus*	*Humulus scandens*	Herb
70	Portulacaceae	*Portulaca*	*Portulaca oleracea*	Herb
71	Iridaceae	*Iris*	*Iris lactea*	Herb
72	Poaceae	*Digitaria*	*Digitaria sanguinalis*	Herb
73	Solanaceae	*Datura*	*Datura stramonium*	Herb
74	Fabaceae	*Gueldenstaedtia*	*Gueldenstaedtia verna*	Herb
75	Asteraceae	*Artemisia*	*Artemisia japonica*	Herb
76	Fabaceae	*Medicago*	*Medicago sativa*	Herb
77	Cucurbitaceae	*Cucurbita*	*Cucurbita moschata*	Herb
78	Asteraceae	*Hemisteptia*	*Hemisteptia lyrata*	Herb
79	Poaceae	*Eleusine*	*Eleusine indica*	Herb
80	Asteraceae	*Artemisia*	*Artemisia dubia*	Herb
81	Poaceae	*Elymus*	*Elymus dahuricus*	Herb
82	Plantaginaceae	*Plantago*	*Plantago depressa*	Herb
83	Asteraceae	*Taraxacum*	*Taraxacum mongolicum*	Herb
84	Asteraceae	*Artemisia*	*Artemisia igniaria*	Herb

Table A1. *Cont.*

No.	Family	Genus	Latin Scientific Name	Type
85	Brassicaceae	*Capsella*	*Capsella bursa-pastoris*	Herb
86	Rubiaceaea	*Rubia*	*Rubia cordifolia*	Herb
87	Malvaceae	*Abutilon*	*Abutilon theophrasti*	Herb
88	Asteraceae	*Lactuca*	*Lactuca tatarica*	Herb
89	Convolvulaceae	*Ipomoea*	*Ipomoea triloba*	Herb
90	Asteraceae	*Ambrosia*	*Ambrosia trifida*	Herb
91	Crassulaceae	*Phedimus*	*Phedimus aizoon*	Herb
92	Asteraceae	*Bidens*	*Bidens pilosa*	Herb
93	Boraginaceae	*Tournefortia*	*Tournefortia sibirica*	Herb
94	Papaveraceae	*Chelidonium*	*Chelidonium majus*	Herb
95	Rosaceae	*Duchesnea*	*Duchesnea indica*	Herb
96	Polygonaceae	*Rumex*	*Rumex japonicus*	Herb
97	Fabaceae	*Vicia*	*Vicia unijuga*	Herb
98	Convolvulaceae	*Convolvulus*	*Convolvulus arvensis*	Herb
99	Euphorbiaceae	*Acalypha*	*Acalypha australis*	Herb
100	Mazaceae	*Mazus*	*Mazus pumilus*	Herb
101	Rosaceae	*Potentilla*	*Potentilla chinensis*	Herb
102	Lamiaceae	*Leonurus*	*Leonurus sibiricus*	Herb
103	Lamiaceae	*Lagopsis*	*Lagopsis supina*	Herb
104	Lamiaceae	*Elsholtzia*	*Elsholtzia ciliata*	Herb
105	Asteraceae	*Helianthus*	*Helianthus annuus*	Herb
106	Poaceae	*Eragrostis*	*Eragrostis minor*	Herb
107	Asteraceae	*Cirsium*	*Cirsium arvense* var. *integrifolium*	Herb
108	Amaranthaceae	*Chenopodium*	*Chenopodium ficifolium*	Herb
109	Asteraceae	*Erigeron*	*Erigeron canadensis*	Herb
110	Asteraceae	*Inula*	*Inula japonica*	Herb
111	Commelinaceae	*Commelina*	*Commelina communis*	Herb
112	Lamiaceae	*Leonurus*	*Leonurus japonicus*	Herb
113	Asteraceae	*Artemisia*	*Artemisia capillaris*	Herb
114	Poaceae	*Zea*	*Zea mays*	Herb
115	Convolvulaceae	*Ipomoea*	*Ipomoea purpurea*	Herb
116	Violaceae	*Viola*	*Viola prionantha*	Herb
117	Brassicaceae	*Eruca*	*Eruca vesicaria* subsp. *sativa*	Herb
118	Asteraceae	*Ixeris*	*Ixeris chinensis*	Herb
119	Amaranthaceae	*Salsola*	*Salsola collina*	Herb
120	Asteraceae	*Artemisia*	*Artemisia scoparia*	Herb
121	Violaceae	*Viola*	*Viola philippica*	Herb
122	Fabaceae	*Medicago*	*Medicago lupulina*	Herb
123	Lamiaceae	*Perilla*	*Perilla frutescens*	Herb
124	Oxalidaceae	*Oxalis*	*Oxalis corniculata*	Herb
125	Brassicaceae	*Descurainia*	*Descurainia sophia*	Herb
126	Poaceae	*Eragrostis*	*Eragrostis pilosa*	Herb
127	Asteraceae	*Carduus*	*Carduus nutans*	Herb
128	Asteraceae	*Aster*	*Aster tataricus*	Herb
129	Asteraceae	*Aster*	*Aster altaicus*	Herb
130	Euphorbiaceae	*Euphorbia*	*Euphorbia esula*	Herb
131	Primulaceae	*Androsace*	*Androsace umbellata*	Herb
132	Asteraceae	*Youngia*	*Youngia japonica*	Herb
133	Brassicaceae	*Rorippa*	*Rorippa palustris*	Herb
134	Amaranthaceae	*Achyranthes*	*Achyranthes bidentata*	Herb
135	Asteraceae	*Artemisia*	*Artemisia caruifolia*	Herb
136	Urticaceae	*Urtica*	*Urtica angustifolia*	Herb
137	Fabaceae	*Vicia*	*Vicia sepium*	Herb
138	Poaceae	*Poa*	*Poa annua*	Herb
139	Papaveraceae	*Corydalis*	*Corydalis bungeana*	Herb
140	Poaceae	*Cleistogenes*	*Cleistogenes hancei*	Herb
141	Cyperaceae	*Carex*	*Carex breviculmis*	Herb
142	Menispermaceae	*Menispermum*	*Menispermum dauricum*	Herb

Table A1. *Cont.*

No.	Family	Genus	Latin Scientific Name	Type
143	Fabaceae	*Amphicarpaea*	*Amphicarpaea edgeworthii*	Herb
144	Fabaceae	*Trifolium*	*Trifolium repens*	Herb
145	Asteraceae	*Artemisia*	*Artemisia selengensis*	Herb
146	Asteraceae	*Artemisia*	*Artemisia desertorum*	Herb
147	Asteraceae	*Artemisia*	*Artemisia mongolica*	Herb
148	Amaranthaceae	*Amaranthus*	*Amaranthus spinosus*	Herb
149	Amaranthaceae	*Amaranthus*	*Amaranthus viridis*	Herb
150	Fabaceae	*Melilotus*	*Melilotus albus*	Herb
151	Euphorbiaceae	*Euphorbia*	*Euphorbia maculata*	Herb
152	Euphorbiaceae	*Euphorbia*	*Euphorbia hypericifolia*	Herb
153	Equisetaceae	*Equisetum*	*Equisetum arvense*	Herb
154	Euphorbiaceae	*Euphorbia*	*Euphorbia dentata*	Herb
155	Asteraceae	*Ambrosia*	*Ambrosia artemisiifolia*	Herb
156	Asteraceae	*Erigeron*	*Erigeron annuus*	Herb
157	Asteraceae	*Xanthium*	*Xanthium spinosum*	Herb
158	Rubiaceaea	*Paederia*	*Paederia foetida*	Herb
159	Amaranthaceae	*Alternanthera*	*Alternanthera sessilis*	Herb
160	Brassicaceae	*Lepidium*	*Lepidium densiflorum*	Herb
161	Papaveraceae	*Corydalis*	*Corydalis yanhusuo*	Herb
162	Cyperaceae	*Carex*	*Carex giraldiana*	Herb
163	Asteraceae	*Echinacea*	*Echinacea purpurea*	Herb
164	Asteraceae	*Gaillardia*	*Gaillardia aristata*	Herb
165	Asteraceae	*Coreopsis*	*Coreopsis lanceolata*	Herb
166	Asteraceae	*Artemisia*	*Artemisia anethifolia*	Herb

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