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A Preliminary Vegetation-Ecological Study of *Davidia involucrata* Forest

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Abstract

***Davidia involucrata* is a rare endangered species belonging to the paleo-tropical flora of the Tertiary period, endemic to China, and has an important protection and ornamental value. However, the natural populations and distribution areas of this ancient plant have been decreased sharply, because it suffers much disturbance from human activity in many regions. In this paper, data on *Davidia involucrata* forest in its most natural distribution areas were collected; the percentages of geographical areal types of seed-plant genera (Sensu Wu 1991) were summed; the community types were summarized using Braun-Blanquet methodology; and the geographical differentiation among communities was analyzed by detrended canonical correspondence analysis. The analysis of geographical types shows that temperate species are dominant and that tropical species also make up a high percentage. This indicates that *Davidia involucrata* forest is mainly temperate vegetation. In total, 16 communities were recognized by classification, and these communities were usually dominated by deciduous broad-leaved species, sometimes mixed with some evergreen species. The shrub layer of *Davidia involucrata* forest is generally occupied by bamboos. The geographical patterns among the communities are influenced mainly by temperature and moisture availability, and the forest is most likely to grow in warm, humid habitats.**

Keywords

China, Community, Classification, Phytogeographical Areal Type, *Davidia involucrata*

1. Introduction

Davidia involucrata is a deciduous broad-leaved tree species in the monotypic family Davidiaceae [1]. It occurred widely in many areas of the world in the late Tertiary, but natural *Davidia involucrata* has now survived

only in mountain areas of mainly south-central China (Sichuan, Hubei, Hunan, Guizhou, Yunnan, Chongqing city, and southernmost Gansu and Shaanxi), which were influenced only weakly by the Quaternary glaciations [1]-[3]. This species is well known as a Tertiary relict plant and "botanic living fossil"; it also has small but beautiful flowers with two pure white bracts [4] [5]. Since *Davidia involucrata* was introduced from China to Europe and North America in 1904, it has gradually become a popular ornamental tree species in parks and larger gardens [6]-[8]. However, the natural distribution range of *Davidia involucrata* forests is being reduced rapidly, because these suffer much disturbance from human activity in many regions [9] [10]. Therefore, protection for the natural populations and forests of *Davidia involucrata* is needed.

Since the 1970s, *Davidia involucrata* has been widely studied in many fields such as anatomy, genetics, biology, ecology, introduction cultivation [11]-[14], etc. Synecological study of *Davidia involucrata* forest has also been carried out, and community types in some areas have been classified [15]-[18]. However, these studies of *Davidia involucrata* forest are still local and incomplete, and synthetic, systematic phytosociological reviews are rarer.

Wu classified the Chinese genera of seed plants into 15 areal types according to their contemporary geographical distribution in the world [19]. The geographical areal types include 6 tropical types, 7 temperate types, 1 cosmopolitan type and 1 type for endemics to China. Areal types represent a concept described and is widely used in Chinese vegetation literature, because the proportions of tropical types and temperate types can indicate the forest property. In this paper, we try to summarize community types of *Davidia involucrata* forest, using the Braun-Blanquet methodology, and to describe characteristics of the communities and analyze their different geographical distributions. Our goal is to provide synthetic, systematic phytosociological data for protecting this relic species resource in China.

2. Material and Methods

2.1. Study Area

The study sites comprise most of the distribution areas of natural *Davidia involucrata* forests in south-central China, from 102˚25'E to 111˚11'E and 26˚57'N to 31˚30'N. Usually, the climate of the study area is hot in summer and cold in winter, the duration of sunshine is from 1200 h to 1400 h, the mean annual temperature is 8˚C - 16˚C, the mean temperature of the coldest month (January) is 0.4˚C - 3.6˚C, and the mean temperature of the warmest month (July) is 18.4˚C - 22.5˚C. Also, the study areas are rainy and foggy, the mean annual rainfall varies from 600 mm to 2600 mm, and the average relative humidity is more than 80%. The altitude range of the *Davidia involucrata* forests is from 600 m to 3200 m above sea level. The main rock type is sandstone in some areas and slate in other areas. The predominant soil types in the study regions are mountain yellow soil and mountain yellow-brown soil.

2.2. Data Collection

As a rare endangered species, *Davidia involucrata* occurs in relatively few extant forests, but the range of its geographical distribution is wider. In this research, vegetation data were obtained from relevés made by the authors according to Braun-Blanquet methodology [20] and from published literature (see **Table 1**, **Figure 1**). All constituent species of *Davidia involucrata* forests were recorded in detail in our relevés, but the data collected from literature did not include all species appearing in herb layer. In Hubei, only some relevés followed the full-floristic methodology. Therefore, the omitted species were not included in this study.

2.3. Analysis

The floristic composition of *Davidia involucrata* forest was classified according to the geographical areal types of Chinese genera established by Wu [19], and the numbers and proportions of seed plants (including species and genera) in each geographical areal type were computed. Also, in order to explore the geographical properties of *Davidia involucrata* forest, we summarized the 15 geographical areal types into four types (*i.e.* cosmopolitan, tropical, temperate and Chinese endemic), and counted their numbers and proportions.

The original data were classified (qualitatively and quantitatively) according to species abundance, at each site, by the tabular comparison method [34], and the number of tree species was used to determine the types of *Davidia involucrata* communities. The herb species were not used to distinguish community types, because
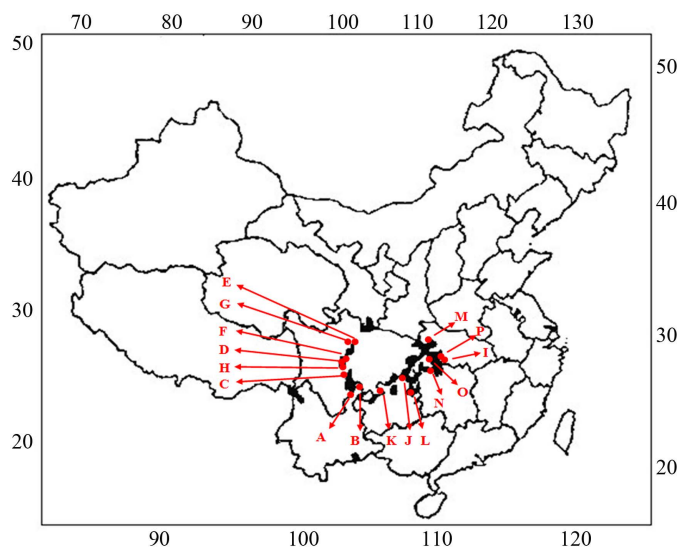
Figure 1. Geographical distribution areas of *Davidia involucrata* (black, from Higher Plants of China 2001 [1]) and locations of study areas (red dots).

Table 1. Basic environmental information for each *Davidia involucrata* community in the study area [18] [21]-[33].

Site	Longitude	Latitude	Altitude (m)	Aspect	Slope (°)	Average annual temperature (°C)	Average annual precipitation (mm)
A	104.0	27.1	1855 - 1858	N	12 - 20	15.0	950
B	104.7	28.1	1530 - 2039	S, W, E, N	0 - 12	15.0	950
C	103.1	29.1	1730 - 1750	NW16	20	10.5	2100
D	102.4	30.7	1620 - 2010	NW, NE	25 - 37	15.1	1732
E	103.6	31.1	2000 - 2100	NE, SE, NW	0 - 30	6.5	1264
F	102.9	30.9	1500 - 1800	S	22 - 35	10.9	861
G	102.5	31.1	1525 - 1670	SW, SE	22 - 28	10.2	1100
H	102.5	30.4	1500 - 1620	N, NW	20 - 35	10.8	1100
I	110.7	30.0	1400	SE	30 - 35	9.2	1898
J	107.6	28.9	1940 - 1960	N28E	25 - 27	8.4	1382
K	105.3	27.0	1750	SW, SE	28	11.8	1181
L	108.1	27.2	1200 - 1300	SW, SE	30	11.8	2600
M	109.9	31.5	1600 - 1730	SW, NW, NE	50 - 64	14.9	1400
N	110.0	29.1	1400 - 1600	S	28	11.5	2105
O	110.1	30.0	980 - 1427	NW, SE, NE	22 - 42	10.8	1700
P	111.0	30.1	1200 - 1700	NE, NW	8 - 18	10.0	1342

many herbs in samples from published literature had been omitted by the authors. For the communities with fewer than 5 samples, the constancy values of constituent species are represented by the number of samples in which each species was present; for those with 5 or more samples, the constancy values of the species are represented by the percent frequency classes for the samples in which the species was present (*i.e.* r: 0% - 5%, +: 6% - 10%, I: 11% - 20%, II: 21% - 40%, III: 41% - 60%, IV: 61% - 80%, V: 81% - 100%). All samples, from field data and literature, are summarized in a synoptic table (**Table 2**).

Table 2. Synoptic table of *Davidia involucrata* forest in China.

Running code	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Number of relevés	2	6	1	3	5	12	3	3	1	1	2	2	7	11	7	5
Mean species number	15	16	70	42	48	67	53	60	65	29	20	42	41	60	63	43

Differential species of *Yushania suijiangensis-Davidia involucrata* community

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Yushania suijiangensis	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sycopsis triplinervia	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polystichum longipaleatum	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aulacolepis treutleri	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acanthopanax evodiifolius var. *gracilis*	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Differential species of *Chimonobambusa tumidissinoda-Davidia involucrata* community

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Chimonobambusa tumidissinoda	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Camellia pitardii	.	IV	1	.	.	.	.	.	.	.	.	1	.	+	.	.
Athyrium iseanum	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elatostema nasutum	.	III	.	.	I	.	.	.	.	.	.	.	.	.	.	.
Allantodia crenata	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Differential species of *Rhododendron ririei-Davidia involucrata* community

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Padus napaulensis	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.
Machilus longipedicellata	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Cornus wilsoniana	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Camellia yunnanensis	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Styrax rosea	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhododendron ririei	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Cunninghamia lanceolata	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer robustum	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Prunus sericea	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Litsea elongata	.	.	1	.	.	.	.	.	.	.	.	.	.	.	I	.

Differential species of *Fargesia spathacea-Davidia involucrata* community

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Lindera limprichtii	.	.	.	3	.	.	1	.	.	.	.	.	.	.	.	.
Fargesia spathacea	.	.	.	3	.	.	.	.	1	.	.	.	.	.	II	.
Parathelypteris glanduligera	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
Salix coerulea	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Litsea populifolia	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.

Differential species of *Maddenia wilsonii-Davidia involucrata* community

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Maddenia wilsonii	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.
Hydrangea xanthoneura	.	.	.	.	V	.	.	.	.	.	.	.	.	.	.	.
Acer maximowiczianum	.	.	1	.	V	.	.	.	.	.	.	.	.	.	.	.

Continued

Acer davidii	·	·	·	·	IV	·	·	·	·	·	2	·	·	·	·	·
Pilea martinii	·	·	·	·	IV	·	·	·	·	·	·	·	·	·	·	·
Litsea moupinensis var. *szechuanica*	·	·	·	·	IV	·	·	·	·	·	·	·	·	·	·	·
Sinarundinaria fangiana	·	·	1	·	IV	·	·	·	·	·	·	·	·	·	·	·
Ligularia dentata	·	·	·	·	IV	·	·	·	·	·	·	·	·	·	·	·
Padus obtusata	·	·	1	·	III	·	·	·	·	·	·	·	·	·	·	·
Schisandra rubriflora	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·	·
Hydrangea anomala	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·	·
Chrysosplenium davidianum	·	·	·	·	III	·	·	·	1	·	·	·	·	·	·	·

Differential species of *Cerasus dielsiana-Davidia involucrata* community

Cerasus dielsiana	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Rubus chingii	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Adiantum capillus-veneris	·	·	·	·	·	III	·	·	·	·	·	·	·	·	I	·
Mahonia fortunei	·	·	·	·	·	III	·	·	·	·	·	·	·	·	I	·
Arisaema erubescens	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Hemarthria compressa	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Paris thibetica	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Ranunculus ficariifolius	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Paeonia lactiflora	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Polygonatum odoratum	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Polystichum tsus-simense	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Pilea plataniflora	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·
Ophiopogon bodinieri	·	·	·	·	·	III	·	·	·	·	·	·	·	·	·	·

Differential species of *Pterocarya insignis-Davidia involucrata* community

Pterocarya insignis	·	·	·	·	·	·	·	3	·	·	·	·	·	·	·	·
Symplocos anomala	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·
Aristolochia moupinensis	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·

Differential species of *Ilex fargesii-Davidia involucrata* community

Ilex fargesii	·	·	·	·	·	·	·	3	·	·	·	·	·	·	·	·
Litsea coreana var. *sinensis*	·	·	·	·	·	·	·	3	·	·	·	·	·	·	·	I

Differential species of *Betula fargesii-Davidia involucrata* community

Betula fargesii	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
Zelkova schneideriana	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
Litsea pedunculata	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
Sycopsis sinensis	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
Celtis sinensis	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·

Continued

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Alangium platanifolium								1						
Meliosma flexuosa								1						
Lonicera chrysantha								1						
Beesia calthifolia								1						
Differential species of *Chimonobambusa quadrangularis-Davidia involucrata* community														
Chimonobambusa quadrangularis								1						
Sassafras tzumu								1						
Morus mongolica								1						
Yulania sprengerii								1						
Eurya japonica								1						
Rubus irenaeus								1						
Differential species of *Chimonobambusa utilis-Davidia involucrata* community														
Chimonobambusa utilis									2					
Corylus heterophylla var. *sutchuenensis*									2					
Sorbus caloneura									2					
Neolitsea confertifolia									2			III		
Differential species of *Styrax hypoglauca-Davidia involucrata* community														
Styrax hypoglauca									2					
Weigela japonica var. *sinica*								1	2					
Rubus peltatus									2					
Cornus capitata									2					
Differential species of *Fargesia robusta-Davidia involucrata* community														
Fargesia robusta						1					V			
Taxus wallichiana var. *chinensis*											III			
Rhododendron stamineum								1			III			
Primula hupehensis											III			
Dryopteris labordei											III			
Platycarya strobilacea				I							III		I	
Akebia quinata											III		I	
Acer wilsonii											III		I	
Differential species of *Meliosma veitchiorum-Davidia involucrata* community														
Meliosma veitchiorum												III		
Photinia glabra												III		
Ribes tenue												III		
Ribes glaciale												III		
Lonicera gynochlamydea												III		

Continued

Species														
Sinofranchetia chinensis	·	·	·	·	·	·	·	·	·	·	·	III	·	·
Pileostegia viburnoides	·	·	·	·	·	·	·	·	·	·	·	III	·	·
Sanicula orthacantha	·	·	·	·	·	·	·	·	·	·	·	III	·	·
Astilbe chinensis	·	·	·	·	·	·	·	·	·	·	·	III	·	·
Toona ciliata	·	·	·	·	·	·	·	·	·	·	·	III	I	·
Cyclocarya paliurus	·	·	·	·	·	·	·	·	·	·	·	III	I	·
Differential species of *Viburnum rhytidophyllum-Davidia involucrata* community														
Liriope graminifolia	·	·	·	·	·	·	·	·	·	·	·	·	V	·
Elaeagnus pungens	·	·	·	1	·	·	·	·	·	·	·	·	V	·
Carex henryi	·	·	·	·	·	·	·	·	·	·	III	·	V	·
Chloranthus serratus	·	·	·	·	·	·	·	·	·	·	·	·	IV	·
Ophiorrhiza japonica	·	·	·	·	·	·	·	·	·	·	·	·	IV	·
Machilus ichangensis	·	·	·	·	·	·	·	·	·	·	·	·	IV	·
Viburnum rhytidophyllum	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Phoebe faberi	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Machilus thunbergii	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Zanthoxylum dissitum var. *dissitum*	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Litsea pungens	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Rubus corchorifolius	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Euonymus alatus	·	·	·	·	·	·	·	·	·	·	1	·	III	·
Aster ageratoides	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Epimedium sagittatum	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Cypripedium formosanum	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Arisaema bockii	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Polystichum tripteron	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Campylandra chinensis	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Dryopteris enneaphylla	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Urtica fissa	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Polygonatum humile	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Asarum sieboldii	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Globba racemosa	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Parthenocissus tricuspidata	·	·	·	·	·	·	·	·	·	·	·	·	III	·
Differential species of *Arisaema heterophyllum-Davidia involucrata* community														
Arisaema heterophyllum	·	·	·	·	·	·	·	·	·	·	·	·	·	IV
Paris polyphylla	·	·	·	·	·	1	·	·	·	1	·	·	I	IV
Camellia cuspidata	·	·	·	·	·	·	·	·	·	1	·	·	III	IV
Saxifraga stolonifera	·	·	·	·	·	·	·	·	·	·	·	+	·	III
Paeonia obovata	·	·	·	·	·	·	·	·	·	·	·	·	·	III

Continued

Epimedium brevicornu	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III
Lithocarpus henryi	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III

Character species of the *Davidia involucrata* forest

Davidia involucrata	1	V	1	3	V	V	3	3	1	2	2	2	V	V	V	V
Tetracentron sinense	2	·	1	·	·	·	2	1	1	·	2	1	III	IV	I	II
Cornus controversa	·	·	1	2	II	V	3	·	·	·	2	·	I	II	III	II
Cercidiphyllum japonicum	·	·	1	1	·	·	2	1	·	·	·	·	III	III	I	·
Juglans cathayensis	·	·	1	2	·	V	1	3	·	·	·	2	·	·	II	·
Aesculus chinensis var. *wilsonii*	·	·	1	·	·	·	2	·	·	1	·	2	·	III	III	·
Pterostyrax psilophyllus	·	·	1	·	·	·	·	·	·	1	·	2	·	III	II	III
Padus avium	2	III	·	·	·	·	2	·	·	·	2	·	·	·	II	·
Acer henryi	·	·	·	·	·	·	1	·	·	·	2	1	·	I	II	·
Acer oliverianum	2	III	·	·	·	III	2	·	·	·	·	·	·	·	Ⅲ	·
Davidia involucrata var. *vilmoriniana*	·	·	·	·	·	·	2	3	·	·	·	·	·	·	I	V
Acer palmatum	·	·	·	·	·	·	·	·	·	·	·	1	II	·	II	III
Euptelea pleiospermum	·	·	1	·	·	·	1	1	·	·	·	·	·	·	I	·
Acer flabellatum	·	·	1	1	III	·	·	·	·	·	·	·	·	·	I	·
Meliosma cuneifolia	·	·	·	1	IV	·	1	·	·	·	·	·	·	·	V	·
Chrysosplenium macrophyllum	·	·	·	·	·	·	·	·	·	1	·	·	·	III	V	·
Padus grayana	·	·	·	·	·	·	·	1	·	·	·	·	·	·	I	I
Staphylea holocarpa	·	·	1	·	·	·	·	·	·	·	·	·	·	I	I	·
Ficus heteromorpha	·	·	·	·	·	·	1	·	1	·	·	·	·	·	III	·
Dipteronia sinensis	·	·	·	·	·	·	·	·	1	·	·	·	·	II	III	·
Hemiboea henryi	·	·	·	·	·	·	·	·	1	·	·	·	·	II	III	·
Schizophragma integrifolium	·	·	·	·	·	·	·	·	1	·	·	·	·	I	I	·
Litsea mollis	·	·	·	·	·	·	1	·	·	1	·	·	·	·	·	II
Tapiscia yunnanensis	·	·	·	·	·	·	·	·	·	·	·	·	·	II	II	·

Other species

Ilex pernyi	·	·	·	1	IV	IV	2	1	·	·	·	1	·	·	II	·
Symplocos sumuntia	2	IV	·	·	·	IV	·	·	·	·	·	·	·	II	I	III
Oxalis griffithii	·	·	·	·	·	Ⅲ	1	·	·	·	·	1	·	II	Ⅲ	·
Cyclobalanopsis multiervis	·	·	·	·	·	·	·	1	1	1	·	·	·	III	Ⅲ	·
Hedera sinensis	·	·	1	·	·	III	1	·	·	·	·	·	·	II	II	·
Cyclobalanopsis oxyodon	·	·	·	1	·	·	2	1	·	·	·	2	·	·	III	·
Smilax china	·	·	·	·	·	III	3	·	·	·	·	·	III	·	III	IV
Illicium henryi	·	·	·	·	·	·	·	·	·	1	·	·	·	+	IV	I
Akebia trifoliata	·	·	·	3	·	·	·	·	·	·	·	2	·	·	II	IV
Celastrus orbiculatus	·	·	·	·	·	·	·	·	1	·	·	1	·	I	I	·
Symplocos lucida	·	III	1	·	IV	·	3	·	·	·	·	·	·	·	·	·

Continued

Species															
Phoebe neurantha	·	·	·	·	·	IV	1	·	·	·	·	·	·	III	·
Dysosma versipellis	·	·	·	·	·	·	·	1	·	·	1	I	·	·	·
Fagus longipetiolata	·	·	·	·	·	·	·	·	1	·	1	·	·	I	·
Cyclobalanopsis glauca	·	·	·	·	·	·	·	·	·	·	·	·	III	I	II
Actinidia chinensis	·	·	·	3	·	·	·	·	·	2	·	·	·	II	·
Viburnum dilatatum	·	·	·	·	III	·	·	·	·	·	·	·	II	III	·
Mahonia bealii	·	·	·	·	·	·	·	1	·	·	1	·	·	·	I
Castanopsis platyacantha	2	IV	1	·	·	·	·	·	·	·	·	·	·	·	·
Carpinus fangiana	2	IV	·	·	·	·	·	·	·	·	1	·	·	·	·
Rehderodendron macrocarpum	2	III	1	·	·	·	·	·	·	·	·	·	·	·	·
Acer sinense var. *longilobum*	2	III	·	·	·	·	·	·	·	1	·	·	·	·	·
Sambucus williamsii	·	·	·	·	·	·	·	·	·	·	1	·	II	I	·
Betula insignis	·	·	·	2	·	·	·	·	·	·	1	·	II	·	·
Stachyurus chinensis	·	·	·	1	I	·	·	·	·	·	2	·	·	·	·
Machilus microcarpa	·	·	·	1	·	·	·	1	·	·	1	·	·	·	·
Ophiopogon japonicus	·	·	·	·	·	III	1	·	·	·	·	·	·	II	·
Torreya fargesii	·	·	·	·	·	·	·	·	1	·	·	·	III	I	·
Toxicodendron succedaneum	·	·	·	·	·	·	·	·	1	·	·	I	·	II	·
Enkianthus chinensis	2	III	·	·	·	·	·	·	·	·	·	·	·	·	·
Viburnum betulifolium	·	·	·	3	V	·	·	·	·	·	·	·	·	·	·
Betula luminifera	·	·	·	1	I	·	·	·	·	·	·	·	·	·	·
Corylus ferox var. *thibetica*	·	·	·	1	I	·	·	·	·	·	·	·	·	·	·
Lindera pulcherrima var. *hemsleyana*	·	·	·	·	·	III	3	·	·	·	·	·	·	·	·
Ligustrum pricei	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Viburnum cordifolium	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Rubus mesogaeus	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Senecio scandens	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Polygonum suffultum	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Polygonatum verticillatum	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Astilbe rivularis var. *myriantha*	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Smilax menispermoidea	·	·	·	·	·	III	1	·	·	·	·	·	·	·	·
Acer mono	·	·	·	·	·	·	·	·	·	2	·	·	·	III	·
Fagus lucida	·	·	·	·	·	·	·	·	·	·	·	·	I	I	·
Elatostema involucratum	·	·	·	·	·	·	·	·	·	·	·	·	II	IV	·
Liquidambar acalycina	·	·	·	·	·	·	·	·	·	2	·	·	III	·	·
Cyrtomium fortunei	·	·	·	·	·	·	·	·	·	·	·	III	·	III	·
Phoebe shearreri	·	·	·	2	·	·	·	·	·	·	·	·	·	·	III

Note: the other species were omitted.

Detrended canonical correspondence analysis (DCCA, Canoco for Windows 4.5) was used to identify patterns of environmental variation among communities. The values of seven environmental factors were determined for all communities, namely longitude (LO), latitude (LA), altitude (AL), aspect (AS, on an eight-point scale: 1 = N; 2 = NE; 3 = NW; 4 = E; 5 = W; 6 = SE; 7 = SW; 8 = S), slope (SL), average annual temperature (AT) and average annual precipitation (AP). Square root-transformed percentage frequencies were used as the input species data. The importance values for species were calculated using the following formula [35]:

$$IV_{ijk} = \frac{O_{ijk} \cdot L_{jk}}{\sum_{i=1}^{n} O_{ij}}$$

where IV_{ijk} is the importance value of species i, O_{ijk} is percent cover of species i in layer k of community j with a total of n species, and L_{jk} is the projected cover (in percent) of layer k of community j.

3. Results

3.1. Plant Floristic Characteristics

In this study, a total of 394 species was recorded in *Davidia involucrata* forest, including 382 species of seed plants, 10 fern species and 2 moss species. The seed plants belong to 88 families and 213 genera. The families with more than 10 species are Lauraceae (7 genera and 30 species), Rosaceae (10 genera and 25 species), Saxifragaceae (12 genera and 24 species), Liliaceae (12 genera and 20 species), Caprifoliaceae (5 genera and 19 species), Fagaceae (5 genera and 14 species), Aceraceae (2 genera and 14 species) and Gramineae (11 genera and 13 species).

The statistical results for the geographical areal types show that, except for the Central Asian type, all the other 14 types appeared in *Davidia involucrata* forest (**Table 3**). The plant genera belonging to the north-temperate distribution type showed the highest proportion (23.47%) of all distribution types. Other areal types with

Table 3. Proportions of seed-plant genera in the geographical areal types in *Davidia involucrata* forests.

Geographical Areal Types	Genus		Species		No. of Species per Genus
	Number	Percentage (%)	Number	Percentage (%)	
Cosmopolitan	**17**	**7.98**	**29**	**7.59**	**1.7**
Tropical	**55**	**25.83**	**99**	**25.91**	**1.8**
Pantropic	22	10.33	38	9.94	1.7
Tropical Asia & Tropical America Disjuncted	5	2.35	21	5.50	4.2
Old World Tropics	5	2.35	7	1.83	1.4
Tropical Asia to Tropical Australasia	5	2.35	5	1.31	1.0
Tropical Asia to Tropical Africa	2	0.94	2	0.52	1.0
Tropical Asia (Indo-Malesia)	16	7.51	26	6.81	1.6
Temperate	**118**	**55.39**	**227**	**59.43**	**1.9**
North Temperate	50	23.47	126	32.98	2.5
East Asia & North Americas Disjuncted	27	12.68	48	12.57	1.8
Old World Temperate	5	2.35	5	1.31	1.0
Temperate Asia	1	0.47	3	0.79	3.0
Mediterranean, West Asia to Central Asia	4	1.88	6	1.57	1.5
Central Asia	0	0.00	0	0.00	-
East Asia	31	14.55	39	10.21	1.3
Endemic to China	**23**	**10.80**	**27**	**7.07**	**1.2**
Total	**213**	**100**	**382**	**100**	

more genera are the East Asian type (14.55%), East Asia-North America disjuncts (12.68%), Chinese endemics (10.80%) and pantropical (10.33%). Temperate genera are most common (55.39% of all genera) followed by tropical genera (25.83%), cosmopolitan genera 10.80% and genera endemic to China 7.98%. North-temperate species were most numerous (126 species), followed by East Asia-North America disjuncts (48 species), East Asian species (39 species), and pantropic species (38 species). Thus, *Davidia involucrata* forest has the properties of temperate forests but is associated closely with tropical floristics. In addition, most genera contain more than one species, the average being 1.8. The ratio of species to genera among "tropical Asia-tropical America disjuncts" is 4.2, indicating that interspecific differentiation among the constituent species of *Davidia involucrata* forest is significant.

3.2. Community Description

The 72 samples of *Davidia involucrata* forest were summarized as 16 communities, and the characteristics of these communities are quite different (see **Table 2**).

1) *Yushania suijiangensis-Davidia involucrata* community (Community A)

The stands of this community appear on north-facing slopes at an average altitude of 1855 m in Yiliang County of northeastern Yunnan [21]. This community is characterized mainly by species such as *Yushania suijiangensis*, *Sycopsis triplinervia*, *Acanthopanax evodiaefolius* var. *gracilis*, *Polystichum longipaleatum* and *Aulacolepis treutleri*. Stratification of this community shows four layers, and mean cover of the canopy is about 60%. The tree layer reaches 10 - 17 m and is dominated by *Davidia involucrata*, *Acer oliverianum*, *Tetracentron sinense*, *Rehderodendron macrocarpum*, *Enkianthus chinensis*, *Acanthopanax evodiaefolius* var. *gracilis*, etc. The shrub layer attains 1.4 m, is dominated by *Yushania suijiangensis*, and there are relatively few individuals of the companion species. The herb layer has a mean cover of 60% and is often occupied by some shade-tolerant species such as *Aulacolepis treutleri* and *Polystichum longipaleatum*.

2) *Chimonobambusa tumidissinoda-Davidia involucrata* community (Community B)

Stands of this community are situated on slight slopes at altitude from 1530 m to 2039 m in northeastern Yunnan [21]. The differential species of this community include *Chimonobambusa tumidissinoda*, *Camellia pitardii*, *Athyrium iseanum*, *Elatostema nasutum* and *Allantodia crenata*. This community consists of four layers, and the cover of tree layer reaches 60% - 85%. The tree layer attains 10 - 25 m and is constituted mainly by *Davidia involucrata*, *Carpinus fangiana* and some evergreen trees such as *Castanopsis platyacantha*, *Camellia pitardii*, *Symplocos sumuntia* and *Symplocos lucida*. The shrub layer attains 3 m and dominated mainly by *Qiongzhuea tumidissinoda*. The herb layer is affected by the upper layers and has cover ranging from 3% to 85%, with predominant species *Elatostema nasutum*, *Impatiens scutisepala*, *Athyrium iseanum* and *Allantodia* spp.

3) *Rhododendron ririei-Davidia involucrata* community (Community C)

This community is located on a 20° northwest-facing slope at an average altitude of 1740 m, on Emei-Shan mountain of Sichuan [22]. The differential species include *Padus napaulensis*, *Machilus longipedicellata*, *Cornus wilsoniana*, *Camellia yunnanensis*, *Styrax roseus*, *Rhododendron ririei*, *Cunninghamia lanceolata*, *Acer robustum*, *Prunus sericea* and *Litsea elongata*. Stratification of this community can be divided into three tree layers, one shrub layer and one herb layer. The canopy reaches an average height of 22.5 m, with an average cover of 75%. The main species of the tree layers are *Davidia involucrata*, *Tetracentron sinense*, *Litsea elongata*, *Juglans cathayensis*, *Prunus napaulensis*, *Machilus longipedicellata* and *Castanopsis platyacantha*. The shrub layer attains 2.5 m with a cover of 70%, and is composed by the single species *Sinarundinaria fangiana*. The herb layer reaches 0.4 m, and is dominated by *Pilea sinofasciata*. The species composition of this community is relatively rich, and 70 species were identified.

4) *Fargesia spathacea-Davidia involucrata* community (Community D)

The stands of this community occur at altitude 1620 m to 2010 m, on steep slopes (25° to 37°), in the Labahe nature reserve of Sichuan [23]. The differential species are *Lindera limprichtii*, *Fargesia spathacea*, *Parathelypteris glanduligera*, *Salix clolia* and *Litsea populifolia*. The structure of this shorter forest generally consists of only three layers, but the cover of the tree layer attains 70% - 85%. The tree layer reaches 7.2 m, and the most constant species are *Davidia involucrata*, *Lindera limprichtii*, *Viburnum betulifolium*, *Phoebe sheareri*, *Litsea populifolia*, *Cornus controversa*, *Salix clolia*, *Juglans cathayensis* and *Betula albo-sinensis*. The shrub layer includes few individuals and is usually composed by *Lindera limprichtii*, *Juglans cathayensis*, *Fargesia spathacea*

and *Cornus controversa*. The herb layer has an average height of 0.25 m, and the main species are *Parathelypteris glanduligera*, *Arthraxon hispidus*, *Actinidia chinensis*, *Akebia trifoliata*, *Cyperus* sp. and *Smilax* sp. The average stand richness reaches 42 species.

5) *Maddenia wilsonii-Davidia involucrata* community (Community E)

Sites of this community are on gentle slopes of 15˚ to 30˚ facing northeast, southeast and northwest, at altitude 2000 m to 2100 m, within the area of Chengdu city of Sichuan [24]. The diagnostic species of this community are *Maddenia wilsonii*, *Hydrangea xanthoneura*, *Acer maximowiczianum*, *Acer davidii*, *Pilea martini*, *Litsea moupinensis* var. *szechuanica*, *Sinarundinaria fangiana*, *Ligularia dentata*, *Padus obtusata*, *Schisandra rubriflora*, *Hydrangea anomala* and *Chrysosplenium davidianum*. Stratification usually shows four layers. The upper canopy attains 18 m, and is dominated by *Davidia involucrata*, rarely mixed with *Cryptomeria fortunei* and *Tilia nobilis*. The understory tree layer reaches 12 m, and the main species include *Maddenia wilsonii*, *Hydrangea xanthoneura*, *Acer maximowiczianum*, *Litsea moupinensis* var. *szechuanica*, *Meliosma cuneifolia*, *Acer davidii* and *Ilex pernyi*. The height of the shrub layer is 1 - 3 m, and the predominant species are *Viburnum betulifolium*, *Symplocos lucida*, *Hydrangea anomala*, *Schisandra rubriflora*, *Philadelphus delavayi*, and *Smilax* spp. The herb layer attains 0.8 m with a cover of 65% - 80%, and the main species are *Sinarundinaria fangiana*, *Pilea marthnii*, *Ligularia dentata*, *Chrysosplenium davidianum*, *Polystichum hecatopteron*, etc. The average number of species per sample was 48.

6) *Cerasus dielsiana-Davidia involucrata* community (Community F)

This relatively tall forest community is situated at altitude 1500 m to 1800 m in Wolong nature reserve of Sichuan [25]. The diagnostic species of this community are *Cerasus dielsiana*, *Rubus chingii*, *Adiantum capillus-veneris*, *Mahonia fortunei*, *Arisaema erubescens*, *Hemarthria compressa*, *Paris thibetica*, *Ranunculus ficariifolius*, *Paeonia lactiflora*, *Polygonatum odoratum*, *Polystichum tsus-simense*, *Pilea plataniflora* and *Ophiopogon bodinieri*. Stratification of the community can be divided into three tree layers, one shrub layer and two herb layers. The upper canopy reaches 25 m and consists of *Davidia involucrata* and *Juglans cathayensis*; the upper understory tree layer reaches 15 - 20 m and is dominated by *Davidia involucrata* and *Cornus controversum*; and the lower tree layer is 5 - 15 m and is composed by *Davidia involucrata*, *Juglans cathayensis*, *Cornus controversum*, *Symplocos botryantha*, *Phoebe neurantha*, *Ilex pernyi*, *Lindera pulcherrima* var. *hemsleyana*, etc. The individuals of the shrub layer are fewer, and the main species are *Davidia involucrata*, *Phoebe neurantha*, *Rubus palmatus*, *Symplocos botryantha*, *Ilex pernyi*, *Acer oliverianum*, etc. The herb layer attains 0.6 m, and the dominant species are *Oxalis griffithii*, *Polystichum tsus-simense*, *Ophiopogon bodinieri*, etc. The average number of species per sample reaches 67.

7) *Pterocarya insignis-Davidia involucrata* community (Community G)

This open community occurs on south-facing slopes of 22˚ to 28˚ at altitudes of 1525 m to 1670 m in the Wolong nature reserve of Sichuan [26]. The community can be distinguished by the species *Pterocarya insignis*, *Symplocos anomala* and *Aristolochia moupinensis*. Stratification consists of four layers, with an upper canopy at 12 - 16 m but cover of only 10% - 20%; the main canopy species are *Davidia involucrata*, *Davidia involucrata* var. *vilmoriniana*, *Phoebe neurantha*, *Aesculus wilsonii*, *Pterocarya insignis*, *Acer oliverianum*, *Cyclobalanopsis oxyodon* and *Lindera pulcherrima* var. *hemsleyana*. The lower canopy attains 7 - 12 m with cover of 65% - 70%, and the dominant species are *Symplocos lucida* and *Lindera pulcherrima* var. *hemsleyana*, sometimes mixed with *Tetracentron sinense* and *Cercidiphyllum japonicum*. The shrub layer (5 m) has cover of 10% - 15%, and the main species are *Ilex pernyi*, *Clerodendrum trichotomum*, *Viburnum oliganthum, Viburnum cordifolium*, *Acanthopanax henryi*, *Helwingia japonica*, *Mahonia bealii*, *Philadelphus incanus* and *Fargesia robusta*. The cover of the herb layer (0.8 m) is 80% - 85%, and the common species include *Smilax china*, *Aristolochia moupinensis*, *Senecio scandens*, *Polygonum suffultum*, *Polygonatum verticillatum*, *Astilbe rivularis* var. *myriantha*, *Smilax menispermoidea* and *Actinidia kolomikta*. The average number of species obtained is 53 per sample.

8) *Ilex fargesii-Davidia involucrata* community (Community H)

Sites of this forest community are on northwest and north facing slopes of 22˚ to 35˚, at altitude from 1500 m to 1620 m, in the Wolong nature reserve [18]. The diagnostic species are *Ilex fargesii* and *Litsea coreana* var. *sinensis*. Stratification of this community includes three tree layers, and the cover ranges from 75% to 90%. The upper canopy layer reaches 14 - 20 m and consists of *Davidia involucrata*, *Cercidiphyllum japonicum*, *Tetracentron sinense*, *Padus grayana*, *Juglans cathayensis*, *Alniphyllum fortunei*, *Kalopanax septemlobus*, *Euptelea pleiospermum*, etc. The height of the main tree understory ranges from 6 m to 10 m, and the main trees are *Cyclobalanopsis oxyodon*, *Lindera communis*, *Ilex fargesii*, *Litsea coreana* var. *sinensis*, and *Cladrastis wilsonii*.

The common species of the lowest tree layer are *Gmelina hainanensis*, *Cornus officinalis*, *Viburnum erosum*, *Ilex pernyi*, etc. The shrub layer has an average cover of 15%, and the main species are *Viburnum erosum*, *Ilex pernyi*, *Litsea sericea*, *Gmelina hainanensis*, *Cornus officinalis*, *Salix microphyta*, *Kalopanax septemlobus*, etc. The herb layer has higher cover degree (60% - 80%), and the dominant species are *Dysosma versipellis*, *Paris polyphylla*, *Codonopsis convolvulacea* var. *forrestii*, and *Trillium tschonoskii*. The community has an average of 60 species per sample.

9) *Betula fargesii-Davidia involucrata* community (Community I)

This short but species-rich forest community occurs on steep slopes (30˚ to 35˚) facing southeast, at 1400 altitude, in Hupingshan nature reserve of Hunan [27]. The number of constituent species reaches 65. The diagnostic species of this community include *Betula fargesii*, *Zelkova schneideriana*, *Litsea pedunculata*, *Sycopsis sinensis*, *Celtis sinensis*, *Alangium platanifolium*, *Meliosma flexuosa*, *Lonicera chrysantha*, *Smilax davidiana*, and *Beesia calthifolia*. There are generally only three layers. The tree layer attains 75% to 90% cover with an average height of 15 m, and the dominant tree layer species are *Davidia involucrata*, *Tetracentron sinense*, *Betula fargesii*, *Zelkova schneideriana*, *Litsea pedunculata*, *Sycopsis sinensis*, *Celtis sinensis*, *Dipteronia sinensis*, *Cyclobalanopsis multinervis*, and *Cornus officinalis*. The shrub layer usually includes species such as *Alangium platanifolium*, *Meliosma flexuosa*, *Schizophragma integrifolium*, *Smilax davidiana*, *Lonicera chrysantha*, *Ficus heteromorpha*, *Padus napaulensis*, *Fargesia spathacea*, and *Davidia involucrata*. The herb layer has an average cover of 50%, and the dominant species of are *Sedum amplibracteatum*, *Beesia calthifolia*, *Sanicula lamelligera*, *Chrysosplenium grossophyllum*, *Hemiboea subcapitata* and *Celastrus orbiculatus.*

10) *Chimonobambusa quadrangularis-Davidia involucrata* community (Community J)

This short wooded community is situated at altitude ranging from 1570 m to 1700 m in the Kuankuoshui forest area of Guizhou [28]. The diagnostic species are *Chimonobambusa quadrangularis*, *Sassafras tzumu*, *Morus mongolica*, *Yulania sprengerii*, *Eurya japonica*, and *Rubus irenaeus*. Stratification shows usually four layers with two tree sub-layers. The upper canopy reaches 10 - 15 m and is dominated by *Davidia involucrata*, mixed with *Pterostyrax psilophylla*, *Toxicodendron succedaneum*, *Cyclobalanopsis multinervis*, *Magnolia sprengeri*, *Aesculus wilsonii*, *Sassafras tzumu*, *Fagus longipetiolata*, etc. The lower tree layer attains 3 - 8 m, and the main species include *Litsea euosma*, *Weigela japonica* var. *sinica*, *Morus mongolica*, *Eurya japonica*, *Ilex chinensis*, *Rhododendron stamineum*, *Lindera glauca*, etc. The shrub layer (1 m) is a dense cover (80% - 90%) of dominant *Chimonobambusa quadrangularis*. Under the bamboo in the herb layer has a sparse cover of only 10% - 15%, with common species *Lysimachia congetiflora*, *Impatiens siculifer*, *Meehania fargesii*, *Chrysosplenium davidianum*, *Cyrtomium macrophyllum*, *Chrysosplenium macrophyllum*, *Galium asperuloides* var. *hoffmeisteri*, etc.

11) *Chimonobambusa utilis-Davidia involucrata* community (Community K)

This forest community is found on a steep northeast-facing slope of 26˚ at a higher altitude of 1940 m to 1960 m on the Baiqing karst platform of Guizhou [29]. This community can be distinguished by *Chimonobambusa utilis*, *Corylus heterophylla* var. *sutchuenensis*, *Sorbus caloneura* and *Neolitsea confertifolia*. Stratification involves four layers, with two tree sub-layers. The height of upper canopy layer is 12 - 18 m with cover of 60% - 70%, and the main species are *Davidia involucrata*, *Acer oliverianum*, *Tetracentron sinense*, and *Corylus heterophylla* var. *sutchuenensis*. The lower tree layer has 6 - 12 m in height and consists of *Davidia involucrata*, *Acer oliverianum*, *Prunus padus*, *Sorbus caloneura*, *Neolitsea confertifolia*, *Cornus controversum*, *Acer henryi*, etc. The shrub layer is dominated by *Chimonobambusa utilis* and has a few tree saplings. The herb layer (0.3 m) has fewer species, mainly belonging to the Pteridaceae, Urticaceae, Rosaceae, Violaceae and Rubiaceae.

12) *Styrax hypoglauca-Davidia involucrata* community (Community L)

The stands of this forest community are located at altitudes ranging from 1300 m to 1500 m on the Fanjing-Shan (mountain) of Guizhou [30]. The diagnostic species are *Styrax hypoglauca*, *Weigela japonica* var. *sinica*, *Rubus peltatus* and *Cornus capitata*. This community usually has four layers. The canopy layer is 15 - 25 m in height with a cover of about 70%, and its common species include *Davidia involucrata*, *Styrax hypoglauca*, *Liquidambar acalycina*, *Pterostyrax psilophyllus*, *Tetracentron sinense*, *Aesculus wilsonii*, *Acer palmatum*, *Betula insignis*, *Acer davidii*, *Acer sinense*, *Juglans cathayensis*, *Carpinus fangiana*, *Fagus longipetiolata*, *Castanopsis chunii*, *Cyclobalanopsis oxyodon*, etc. The lower tree layer consists of *Camellia cuspidata*, *Symplocos stellaris*, *Camellia pitardii*, *Daphniphyllum macropodum*, *Cornus capitata*, etc. The shrub layer reaches 3 m and its cover is 30% - 60%. The main species of the shrub layer are *Lindera glauca*, *Lindera fragrans*, *Euonymus alatus*, *Rubus peltatus*, *Mahonia bealii*, *Weigela japonica*, *Callicarpa cathayana*, *Stachyurus chinensis*, *Dichroa febrifuga*, *Sambucus williamsii*, *Hydrangea chinensis*, *Ilex pernyi*, *Aucuba chinensis*, and *Rhododendron* spp. The cover of the herb layer is less than 30%, and the predominant species are *Dysosma versipellis*, *Panax transitoxinus*, *Ari-*

saema rhizomatum, *Arthraxon hispidus*, *Reineckia carnea*, *Rohdea japonica*, *Paris polyphylla* and *Oxalis griffithii*. The average number obtained was 42 species per sample.

13) *Fargesia robusta-Davidia involucrata* community (Community M)

The stands of this forest community are on steep slopes (55˚ to 64˚) at altitude from 1600 m to 1730 m, facing northeast, northwest and southwest, in the Baiguo forest farm of Wuxi County near Chongqing [31]. The diagnostic species are *Fargesia robusta*, *Taxus wallichiana* var. *chinensis*, *Rhododendron stamineum*, *Primula hupehensis*, *Dryopteris labordei*, *Platycarya strobilacea* and *Akebia quinata*. These forests have an average cover of 85% and can be divided into five layers, including three tree sub-layers, one shrub layer and one herb layer. The canopy layer attains 25 m and consists of *Davidia involucrata*, *Tetracentron sinense*, *Cercidiphyllum japonicum* and a few individuals of *Platycarya strobilacea*. The middle tree layer reaches 10 - 25 m, and the main species include *Davidia involucrata*, *Tetracentron sinense*, *Cercidiphyllum japonicum*, *Torreya fargesii*, *Carpinus fargesiana*, *Taxus wallichiana* var. *chinensis*, *Acer palmatum* and *Acer wilsonii*. The lower tree layer is 10 m in height, and the predominant species are *Acer palmatum*, *Platycarya strobilacea*, *Davidia involucrata* and *Euptelea pleiospermum*. The cover of the shrub layer reaches 20% with a height of 1 - 3 m, and species such as *Fargesia robusta*, *Carpinus fargesiana*, *Alangium chinense* and *Rhododendron stamineum* are often found in the shrub layer. The herb layer attains 0.5 m, and the dominant species are *Dryopteris labordei*, *Cyrtomium fortunei*, *Primula hupehensis*, *Carex henryi*, and *Dysosma versipellis*. The mean number of species in a sample is 41.

14) *Meliosma veitchiorum-Davidia involucrata* community (Community N)

This community can be found at altitude 1400 m to 1600 m in Hunan [32]. The diagnostic species are *Meliosma veitchiorum*, *Photinia glabra*, *Ribes tenue*, *Ribes glaciale*, *Lonicera gynochlamydea*, *Sinofranchetia chinensis*, *Pileostegia viburnoides*, *Sanicula orthacantha*, *Astilbe chinensis*, *Toona ciliata* and *Cycolocarya paliurus*. Stratification of this community involves four layers, and usually the tree layer and herb layer are developed well. The canopy layer consists of *Davidia involucrata*, *Tetracentron sinense*, *Cercidiphyllum japonicum*, *Meliosma veitchiorum*, *Toona ciliata*, *Pterostyrax psilophyllus*, etc. The dominant species of the lower tree layer include *Dipteronia sinensis*, *Acer henryi*, *Euptelea pleiospermum*, *Photinia glabra*, *Staphylea holocarpa*, *Euonymus oblongifolius*, *Illicium henryi*, *Camellia pitardii*, etc. The main species of the shrub layer are *Ribes glaciale*, *Ribes tenue*, *Stephanandra chinensis*, *Neolitsea confertifolia*, *Viburnum dilatatum*, *Elaeagnus difficilis*, *Symplocos sumuntia*, *Abelia macrotera*, *Lonicera gynochlamydea*, *Lonicera maackii*, *Sambucus williamsii*, etc. The predominant species of the herb layer are *Astilbe chinensis*, *Chrysosplenium griffithii*, *Chrysosplenium macrophyllum*, *Saxifraga stolonifera*, *Tiarella polyphylla*, *Thalictrum acutifolium*, *Oxalis griffithii*, *Elatostema involucratum*, *Hemiboea henryi*, *Sanicula orthacantha*, etc. The average number of species is 60.

15) *Viburnum rhytidophyllum-Davidia involucrata* community (Community O)

Relevés for this forst community were obtained in the Houhe national nature reserve of Hubei. The stands are located on steeper slopes (22˚ to 42˚) between 980 m and 1427 m elevation, facing southeast and northeast. This community is characterized by *Liriope graminifolia*, *Elaeagnus pungens*, *Carex henryi*, *Chloranthus serratus*, *Ophiorrhiza japonica*, *Machilus ichangensis*, *Viburnum rhytidophyllum*, *Phoebe faberi*, *Machilus thunbergii*, *Zanthoxylum dissitum* var. *dissitum*, *Litsea pungens*, *Rubus corchorifolius*, *Euonymus alatus*, *Aster ageratoides*, *Epimedium sagittatum*, *Cypripedium formosanum*, *Arisaema bockii*, *Polystichum tripterpon*, *Campylandra chinensis*, *Dryopteris enneaphylla*, *Urtica fissa*, *Polygonatum humile*, *Asarum sieboldii*, *Globba racemosa* and *Parthenocissus tricuspidata*. Stands can be divided into four layers. The canopy reaches 17 - 26 m with an average cover of 65%, and the predominant species are *Davidia involucrata*, *Pterocarya hupehensis*, *Phoebe shareri*, *Cyclobalanopsis oxyodon*, *Fagus longipetiolata*, *Phoebe neurantha* and *Machilus ichangensis*. The height of lower tree layer is 9 - 17 m, and the cover ranges from 20% to 40%. The main species of the lower tree layer include *Davidia involucrata*, *Elaeagnus lanceolata*, *Meliosma cuneifolia*, *Acer mono*, *Phoebe faberi*, *Machilus thunbergii*, *Dipteronia sinensis*, *Aesculus wilsonii*, *Cornus controversa*, *Litsea pungens*, *Acer oliverianum*, etc. The shrub layer is 2 - 3 m in height and attains 15% - 35% in cover. The dominant species of the shrub layer are *Viburnum rhytidophyllum*, *Zanthoxylum dissitum* var. *dissitum*, *Rubus corchorifolius*, *Sabia japonica*, *Viburnum dilatatum*, *Camellia cuspidata*, *Ficus heteromorpha*, *Euonymus alatus*, etc. The cover of the herb layer ranges from 40% to 60%, with an average height of 0.5 m, and the predominant herb species include *Chloranthus serratus*, *Chrysosplenium macrophyllum*, *Liriope graminifolia*, *Elatostema involucratum*, *Carex henryi*, *Epimedium sagittatum*, *Cyrtomium fortunei*, *Hemiboea henryi*, *Aster ageratoides*, *Cypripedium formosanum*, *Arisaema sikokianum* var. *serratum*, *Polystichum tripterpon*, *Dryopteris enneaphylla*, *Urtica fissa*, *Polygonatum humile*, *Asarum sieboldii*, *Globba racemosa*, and *Parthenocissus tricuspidata*. The species composition is relatively rich, with an average of 63 species per relevé.

16) *Arisaema heterophyllum-Davidia involucrata* community (Community P)

The samples of this forest community are at altitudes from 1200 m to 1700 m in Changyang County of western Hubei [33]. The differential species are *Arisaema heterophyllum*, *Paris polyphylla*, *Camellia cuspidata*, *Saxifraga stolonifera*, *Paeonia obovata*, *Epimedium brevicornu* [sic] and *Lithocarpus henryi*. Stratification can be divided into four layers. The canopy layer is 17 - 20 m in height and is dominated by *Davidia involucrata*, mixed with *Tetracentron sinense*, *Davidia involucrata* var. *vilmoriniana*, *Cerasus conradinae*, *Pterostyrax psilophyllus*, *Cyclobalanopsis glauca*, *Pterocarya hupehensis*, and *Phoebe sheareri*. The lower tree layer reaches 6 - 11 and is dominated by Davidia involucrata, with companion species *Ilex chinensis*, *Cornus controversum*, *Lithocarpus henryi*, *Acer palmatum*, *Litsea coreana* var. *sinensis*, *Carpinus turczaninowii*, and *Quercus fabri*. The shrub layer attains 2.5 m and has an average cover of 30%. The main species of the shrub layer include *Camellia cuspidata*, *Symplocos sumuntia*, *Padus grayana*, *Eurya nitida*, *Cerasus pseudocerasus*, *Symplocos paniculata* and *Illicium henryi*. The herb layer reaches 0.8m, and its cover ranges from 40% to 60%, with predominant species *Arisaema heterophyllum*, *Saxifraga stolonifera*, *Paeonia obovata*, *Epimedium brevicornu*, *Paris polyphylla*, *Mahonia bealii*, *Matteuccia orientalis*, *Smilax china*, *Akebia trifoliata*, *Rodgersia podophylla*, and *Tiarella polyphylla*. The average species number was 43 per sample.

3.3. Phytogeographical Differentiation

The results of detrended canonical correspondence analysis show that the first three axes are correlated with environmental conditions included in the analysis. The species-environment correlation coefficients for these three axes are 0.979, 0.963 and 0.939, respectively (**Table 4**).

The results of a Monte Carlo test show that seven environmental variables are related significantly to the first axis ($P < 0.05$) and all canonical axes ($P < 0.005$). The first two axes explained 42.5% of the total variance, and the correlation coefficient between the two axes is lower ($r = 0.006$). Therefore, the general pattern of environmental variation among communities is expressed most clearly by the combination of the first two axes. The first axis is most closely connected with the slope ($r = -0.670$), latitude ($r = -0.567$) and average annual temperature ($r = 0.402$), indicating effective micro-environmental temperatures and micro-topography. The second axis is most closely correlated with average annual precipitation ($r = -0.630$) and aspect ($r = 0.582$), reflecting overall humidity and water availability.

Figure 2 shows that the distribution of the communities along the two axes is uneven. The communities A, B, K, D, E, O, I and M are strongly influenced by the first axis, and the communities C, J, P, N, L, D, H, G and F

Table 4. Results of detrended canonical correspondence analysis.

| Index		Axis			
		1	2	3	4
Eigenvalue		0.530	0.435	0.257	0.422
Species-environment correlation coefficients		0.979	0.963	0.939	0.000
Cumulative percentage variance of species data		12.5	22.8	28.9	38.9
Cumulative percentage variance of species-environment relation		23.4	42.5	53.9	0.0
Sum of all eigenvalues		4.229			
Sum of all canonical eigenvalues		2.268			
Monte Carlo test	Test of significance of first canonical axis	$P = 0.0280 < 0.05$			
	Test of significance of all canonical axes	$P = 0.0020 < 0.005$			
Species-environment correlations	Longitude (LO)	−0.415	−0.442	0.222	0.000
	Latitude (LA)	−0.567	0.487	−0.537	0.000
	Altitude (AL)	0.319	0.134	−0.340	0.000
	Aspect (AS)	−0.075	0.582	0.234	0.000
	Slope (SL)	−0.670	0.186	0.268	0.000
	Average annual temperature (AT)	0.402	0.097	−0.079	0.000
	Average annual precipitation (AP)	−0.272	−0.630	0.272	0.000
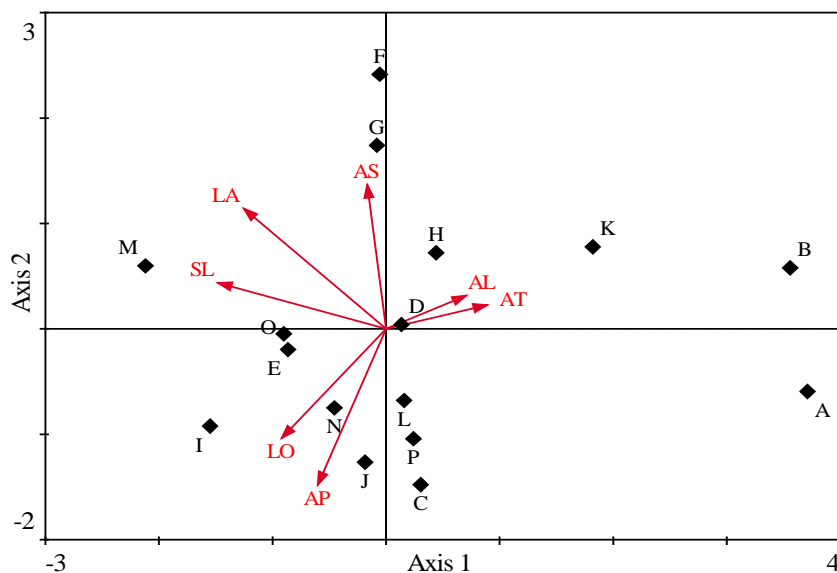
Figure 2. DCCA ordination diagram of 16 communities of *Davidia involucrata* forest.

are significantly affected by the second axis. Especially, the communities A, B and K are more likely to occur in warmer areas at low latitude (south of 28.1˚N); the communities M, I and O more frequently occupy habitats on shady steep slopes (more than 32˚); the communities F and G are more likely located in sunny, dry environments; and the communities C, J, P, N and J are found in more humid environments. However, many communities were scattered along the second axis, indicating that the forests adapt more to habitats with intermediate temperature, although the temperature tolerance range is wider.

4. Discussions

This study analyzed *Davidia involucrata* forests, which occur from 27˚35'N to 31˚25'N and from 102˚17'E to 110˚20'E in south-central China. The 72 total samples of *Davidia involucrata* forest were summarized into 16 communities. *Davidia involucrata* communities are predominantly made up of deciduous broad-leaved trees, mixed with some evergreen broad-leaved species belonging to the genera of *Castanopsis*, *Lithocarpus*, *Machilus*, *Cyclobalanopsis*, *Ilex*, *Camellia*, etc. *Davidia involucrata* forest is usually differentiated from other deciduous forests by the species *Davidia involucrata*, *Tetracentron sinense*, *Cornus controversa*, *Cercidiphyllum japonicum*, *Juglans cathayensis*, *Aesculus chinensis* var. *wilsonii*, *Pterostyrax psilophyllus*, *Padus avium*, *Acer henryi*, *Acer oliverianum*, *Davidia involucrata* var. *vilmoriniana*, *Acer palmatum*, *Euptelea pleiospermum*, *Acer flabellatum*, *Meliosma cuneifolia*, *Chrysosplenium macrophyllum*, *Padus grayana*, *Staphylea holocarpa*, *Ficus heteromorpha*, *Dipteronia sinensis*, *Hemiboea henryi*, *Schizophragma integrifolium*, *Litsea mollis* and *Tapiscia yunnanensis*. Also, the shrub layer of *Davidia involucrata* forest is usually dominated by different bamboos, just like *Fagus* forest [36].

Plants belonging to the temperate element are dominant, but species belonging to the tropical element also occur in large proportions, indicating that *Davidia involucrata* forest has the features of temperate forests but is also connected closely with tropical floristics. The general pattern of geographical variation among the communities is explained clearly by the temperature and water availability (including air humidity), and the forest is more likely to grow in warm, moist habitats.

Acknowledgements

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