Postprint: Coppice Regeneration Characteristics of Woody Plants in the Evergreen Broad-Leaved Forest at Gutian Mountain, Qianjiangyuan National Park

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Abstract

Sprouting regeneration is an effective mechanism for woody plants to regenerate in situ, endowing communities with strong resilience. However, previous studies have emphasized seed regeneration, and the characteristics of sprouting regeneration of woody plants in forests and their role in forest communities remain insufficiently understood. Based on community data from a 5 hm² subtropical evergreen broad-leaved forest plot in Gutianshan National Nature Reserve, Qianjiangyuan National Park, we analyzed the quantitative characteristics of sprouting regeneration in woody plants and compared sprouting ability among different taxonomic units and functional groups. The results showed that: (1) 64% of species and 20% of seed-derived individuals in the plot had undergone sprouting regeneration, and the number of sprouting stems accounted for 24% of the total number of individuals in the plot; (2) Sprouting ability exhibited significant differences at both the species level and family level ($F = 13.11$, $P < 0.001$; $F = 27.45$, $P < 0.001$). Species such as Corylopsis glandulifera, Chimonanthus salicifolius, Viburnum erosum, Eurya rubiginosa var. attenuata, and Pieris formosa showed strong sprouting ability, and families such as Calycanthaceae, Caprifoliaceae, Magnoliaceae, and Fagaceae exhibited strong sprouting ability; (3) Sprouting ability differed significantly among different vertical structural layers (canopy layer, sub-canopy layer, shrub layer) ($F = 117.5$, $P < 0.001$), with the sprouting ability of shrub layer species being approximately double that of canopy and sub-canopy layer species. Sprouting ability also differed significantly between different life forms (evergreen component vs. deciduous component), with evergreen groups showing significantly higher sprouting ability than deciduous groups ($P < 0.001$). Sprouting regeneration holds an important position in subtropical evergreen broad-leaved forests and may represent one of

the mechanisms for maintaining species diversity, community regeneration, and succession. Shrub species and evergreen species possess strong sprouting ability, suggesting that sprouting may be an ecological strategy for plants to adapt to shaded environments.

Full Text

Sprouting Characteristics of Woody Species in a Subtropical Evergreen Broad-Leaved Forest in Gutianshan of Qianjiangyuan National Park, East China

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Abstract

Sprouting is an effective means of in-situ regeneration in woody plants that confers strong resilience to forest communities. However, most previous studies have focused on seedling regeneration, leaving the characteristics and ecological significance of sprouting regeneration in forest communities insufficiently understood. Based on community data from a 5 hm² plot of subtropical evergreen broad-leaved forest in the Gutianshan National Nature Reserve of Qianjiangyuan National Park, we quantitatively analyzed the basic characteristics of sprouting regeneration in woody plants, variations in sprouting ability among different taxonomic and functional groups. Our results showed that: (1) 64% of species and 20% of individuals exhibited sprouting, with sprouted stems accounting for 24% of total individuals in the plot. (2) Sprouting ability varied significantly among species and families ($F = 13.11$, $P < 0.001$; $F = 27.45$, $P < 0.001$). Specifically, *Corylopsis glandulifera*, *Chimonanthus salicifolius*, *Viburnum erosum*, *Eurya rubiginosa* var. *attenuata*, and *Pieris formosa* showed strong sprouting ability, as did families including Calycanthaceae, Caprifoliaceae, Magnoliaceae, and Fagaceae. (3) Significant differences in sprouting ability were detected among vertical structural layers ($F = 117.5$, $P < 0.001$), with shrub layer species showing approximately twice the sprouting ability of canopy and sub-canopy layers. Significant differences also existed between life forms (evergreen vs. deciduous), where evergreen groups exhibited higher sprouting ability than deciduous groups ($F = 27.45$, $P < 0.001$). Sprouting regeneration plays an important role in subtropical evergreen broad-leaved forests and may represent one of the mechanisms underlying species diversity maintenance and community succession. The strong sprouting ability of shrub and evergreen species suggests that sprouting may be an ecological strategy for shade tolerance.

Keywords: sprouting; regeneration; functional groups; evergreen broad-leaved forest; Gutianshan; Qianjiangyuan National Park

Introduction

Sprouting is an important regeneration strategy in the life history of woody plants [1-3]. Through sprouting, plants can rapidly produce new stems to compensate for biomass loss caused by disturbances [4]. As an effective means of in-situ regeneration, sprouting enables forest communities to recover strongly after disturbance [5-6] and allows plants to continuously occupy their original niches [3,7], thereby enhancing community stability. Compared to seedling regeneration, sprouting requires less time and promotes individual survival and longevity [8-10]. However, previous forest community research has predominantly focused on seedling regeneration, largely overlooking the distinctions between sprouting and seedling regeneration.

Sprouting regeneration is ubiquitous in forest ecosystems [3,11], primarily occurring through stem base sprouting that forms multi-stemmed individuals [12-13]. While particularly common in low-stature forest types such as shrublands [14], sprouting species and individuals also constitute a significant proportion in tall forests [12,15]. Sprouting ability varies among species [16], and different forest types with distinct species compositions exhibit different sprouting regeneration patterns [15]. Functional groups such as trees versus shrubs, as well as variations in diameter class and habitat, may also lead to different sprouting abilities, ultimately resulting in different ecological processes and effects. Therefore, understanding the sprouting regeneration characteristics of different evolutionary and functional groups is essential for elucidating species coexistence and community dynamics.

China' s subtropical evergreen broad-leaved forests, characterized by extensive area and rich biodiversity, represent the main distribution of global evergreen broad-leaved forests and provide important environmental and ecological benefits [17]. However, due to overexploitation and massive human disturbance, most primary evergreen broad-leaved forests have been replaced by secondary forests or degraded shrublands, creating an urgent need for ecological restoration [18]. The Gutianshan National Nature Reserve within Qianjiangyuan National Park preserves intact evergreen broad-leaved forest [18], where previous studies have documented sprouting phenomena and suggested that sprouting regeneration may be one mechanism maintaining community biodiversity [19]. Nevertheless, detailed characteristics of sprouting regeneration remain inadequately observed.

Based on a subtropical evergreen broad-leaved forest plot in Qianjiangyuan National Park' s Gutianshan region, this study analyzed the basic characteristics of woody plant sprouting regeneration to understand the role of sprouting species in forest communities. By comparing sprouting characteristics among different species, taxonomic groups, and functional groups, we aim to provide a scien-

tific basis for effective conservation and restoration of degraded vegetation in subtropical evergreen broad-leaved forests.

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1. Study Area

The study was conducted in a 5 hm² (200 m × 240 m) permanent plot established according to the Center for Tropical Forest Science (CTFS) standards [20], located in the Gutianshan National Nature Reserve of Qianjiangyuan National Park (29°10 19.4 –29°17 41.4 N, 118°03 49.7 –118°11 12.2 E, elevation 350–800 m). The region experiences a mid-subtropical humid monsoon climate with mean annual temperature of 15.3°C (27.6°C in July, 4.1°C in January) and mean annual precipitation of 1963.7 mm. The main vegetation types include evergreen broad-leaved forest (350–800 m), coniferous-broadleaved mixed forest (800–1100 m), and montane dwarf forest (1100–1800 m). Evergreen broad-leaved forest is the dominant vegetation type [18], with *Castanopsis eyrei*, *Schima superba*, *Pinus massoniana*, and *Camellia fraterna* as dominant species.

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2. Sprouting Indices and Functional Group Classification

This study defined sprouting regeneration as the phenomenon where new stems sprout from the base of main stems to form multi-stemmed individuals. During plot surveys, we recorded sprouting species, number of new stems, and diameter at breast height (DBH). Sprouting ability at the species level was calculated as: (number of sprouting individuals of the species)/(total individuals of the species), representing the intensity of sprouting for that species in the community. At the taxonomic or functional group level, sprouting ability was calculated as: (total sprouting individuals of all species in the group)/(total individuals of all species in the group), representing the group' s sprouting intensity.

Taxonomic comparisons were made at both species and family levels. For species-level analysis, we included species occurring in more than 10 quadrats; for family-level analysis, families occurring in more than 10 quadrats were included. Functional groups were classified by vertical structural layer and life form. Vertical structure was divided into canopy layer, sub-canopy layer, and shrub layer. Life forms were categorized as evergreen or deciduous. Both vertical layer and life form analyses included species occurring in more than 5 quadrats.

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3. Data Analysis

Statistical analyses and graphing were performed in R 3.3.1 [21]. One-way ANOVA was used to test differences in sprouting ability among species, families,

and vertical structural layers. *t*-tests were used to compare sprouting ability between evergreen and deciduous groups.

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2. Results

2.1 Composition of Sprouting Individuals in the Plot A total of 89 tree species exhibited sprouting regeneration, accounting for 63.95% of all species. Among 23,636 recorded stems, 14,066 were single-stemmed (59.54%) and 9,570 were sprouting stems (40.46%). Of 13,657 individual plants, 8,397 were single-stemmed (61.49%) and 5,260 were multi-stemmed sprouting individuals (38.51%). Thus, 38.51% of stems in the plot had potential sprouting capacity, while 61.49% of species showed no sprouting.

Composition characteristics of sprouting individuals in the 5 hm² plot

2.2 Variation in Sprouting Ability Among Taxonomic Groups At the species level, sprouting ability varied significantly ($F = 13.11$, $P < 0.001$). The top 20 species with strongest sprouting ability included *Corylopsis glandulifera*, *Chimonanthus salicifolius*, *Viburnum erosum*, *Eurya rubiginosa* var. *attenuata*, and *Pieris formosa*, all exceeding 0.5 sprouting ability. These species had large individual numbers, wide distribution across vertical layers, and were predominantly evergreen.

At the family level, sprouting ability also differed significantly ($F = 27.45$, $P < 0.001$). Families with strong sprouting ability included Calycanthaceae, Caprifoliaceae, Magnoliaceae, and Fagaceae. Ericaceae and Calycanthaceae had large individual numbers and wide distribution.

Variations in sprouting capacity at species level in 5 hm² plot
Sprouting abilities of top 20 species in 5 hm² plot
Variations in sprouting capacity at family level in 5 hm² plot
Sprouting abilities of top 10 families in 5 hm² plot

2.3 Variation in Sprouting Ability Among Functional Groups Sprouting ability differed significantly among vertical structural layers ($F = 117.5$, $P < 0.001$). Shrub layer species showed the strongest sprouting ability (0.59 ± 0.21), far exceeding sub-canopy (0.30 ± 0.13) and canopy layers (0.29 ± 0.15). The difference between sub-canopy and canopy layers was not significant ($P = 0.84$).

Life form also significantly influenced sprouting ability. Evergreen groups showed significantly higher sprouting ability (0.37 ± 0.11) than deciduous groups (0.21 ± 0.25, $t = 27.45$, $P < 0.001$).

[Figure 1: see original paper] Sprouting abilities in different functional groups of vertical layer and life form

3. Discussion

3.1 The Role of Sprouting Regeneration in the Community This study found that 63.95% of species and 38.51% of stems exhibited sprouting regeneration, indicating that sprouting holds both taxonomic and numerical dominance in the Gutianshan evergreen broad-leaved forest. Previous research also showed that after logging disturbance, recovery of mid-montane evergreen broad-leaved forest in Ailao Mountain relied primarily on sprouting rather than seed germination [22]. In Tiantong Mountain, sprouting abundance reached 67.3% and 31.7% in two differently disturbed communities [5]. These findings demonstrate that sprouting regeneration plays a crucial role in China' s subtropical evergreen broad-leaved forests.

Forest species' sprouting capacity is influenced by external factors such as habitat and resource availability, as well as internal factors like nutrient levels and hormone synthesis [11-12]. The Gutianshan Nature Reserve has not experienced large-scale fire or flooding in recent decades, though an ice-snow disaster occurred in early 2008. The plot features high rock exposure rates that affect soil and moisture conditions, potentially hindering seedling regeneration while promoting sprouting. The prevalence of sprouting in this forest suggests it represents an important life history strategy for vegetation regeneration in this region.

3.2 Sprouting Ability Among Taxonomic Groups Both species- and family-level sprouting abilities varied significantly in our plot. Previous studies have documented interspecific variation in sprouting ability [16,24]. Vesk and Westoby [15] found that across 252 species globally, sprouting ability was not phylogenetically conserved, suggesting sprouting strategies may be evolutionarily unstable or have multiple origins. Some species such as *Corylopsis glandulifera*, *Eurya rubiginosa* var. *attenuata*, *Pieris formosa*, and *Cyclobalanopsis glauca*, along with families like Fagaceae, Magnoliaceae, and Calycanthaceae, employ more sprouting strategies than others, contributing to forest community stability. Studies in Tiantong Mountain and Gutianshan also found strong sprouting ability in *Schima superba* (Theaceae), *Lithocarpus glaber* (Fagaceae), *Chimonanthus salicifolius* (Calycanthaceae), *Viburnum erosum* (Caprifoliaceae), and some Ericaceae species [5,23]. These taxa should be prioritized as pioneer species for restoration of mid-subtropical evergreen broad-leaved forest ecosystems.

3.3 Sprouting Ability Among Functional Groups Significant differences in sprouting ability existed among vertical structural layers, with shrub layer species showing the strongest capacity. Previous research also found sprouting more common in shrub layers [25-26]. Non-sprouting trees allocate resources to rapid vertical growth to reach the canopy, while sprouting trees divide re-

sources among multiple stems, limiting rapid vertical growth of any single stem and typically forming low shrub layers [25,27-28]. In our plot, the top 20 sprouting species were mostly shrubs, particularly *Chimonanthus salicifolius*, which occurred in nearly every quadrat with the highest individual numbers. From a disturbance avoidance perspective, more tree species may grow rapidly to escape or resist environmental stress, while shrub species, constrained by height and growth disadvantages, may adopt more sprouting strategies to tolerate and survive disturbances [8,29].

We also found significant differences between life forms, with evergreen groups showing higher sprouting ability than deciduous groups. Evergreen and deciduous species represent two important life form components in evergreen broad-leaved forests [17]. Evergreen species have smaller specific leaf area and lower photosynthetic nitrogen use efficiency, allowing them to save leaf nutrient costs and allocate more energy to structural materials, which may confer advantages in nutrient-poor soils [30-31]. In our 5 hm^2 plot, evergreen species were more common on slopes with thin soil layers and high rock exposure, while deciduous species dominated valleys with thicker soils. The higher sprouting ability of evergreen species may reflect this trade-off in structural material investment and suggests sprouting regeneration may be associated with tolerance to soil infertility.

4. Conclusion

Sprouting regeneration occupies an important position in subtropical evergreen broad-leaved forests, with substantial variation among evolutionary lineages and functional groups. Understory shrub species and evergreen species exhibit strong sprouting ability, suggesting that sprouting may be an ecological strategy for adapting to shaded environments. Sprouting represents an important regeneration mechanism in these communities. Future research should investigate the evolutionary history of sprouting ability in evergreen broad-leaved forest species and conduct tolerance experiments comparing sprouting and seedling strategies to deepen our understanding of sprouting regeneration' s role in community dynamics.

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Note: Figure translations are in progress. See original paper for figures.