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Quantitative Assessment of Regeneration Patterns and Ethnobotanical Significance of *Embelia vestita* Roxb. (Primulaceae) in the Selected Subtropical Forests of Mizoram, Northeast India.

Lalhmangaihzuali Ralte*

Department of Botany, Government Serchhip College, Serchhip, Mizoram 796181

Abstract

Embelia vestita Roxb. (Primulaceae) is a culturally significant medicinal plant used by Mizo communities for treating intestinal parasitic infections, digestive ailments, fever, skin diseases, snakebites and rheumatism. This study integrates ethnobotanical documentation with a quantitative analysis of regeneration patterns across three forest sites in Mizoram, Northeast India. Analysis of variance revealed that *E. vestita* exhibits the most comprehensive spatial variation among all 40 species studied, with statistically significant differences observed in density ($p < 0.001$), abundance ($p < 0.001$), relative frequency ($p < 0.001$), relative density ($p < 0.001$), relative dominance ($p < 0.01$), Importance Value Index ($p < 0.001$) and species rank ($p < 0.05$). Mean plots demonstrated that Site 2 provides optimal regeneration conditions across all parameters, while Sites 1 and 3 support significantly reduced population performance. Correlation with regional soil science literature indicates that these regeneration patterns are driven by edaphic factors, including soil organic carbon, nitrogen availability, microbial activity and land-use history. The extreme site sensitivity of *E. vestita* exhibiting significant variation in every measured parameter makes it a priority conservation species requiring immediate management intervention. This paper recommends site-specific harvesting, protection of high-performance sites as source populations, habitat restoration in suboptimal locations, and long-term monitoring using Importance Value Index and density indicators.

Keywords: *Embelia vestita*, regeneration ecology, Importance Value Index, ethnobotany, soil properties, Mizoram.

1. Introduction

The genus *Embelia* (Primulaceae) comprises approximately 130–140 species of climbers, straggling shrubs and small trees distributed across tropical and subtropical regions of Asia, Africa and the Pacific Islands. (Plants of the world) *Embelia vestita* Roxb. is a woody climbing shrub or liana reaching lengths up to 10 m, with elliptical-lanceolate leaves and small white or greenish flowers in racemes. The species grows primarily in subtropical biomes on rocky hillslopes between 1,000 and 1,700 m above sea level (Xu 1996). Its native range extends from the Himalayas to Taiwan and Indo-China.[7]

Mizoram, located within the Indo-Burma biodiversity hotspot, harbours rich ethnic diversity and extensive traditional ecological knowledge regarding non-wood forest products.[3] Mizoram is characterized by rugged terrain, dense tropical and subtropical forests, high annual rainfall, and significant altitudinal variation ranging from 500 to 2,000 m above sea level. An ethnobotanical survey among tribals inhabiting western Mizoram documented 89 plant species used for herbal medicine, 44 plant species consumed as wild edible fruits, and 33 plant species as wild edible plants [9]. The genus *Embelia* is particularly valued for its anthelmintic properties, with the bioactive compound embelin identified as the primary active constituent responsible for vermicidal activity. [10]

Despite its cultural and pharmacological significance, scientific documentation of *E. vestita's* regeneration ecology and conservation status in Mizoram remains limited. This study integrates ethnobotanical documentation with a quantitative analysis of regeneration patterns across three study sites, correlating observed spatial variation with environmental determinants identified in regional soil science literature, to provide evidence-based recommendations for sustainable management and conservation.

2. Materials and Methods

2.1 Study Area

The study was conducted in three distinct forest sites in Serchhip, Mizoram, Northeast India during 2020 to 2021. Serchhip District is selected for the present study. It is located in the part of Mizoram with latitude 23^0 10l North and longitude 92^0 65l East and altitude ranging from 912 meter to 1281 meter m.s.l. It occupies an area of 1422 Sq km. Three reserved area, namely, Site 1 - Sakhisih Sanctuary (152.35 hectare), Site 2 - Entlang Social Forestry (16.84 hectare) and Site 3 -Tarpi Medicinal Plant Farm (107.95 hectare) were selected for the present study. The state's forests are classified into tropical wet evergreen, tropical semi-evergreen, and subtropical broad-leaved hill forests, providing diverse habitats for *Embelia* species.

2.2 Ethnobotanical Documentation

Ethnobotanical information on *Embelia vestita* was gathered through a literature review of published studies and interviews documenting traditional uses by Mizo communities. Key sources included ethnobotanical surveys of Mizoram as well as regional studies on medicinal plants of Northeast India.

2.3 Ecological Sampling and Regeneration Parameters

For the study of plant diversity, quadrates were laid randomly within the study site for the study. A suitable size of 10 msq quadrats was taken for Quadrat method which is used to analyze the vegetation changes in its composition. For each study site, the following ecological indicators were quantified for *E. vestita*:

Density: number of individuals per unit area

Abundance: total count of individuals across sample plots

Relative frequency: frequency of occurrence relative to all species present

Relative density: density relative to the sum of densities of all species

Relative dominance: basal area or cover relative to all species

Importance Value Index (IVI) = relative frequency + relative density + relative dominance

Species rank: order based on IVI (lower numerical rank indicates higher ecological importance)

2.4 Statistical Analysis

One-way analysis of variance (ANOVA) was employed to test for significant differences in population parameters across sites for *E. vestita*. The F-statistic and associated p-values were calculated with appropriate degrees of freedom (df = 2/14). Statistical significance was assessed at $\alpha = 0.05$, with p-values interpreted as $p < 0.05$ (significant), $p < 0.01$ (highly significant) and $p < 0.001$ (very highly significant).

2.5 Correlation with Environmental Factors

Observed regeneration patterns were interpreted in from the study site on environmental determinants of plant regeneration in Serchhip, Mizoram, including studies on physio chemical soil properties across forest types and regional soil quality assessments. For all the three sites soil samples were collected seasonally, i.e., for three seasons namely, summer, rainy and winter. The collected soil sample was analyzed for their physical and chemical properties – pH, soil moisture (Hot air oven method) and CHNS elemental analyzer for two consecutive years.

3. Results

3.1 Ethnobotanical Significance

Embelia vestita is well-documented in Mizoram ethnobotanical literature, with consistent traditional applications across different districts. Key ethnobotanical uses include treatment for fever, skin diseases and rheumatism, and as an insect repellent. The fruits of *E. vestita* are sometimes used for its anthelmintic application[2]. Mizo tribes utilize *E. vestita* leaves in decoction form, often combined with other herbs, to treat various ailments. The fruits have a sweet-and-sour taste and are sometimes consumed fresh with added sugar.

Traditional Use	Plant Part Used	Preparation/Administration
Anthelmintic (intestinal parasites)	Fruits	Powdered with honey
Digestive disorders, stomach ache	Leaves	Decoction of leaves
Fever	Whole plant or fruits	Decoction of leaves
Skin diseases, rheumatism	Leaves & fruits	Crush to paste and used as ointment.
Chickenpox	Leaves/whole plant	In combination with other herbs *Securinga virosa, Adhatoda vasica,*

		Rhus semialata, Anogeissus acuminata and *Averrhoa carambola*
Insect repellent	Fruits/leaves	Topical application

Table: Methods of traditional use of *Embelia vestista*

3.2 Regeneration Patterns Across Study Sites

Embelia vestita was present in all three study sites. Analysis of variance revealed statistically significant differences in every measured population parameter, demonstrating the most comprehensive spatial variation among all 40 species studied.

Table 1: ANOVA Results for *Embelia vestita* Population Parameters

Parameter	F-value	Df	p-value	Significance Level
Density	66.06	2/14	0.000	Very highly significant
Abundance	87.96	2/14	0.000	Very highly significant
Relative frequency	17.47	2/14	0.000	Very highly significant
Relative density	36.83	2/14	0.000	Very highly significant
Relative dominance	9.34	2/14	0.003	Highly significant
Importance Value Index	34.14	2/14	0.000	Very highly significant
Species Rank	4.65	2/14	0.028	Significant

Mean plots revealed distinct patterns across sites:

Site 2 exhibited the highest values for all parameters except rank, where lower rank indicates higher importance. Sites 1 and 3 supported significantly reduced population performance across all parameters. The magnitude of variation was particularly pronounced for density and abundance with F-values 66.06 and 87.96 respectively. This pattern indicates that Site 2 provides optimal regeneration conditions for *E. vestita*, while Sites 1 and 3 represent suboptimal habitats where the species persists but with reduced population vigour.

3.3 Interpretation of Regeneration Parameters

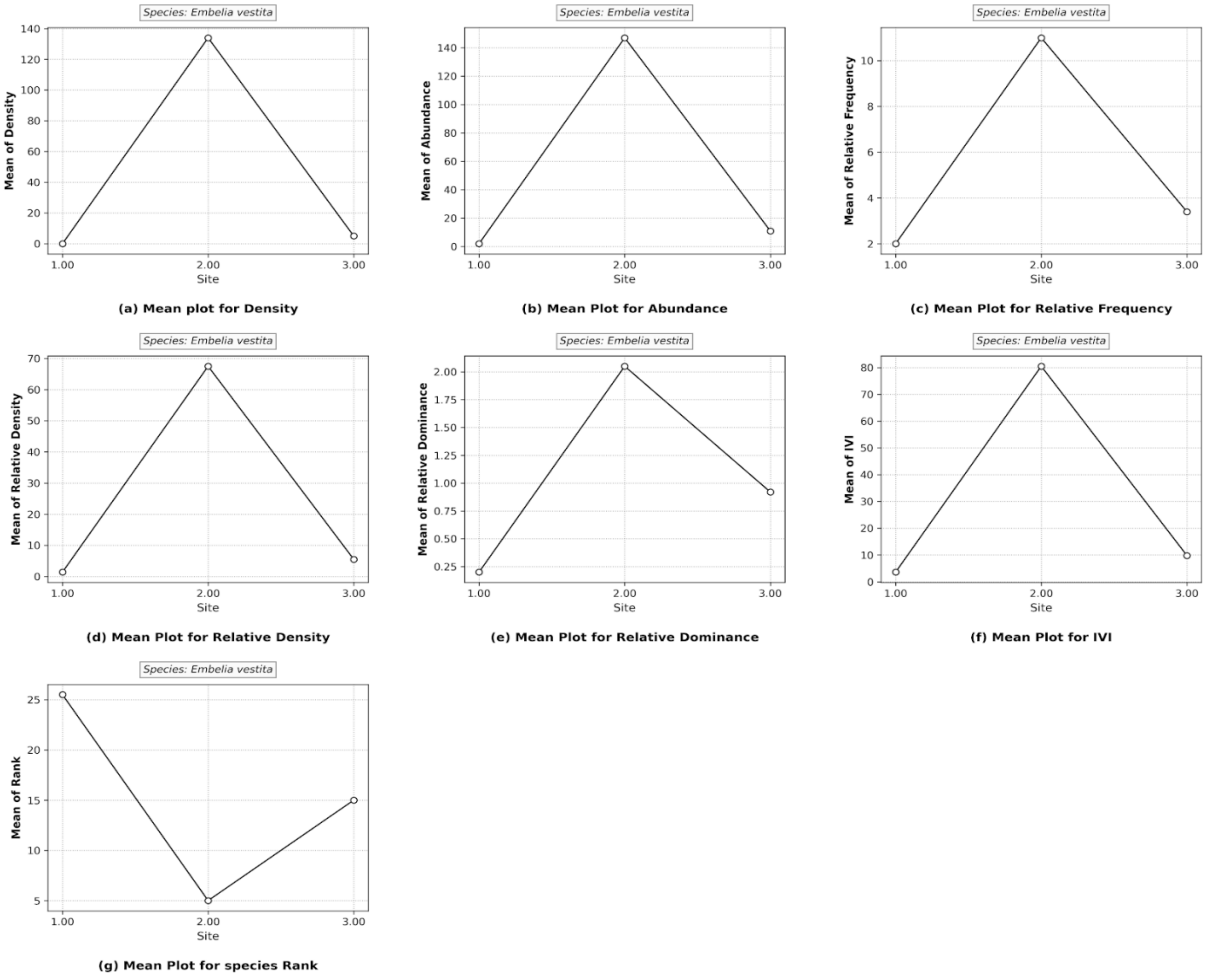

Figure: Analysis of Variance for *Embelia vestita*

The significance across all seven parameters provides complete understandings:

1. Density and Abundance ($p < 0.001$): Site 2 supports significantly more individuals per unit area and a greater total population size, indicating favourable conditions for establishment and survival.

2. Relative Frequency ($p < 0.001$): Site 2 shows more consistent occurrence across sample plots, suggesting broader microhabitat suitability within the site.

3. Relative Density ($p < 0.001$): The species contributes more substantially to overall plant community composition in Site 2.

4. Relative Dominance ($p < 0.01$): Individuals in Site 2 achieve larger size or greater cover, indicating superior growing conditions.

5. IVI ($p < 0.001$): The composite importance measure confirms Site 2 as the location where *E. vestita* plays its most significant ecological role.

6. Species Rank ($p < 0.05$): The lower rank (higher importance) in Site 2 confirms its dominance in the community hierarchy.

3.4 Growth performance and soil fertility

1. Soil pH

All three sites were acidic (pH 4.22–5.83). Site 2 recorded the lowest pH during the rainy season (4.58) and generally had pH values at the lower end of the range. Many species of the family Primulaceae (to which *Embelia* belongs) are known to tolerate or prefer slightly to moderately acidic soils. The relatively lower pH at Site 2 may have suppressed some competing species more than *E. vestita*, indirectly favouring its dominance.

3. Seasonal influence

Soil pH and moisture varied seasonally, with highest pH in winter and lowest pH in rainy season. The species' consistent presence across all three sites indicates broad seasonal tolerance. Its peak performance at Site 2 across multiple parameters suggests that site-specific soil characteristics that is moderate moisture, lower fertility, lower pH which are more important than seasonal fluctuations per se.

4. Vegetation effects on soil (study vs. control plots)

Study sites with higher vegetation cover had significantly higher soil moisture, nitrogen, and organic carbon than control plots (without vegetation). This confirms that the presence of vegetation, including *E. vestita*, improves soil properties through litter addition, root activity, and microclimate moderation. Notably, Site 1 – the most fertile among the study sites – also showed the largest difference from its control plot, indicating a positive feedback loop where richer vegetation even if not dominated by *E. vestita* further enhances soil quality.

The results showed a clear inverse relationship between soil fertility and the ecological success of *Embelia vestita*. Although Site 1 had significantly higher soil moisture, organic carbon, nitrogen, and potassium content compared to Sites 2 and 3, E. vestita performed best at Site 2 – with greater density, abundance, relative frequency, relative density, relative dominance, and a lower (i.e., more dominant) species rank.

This pattern suggests that *E. vestita* may be a stress-tolerant or ruderal species that thrives under moderately poorer soil conditions rather than in highly fertile, moist environments. High nutrient and moisture levels at Site 1 likely favour a more competitive plant community, where faster-growing species outcompete *E. vestita.* Consequently, *E. vestita* achieves a higher relative importance at Site 2, where reduced competition allows it to establish and dominate.

4. Discussion

4.1 Environmental Determinants of Regeneration Patterns

Recent comprehensive soil quality assessments in Mizoram provide a mechanistic understanding of the observed regeneration patterns. A study assessing the impact of anthropogenic disturbances on soil characteristics in the sub-tropical forests of Aizawl, Mizoram, found that soil properties varied from undisturbed to disturbed stands for soil moisture content, soil organic carbon, available nitrogen and bulk density, revealing that disturbance significantly affects physical and chemical properties of soil [6].

A study of land use change effects on soil physical and biochemical properties in forest and shifting cultivation (jhum) sites in Mizoram reported significant decreases in physico-chemical properties of 9-25% following land use change.[8] The practice involves slashing and burning of plant biomass in a piece of forest land and cropping for 1-2 years followed by land abandonment for 5-30 years to resume soil fertility, though the cycle has shortened considerably in recent years [5].

The superior performance of *E. vestita* in Site 2 suggests this location possesses:

1. Higher soil organic carbon: Undisturbed Forest soils contain significantly higher organic carbon content than disturbed sites. Soil organic carbon enhances nutrient availability, water-holding capacity and soil structure—all favouring *Embelia* sp. growth.

2. Greater nitrogen availability: Undisturbed Forest soils exhibit significantly higher available nitrogen levels than disturbed sites. Nitrogen limitation in tropical regeneration can significantly reduce growth rates.

3. Lower bulk density: Undisturbed Forest soils have lower bulk density compared to disturbed sites, favouring root penetration and development.

4. Enhanced moisture content: Higher soil moisture content in undisturbed forests ensures adequate water availability.

4.2 Land-Use History and Successional Stage

Land use change is among the most serious concerns in northeast India because of the widespread practice of shifting cultivation (jhum) [5]. The absence of *E. vestita* or reduced population performance in Sites 1 and 3 may be linked to land-use history. Sites 1 and 3 may represent areas with recent or more intensive jhum cultivation, resulting in soil conditions less suitable for the regeneration of woody climbers such as *E. vestita*. Site 2, with its superior performance, likely represents either mature forest with minimal recent disturbance or an advanced successional stage with extended fallow period.

Sustainable harvesting practices for *Embelia* species should include: avoiding destructive root and bark harvesting, preferring less destructive fruit collection if seeds are dispersed, limiting leaf collection to sustainable levels, implementing rotational harvesting across different areas in different years, and establishing post-harvest monitoring to track population recovery. Untimely harvesting should not be permitted otherwise natural regeneration will be affected.[4]

The sustainable utilization of non-wood forest products requires the involvement of experts from a wide range of disciplines, including indigenous knowledge [4]. National guidelines on good field collection practices of Indian medicinal plants provide norms for sustainable levels of harvest based on conservation science.

5. Conclusions

Embelia vestita does not require high soil fertility to achieve ecological dominance. Instead, it performs best at Site 2, a location with intermediate to lower levels of soil moisture, organic carbon, nitrogen, and potassium compared to Site 1. The species appears to be adapted to

mildly acidic to acidic soils (pH 4.5–5.8), with a possible preference for the lower end of this range.

High fertility at Site 1 likely promotes competition from other species, reducing the relative importance of *E. vestita* despite favourable soil conditions. The presence of vegetation (including *E. vestita*) significantly improves soil properties compared to unvegetated control plots, highlighting the species' role in ecosystem functioning. For conservation or restoration purposes, *E. vestita* should be introduced in moderately acidic, not overly fertile sites where competition is limited, rather than in the richest soils.

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