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Impact on Density of *Paeonia emodi* along Altitudinal Gradient in Garhwal Himalaya, India

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Abstract In the present study we have described the impact of altitudinal gradient on the density of *Paeonia emodi* in the Garhwal Himalayan region. The study site was divided into three altitudinal gradient viz., between 1800 to 2000, 2200 to 2400 and 2600 to 2800 m asl. The maximum density (3.80 individual/m^2) and frequency (80 percentage) was found in lower altitude (1800-2200 m asl), medium density (2.76 individual/m^2) and 76 frequency percentage) at mid-altitude (2200-2400 m asl) and minimum density 2.08 individual/m^2 and 60 frequency percentage at the maximum altitude between 2600 and 2800 m asl. Low population density of *P. emodi* along with increasing elevation is due to the unfavorable climatic conditions and lack of association with tree species like *Oak* and *Rhododendron.* This association provides the canopy cover and moist land as well as suitable habitat to many herbaceous species. The present investigation regarding species availability of target species can be used in understanding the distribution pattern and the relationship with altitudinal gradient of density would help in designing appropriate conservation and management policy to this important medicinal plant in terms of ethnobotanical view.

Keywords: *altitudinal gradient, Garhwal Himalayan Region, High altitude, Paeonia emodi, population density*

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1. Introduction

The Indian Himalayan Region (IHR) with wide-ranging elevations, deep glacial and river valleys is centre of endemism for biodiversity, harboring endangered species and ecosystems, and sustaining the lives of millions peoples [1]. A total of 1748 species of Medicinal and Aromatic Plant (MAPs) with various traditional and modern therapeutic uses [2]. Altitude and disturbance from human settlements in mountain area significantly influences the species richness and diversity and species cover in mountain region [3,4]. Ecologists have attempted to understand the variation in species density along altitudinal gradients in Himalayan ecosystem [5,6,7,8]. Hence, the Himalayan region can serve as an excellent system for the evaluation of medicinal plant density along an altitudinal gradient [9].

Paeonia emodi Wall. ex Royle (family Paeoniaceae), a perennial herb commonly known as **'Chandra'** or '**Dhanduru**' is distributed in IHR, between 1500-3000 m asl [10,11]. It generally grows in various forest habitats under moist conditions. The flowers are whitish, born from the axils of upper leaves, 6-10 cm in diameter, hermaphrodite and pollinated by insects. Fruits are oval shaped-pod with leathery in texture. Seeds are black, smooth, and shiny with hard seed coat. The flowering occurs between March-June and fruits appear at the beginning of monsoon [12]. *P. emodi* has several applications in traditional medicinal health care systems; the rhizomes and leaves are used to cure dropsy, epilepsy, headache, vomiting [13,14]. An infusion of the dried flowers is useful in treatment of diarrhea, whooping cough, hemorrhoids and intestinal pain [15]. However, limited studies are available on medicinal plants densities among different habitats and with changing altitude, specifically in Garhwal region. Therefore, the objective of present study was to investigate the population density of ethnobotanically important species along with changing altitude in Garhwal Himalaya.

2. Material and Method

2.1. Study Area

Present study was conducted at Pothivasa region (30°30'0"N and 79°09'50"E) in Garhwal Himalaya, Uttarakhand, India (Figure 1). The study area is characterized by its typical temperate to near alpine climatic conditions. The dominant tree species in the area are *Quercus leucotrichophora*, *Rhododendron arboreum*, *Aesculus indica*, *Lyonia ovalifolia*,etc. Local community adjacent to the forest mostly depend on forest resources for fodder, fuel wood, livestock grazing, timber and non-timber forest products.

2.2. Sampling Design and Plot Selection

Vegetation sampling was carried out during the rainy season between July and September, 2018. The study site has been divided into three altitudinal gradient viz., between 1800 to 2000, 2200 to 2400 and 2600 to 2800 m asl for the study (Figure 2). A single line-transect was used along the altitudinal gradient (1800-2800 m asl) for assessing the status of *P. emodi* and associated herbs. Quadrat method [16] was used to study the plant density and distribution of species across the altitudinal gradient. For sampling, 1×1 m quadrats were randomly laid down at equal intervals with the distance of 200 m along transects. In each sampling quadrat, all plant species were identified and individuals of each species were enumerated. A voucher specimen of *P. emodi* was preserved by following the standard herbarium methods [17] and submitted in the herbaria of Botanical Survey of India, Dehradun, Uttarakhand (BSI/NRC-Tech/Herb/Ident./2017-18/plant accession no.118052). Further, species were analyzed for various ecological parameters (frequency, density and abundance) following Curtis and McIntosh [18]. Importance value index (IVI) was calculated by the sum of relative values of frequency, density and abundance following earlier study Suyal et al. [19].

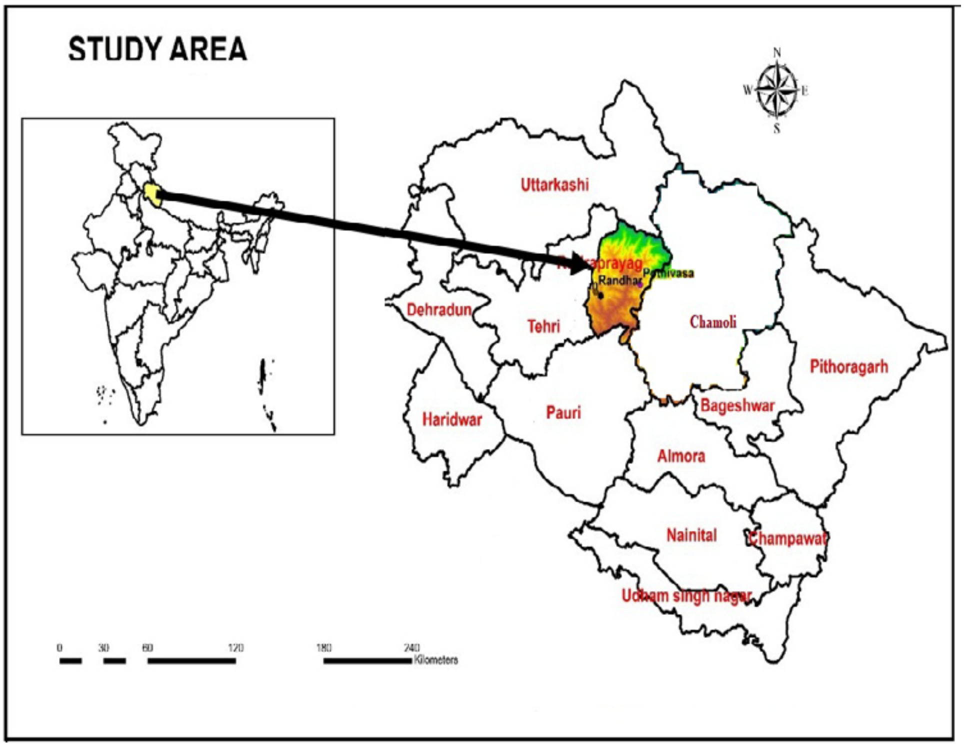

Figure 1. Location map showing study area

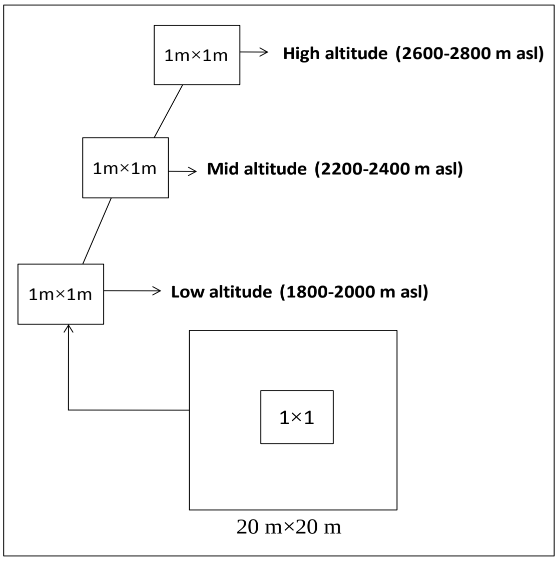

Figure 2. Pictorial diagram of phytosociological sampling method

3. Results

During the distribution analysis of herbaceous species along the altitudinal gradient at low altitude (1800-2000 m asl), the dominant species was *Stellaria himalayensis* (IVI= 35.98) with co-dominant species such as *Paeonia emodi* (IVI = 35.83) and *Geranium wallichianum* (IVI=34.91). The maximum density was found for *Stellaria himalayensis* (3.84 individual/m^2) and minimum for *Hedychium spicatum* (1.36 individual/m^2). The density for *P. emodi* was reported 3.80 individual/m^2 and the frequency was 80% while the distribution pattern was found contagious (Table 1 and Figure 3).

Similarly, at the mid altitude between 2200 to 2400 m asl the dominant species was *G. wallichianum* with an IVI of 37.73. The co-dominant species were *P. emodi* (IVI=36.09), *Potentilla fulgance* (IVI=30.49) and *Viola pilosa* (IVI=29.72). The highest density was reported for *G. wallichianum* (2.92 individual/m^2) and the lowest for *Paris poliphylla* (0.80 individual/m^2). At this altitude, the density reported for *P. emodi* was 2.76 individual/m^2 and frequency was 76% while the contagious distribution pattern was observed (Table 2 and Figure 3).

At the high altitude (2600-2800 m asl) the dominant species was found *V. pilosa* (IVI=46.18) with its co-dominant species namely; *Geum roylei* (44.10), *G. wallichianum* (41.21) and *P. emodi* (38.79). Among all the species, the highest density was recorded for *V. pilosa* (2.64 individual/m^2) followed by *G. roylei* (2.52 individual/m^2), *G. wallichianum* (2.24 individual/m^2), *P. emodi* (2.08 individual/m^2), *Legularia amplexicaulis* (1.96 individual/m^2), *Arisaema tortusum* (1.68 individual/m^2) and so on. The density observed for *P. emodi* was 2.08 individual/m^2 and frequency was 60% while the distribution pattern was found contagious at this altitude (Table 3 and Figure 3).

Table 1. Population density of *P. emodi* and its associates between 1800 and 2000 m asl

Species	F %	D	A	A/F	IVI
Paeonia emodi	80	3.80	4.75	0.06	35.83
Paris poliphylla	72	1.48	2.06	0.03	19.49
Viola pilosa	80	2.72	3.40	0.04	28.42
Hedychium spicatum	56	1.36	2.43	0.04	18.12
Legularia amplexicaulis	64	1.60	2.50	0.04	20.13
Arisaema tortusum	76	2.28	3.00	0.04	25.32
Stellaria himalayensis	84	3.84	4.57	0.05	35.98
Geranium wallichianum	84	3.68	4.38	0.05	34.91
Geum roylei	80	2.56	3.20	0.04	27.32
Potentilla fulgance	80	3.36	4.20	0.05	32.81
Calanthi tricarinata	64	1.80	2.81	0.04	21.67

A=Abundance; D= Density (individual/m^2); F= Frequency (%); A/F= Ratio of abundance to frequency; IVI= Importance Value Index.

Table 2. Population density of *P. emodi* and its associates between 2200 and 2400 m asl

Species	F %	D	A	A/F	IVI
Paeonia emodi	76	2.76	3.63	0.05	36.09
Paris poliphylla	56	0.80	1.43	0.03	16.38
Viola pilosa	72	2.08	2.89	0.04	29.72
Hedychium spicatum	56	1.00	1.79	0.03	18.55
Legularia amplexicaulis	68	1.72	2.53	0.04	26.21
Arisaema tortusum	68	1.76	2.59	0.04	26.60
Geranium wallichianum	72	2.92	4.06	0.06	37.73
Geum roylei	68	2.04	3.00	0.04	29.35
Potentilla fulgance	72	2.16	3.00	0.04	30.49
Calanthi tricarinata	52	1.20	2.31	0.04	20.72
Anemone revolaris	68	1.92	2.82	0.04	28.17

A=Abundance; D= Density (individual/m^2); F= Frequency (%); A/F= Ratio of abundance to frequency; IVI= Importance Value Index.

Table 3. Population density of *P. emodi* and its associates between 2600 and 2800 m asl

Species	F %	D	A	A/F	IVI
Paeonia emodi	60	2.08	3.47	0.06	38.79
Paris poliphylla	56	0.88	1.57	0.03	22.63
Viola pilosa	60	2.64	4.40	0.07	46.18
Hedychium spicatum	32	0.40	1.25	0.04	13.66
Legularia amplexicaulis	80	1.96	2.45	0.03	37.74
Arisaema tortusum	60	1.68	2.80	0.05	33.52
Geranium wallichianum	56	2.24	4.00	0.07	41.21
Geum roylei	76	2.52	3.32	0.04	44.10
Potentilla fulgance	48	0.88	1.83	0.04	22.16

A=Abundance; D= Density (individual/m^2); F= Frequency (%); A/F= Ratio of abundance to frequency; IVI= Importance Value Index.

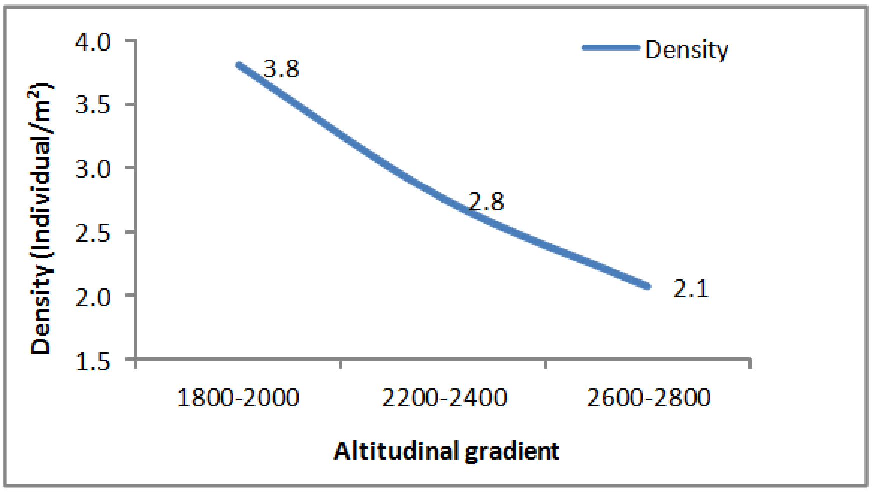

Figure 3. Population density of *P. emodi* under different altitudinal gradient

4. Discussion

The vegetation of any place is the outcome interaction of many factors such as mesotopographic gradients (i.e. slope, aspects and elevation), soil nutrients, species composition and biotic interferences [20,21]. Moreover, these factors influence the species richness and dispersion behavior of plant species [22,23]. Diversity of life-forms usually decreases with increasing altitude and only one or two life forms remain at extreme altitudes [24]. The low altitudinal sites was relatively dense populated probably because of human interference in these areas facilitates the introducing and establishment of non-native species [6,25]. Since the availability of any species in the forest is determined by elevation and habitat types [8,26]. In the present study it has been revealed that *P. emodi* is distributed in temperate to subalpine regions, ranging in altitudinal gradient between 1800 to 800 m asl across Garhwal Himalayan range inhabiting moist shady and slope habitat. The habitat of low altitude between 1800 to 2400m was suitable for the growth of *P. emodi* as compared to high altitudes because low altitudes and moderate slopes constitute suitable growth conditions for many herbaceous species suggested by Sharma et al. [5] and Gairola et al. [27]. However, Malik and Nautiyal [7] suggested that the growth activity increases with increase in temperature and moisture. It was found that lower altitudes having the high population density of *P. emodi* in the studied area is due to the presence of other herbaceous species. This is in line with the observations of Siddique [28] and Gurevitch [29] that severe climatic conditions operative at higher altitudes have a negative impact on the overall growth of a plant. Similar findings by Nazir et al. [30] observed a great degree of phenotypic variability and on an average, this species found with low population density with increasing altitude gradient in Kashmir Himalaya.

Our study revealed that density of *P. emodi* was found 3.80 individual/m^2 at low altitude which declined up to 2.08 individual/m^2 with increasing altitudes (Figure 3). It was nominal as compared to earlier assessed by Rawat et al. [31] and they observed highest density (8.75±5.52 individual/m^2) at low altitude (1800 to 2400 m asl) from Badrinath forest division (FD) in Chamoli district. Similar study was done by Rawat et al. [11] reported comparatively low density for *P. emodi* (2.40-1.60 individual/m^2) at higher elevation between 2500 and 2800 m asl from Kumaun Himalaya and concluded that the species has tendency to spread over a wide space in a given area but is unable to exhibit thick stocking due to the over harvesting, trampling and highly market demand. Vegetation analysis of *P. emodi* was conducted by Pandeya [32] and Negi et al. [33] revealed the low densities (1.15-0.85 individual/m^2 and 1.42-0.82 individual/m^2) under Kumaun Himalaya and Western Himalaya respectively. However, very less density (0.05-0.18 individual/m^2) for *P. emodi* was recorded by Bhat et al. [34] from Garhwal Himalaya due to the excessive anthropogenic activities. Low population density of *P. emodi* along with increasing elevation in the studied site indicates poor availability due to the unfavorable climatic conditions and lack of association with tree species like *Oak* and *Rhododendron* which provides the canopy covers and moisture land as well as suitable habitats to many herbaceous species. The present study reveals that density of *P. emodi* varies along the altitude; it decreases gradually from lower altitude (1800-2000 m) to high altitude (2600-2800 m).

5. Conclusion

This present study revealed that the quantitative information of a species plays a fundamental role in designing conservation and management plans as well as in understanding the ecological behavior of the species. In this study the target species is restricted to some specific habitats with declining density with the increasing altitudinal gradients. This indicated that elevation has different impact on species density in the study area. The present data regarding species availability of target species can be utilized in understanding the distribution pattern and the relationship of different altitudinal gradient with density. This type of study would help in designing appropriate conservation and management plans to conserve economically important species. In view of this, more detailed research on ecological analysis is needed to develop sustainable utilization and greater attention to maintain the population structure in the natural habitats.

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Conflict of Interest

Authors have no conflict of interest.

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