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DIVERSITY AND DISTRIBUTION OF *PRIMULA* SPECIES IN WESTERN ARUNACHAL PRADESH, EASTERN HIMALAYAN REGION, INDIA

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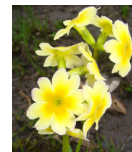
Abstract: The paper highlights the diversity, distribution and population status of *Primula* species in western Arunachal Pradesh. The present study has established the rich diversity of *Primula* species in western Arunachal Pradesh with a record total of 25 species, out of which five species, viz., *Primula ioessa* W.W.Sm., *Primula munroi* Lindley, *Primula obliqua* W.W.Sm., *Primula prolifera* Wall. and *Primula jigmediana* Hook. f. & Thomson ex Watt, are new to Arunachal Pradesh. More than 60% of the taxa of *Primula* of the state occurs in two districts of the western part of the state. A maximum diversity (76%) of *Primula* species was recorded between 3500m and 4000m and a minimum (4%) was between 1500m and 2000m. This study showed the poor population of some *Primula* species in the study area. Among the four sampling sites the Panga-Teng-Tso is highly disturbed which is clearly reflected by very poor population density of *P. hookeri* (1.36 individuals m⁻²). Various natural and anthropogenic threats have led to the pressure on the habitat of *Primula* species. Considering the rich species diversity of *Primula* and their distributional affinities, western Arunachal Pradesh may be considered as a centre of diversity of Indo-Chinese *Primula* species and appropriate conservation strategies should be adopted for the conservation of this genus.

Keywords: Arunachal Pradesh, distribution, diversity, population, *Primula*, threats and conservation.



DATA DEFICIENT	LEAST CONCERN	NEAR THREATENED	VULNERABLE	ENDANGERED	CRITICALLY ENDANGERED	EXTINCT IN THE WILD	EXTINCT
DD	LC	NT	VU	EN	CR	EW	EX

Primula dickieana



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INTRODUCTION

North Eastern Himalayan Region (NEHR) is very rich in biodiversity because of its varied climatic, edaphic conditions and diverse topography. Arunachal Pradesh, as a part of this region and possessing a rich diversity of plant species is truly recognized as one of the 200 globally important ecoregions (Olson & Dinerstein 1998). The flora of Arunachal Himalaya comprises well over 4000 species of flowering plants. The region is also considered as a centre of active speciation for *Rhododendron* L., *Primula* L. and *Gentiana* L. (Takhtadzhin 1969; Rao 1994). The vegetation of Arunachal Himalaya has been categorised into six broad types, viz.: tropical, subtropical, temperate, sub-alpine, alpine and secondary forests (Kaul & Haridasan 1987). Although the state has a rich diversity of flora and fauna, the state's biodiversity is yet to be explored and documented scientifically to a great extent.

The genus *Primula* L. belongs to the Primulaceae family consisting of herbaceous angiosperm plants and distributed in the high altitude areas. This genus is well known for its medicinal and horticultural values (Richards 2003). Many species are cultivated in the gardens for their attractive flowers. Globally, the genus is widely distributed throughout Asia and Europe in the temperate and cold regions and in the tropical mountains of the northern hemisphere (Richards 2003). The genus includes 38 sections and 430 species worldwide. Out of 38 sections, the Sino-Himalayan region represents 26 sections of the genus with more than 300 species (Richards 2003). So the Sino-Himalayan region is regarded as the geographical origin and centre of diversity and distribution of the genus *Primula* L. (Richards 2003).

The Indian Himalayan region is also considered as one of the centres of the rich species diversity of *Primula* L. with 106 species distributed from western to eastern Himalaya (Basak et al. 2014). Hooker (1882) reported 43 species of *Primula* from different parts of the Indian Himalayan region, whereas about 40 species of *Primula* have been reported only from Arunachal Pradesh (Basak & Maiti 2000; Giri et al. 2008; Boardman et al. 2010). Furthermore, the occurrence of about 50 species from Sikkim Himalaya (Grierson & Long 1999) and 16 species from Himachal Pradesh (Chowdhery 1984) has been reported. The complete *Primula* diversity of the Himalayan state of Arunachal Pradesh is still unknown, as no extensive study on *Primula* species has so far been conducted in this area, which is biogeographically linked with China, Bhutan and Myanmar. Therefore, extensive

field survey of *Primula* in the region was carried out to know the diversity, distribution and the status of the species so that conservation and management practices could be initiated.

MATERIALS AND METHODS

Study area

The study has been carried out in West Kameng and Tawang districts of Western Arunachal Pradesh (Fig. 1). West Kameng District (area 7,422km²) lies between 26°54'–28°01'N & 91°30'–92°40'E. The district is bordered by Tibet region in the north, Tawang and East Kameng districts of Arunachal Pradesh are in the north-west and east, respectively. The southern boundary adjoins Sonitpur and Darrang districts of Assam in the south and Bhutan in the west. The district is mostly mountainous. The vegetation types range from tropical to alpine between altitudinal ranges of 500m to 6000m.

Tawang District (area 2,172km²) lies between 27°25'–27°52'N & 91°16'–91°59'E. It is surrounded by Tibet in the north, Bhutan in the south-west and Sella ranges separate it from West Kameng District in the east. The vegetation types range from temperate to alpine between altitudinal ranges of 1500m to 6000m.

Four study sites, viz., Panga-Teng-Tso (PTSO), Maratha Ground, Senge and Bomdila, were selected from the study area on the basis of the occurrence of *Primula* species, for detailed community analysis and population status (Fig. 1). Maratha Ground and PTSO were selected for *Primula prolifera* Wall. and *Primula hookeri* Watt from Tawang District while Senge and Bomdila were selected for *Primula denticulata* W.W.Sm. and *Primula irregularis* Craib from West Kameng District. The complete physiographic features of the study sites are given in Table 1.

Methods

Extensive field surveys were conducted during the growing season from February 2011 to September 2012 at elevations between 1500m and 4500m in the selected area for the analysis of diversity and distribution of the *Primula* species. Although *Primula* is a perennial species, it possesses a dormant stage and is not found round the year. Therefore, the study was conducted only during their growing seasons. The quadrat method was adopted for community analysis. In each site 50 quadrats (1×1 m) were laid randomly. Specimens of various associate plant species were collected and herbarium of each species was prepared following the

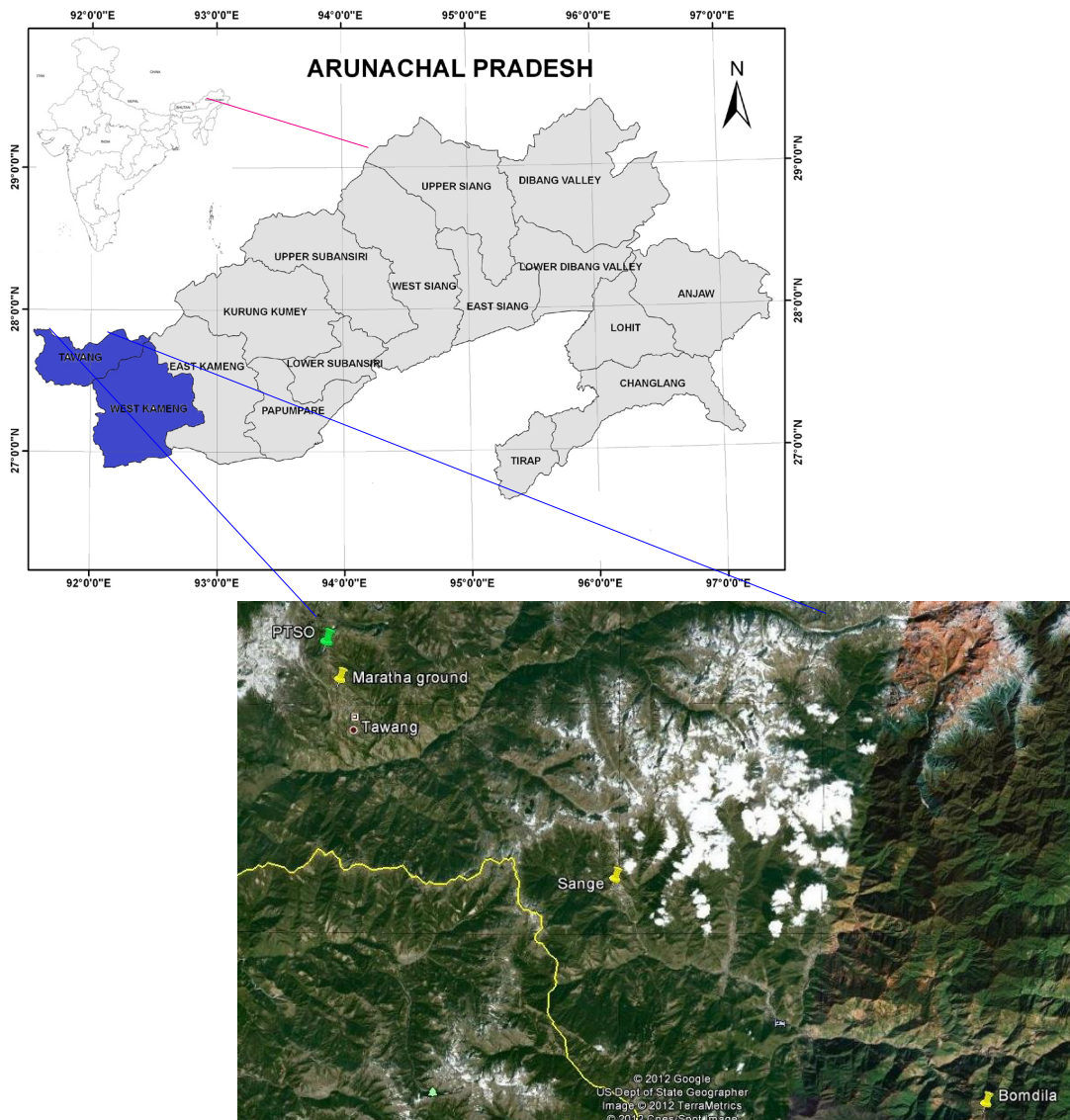


Figure 1. Location of the study sites in West Kameng and Tawang districts of Arunachal Pradesh.

methods outlined by Jain & Rao (1977) and preserved for identification. The herbarium specimens thus prepared have been deposited in the herbarium of Forestry Department, North Eastern Regional Institute of Science and Technology, Nirjuli. The species were identified with the help of various floras (Hooker 1882; Chowdhery 1984; Richards 2003; Giri et al. 2008) and herbarium specimens at the major Indian herbaria namely ARUN, ASSAM, BSHC, CAL, BSD, and DD. In addition, information regarding geo-coordinates (latitude, longitude and altitude) were recorded with the help of GPS (Garmin). Important community parameters such as frequency and density were calculated following the standard method outlined by Curtis & McIntosh (1950). The species richness index was determined following

Table 1. Physiographic features and forest types of the study sites.

Study sites	Geo-coordinate			Forest types
	Altitude (m)	Latitude N	Longitude E	
Maratha Ground	3254	27°36'34.5"	91°51'49.5"	Sub alpine
PTSO	3823	27°38'11.4"	91°51'13.9"	Alpine
Senge	2974	27°27'25.5"	92°06'09.1"	Temperate
Bomdila	2747	27°16'21.9"	92°26'03.1"	Temperate

the methodology outlined by Magurran (1988). The importance value index (IVI) which is defined as the sum of the relative density, relative frequency and relative dominance was calculated following the methods outlined by Curtis (1959). The species diversity index

was calculated using the formula given by Shannon & Wiener (1963), while the dominance index was calculated following Simpson (1949).

RESULTS

Diversity and distribution of *Primula* species

The present study exhibited the occurrence of 25 species in all the study sites (Table 2, Image 1a–h). Among the identified species, five species, viz., *Primula prolifera* Wall., *Primula ioessa* W.W.Sm., *Primula munroi* Lindley, *Primula obliqua* W.W.Sm. and *Primula jigmediana* W.W.Sm., are recorded for the first time from Arunachal Pradesh. The detailed distributional records along the altitudinal range reveal that the *Primula* species confined their distribution between 1500m and 4500m altitude in the study area (Table 3). The highest

diversity of *Primula* species was recorded between 3500m and 4000m with records of a total of 19 species and the lowest (1 species) is found between 1500m and 2000m. *Primula denticulata* was found to be common and widely distributed between 1500m and 3500m (Table 3).

Community analysis

Species richness

The highest species richness index (2.76) was recorded from Senge study stand, while the lowest (0.65) was recorded in PTSO. In Maratha Ground, it was 2.66, while in Bomdila it was 1.19 (Table 4).

Density

The density of the plant species varied from stand to stand. The highest plant species density (114.80 individuals m⁻²) was recorded in Senge, while the lowest

Table 2. Distributional record of *Primula* species in western Arunachal Pradesh, India.

Species	Area of occurrence		Altitude (m)	Flowering and fruiting season
	West Kameng	Tawang		
<i>P. atrodentata</i> W.W.Sm.	-	Maratha Ground	3000–4000	April–July
<i>P. bracteosa</i> Craib	Senge and Eagle Nest	-	2500–3500	March–May
<i>P. calderiana</i> ssp. <i>calderiana</i> Balf. f. et Cooper	-	PTSO	3500–4000	May–July
<i>P. calderiana</i> ssp. <i>strumosa</i> Balf.f. et Cooper	-	Sella Pass	3500–4500	May–July
<i>P. capitata</i> Hook.	Baishakhi	Maratha Ground	3500–4000	July–Oct
<i>P. dickieana</i> Watt	-	Sella Top	3500–4500	July–Aug
<i>P. denticulata</i> W.W.Sm.	Eagle Nest, Shergaon and Senge	Maratha Ground	1500–3500	March–June
<i>P. gambeliana</i> Watt	-	Sella Top and PTSO	3500–4000	July–Aug
<i>P. glabra</i> Klatt	Naga GG	PTSO and Sella Pass	3500–4500	May–July
<i>P. gracilipes</i> Craib	Naga GG	PTSO and Maratha Ground	3000–4000	May–July
<i>P. hookeri</i> Watt	-	PTSO and Maratha Ground	3500–4000	May–July
<i>P. irregularis</i> Craib	Bomdila and Eagle Nest	-	2500–3500	Feb–May
<i>P. ioessa</i> * W.W.Sm.	-	Sella Top	3500–4000	July–Aug
<i>P. jigmediana</i> * Hook.f. & Thomson ex Watt	-	PTSO and Sella Top	3500–4500	July–Aug
<i>P. kingii</i> Watt	Naga GG	-	3500–4500	June–Sept
<i>P. mollis</i> Nutt. ex Hook.	Bomdila	-	2000–3000	July– Aug
<i>P. munroi</i> * Lindley	-	PTSO and Sella Top	3500–4500	July–Aug
<i>P. obliqua</i> * W.W.Sm.	-	PTSO and Sella Top	3500–4000	June–Aug
<i>P. primulina</i> (Sprengel) H. Hara	Naga GG	-	3500–4500	June–Sept
<i>P. prenantha</i> Balf. f. & W.W.Sm.	Baishakhi	-	3000–3500	June–Aug
<i>P. prolifera</i> * Wall.	-	Maratha Ground	3000–3500	May–Aug
<i>P. sikkimensis</i> Hook.	Naga GG	PTSO and Sella Pass	3000–4000	July–Oct
<i>P. sessilis</i> Royle ex Craib	Baishakhi	-	3500–4000	Apr–June
<i>P. waltonii</i> Watt ex Balf.f.	-	PTSO	3500–4000	July–Sept
<i>P. whitei</i> W.W.Sm.	Naga GG	PTSO	3000–4000	May–July

* New distribution records from Arunachal Pradesh



Image 1. *Primula* species in their natural habitat in Arunachal Pradesh. a - *P. calderiana* ssp. *calderiana*; b - *P. calderiana* ssp. *strumosa*; c - *P. waltonii*; d - *P. kingii*; e - *P. dickieana*; f - *P. gracilipes*; g - *P. denticulata*; h - *P. whitei*.

was exhibited (28.92 individuals m⁻²) in Bomdila. In Maratha Ground it was (74.12 individuals m⁻²), while it was (50.72 individuals m⁻²) in PTSO study stand (Table 4).

Dominance

Dominance was calculated on the basis of the IVI of different herbaceous species and was found to be

Table 3. Number of *Primula* species along with altitudinal gradient in the study area.

Altitude (m)	Name of the species	Number of taxa
1500–2000	<i>P. denticulata</i>	1
2000–2500	<i>P. denticulata</i> , <i>P. mollis</i>	2
2500–3000	<i>P. denticulata</i> , <i>P. bracteosa</i> , <i>P. irregularis</i> , <i>P. mollis</i>	4
3000–3500	<i>P. bracteosa</i> , <i>P. denticulata</i> , <i>P. hookeri</i> , <i>P. irregularis</i> , <i>P. prolifera</i> , <i>P. sikkimensis</i> , <i>P. whitei</i> , <i>P. prenantha</i> , <i>P. atrodentata</i>	9
3500–4000	<i>P. calderiana</i> ssp. <i>calderiana</i> , <i>P. calderiana</i> ssp. <i>strumosa</i> , <i>P. capitata</i> , <i>P. dickiana</i> , <i>P. gambeliana</i> , <i>P. glabra</i> , <i>P. gracilipes</i> , <i>P. hookeri</i> , <i>P. munroi</i> , <i>P. ioessa</i> , <i>P. jigmediana</i> , <i>P. kingii</i> , <i>P. obliqua</i> , <i>P. prenantha</i> , <i>P. primulina</i> , <i>P. sikkimensis</i> , <i>P. sessilis</i> , <i>P. waltonii</i> , <i>P. whitei</i>	19
4000–4500	<i>P. primulina</i> , <i>P. glabra</i> , <i>P. calderiana</i> ssp. <i>strumosa</i> , <i>P. kingii</i> , <i>P. dickiana</i> , <i>P. munroi</i> , <i>P. jigmediana</i>	7

varying from stand to stand. *Primula denticulata*, *Fragaria vesca*, *Gnaphalium affine*, and *Senecio diversifolius* were the main dominant plant species in Senge study stand, while *Primula irregularis*, *Fragaria vesca*, *Plantago erosa*, *Rubia manjith* and *Selaginella* sp. were the dominant species in the Bomdila study stand. In Maratha Ground, *Primula prolifera*, *Lycopodium* sp., *Asplenium* sp., *Senecio diversifolius* and *Artemisia indica* were dominant and *Gnaphalium affine*, *Senecio diversifolius*, *Rumex nepalensis*, *Fragaria vesca*, *Hemiphragma heterophyllum*, *Artemisia indica* were the dominant species in the PTSO study stand. The Simpson dominance index (D) was recorded as 0.08, 0.07, 0.05 and 0.04 in Maratha Ground, Senge, PTSO and Bomdila, respectively (Table 4).

Species diversity

The Shannon-Wiener's index was the highest (H=3.28) in Bomdila, while it was the lowest (H=2.77) in Maratha Ground. In PTSO and Senge it was 2.86 and 2.97, respectively (Table 4).

Population status of *Primula* species

The highest population density and IVI of *Primula denticulata* and *Primula prolifera* was 30.84 individuals m⁻² and 37.21, respectively. And the lowest density and IVI was of *Primula hookeri* at 1.36 individuals m⁻² and 7.91, respectively. The density of *Primula prolifera* and *Primula irregularis* were 17.40 and 4.12 individuals m⁻², respectively (Table 5).

Table 4. Ecological attributes of *Primula* communities at the study sites.

Study sites	Density (individuals/m ²)	Species diversity		Species richness	Species richness index
		D*	H**		
Maratha Ground	74.12	0.08	2.77	21	2.66
PTSO	50.72	0.05	2.97	23	0.65
Senge	114.80	0.07	2.86	23	2.76
Bomdila	28.92	0.04	3.28	32	1.19

* Simpson's Dominance Index; ** Shannon Wiener's Diversity Index

Table 5. Population status of *Primula* species recorded in their respective stands.

Study sites	Species	Density (individuals/m ²)	Frequency (%)	IVI
Maratha Ground	<i>Primula prolifera</i>	17.40	100	37.21
PTSO	<i>Primula hookeri</i>	1.36	64	7.91
Senge	<i>Primula denticulata</i>	30.84	100	35.17
Bomdila	<i>Primula irregularis</i>	4.12	72	25

Threats to *Primula*

Several anthropogenic and natural threats, viz., grazing, plant harvesting, developmental activities (road and building construction) and landslides have been observed in the study sites. Grazing is found to be the commonest problem prevailing in all the areas. As the genus *Primula* is a small perennial herb and found in open areas, grazing animals, particularly the Yak, which are heavy animals sometimes destroy the population by stepping on them while browsing grasses. Developmental activities, mostly widening of roads and medicinal plant harvesting activity is the problem next only to grazing affecting the habitat of *Primula* species.

DISCUSSION

The diversity of *Primula* species in the temperate and sub alpine forests in western Arunachal Pradesh, India forms an important distribution centre and ecological niche of the taxa in the eastern Himalayan region. Such a rich diversity of *Primula* species in high altitudes areas in western Arunachal Pradesh may be due to its geographic location adjacent to countries like China and Bhutan with similar climatic as well as edaphic factors (Grierson & Long 1999; Richards 2003). Interestingly all the 24 species recorded and identified in the present study are also found in China except *Primula prolifera*

(Hu & Kelso 1996). It is noteworthy that more than 60% taxa of *Primula* of the Arunachal Himalaya occur in western Arunachal Pradesh with five new species which are not included in the floristic account by Giri et al. (2008) or any other worker. So, the Indian eastern Himalaya, China and Bhutan form a centre of species diversity and speciation of the genus *Primula*.

The high altitudes areas of western Arunachal Pradesh in eastern Himalaya harbours a rich plant diversity. The average species diversity index 2.97 recorded from the present study sites is similar to other Himalayan regions such as 1.53–2.88 in the western Himalayas (Samant et al. 1998; Gangwar & Joshi 2006), 2.39–4.63 in the Garhwal Himalayas (Bhandari et al. 1999), 3.10 in the Kashmir Himalaya (Shaheen et al. 2011) and 2.5–3.10 in the trans-Himalayan alpine of Nepal (Panthi et al. 2007). The highest species richness index (2.76) and plant species density (114.80 individuals/m²) was recorded in Senge study stand, as the sites found to be least disturbed where only grazing was observed. The study site PTSO is highly disturbed which is clearly reflected by very poor species richness index (0.65) and the low population density of the *Primula hookeri* (1.36 individuals m⁻²). *Senecio diversifolia*, *Gnaphalium affine*, *Fragaria vesca*, etc. are common dominant species in all the study sites. Although it is difficult to compare the result on density due to unavailability of literature, the result on density of *Primula* species showed poor population. The present recorded density of *Primula* species concur with the finding of Singh et al. (2008) who also observed nearly a similar result of high altitudes threatened medicinal plant species of Himachal Pradesh, western Himalaya.

It has been observed that both natural and anthropogenic threats have led to the tremendous pressure on the habitat of *Primula* species in western Arunachal Pradesh. Natural disturbances like landslides and wash out of smaller patches by runoff are frequent, which affects the natural habitat of *Primula* and along with other plant species and as a consequence of threats, a few of them may become threatened. Grazing is a serious anthropogenic threat throughout the western Arunachal Pradesh as the inhabitants rear Yaks on a large scale, as an important livelihood aspect. These activities may cause a significant decline in populations and species diversity of *Primula* as the species are herbaceous in nature and a few species are Yak fodder. Hence, many more species are likely to become threatened in the near future. A few species which lack farinose or mealy substances like *Primula dickieana*, *Primula hookeri*, *Primula kingii* and *Primula jigmediana*

are found to be fodder species of Yak, while the other species are also affected during grazing as many of them are either uprooted or trampled upon. The population study in some selected stands clearly indicated that the habitat of both *Primula hookeri* and *Primula irregularis* is severely affected by the major identified threats like grazing, plant harvesting, developmental activities, and landslides; a low density of these species was recorded when compared to other species. These species are distributed in some isolated pockets with a few numbers of individuals. The findings of the population density of these two *Primula* species revealed that they need special attention for conservation. Based on the present field observation and study the species namely *Primula hookeri*, *Primula irregularis*, *Primula jigmediana*, *Primula kingii* and *Primula waltonii* may be considered as threatened species of the region.

CONCLUSION

The conservation of biodiversity remains one of the basic needs in terms of preserving biotic diversity which, in time, translates into a richness of biotic wealth (Paul et al. 2005). The Himalayan alpine region is rich in biodiversity. The rich plant diversity of Indian Himalaya has been utilized by the native people for medicines, food (edible), fuel, fodder, agricultural tools, house construction, small scale enterprise (i.e., baskets, mats, hats making etc.), and in religious ceremonies (Ram 2005). Various anthropogenic activities, illegal exploitation of medicinal and other useful plants are the main threats to the high altitude biodiversity of Arunachal Pradesh. There is a need to control the degradation and disturbance processes deteriorating the community structure and plant biodiversity of the eastern Himalayan temperate and alpine regions. However, this requires a detailed socio-economic study in the area, which is beyond the scope of the present study.

As western Arunachal Pradesh harbours a rich diversity of *Primula* species, this part of the state should be considered an important landscape for the conservation of the genetic diversity of Indo-Chinese *Primula* species. Various reports are available on the conservation and research development of *Primula* species internationally; however, studies on diversity, ecology, taxonomy, breeding methods, conservation and management are yet to be carried out in Arunachal Pradesh. The development and implementation of regional conservation strategies are necessary to protect

alpine biodiversity and conservation of the *Primula* species of the state.

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Author Contribution: AB this manuscript is a part of his PhD research work. Field survey, data collection, evaluation, representation and preparation of manuscript. PRG is the supervisor of AB's PhD and he has executed the field work and preparation of manuscript, guided the work and helped finalization of the manuscript. AP assisted in field survey, analysis of ecological data, representation and preparation of manuscript. MLK is the co-supervisor of AB's PhD, he helped in technical improvement and finalization of the manuscript. He executed the work on *Primula* with PRG.

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