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On the present status of distribution and threats of high value medicinal plants in the higher altitude forests of the Indian eastern Himalaya

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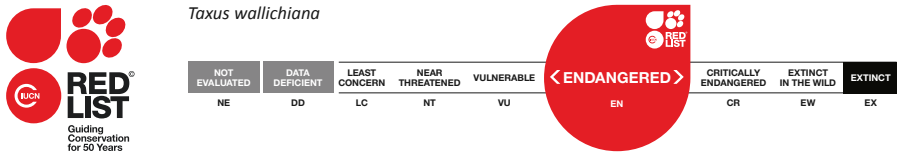
Abstract: The eastern Himalaya region is a rich repository of medicinal plants. Excessive collection and unsustainable harvesting of medicinal plants from the wild are leading to a depletion of populations and threatening species in the region. A study was conducted to explore the diversity, distribution and population status of selected medicinal plants species in the higher altitudes of Arunachal Pradesh, India through extensive field surveys and consultations with the local communities. Out of about 75 medicinal plants recorded, 41 rare and commercially important medicinal plants were observed in the sub-temperate to alpine forest within an altitudinal range of 1500–4500 m. Taxonomically these species fall under 25 families of higher plants, of which 31 are dicots, seven are monocots and three gymnosperms. Many threatened species like *Taxus wallichiana*, *Coptis teeta*, *Panax pseudoginseng*, *Panax sikkimensis* were recorded in specific localities. The western part of the state exhibits maximum species diversity. Out of the various threats observed, improper harvesting, habitat loss and trade are found to be more destructive to the population. Intensive efforts from both in situ and ex situ conservation practices are necessary for sustainable management and conservation of these species.

Keywords: Arunachal Pradesh, distribution, eastern Himalaya, medicinal plants, population, threats and conservation.



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Author Details: Dr. Padma Raj Gajurel is an Associate Professor. He is a field botanist by profession and engaged in research works on taxonomy and diversity of higher plant groups, ethnobotany and conservation of medicinal plants. He has been extensively working on the taxonomy of *Piper* species. Khumukcham Ronald is a PhD scholar. His research interest focuses on forest ecology and mapping and conservation of biodiversity, especially endangered plant species. Rubul Buragohain did his doctoral research on diversity of Moraceae family in Arunachal Pradesh under Dr. P.R Gajurel. Also work in the NEC funded research project on medicinal plant and extensively surveyed the state. Prof. P. Rethy is a Professor in the Department of Forestry, NERIST. She has a long research experience in flora of the state. Her field of research interest is systematic and ethnobotany. Prof. Binay Singh is a Professor in the Department of Forestry, NERIST. He is a horticulturist by profession and has taken up many research including diversity of citrus and other ediblefruits in Arunachal Pradesh. Shivakanta Potsangbam is a PhD scholar. His research interest focus on NTFPs, analysis of market potential and value addition of NTFPs.

Author Contribution: PRG contributed for site selection, field survey, data collection and analysis, specimen identification and finalization of the manuscript. He investigated the research project on medicinal plants funded by NEC. KR has helped in the field work, evaluation of data, preparation and finalization of the manuscript. RB has participated in field work, data collection and herbarium preparation and compilation of data. PR has constantly guided the work and help in preparation the Manuscript. BS provided all the necessary technical supports and guided the work. SP has assisted in the field work and analysis of data.

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INTRODUCTION

Medicinal plants have always received a high priority among the wild plant resources, for their exploitation, management and conservation. As for plant diversity, medicinal plants have been considered to have the highest relative value in societies (Hamilton 2004). Herbal medicine coming into vogue world-wide due to a growing appreciation of natural products being cheaper and safer, has elevated the degree of threat (Pareek 1996). About 80% of the population in developing countries depends directly on plants for its primary health care needs (Bannerman 1983). Two-thirds of the estimated 50,000 medicinal plant species used for herbal medicine are harvested from the wild, of which, 4,000–10,000 species may be endangered (Hamilton 2003). Indiscriminate collection without proper management has escalated the rate of depletion causing a faster rate of extinction (Hussain & Hore 2008). It is also estimated that about 1800 populations of plants are being destroyed every hour, i.e., 16 million annually in tropical forests alone (Hughes et al. 1997). It is estimated that out of about 18,000 flowering plant species found in India, about 2500 plants species are used only by traditional herbal healers and about 500 plant species are used by various pharmaceutical companies (Chandel et al. 1996; Dhiman & Tripathi 2009). The growing demand for medicinal plants combined with degradation and fragmentation of natural habitats in the country has pushed over 300 species of Indian medicinal plants into various threatened categories (FRLHT 2007).

The state of Arunachal Pradesh, which covers a major portion of the eastern Himalaya, is known for its rich diversity of flora and fauna. More than 500 medicinal plants have been recorded from the state from various climatic zones (Haridasan et al. 2003). Among them species like *Aconitum ferox, Berberis aristata, Campylandra aurantiaca, Illicium griffithii, Panax pseudoginseng, Paris polyphylla, Coptis teeta, Picrorhiza kurroa, Swertia chirayita, Taxus wallichiana, Valeriana jatamansi*, which are found in the higher altitudes are recognised as potential pharmaceutical species. Records of various valuable phytochemical compound and bioactive principles have been made from such species and many new chemical compounds are being added. Antioxidant activity in *Podophyllum hexandrum* (Chawla et al. 2005); anti-tumor constituent in *Paris polyphylla* (Wang et al. 2007); anti-asthmatic effect of *Picrorhiza kurroa* (Dorsch et al. 1991); anti-viral activity present in *Swertia chirayita* (Verma et al. 2008); anti-convulsant, analgesic and antipyretic activities in *Taxus wallichiana* (Nisar et al. 2008); hypoglycemic effect and activity of streptozotocin induced diabetic rats from the methanolic extract of *Berberis aristata* Stem (Upwar et al. 2011). Many other researchers have also shown an interest in studying the phytochemical compounds present in the following plants *Coptis teeta, Illicium grifithii, Panax pseudoginseng* and *Panax sikkimensis* (Shukla & Thakur 1985; Latif et al. 2008; Mathur et al. 2010; Vijayakumar et al. 2012) as the continuous discovery of various phytochemicals from traditional medicinal plants has opened up a new source for the pharmaceutical industry. And the large scale harvesting for their high medicinal value both locally and commercially, has resulted in rapid population decline of these species. Hussain & Hore (2008) reported the vast exploitation of these medicinal plants species from the wild. Although very few publications appeared during the past two decades in the field of medicinal plants' research (Singh et al. 1995; Haridasan et al. 1995, 1996, 2003; Pandey 1998; Bhuyan 1999, 2000; Sarmah et al. 2000; Rawat & Ramasankar 2001), they are mostly specific to ethnobotany, utilization pattern and cultivation, while limited attempts have been made to document the diversity and distributional status of the medicinal plant species including the exact possible cause of threats. To fill the gap extensive field surveys on the distribution of medicinal plants of the state have been carried out. The present paper deals with the diversity, distribution and an analysis of threats.

MATERIAL AND METHODS

Study area and site selection

The study has been conducted in the eastern Himalayan state of Arunachal Pradesh situated between $26^0 28'–29^0 30'$N & $91^0 30'–97^0 30'$E and having a geographical area of 83,743km^2. The State is predominantly mountainous in nature and is inhabited by 26 major tribes. The vegetation of Arunachal Pradesh is mainly classified into five broad forest types, viz.: tropical, subtropical, temperate broad-leaved and temperate coniferous, sub alpine, and alpine (Champion & Seth 1968). Later Kaul & Haridarshan (1987) included secondary forests consisting of degraded forest, bamboo forest and grassland. The high altitude areas are covered by sub-temperate to alpine types of forests and are rich repositories of biodiversity with an occurrence of some rare and endemic species but limited in numbers (Paul 2008). Based on secondary information on the availability of medicinal plants and to represent the

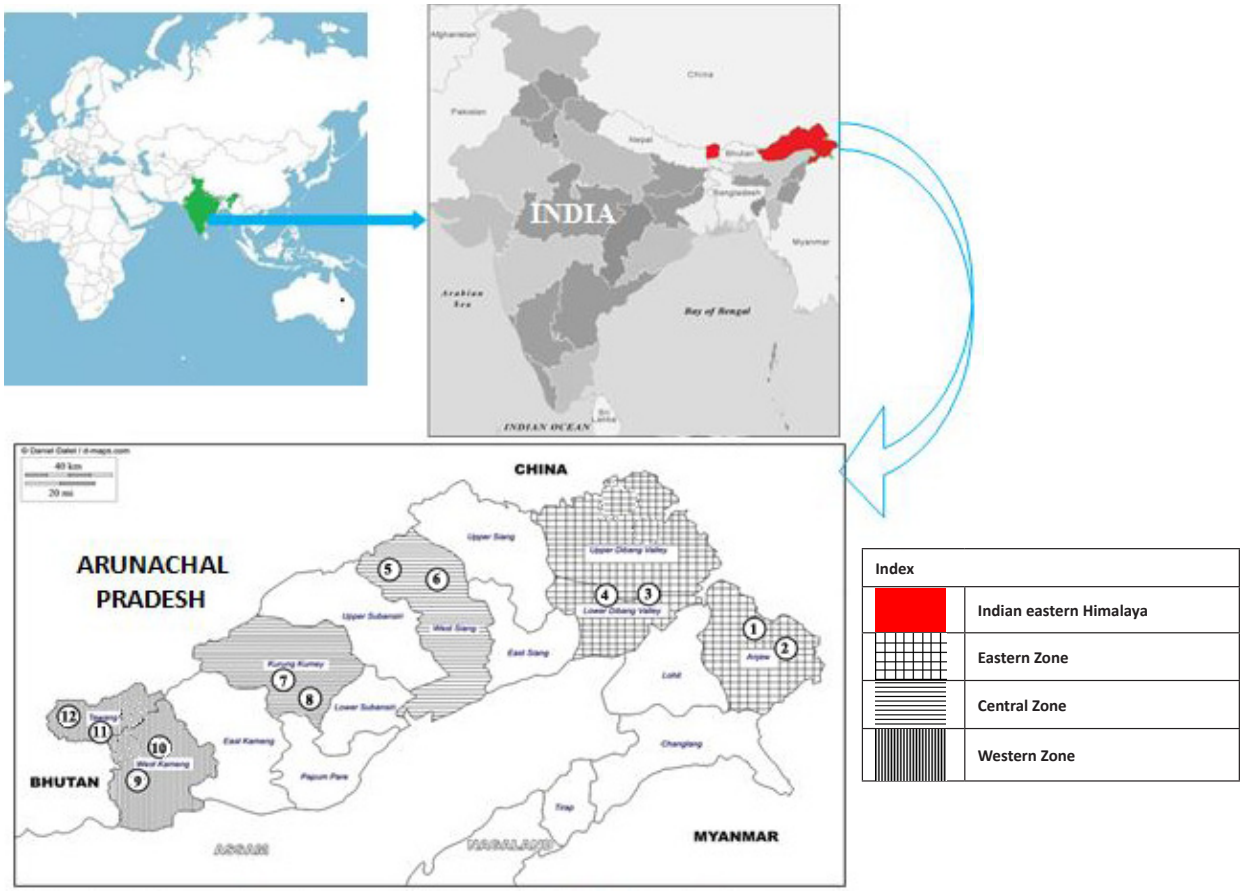

Figure 1. Selected study sites in the East Himalayan State of Arunachal Pradesh, India. (Map source: http://www.mapsopensource.com/)

entire region the state was divided into three zones, i.e., eastern, central and western zones (Fig .1). A total of six districts, two each from the western, central and eastern parts were selected for the field survey to understand the distribution and diversity. Twelve specific locations in higher altitudinal range (between 1600–3800 m) were selected from the six districts based on accessibility (Table 1).

Field survey and data collection

Extensive field surveys were conducted for two years from 2010–2012 in the selected areas for collection and understanding the distribution patterns and population status in a natural habitat. At least two surveys were conducted at each site to locate and collect samples of medicinal plants with the help of forests staff and local people and all possible data were collected from the field. The GPS (Garmin e-Trex 30) was used to record geo-coordinates and altitudes. Herbarium specimens of all species were collected and processed as per Jain & Rao (1977) and identification was done following taxonomic literature and herbarium specimens of regional and national herbaria (CAL, ASSAM and ARUN). All the specimens were deposited at Forestry Herbarium, NERIST. Various formal and informal interviews followed by group discussions were conducted in the villages of the selected study sites with various people (i.e., the village chief, the local healer, farmers, head of the house and medicinal plant trader) having knowledge and experience of medicinal plants. Different types of threats were analysed by preparing standard questionnaires emphasising types of exploitation, population and habitat loss. An attempt was also made to assign the present degree of threats based on the personal observation in the field and information from villagers and traders. Three parameters—high, moderate and low—were used to indicate the threat level of species. Besides, the reported threat status is also indicated following Ved et al. (2003).

Table 1. Selected study sites for medicinal plant survey in the eastern Himalayan state of Arunachal Pradesh

Selected study site		District	Geographic location	Altitude (m)	Forest type
1	Kibitho	Anjaw	28°08'05.99"N & 97°01'02"E	1500–2400	Sub-tropical and Temperate
2	Walong		28°08'19.00"N & 97°01'00"E		
3	Mayodia	Lower Dibang Valley	28°15'04"N & 97°55'33"E	1600–2655	Temperate Broad-leaved forest
4	Hunli		28°19'33"N & 95°57'43"E		
5	Mechuka	West Siang	28°34'49"N & 94°07'56"E	1600–2500	Temperate Pine forest
6	Yarlung		28°40'17"N & 93°58'11"E		
7	Palin	Kurung Kumey	27°39'47"N & 93°37'38"E	1500–2000	Sub-tropical and Temperate
8	Sangram		27°41'03"N & 93°38'01"E		
9	Bomdila	West Kameng	27°17'19"N & 92°25'53"E	1954–2700	Temperate to Sub-temperate
10	Shergoan		27°06'18"N & 92°16'17"E		
11	Tawang	Tawang	27°37'20"N & 91°48'24"E	3200–3500	Sub-alpine to Alpine
12	Selapass		27°30'20"N & 92°06'17"E		

RESULTS

Diversity and distribution of the medicinal plants

The present field investigation records the occurrence of 41 high value medicinal plant species from the sub-temperate to alpine vegetation of Arunachal Pradesh. The details of all these species including their botanical identity, common and trade name, distributional range, status and degree of threats are provided (Table 2). Out of these 41 species, 31 belong to 20 families of dicotyledons, six species belong to two monocotyledon families and two species, namely, *Abies densa* and *Taxus wallichina* belong to two gymnospermic families. Habitat-wise grouping reveals that a majority of these species belong to rhizomatous herbs (24 spp.), whereas trees and shrubs are represented only by eight species and *Rubia manjith* is the only climbing species (Table 2). These species are found to be distributed in different forest types and mostly confined in their distribution between 1800–3500 m. When the distribution is analysed across the state from west to east the highest diversity of species is found in the western part (38 spp.) followed by the eastern part (16 spp.) and the central part (13 spp.) (Fig. 2). The distribution features show that about 35% of species (like *Illicium griffithii, Panax sikkimensis, Podophyllum hexandrum, Paris polyphylla, Rubia manjith, Taxus wallichiana*) have wider distribution ranges and are represented in all the three zones while 47% of species (like *Abies densa*, *Coptis teeta, Gymnadenia orchidis, Picrorhiza kurroa, Valeriana hardwickii*) are narrowly distributed and limited to only one zone. The remaining 18% (like *Rhododendron anthopogon, Aconitum ferox*) represent

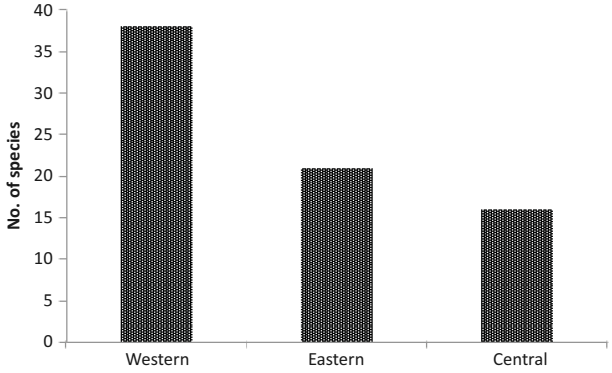

Figure 2. Representation of distributional pattern of medicinal plants in three different zones of the state

normal distribution ranges and are found to occur in two zones (Fig. 3; Table 2) in the study area. Among the species common in all the three zones, i.e., *Illicium griffithii*, *Taxus wallichiana*, *Panax sikkimensis*, *Berberis aristata*, *Zanthoxylum nitidum*, *Rubia manjith* were observed to have a better density and distribution in the western part.

Threat analysis

A series of group discussions and interviews conducted in different areas in adition to observations revealed that a majority of the species are faced with a number of threats. Habitat loss is one of the major threats observed and common to all the species which is due to landslides, jhum cultivation, occasional forest fire, human settlement, and various other development activities such as road and building construction. The other important threats that are species-specific are

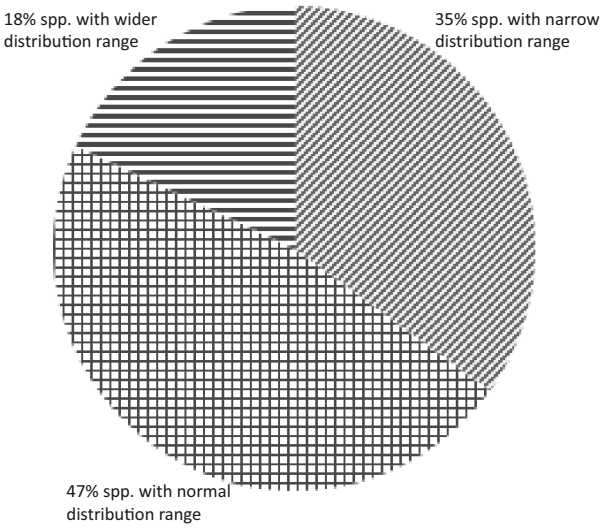

Figure 3. Percentage of species with diverse distribution range

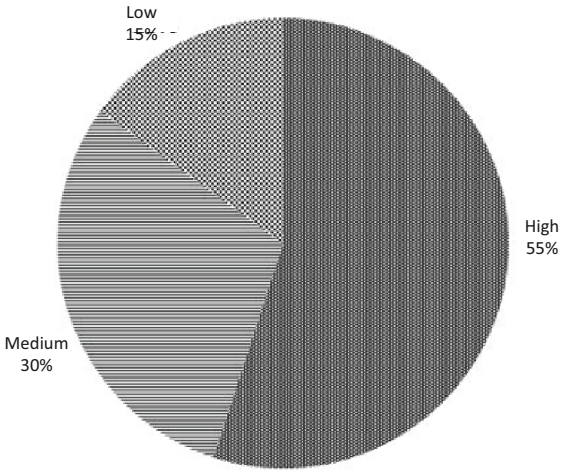

Figure 5. Degree of threats on medicinal plants

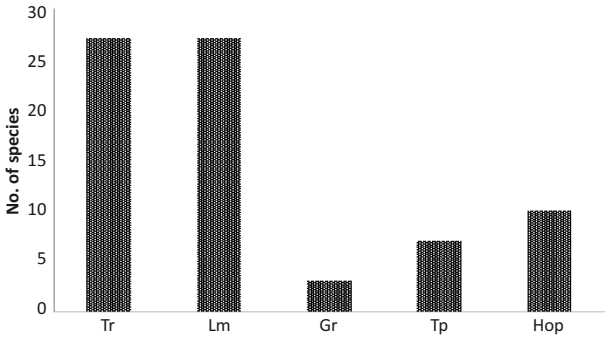

Figure 4. Species affected by different types of threats (Tr - trading; Lm - Local medicinal used; Gr - Grazing; Tp - Harvested for other purposes)

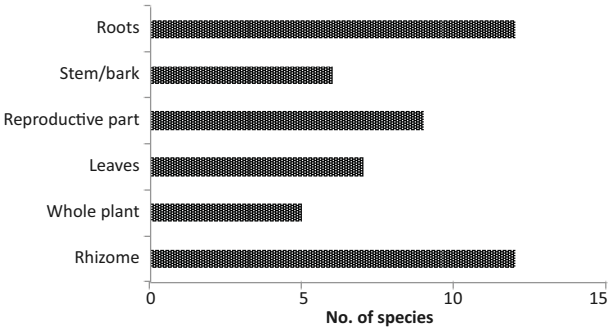

Figure 6. Utilization pattern of medicinal plants parts.

harvesting of species for local medicine (27 spp.), commercial trading (27 spp.), harvested for other purposes (10 spp.) like food, fodder, fuel wood and rituals. Grazing (3 spp.) and trampling (7 spp.) are found to be two other factors affecting most of the herbaceous species (Fig. 4). Medicinal plant species like *Gymnadenia orchidis, Plantago erosa, Selinum wallichianum,* which grow among grasses are commonly grazed and also get uprooted while grazing. Either loose soil or a shallow root system may result in the destruction of these medicinal plants species. *Aconitum* sp., *Bergenia ciliata, Campylandra aurantiaca* and *Panax pseudoginseng* are observed to be trampled by domestic animals like Mithun *Bos frontalis* and Yak *Bos grunniens.* Trampling is not only caused by animals but also humans such as tourists, researchers and members of the local community who visit the forest for various forestry and non-forestry activities causing enormous damage to the population. Based on the specific threats that directly deplete the population of a species, the study reveals that out of the total species recorded, 55% are found to be highly threatened followed by 30% with medium threats and 15% with low threats (Fig. 5). An analysis of utilization of plant parts reveals that rhizomes and roots are the most used parts (12 spp.), followed by reproductive parts, i.e., fruit, flower, seed (9 spp.), leaves (7 spp.), stem and bark (6 spp.), and whole plant (5 spp.) (Fig. 6). Among the species of the present report, 15 species are found under various threat categories (Nayar & Sastry 1987, 1988, 1990) and other regional classification of threats (Ved et al. 2003; FRLHT 2007), where one species is considered to be Critically Endangered, four species are considered to be Endangered, seven species are considered to be Vulnerable and three are considered to be Near Threatened (Table 2). Species like *Coptis teeta, Taxus wallichiana, Swertia chirayita, Aconitum* sp., *Panax* sp., *Berberis* sp., *Gymnadenia orchidis* have higher commercial demands with local uses and narrow distribution ranges that show a high degree of threat (Table 2).

Table 2. High altitude medicinal plant species of Arunachal Pradesh with their distribution and threats status

Sno	Botanical name	Collection number	Family	Common/ trade name	Habit	Parts used	Area of occurrence/ Population status	Altitude (m)	Types and degree of threats	Reported threat status (Ved et al. 2003)
1	*Abies densa* Griff.	KH125	Pinaceae	-	Tree	Leaves	W(***h***)	2600-3800	Lm*	NT
2	*Aconitum ferox* Wall. ex Ser.	AB 95	Ranunculaceae	Tsando	Herb	Rhizome	W(***I***), E(***I***)	3000-5000	Lm, Tr, Tp***	EN
3	*Aconitum* sp.		Ranunculaceae	Aconite / Atish	Herb	Root	W(***I***), E(***I***)	3000-4000	Lm, Tr, Tp***	
4	*Berberis aristata* DC.	KH126	Berberidaceae	Dal haidi	Shrub	Bark and fruits	W(***m***),E(***I***), C(***m***)	2000-3000	Tr, Gr**	-
5	*Berberis insignis* Hook. f. & Thomson	PRG851	Berberidaceae	Dal haidi	Shrub	Bark	W(***I***), C(***I***)	2000-2700	Tr, Gr**	-
6	*Bergenia ciliata* (Haw.) Sternb.	KH127	Saxifragaceae	Brah-mentoh	Herb	Whole plant	W(***I***)	1200-2000	Lm, Tr, Tp***	VU
7	*Campylandra aurantiaca* Baker	PRG850	Liliaceae	Kekong	Herb	Rhizome	C(***I***), E(***I***)	2300-2500	Lm, Tp***	-
8	*Coptis teeta* Wall.	PRG301	Ranunculaceae	Mishimiteeta	Herb	Rhizome	E(***m***)	2500-4000	Lm, Tr, Tp***	EN
9	*Crepidium acuminatum* (D. Don) Szlach.	PRG859	Orchidaceae	-	Herb	Stem	W(***I***)	1500-3300	Tr**	-
10	*Dactylorhiza hatagirea* D. Don	PRG 960	Orchidaceae	Salam-Panch.	Herb	Rhizome	W(***I***)	2500-3200	Tr***	-
11	*Gaultheria fragrantissima* Wall.	AB 121	Ericaceae	Gandapura	Shrub	Leaves	W(***m***), C(***m***), E(***m***)	2100-2600	Lm, Tr**	-
12	*Gymnadenia orchidis* Lindl.		Orchidaceae	Okhery	Herb	Tubers	W(***I***)	3000-4000	Tr***	VU
13	*Gymnocladus assamicus* Kanjilal	KH133	Fabaceae	Menang-manba-Shi	Tree	Fruits	W(***I***)	2200-3000	Tr, Hop***	CR
14	*Illicium griffithii* Hook. f. & Thomson	PRG790	Illiciaceae	Star anise / Lyssi	Tree	Fruit	W(***h***), E(***I***), C(***I***)	2000-2800	Lm, Tr, Hop**	NT
15	*Curculigo orchioides* Gaertn.	KH129	Hypoxidaceae	-	Herb	Rhizome	C(***m***), E(***m***)	1800-2400	Lm, Tr***	-
16	*Mahonia napaulensis* DC.	KH130	Berberidaceae	Taming	Shrub	Bark and fruits	W(***m***), E(***m***), C(***I***)	1800-2600	Lm, Tr, Gr**	VU
17	*Meconopsis aculeata* Royle	KH137	Papaveraceae	Kunda	Herb	Root	W(***I***)	2800-3500	Tr,Gr, Tp**	-
18	*Panax pseudoginseng* Wall.	PRG858	Araliaceae	Ginseng	Herb	Rhizome	W(***I***), E(***I***)	2500-3300	Tr, Tp***	-
19	*Panax sikkimensis* R.N. Banerjee	PRGG363	Araliaceae	Ginseng	Herb	Rhizome	W(***I***), E(***I***), C(***I***)	1000-2000	Tr, Tp***	-
20	*Paris polyphylla* Smith	AB 114	Liliaceae	Do-tala	Herb	Rhizome	W(***I***), C(***I***)	2000-3000	Tr, Tp***	-
21	*Perilla frutescens* (L.) Britton	PRG859	Lamiaceae	-	Shrub	Leaves and seed	W(***h***)	2000-2300	Lm**	-
22	*Picrorhiza kurroa* Royle ex Benth.		Scrophulariaceae	Kutki	Herb	Whole plant	W(*I*)	3000-4500	Tr, Tm**	EN
23	*Plantago erosa* Wall.	PRG857	Plantaginaceae	-	Herb	Whole plant	W(***h***), E(***h***), C(***h***)	1800-3000	Tr, Lm*	-
24	*Podophyllum hexandrum* Royle	AB129	Berberidaceae	Giriparpat (H)	Herb	Rhizome	W(***I***), E(***I***), C(***I***)	2500-4500	Tr,***	VU
25	*Polygala arillata* Buch.-Ham. ex D. Don	PRG861	Polygalaceae	-	Shrub	Roots	W(***I***)	1800-2500	Lm*	-

Sno	Botanical name	Collection number	Family	Common/ trade name	Habit	Parts used	Area of occurrence/ Population status	Altitude (m)	Types and degree of threats	Reported threat status (Ved et al. 2003)
26	*Polygonatum vercillatum* (L.) All.	KH134	Liliaceae	Meda	Herb	Roots	W(***l***), E(***l***), C(***m***)	3000-4000	Lm, Tr,***	VU
27	*Potentilla nepalensis* Hook.	KH136	Rosaceae	Dorighas	Herb	Roots	W(***m***)	2000-3500	Lm, Tr,**	-
28	*Rheum nobile* Hook. f. & Thomson	KH132	Polygonaceae	-	Herb	Rhizome and root	W(***l***), E(***l***)	3000-5000	Tr***	NT
29	*Rhododendron anthopogon* D.Don	PRG852	Ericaceae	Dhupi	Shrub	Leaves	W(***m***), C(***l***)	3500-4200	Lm, Hop***	VU
30	*Rhododendron arboreum* Sm.	PRG853	Ericaceae	-	Tree	Bark and flowers	W(***h***), C(***h***)	2000-3000	Lm, Hop**	-
31	*Rubia manjith* Roxb. ex Fleming	PRG780	Rubiaceae	Rubia/ Manzisth / Laal-rashi	Climber	Roots and leaves	W(***m***), E(***l***), C(***m***)	1200-2500	Lm, Tr***	-
32	*Centella asiatica* L.	PRG73	Apiaceae	-	Herb	Root and shoot	W(***m***, E(***m***), C(***l***)	1800-2600	Lm, Hop*	-
33	*Saussurea gossypiphora* D. Don		Asteraceae	-	Herb	Flower	W(***l***)	3000-3800	Lm, Tr***	-
34	*Selinum wallichianum* (DC.) Raizada & H.O. Saxena	KH135	Apiaceae	-	Herb	Whole plant	W(***l***)	3000-3500	Lm**	-
35	*Swertia chirayita* (Roxb. ex Fleming) Karsten	RB011	Gentianaceae	Chiraita	Herb	Whole parts	W(***l***)	2000-4000	Tr, Lm***	VU
36	*Swertia hookeri* C.B. Clarke	PRG863	Gentianaceae	-	Herb	Roots	W(***l***)	3000-3500	Tr, Lm***	-
37	*Taxus wallichiana* Zucc.	PRG756	Taxaceae	Himalyan Yew	Tree	Bark and leaves	W(***l***), E(***l***), C(***l***)	1800-3000	Tr, Hop***	EN
38	*Valeriana hardwickii* Wall.		Valerianaceae	Jatamansi / Sugandi	Herb	Roots and rhizome	W(***l***)	1800-4000	Lm***	VU
39	*Valeriana jatamansii* Jones	PRG856	Valerianaceae	Jatamansi / Sugandi	Herb	Roots and rhizome	W (***l***)	1500-3600	Lm, Tr***	VU-
40	*Zanthoxylum acanthopodium* Cand.	PRG854	Rutaceae	Timur	Tree	Fruit s	W(***m***), E(***l***)	2300-3000	Lm, Hop**	-
41	*Zanthoxylum nitidum* (Roxb.) DC.	PRG769	Rutaceae	Gagra	Shrub	Roots and Fruit	W(***l***), E(***m***), C(***m***)	1800-2600	Lm, Hop*	-

Abbreviation used: Area of occurrence: W = Western part, E = Eastern part, C = Central part; Population status: Population of species: *h* = high(>5000), *m* = medium (<3000), *l* = Low (<1000); Status: CR = Critically Endangered, NT = Near threatened, EN = Endangered, VU = Vulnerable; Type of threats: LM = Local medicine, Gr = Grazing, Hop = Harvested for other purpose, Tp = Trampling, Tr = Trade; Degree of Threats: *** = High, ** = Medium, * = Low.

DISCUSSION

The state of Arunachal Pradesh that represents a major part of the eastern Himalayan region is known for its rich diversity of medicinal plants. Many threatened medicinal plants occur in the temperate as well as alpine forests in the state. The result of the present work revealed that a good number of species with high commercial potential are distributed in the higher altitudinal ranges particularly between 1800–3600 m altitude range as also reported by Haridasan et al. (1995, 1996); Bhuyan (1999); Hussain & Hore (2008). The recent study of Kalita & Khan (2013) on higher altitude medicinal plants of the western part of the state also recorded the occurrence of 40 species including 16 tree species. However, the tree species like *Terminalia chebula, T. bellirica, Gynocardia odorata, Oroxylum indicum, Dillenia indica, Hydnocarpus kurzii* are mostly confined to lower altitudes in tropical and sub-tropical forests and are not included in the present study. Moreover the critically endangered species, *Coptis teeta* previously reported as an endemic only to the eastern

part, i.e., from undivided Lohit and Dibang districts (Ved et al. 2003), has also been recorded from the central part of the state (the present Kurung Kumey and Upper Siang District except the western part). The present study revealed that the diversity of these medicinal plants is higher in the western part of the state in comparison to the eastern and central parts (Fig. 2). The occurrence of least diversity in the central and eastern part is assumed to be due to: (i) inaccessibility of most of the higher elevated area, and (ii) nature of the forests where broad-leaved temperate forests with close canopy and dense vegetation do not support the luxuriant growth of the herbaceous plants. In contrast, the western part has common accessibility in most of the areas and comprises temperate forests with open canopy that support the diversified herbaceous flora. Moreover the western part exhibits comparatively lower rainfall and temperature that could support better adaptation of rhizomatous seasonal herbs. In the present study the higher altitudes of eastern Himalaya have been found to be dominated with rhizomatous herbs species as was also reported by Kala & Ratajc (2012). From field observation the overall population of these high value species are either very low or found in patches at a specific area or climatic zone. The edaphic factors may also affect the diversity and population. However, correlation of all the physiographical data with climatic variability will lead to the establishment of the actual cause of determining the diversity and population which is beyond the scope of the present study.

The threats observed during the present field studies were also reported as major causes of depletion of population during assessments of threats of medicinal plant of the state (Ved et al. 2003). The various types of threats recorded for all the species in the present study (Fig. 4), also supports the assessments made by Ved et al. (2003) except the trampling effect on the species population. Grazing, trampling and biotic interference are always reported as responsible for the reduction in the population of highly utilized medicinal plants (Nautiyal et al. 1997; Pandey et al. 2000; Baig et al. 2013). As a majority of the species are either exploited for their roots and rhizome without using proper harvesting methods and at the same time the unskilled harvesting and other forestry activities add to the population degradation, these species become threatened in the forests. Change in climate and competition with other species may also be one of the threats for these medicinal plants. The available protected areas like Mehao, Eaglenest and Talle wildlife sanctuaries that comprise some higher altitude vegetation mostly the temperate forests are not enough for complete legal protection of the species. The protected areas are not always safe and are vulnerable to loss and destruction (Singh & Chowdhery 2002). The recent initiative of the state forest department for establishment of MPCA through GOI-UNDP programme may help in the protection and sustainable management of the medicinal flora (Gajurel 2012). Out of the seven MPCAs, three are proposed in the temperate and alpine vegetation for conservation of higher altitude medicinal plants. The present study also strongly justifies the inclusion of the species like *Aconitum ferox, Gymnocladus assamicus, Taxus wallichiana, Coptis teeta, Picrorhiza kurroa, Swertia chirayita* in the threatened categories (Ved et al. 2003; CUTS 2004). Moreover, some other species namely *Campylandra aurantiaca*, *Curculigo orchioides, Panax sikkimensis*, *Panax pseudoginseng*, *Paris polyphylla*, *Saussurea gossypiphora*, *Swertia hookeri* which are yet to be included in any of the threat categories are found to be distributed only in some specific localities with limited population and subjected to high degree of threats as revealed in the present studies (Table 2). The indication of restricted distribution of some high value medicinal plants with high degree of threats, through the present work, warrant immediate attention for their conservation.

RECOMMENDATION

The medicinal plant diversity of the state is remarkably rich and has the potential for contributing socio-economic development of the region. A large number of globally significant medicinal plants are found distributed in various forest types particularly in the higher altitudinal ranges. The places like Mechuka in Upper Siang District, Panga-Teng-Tso in Tawang, Dirang in West Kameng, and Dong and Kibitho in Anjaw are some of the potential areas with many rare and highly important medicinal plants like *Bergenia ciliata*, *Curculigo orchioides, Campylandra aurantiaca, Dactylorhiza hatagirea, Saussurea gossypiphora, Picrorhiza kurroa, Panax pseudoginseng, Rheum nobile, Swertia chirayita*. Many of the species presently face various threats leading to the reduction in population size and their endangerment in nature. Hence these areas can be protected for in situ conservation. Considering the present status of occurrence and various threats to medicinal plants, the following activity can be adopted for sustainable management and conservation of these threatened species:

Image 1. Some high value medicinal plants of Arunachal Pradesh in their wild Habitat.
A - *Berberis insignis*, B - *Campylandra aurantiaca*, C - *Illicium griffithii*, D - *Panax pseudogingseng*, E - *Paris polyphylla*, F - *Coptis teeta*, G - *Rubia manjith*, H - *Swertia chirayita*, I - *Saussurea gossypiphora*, J - *Zanthoxylum acanthopodium*, K - *Taxus wallichiana*, L - *Valeriana jatamansii*. Photo credit: P.R. Gajurel.

- Conducting awareness campaigns on the importance and vulnerability of threatened medicinal plants

- Implementation of improved harvesting techniques with less mortality of species.

- Establishment of a protected area for threatened medicinal plants in their natural habitat.

- Extensive efforts for both the in situ and ex situ conservation involving local communities. Establishment of nurseries through the development of propagation and cultivation protocols.

- Large scale cultivation of the prioritized medicinal plants for commercial purposes

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