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Ecological Studies of *Nardostachys grandiflora*: An Endangered Medicinal Plant of Sikkim Himalaya

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ABSTRACT

Nardostachys grandiflora is a perennial rhizomatous herb found in the alpine part of Sikkim and is known for its medicinal and aromatic properties. Collected for its rhizome, *N. grandiflora* is used to cure conditions including neurosis, insomnia, convulsions, epilepsy and heart palpitations. It is also a source of fragrant oil, which is used in high-quality fragrances, incense and as a flavoring ingredient. Popular in local communities, this species is in danger of extinct, due to its over-collection, habitat degradation, and climatic changes. Due to its isolated habitat and small population, research on this species is very low and infrequent. Thus, an attempt was made to understand the population distribution of *N. grandiflora* in the alpine regions of Sikkim. The study reveals low population densities in all of the sites of observation. However, two studied sites in the North districts and one site in the East district showed very low population densities and importance value index of *N. grandiflora*. Therefore, urgent action and conservation measures must be taken to protect the highly endangered Himalayan plant.

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INTRODUCTION

Sikkim Himalaya is part of the Eastern Himalayas which lies between 27° 5' N to 20° 9' N latitudes and 87° 59' E to 88° 56' E longitudes and stands at the quadri-national border of Nepal, Bhutan and Tibet Autonomous Region of China as a wider Himalayan sacred landscape in the world with its unique architecture and geography (Bhattarai and Rana 2022). This tiny Himalaya region is home to many rare medicinally important plant species. *N. grandiflora* is a well-known medicinal herb used for its medicinal and aromatic properties found in the alpine region of Sikkim. *N. grandiflora* DC. (f. Valerianaceae), commonly known as Indian nard, spikenard, Balcchar and locally known as Naag Dhup by Sikkimese Nepali, is a 10 – 60 cm high perennial herb, found in Alpine Himalayas ranging from Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh in India, Nepal, and Bhutan at altitudes of 3000–5200 msl (Chauhan *et al.* 2021). It is used to treat various ailments, including hair loss, greyness, growth and luster, hysteria, epilepsy, neurosis, insomnia, excitation, habitual constipation, scorpion stings, Alzheimer's disease, learning, and memory disorders (Yadav *et al.* 2011, Purohit *et al.* 2012, Singh *et al.* 2013, Rashid *et al.* 2018, Kaur *et al.* 2020). The rhizome of the herb being over-exploited for medicinal use, habitat degradation, and other biotic interferences making the plant critically endangered (Dhiman and Bhattacharya 2020).

In today's market, herbal medicines are increasing rapidly as health-conscious people prefer them due to their fewer side effects. So, the unscrupulous collection of these plants by local communities for personal or commercial purposes has cause threatened several valuable medicinal plants. Therefore, conservation, propagation, cultivation, maintenance, and sustainable commercial use of these natural resources are essential. There is no data about the global population of *N. grandiflora*, only fragmented data is available (Chauhan 2022). *N grandiflora* is listed as Critically Endangered on the IUCN Red List of Threatened species (Ved *et al.* 2015, Mehta *et al.* 2020, Chauhan 2021). Sikkim state is one of the hot spots for *N. grandiflora* growing, thus a study on the current status of the population as well as the conservation process of *N. grandiflora* is the need. However, information regarding the *N. grandiflora* from Sikkim Himalaya is insufficient and thus needs immediate attention, with particular attention to the exact status of the species in its natural habitat, its availability and occurrence to determine the threat categories and population density and its associated species in nature.

MATERIALS AND METHODS

N. grandiflora is found in high-altitude habitats (3500 to 5500 m) in the Himalayan region. For the present study as given in Table 1, surveys were conducted in three districts of Sikkim namely; North (Mangan), West (Gyalshing) and East (Gangtok) during its active growing season from May to October (2020 and 2021). From Mangan district, Yumthang and Thangu areas were covered, Dzongri and Lakshmipokhari from Gyalshing and Chhangu, Kupup and Serethang were covered from Gangtok district. The detail of the GPS coordinates of the study areas is given in Table 1. Before starting the field survey of *N. grandiflora*, an extensive literature review and consultation with the state forest department officials, villagers and experienced harvesters to identify possible distribution areas of *N. grandiflora* in Sikkim was conducted.

For each population, the vertical belt transect method (Michael 1990) for sampling, in the natural habitat of the plant, three subplot plots each 20 × 50 m apart from 20 × 150 m main plot. In each subplot, the density of *N. grandiflora* was determined using 15 random quadrats (1 × 1 m), which created 45 quadrats for each population. With each quadrat, the microhabitat occupied by *N. grandiflora* and also enumerated the individuals of associated species were studied. Ecological parameters such as abundance, density, relative density, frequency, relative frequency, coverage, relative coverage, and importance value index of diversity were calculated for the species, and soil pH ranges from 4.5 to 6.1 in studied sites (Table 1).

RESULTS AND DISCUSSION

Population status

N. grandiflora grows in open rocky slopes, alpine meadows, or open slopes in clusters. The total number of occurrences of taxa of the genus *Nardostachys* in Sikkim has not been assessed to date. Indigenous medicinal uses of *N. grandiflora* are very limited in Sikkim, whereas rhizome is also used for incense by most of the habitants of Sikkim.

Comparative analysis of ecological parameters of *N. grandiflora* DC in alpine regions of Sikkim Hima-

Table 1. GPS co-ordinates and soil characteristics of the studied area.

Populations				Parameters					
Districts	Study areas	Latitude	Longitude	Altitude (m)	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)	pH
East Sikkim	Chhangu	27° 19' 995"	088° 50'316"	3959	323	19.12	204.96	0.6	6.1
	Serethang	27° 22' 901"	088° 48'610"	4028	206.97	29.12	236.32	0.6	5.7
	Kupup	27° 41' 14"	088° 55'318"	3934	385.72	30.91	133.28	2.7	5.4
North Sikkim	Thangu	27° 78' 88"	088° 41'636"	3912	398.27	30.91	240.8	1.23	6.0
	Yumthang	27° 47' 736"	088° 41'636"	3984	310.46	29.12	258.72	1.2	6.2
West Sikkim	Dzongri	27° 28' 736"	088° 09'714"	4129	332.41	24.4	174.72	0.6	6.8
	Lakshmipokhari	27° 29' 885"	088° 09'800"	4145	370.04	26.64	219.52	0.6	5.5

Table 2. Ecological details of *N. grandiflora* DC in the alpine region of Sikkim Himalaya. Abundance (A), relative abundance (RA), density (D), relative density (RD), frequency (F), relative frequency (RF), mean coverage (MC), relative cover (RC), and important value index (IVI).

Study area	A	RA	D	RD	F	RF	MC	RC	IVI
Chhangu	10.07	15.84	6.49	26.42	64.44	14.01	17.51	29.11	69.54
Serethang	9.78	15.39	5.87	23.89	60.00	13.04	15.11	29.25	66.18
Kupup	9.21	14.49	3.89	15.83	42.22	9.18	10.84	24.86	49.87
Thangu	7.50	11.80	2.33	9.50	31.11	6.76	6.11	15.35	31.61
Yumthang	7.00	11.01	2.64	10.77	37.78	8.21	8.02	16.12	35.10
Dzongri	9.96	15.67	5.31	21.63	53.33	11.59	14.29	41.45	74.67
Lakshmipokhari	11.25	17.70	5.00	20.36	44.44	9.66	13.16	25.58	55.60

laya is as follows. 1409 individuals of *N. grandiflora* from the seven studied areas, growing in diverse microhabitats. Moist rocky surfaces, boulders, and moss-rich open slopes are the major habitat of *N. grandiflora* in all alpine regions of Sikkim Himalaya. *N. grandiflora* density varied among the studied areas, Yumthang valley and Thangu valley of North Sikkim and Kupup regions of East Sikkim recorded the lowest individuals m^{-2} and the highest in Chhangu and Serethang areas of East Sikkim. The highest (292) number of *N. grandiflora* individuals was found in Chhangu, East Sikkim, and the lowest (105) was recorded in Thangu valley, North Sikkim (Figs.1–2). Out of 315 total studied quadrats from 7 studied areas, *N. grandiflora* were spotted from 150 quadrats whereas, the remaining 165 quadrats didn't encounter any targeted species. Due to the steep habitat, species richness is very low in the alpine regions of the North district in Sikkim. It was noted that frequency distribution was between 31.1% to 64.4% on all sites (Table 2).

Likewise, abundance (11.25) and relative abundance (17.70) were highest in Lakshmipokhari, West Sikkim, and lowest (7.00 and 11.01 respectively) in Yumthang valley, North Sikkim (Table 2). Data on density was recorded as highest (6.49 individuals m^{-2}) in Chhangu, East Sikkim, whereas, the lowest was found in Thangu valley, North Sikkim (2.33 individuals m^{-2}). Thangu valley recorded the lowest value in relation to frequency, relative frequency, and mean cover percentage Table 2. Dzongri, West Sikkim recorded the highest value of relative cover (41.45%), and the lowest was in Thangu valley, North Sikkim (15.35%). Based on the importance value, the highest value was recorded from Dzongri, West Sikkim (74.67), and the lowest was recorded from Thangu valley, North Sikkim (31.61). The results of single-factor ANOVA in Table 3 suggest that variability exists within and between the groups.

The dominant associated species varied among the populations, however, *Persicaria runcinata, Rumex nepalensis, Rhododendron anthopogon*, *Pedicularis excelsa, Gentiana prolata*, Himalayan grass, *Berginia ciliata, Rhododendron setosum, Rhododendron campanulatum, Cyananthus pedunculatus, Polygonum mole, Pedicularis gibbera, Gaultheria tricophylla, Bistorta longispicata, Saussurea gossipiphora, Sweritia multicaulis, Fragaria nubicola*, *Rheum austral* were the main dominant associated species in all the alpine regions of Sikkim Himalayas.

As per the results obtained from the present study sites, the diversity of *N. grandiflora* in all alpine regions of Sikkim Himalaya is in ranges from 2.64 to 6.49 individuals m^{-2} (Table 2). It was found that

Table 3. Single factor one-way ANOVA of *N. grandiflora* individuals in each quadrat.

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	685.8984	6	114.3164	3.415461	0.002806	2.128061
Within groups	10308.84	308	33.47027			
Total	10994.74	314				

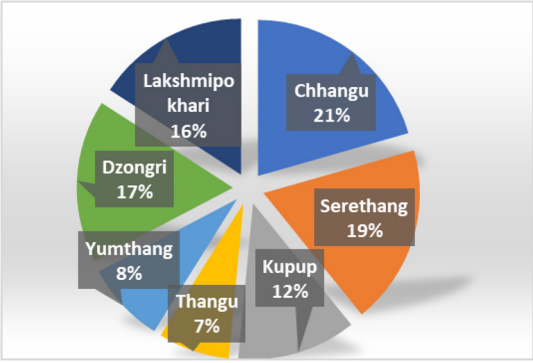

Fig. 1. Total number of *N. grandiflora* in each quadrat.

the two studied sites in North Sikkim and one site in East Sikkim showed low population density and importance value index, which required immediate conservation strategies in these three sites of the alpine regions of Sikkim Himalayas. This shows a great rate of change in species composition between different habitats and sites. Similar population density of the species was reported by Airi *et al.* (2000) and Nautiyal *et al.* (2003), which ranged from 8.52 to 25.58 individuals m^{-2} in Kumau and 19.0 to 32.2 individuals m^{-2} in Garhwal, India. Whereas Lakey and Dorji (2016) estimated *N. grandiflora* density in Jigme Dorji Wagchuk National Park, Bhutan was 8.9 individuals m^{-2}. The natural populations of *N. grandiflora* are affected because of anthropogenic activities like extraction and habitat destruction which lead to its endangerment. Ved *et al.* (2015) also reported that the loss of the natural habitat of *N. grandiflora* is primarily due to over-exploitation of natural resources, road construction, deforestation, human settlement and expansion of agricultural areas. Pradhan and Badola (2015) have also mentioned similar types of anthropogenic activities that threaten the natural populations of *Swertia chirayta* in Sikkim Himalaya. The author has also reported that the species has become rare due to over-harvesting from the wild (Ghimire *et al.* 2008, Kaur *et al.* 2020). As per National Medicinal Plant Board, Government of India, marketing and trade report, the annual demand for the *N. grandiflora* is about 500–1000 metric tons of rhizome and at the same time NMPB, India is promoting its cultivation by providing a 75% subsidy to interested framers. Owing to unsustainable harvesting practices and illegal trade the species had already been categorized as endangered in Arunachal Pradesh, Sikkim and Himachal Pradesh, Critically Endangered in Uttarakhand and Kashmir districts (Kaul 2001) and Vulnerable in Nepal (Bhattarai *et al.* 2002). Our research found that variability exists within and between the groups in each studied location of *N. grandiflora*, which is similar to the findings of Chauhan *et al.* (2011). Various authors have studied the ecological status of *N. grandiflora* in the Himalayas and observed a significant decline in its density (Larson and Olsen 2008, Chauhan *et al*. 2011, Nautiyal *et al.* 2003, Mulliken 2000). Overburden on natural habitat, lack of awareness among the local people, and poor harvesting practices have pushed this species to the list of endangered (Chauhan 2021). Larson and Olsen (2008) assumed that the global population of *N. grandiflora* is declining due to human induced habitat loss and degradation in India and overharvest in Nepal. It has been reported that population declines of 75-80% and classified *N. grandiflora* as Endangered in Arunachal

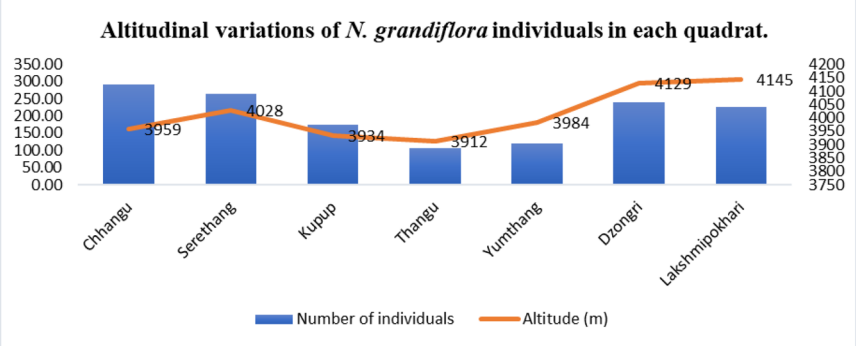

Fig. 2. Altitudinal variations of *N. grandiflora* individuals in each quadrat.

Pradesh, Sikkim and Himachal Pradesh and Critically Endangered in Uttarakhand and Kashmir district according to the IUCN Red list criteria (Mulliken and Crofton 2008). Whereas, in Nepal *N. grandiflora* populations have been reduced by more than 30 % due to overharvesting, resulting slow growth rate after harvesting (Ghimire *et al.* 2008, Larsen, 2005, Pandit and Thapa 2004). It has a long juvenile phase of 3–4 years followed by a short reproductive phase. Seed germination in the natural condition is also very low (10–20 %, Nautiyal *et al*. 2003).

Major threats

A tremendous amount of the population of *N. grandiflora* is declining due to rampant and reckless harvesting. In Sikkim, the species is facing great pressure because of over-exploitation due to its potential market demand. Due to unsustainable harvesting practices, the species has become rare in its native habitat as a result of increasing commercial demand. Major threats include habitat destruction caused by urbanization and even tourism development at high altitudes, among other things, all of which put pressure on the species' survival. In the current study, pristine alpine habitats had higher frequencies of *N. grandiflora* than other surveyed sites. Disturbances which include anthropogenic activities like forest resource collection, logging, road construction, deforestation, human settlement and also grazing by wild animals are affecting the natural habitat of the species. Natural calamities such as heavy rainfall, landslides, also result in habitat loss and population depletion of the species. In addition to this, *N. grandiflora* populations are restricted to specific locations, and due to poor seed setting and low seed germination in natural conditions cause possible population depletion of the species in their natural habitat.

Management and conservation

The present study on the population status of *N. grandiflora* in Sikkim Himalaya revealed very low population density which required immediate conservation action. As per the study and gathered information from various sources, the following strategies may be adopted for the effective management of *N. grandiflora* population in their natural habitat.

Exploration and documentation of the species for identification of major distribution areas.

Sustainable harvesting of the species should be encouraged at very low harvesting intensity with long rotation.

Collection of young rhizomes should be avoided, allowing only mature rhizomes after dispersing of seed should be framed.

Reintroduction of *ex-situ* plants of *N. grandiflora* to their natural habitat could maintain its population in nature.

Area specific threats should be evaluated for the management of this species.

Rotational harvesting of the species from their natural habitat may be beneficial for maintaining their population.

Regular supervision and monitoring for the collection, trade, and status of *N. grandiflora* should be conducted by local, state, and central governments.

CONCLUSION

The conservation of *N. grandiflora*, an economically significant and critically endangered plant is a top priority. The current study on the status of the *N. grandiflora* population in the Sikkim Himalaya revealed that there is variation both within and between the groups in each site under investigation. In comparison to other studied areas, both the location of North Sikkim and the Kupup regions of East Sikkim were identified as having low population densities, as a result, a strategic action plan for conservation must be developed. However, domesticating and growing high-altitude *N. grandiflora* is still quite difficult. The species is mostly threatened by overharvesting in the wild, but it is also vulnerable to other threats such as low population density, highly specific habitat, limited distribution, long life cycles, and slow reproductive maturity.

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REFERENCES

Airi S, Rawal RS, Dhar U, Purohit AN (2000) Assessment of availability and habitat preference of Jatamansi-A critically endangered medicinal plant of west Himalaya. *Curr Sci* 79 (10) : 1467—1470

Bhattarai B, Rana M (2022) Characterization of wild *Begonia* species of Sikkim Himalaya: A study for morphological and antioxidants analysis. *Ind J Ecol* 49 (4) : 1264—1270.

Bhattarai N, Kharki M, Tandon V (2002) Report of the conservation assessment and management plan workshop in Nepal. *Med Pl Conserv* (8) : 28—30.

Chauhan HK (2021) *Nardostachys jatamansi*. The IUCN Red List of Threatened species 2021: E. T50126627A88304158. https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T50126627 A88304158.en.

Chauhan HK (2022) *N jatamansi* : An endemic Himalayan species in Peril. In imperiled : The Encyclopedia of Conservation, pp 789—796.

Chauhan HK, Oli S, Bisht AK, Meredith C, Leaman D (2021) Review of the biology, uses and conservation of the critically endangered endemic Himalayan species *Nardostachys jatamansi* (Caprifoliaceae). *Biodiver Conserv* 30 : 3315 — 3333.

Chauhan RS, Nautiyal MC, Kumar A (2011) Analysis of variabilities in populations of *Nardostachys jatamansi* DC in Garhwal Himalaya, India. *J Pl Breed Crop Sci* 3 (9) : 190—194.

Dhiman N, Bhattacharya A (2020) *Nardostachys jatamansi*— The challenges and opportunities of harnessing the untapped pharmaceutical resources. *J Ethnopharmacol* 246 : 112—211.

Ghimire SK, Gimenez O, Pradel R, McKey D, AumeeruddyThomas Y (2008) Demographic variation and population viability in a threatened Himalayan medicinal and aromatic herb *Nardostachys grandiflora*: Matrix modelling of harvesting effects in two contrasting habitats. *J Appl Ecol* 45 (1) : 41—51.

Kaul MK (2001) Technical report on establishment of gene bank of medicinal plants of N.W. Himalaya. Jammu (India), Department of Biotechnology, Government of India, and Regional Research Laboratory (RRL).

Kaur H, Lekhak MM, Chahal S, Goutam U, Jha P, Naidoo D, Ochatt SJ, Kumar V (2020) *Nardostachys jatamansi* (D.Don) DC. An invaluable and constantly dwindling resource of the Himalayas. *South Afr J Bot* 135 : 252—267.

Lakey Dorji K (2016) Ecological status of high altitude medicinal plants and their sustainability: Lingshi, Bhutan. *BMC Ecol* 16:45.

Larsen HO (2005) Impact of replanting on regeneration of the medicinal plant *Nardostachys grandiflora* DC (Valerianaceae). *Econ Bot* 59 (3) : 213—220.

Larson HO, Olsen CS (2008) Towards valid non-detrimental findings for *Nardostachys grandiflora*. NDF workshop case studies wg 2 -Perennials Case STUDY 3 *Nardostachys grandiflora.*

Mehta P, Sekar KC, Bhatt D, Tewari A, Bisht K, Upadhyay S, Negi VS, Soragi B (2020) Conservation and prioritization of threatened plants in Indian Himalayan Region. *Biodiver Conserv* 29 : 1723—1745.

Michael WP (1990) The estimation of species richness by extrapolation. *Ecology* 71(3) :1195—1198.

Mulliken TA (2000) Implementing CITES for Himalayan Medicinal Plants *Nardostachys grandiflora* and *Picrorhiza kurroa. TRAFFIC Bulletin* 19(2): 63—72. Available at www.traffic.org/traffic-bulletin/traffic_pub_bulletin_18_2.pdf.

Mulliken TA, Crofton P (2008) Review of the status, harvest, trade and management of seven Asian CITES-listed medicinal and aromatic plant species. Federal Agency for Nature Conservation, Bonn.

Nautiyal BP, Chauhan RS, Prakash V, Purohit H, Nautiyal MC (2003) Population studies for the evaluation of germplasm and threat status of the alpine medicinal herb, *Nardostachys jatamansi. Pl Genet Resour News Lett* (136) : 34—39.

Pandit BH, Thapa GB (2004) A tragedy of non-timber forest resources in the mountain commons of Nepal. *Environ Conserv* 30 (3) : 283—292.

Pradhan BK, Badola HK (2015) Swertia chirayta, a threatened high-value medicinal herb : Microhabitats and Conser vation challenges in Sikkim Himalaya, India. *Mount Res Develop* 35 (4) : 374—381.

Purohit VK, Chauhan RS, Andola HC, Prasad P, Nautiyal MC, Nautiyal AR (2012) *Nardostachys jatamansi* DC : Conservation, multiplication and policy issues, Short Communication. *Int J Phytomed Related Industries*. DOI 10.5958/j.0975- 4261.4.3.019ort.

Rashid M, Rahman A, Ahmad QZ, Tajuddin Mian SS (2018) Physico-chemical Analysis of Sumbul-al –Teeb (*Nardostachys jatamansi* DC) Rhizome along with its HPLC Profile. *Pharmacog J* 10 (2) : 278—284.

Singh UM, Gupta V, Rao VP, Sengar RS, Yadav MK (2013) A review on biological activities and conservation of endangered medicinal herb *Nardostachys jatamansi*. *Int J Med Aromatic Pl* 3 (1) : 113—124.

Ved D, Saha D, Ravikumar K, Haridasan K (2015) *Nardostachys jatamansi*. The IUCN red list of threatened species. T50-126627A50131395. https://doi.org/10.2305/IUCN. UK2015-2.RLTS.T50126627A50131395.en.

Yadav S, Gupta K, Prabha S (2011) Hair growth activity of *Nardostachys jatamansi* and *Cyperus rotundus* rhizomes extract on chemotherapy induced alopecia. *Int J Drug Dis Herbal Res* 1 (2) : 52—54.