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Ecological features and traditional knowledge of *Roscoea alpina* Royle a medicinal plant in Himalaya

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Roscoea alpina Royle (Zingiberaceae) commonly known as *Kakoli* is a perennial medicinal plant endemic to the Himalayas. It has been used in vitality strengthening Ayurveda groups i.e., *Astavarga* and *Jeevaniyagana* and in preparation of Ayurvedic formulations e.g., *Chyavanprasha* and *Divya Pidantak Tail*. Considering its medicinal uses, high demand and overexploitation, natural habitats were surveyed in subalpine and alpine regions of Garhwal Himalaya for population estimation and to identify elite germplasm. *R. alpina* frequency was recorded more than 60% in Tungnath, Dayara, Valley of Flowers and Kedarnath populations. However, plant density and area occupied were low compared to other species of subalpine and alpine site. For threat category assessment, IUCN Red List Categories and Criteria were used and conservation status was assigned, based on site to site and for entire Garhwal region of the Western Himalaya. *R. alpina*, based on extent of occurrence was categorized as Vulnerable and based on number of mature individuals as Endangered for the Garhwal Himalaya. Further, habitat destruction and degradation were the major threats for population reduction in the wild. Morphological variation revealed plants from Tungnath and Kedarnath may be used for future propagation and domestication programs.

Keywords: Habitat, Himalaya, Medicinal plant, *Roscoea alpina, Zingiberaceae*

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The genus *Roscoea* is an alpine ginger group reported endemic to the Himalayan region[1,2]. However, other members of the ginger family (Zingiberaceae) are dispersed in tropical and subtropical habitats. The genus is represented by 18 species and most species are concentrated in the eastern Himalayas (Nepal to North India) and mountains of southwest China[2]. The area is declared as a global biodiversity hotspot due to high diversity of species and endemism[3], but few information is available on conservation assessment of endemic *Roscoea* species in the area. In India, the genus is enumerated by ten species[4] but only five are known[5] it shows that general distribution of *Roscoea* species is little known from India. Further, identifying common and rare species of *Roscoea* across local and geographic levels could be important for conservation, management and planning[6,7].

Roscoea alpina Royle (Fig. 1) is a perennial herbaceous plant native to the Himalayas and possibly the smallest species among the Himalayan *Roscoea*. The species is found in Tibet, Nepal, Bhutan and India from 2130 to 4270 m a.s.l.[8,9]. In India, the plant is recorded from Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Sikkim[1]. It is a rhizomatous, tuberous rooted herb and may grow up to 12-20 cm. Leaves are obtuse, broadly elliptic or lanceolate. Flowers are deep purple or lilac and the flowering period is from June to August. The plant develops single inflorescence and at a time only one flower of inflorescence opens. However, an inflorescence may bear up to five flowers. Seeds are small and dark brown[1].

In Ayurveda, *R. alpina* is commonly known as *Kakoli*[10] and its tuberous roots (Fig. 2) are cooling, revitalizing, age-sustainer and restorative, aphrodisiac, galactagogue, expectorant, diuretic, febrifuge, used

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Fig. 1 — Roscoea alpina plant

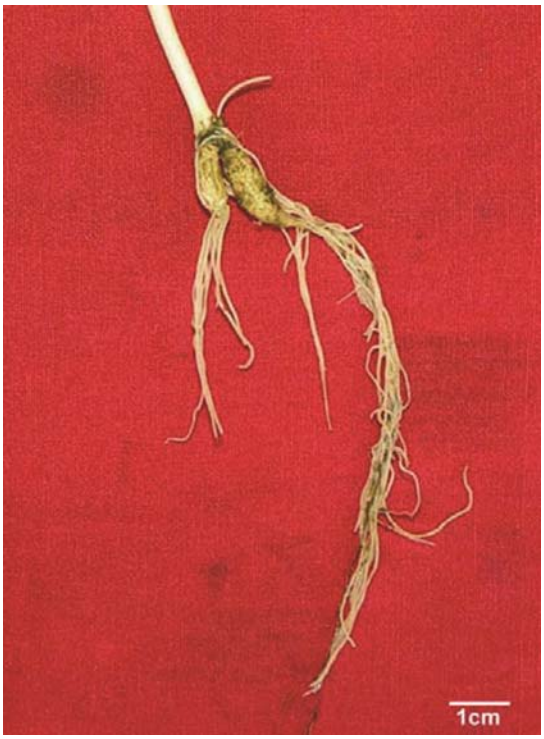

Fig. 2 — Roscoea alpina rhizome

for epistaxis, seminal weakness, burning sensation, inflammations, fever, agalactia, bronchitis and general debility[11]. Traditionally, its root powder is consumed with *Withania somnifera* and milk which is beneficial for burning sensation, debility, oligogalactia and spermacresia. It is also an important part of Ayurvedic groups i.e., *Astavarga*, *Jeevaniyagana* and used in ayurvedic formulations e.g., *Chyavanprasha and Divya Pidantaka Tail*[11,12]. However, it is sometimes also grown as an ornamental plant in gardens[13].

To date research studies has been conducted on history, taxonomy, phylogeny, evolution, phenology, reproductive and pollination biology of *Roscoea* in the Himalayas[1,9,14-19]. It indicates that the genus requirements for its microhabitats are highly specialized and therefore it is threatened due to habitat destruction e.g., forest clearing for road development and mine production. Moreover, these threats to the individual populations may lead some species to the verge of extinction[19]. To our knowledge, information on *R. alpina* conservation status, threats and morphological variations of natural populations are not available. Thus, the current study was conducted to assess the natural populations of *R. alpina* for its site characteristics, population structure, associated species, morphological variations under different climatic conditions. The outcome will help to develop conservation and domestication strategies.

Methodology

Information on medicinal uses of *Kakoli* in Ayurveda was compiled from published literature[20-22]. For field visits, we surveyed available published literature on *R. alpina* and Flora of District Garhwal Northwestern Himalaya[23]. To locate the possible sites for field corroboration, plant specimens were observed in Forest Research Institute herbarium, Dehradun. Exhaustive field surveys were conducted to explore and identify natural populations of *R. alpina* from 2006 to 2010. Latitude, longitude and altitude of identified populations were noted with a Global Positioning System (GPS). Further, we used clinometer to observe the slope at all the identified populations.

For population estimation and threat category assessment, we established a 100×100 m plot for each population and ten quadrates of 1×1 m were laid randomly in the plot. Vegetation sampling was conducted through vertical belt transects[24]. Quantitative features viz., frequency, density and abundance for the population was evaluated by following the standard methods[25,26]. The distribution pattern was analyzed based on abundance to frequency (A/F) ratio. Value of A/F was categorized as follows, <0.025 regular, between 0.026-0.050 random and >0.050 contiguous type of distribution[27].

For threat category assessment, two important criteria, (i) population estimation (density and number of mature individuals) (ii) extent of occurrence (number of populations) were used as per IUCN Red List Categories and Criteria[28]. For present study, mature individuals were the number of individuals known, estimated or inferred to be capable of

reproduction. Species having mature individuals <250 was categorized as Critically Endangered, <2500 as Endangered and <10,000 as Vulnerable. Similarly, species having one population was categorized as Critically Endangered, <5 population as Endangered and <10 populations as Vulnerable. Additionally, the conservation status was assigned separate for each natural site as well as for the entire Garhwal region. Morphological details (plant height, number of leaves, leaf length, rhizome length, root number and length) of ten mature individuals from each stand were sampled randomly.

Result

Kakoli has been used for asthma, bronchitis, gout, sciatica and urinary disorders. *Nagabalasari* (an ayurvedic medicinal formulation) processed with *Kakoli* and other medicinal herbs are used for tuberculosis, haemorrhage, burning sensation, giddiness and premature greying of hair. Its rhizome powder is known for its rejuvenator properties in *Ayurveda*. For child emaciation, consumption of clarified butter administered with *Kakoli* and other herbs was recommended in proper doses (Table 1). *Kakoli* is also a vital ingredient of *Ayurveda* groups i.e., *Astavarga* and *Jeevaniyagana*. *Astavarga* is a group of eight medicinal plants used for treating sexual disorders, physical weakness, to strengthen the immune system, reduce body pain and as a revitalizing tonic. It has also been used in the preparation of ayurvedic formulations e.g., *Amritprasha ghritam*, *Chyavanprasha*, *Balatailam*, *Narayan tailam*, *Balarishtha* and *Kumkumadi ghritam* (Table 2). In the modern market, *Chyavanprasha* and *Divya pidantak tail* are popular for immunity booster and in relieving pain respectively.

Table 1 Medicinal uses of *Kakoli* in Ayurveda

Medicinal uses	Mode of use
Hemorrhage, tuberculosis, giddiness, burning sensation, wrinkles and premature greying of hair.	*Nagabalasari* (medicinal formulation) is processed with *Kakoli* and other ayurvedic herbs
Cough and cardiac diseases	*Kakoli* powder with other medicinal herbs added with honey and crystal sugar
Asthma and bronchitis	*Kakoli* rhizome powder with orange rind powder
Sexual debility	Rhizome powder
Gout	Clarified butter processed with *Kakoli* and other medicinal herbs
Sciatica, kyphosis, urinary disorders	Oil processed with *Kakoli* and other herbs
Rejuvenator	*Chyavanprasha* prepared with *Kakoli* and other medicinal herbs
Body strength, potency, strengthens virility	Ayurvedic tablet prepared with *Kakoli* and other herbs used in proper doses
Galactagogue, tissue promoter, spermatogenic, tuberculosis, emaciation, fever, burning sensation	Intake of powder prepared from *Kakoli* and other medicinal herbs
Immunity booster	Intake of powder prepared from *Kakoli* and other medicinal herbs
Treat emaciation caused due to any injury, atrophy, cardiac diseases, hoarseness, asthma, cough, dipsia	*Chyavanprasha* processed with *Kakoli* and other medicinal herbs
Child emaciation	Intake of clarified butter processed with *Kakoli* and other medicinal herbs in appropriate doses

*Sources: Balkrishna 2012; Mishra et al. 2005; Pandey 2005

Table 2 — Medicinal uses of *Astavarga* plants in Ayurvedic formulations*

Medicinal uses	Formulations
Aphrodisiac, burning sensation, cough, haemorrhagic, urinary disorders	*Amritprasha ghritam*
Physical weakness and sexual debility	*Balatailam*
Anti-aging, asthma, loss of appetite, cough, heart issues, sexual gratification, memory, urinary problems	*Chyavanprasha*
Pain and headache	*Dashmoolatailam swalpamdwitiyam*
Youthfulness, infertility related issues in aged women	*Ekadashsateekprasarni tailam*
Enhance sperm count, physical strength	*Kamdev ghrit*
Constipation, toothache, fever and regain youthfulness	*Narayan tailam*
Arthritis, physical weakness due to disease and sex related issues	*Mahachandanadi tailam*
Improve digestion and enhance physical strength	*Balarishtha*
Breathing problems, cough, haemorrhagic disease, urinary disorders leading to diabetes	*Kumkumadi ghritam*

*Sources: Mishra et al. 2005; Pandey 2005

After field surveys four sites of *R. alpina* were identified in sub alpine and alpine regions of Garhwal Himalaya (Table 3). During winter season, these sites remain under snow cover for 4-6 months; however snow intensity varies from site to site and year to year. During summer season, maximum air temperature may reach up to 25°C during day time followed by nearly freezing temperature in night. Abiotic pressures like high ultraviolet radiation, wind velocity, low atmospheric oxygen level was common feature at all the study sites. Valley of Flowers site is a national park and therefore protected from anthropogenic activities e.g., grazing, harvesting and tourism.

Field survey revealed that the major habitat of *R. alpina* were moist subalpine to alpine slopes under the canopy of timberline trees (*Rhododendron and Quercus species*) in Garhwal Himalaya. Some common associates of the species were *Polygonaum macrophyllum*, *Potentilla atrasanguna*, *Selinum candolii*, *Pedicularis* and *Viola* species. All the natural populations of *R. alpina* having a slope of 15-30° and occurs between an altitude of 3248-3850 m a.s.l. *R. alpina* frequency was recorded maximum in Tungnath and Valley of Flowers (70%) and minimum in Dayara and Kedarnath population (60%). Plant density was high in Valley of Flowers (1.40 plant m^{-2}) followed by Tungnath (1.20 plant m^{-2}), Dayara (1.00 plant m^{-2}) and Kedarnath (0.90 plant m^{-2}). Relative density of species was high in Valley of Flowers (0.81) and low in Kedarnath (0.52). Relative dominance was recorded 6.40 in Tungnath, 9.20 in Dayara, 9.46 in Kedarnath and 12.67 in Valley of Flowers. Pattern of Abundance/frequency ratio revealed regular distribution in Tungnath, Dayara, Kedarnath and random distribution in Valley of Flowers. Total number of mature individuals were recorded maximum in Valley of Flowers (279) followed by Kedarnath (184), Tungnath (134), Dayara (98) (Table 4).

Morphological variation was recorded in the field among natural populations. Plants in Tungnath and Valley of Flowers have an almost similar height (21 cm) compared to Dayara (18 cm) and Kedarnath (19 cm). Leaf number was 2-3 in all the populations. Leaf length was recorded maximum in Kedarnath (13.25 cm) followed by Tungnath (11.80), Valley of flowers (11.41 cm), Dayara (10.50 cm). Rhizome length was observed maximum in Kedarnath (5.20 cm) followed by Dayara (4 cm) and minimum in Tungnath and Valley of Flowers (3.80 cm). Root number varies from 9.30 in Tungnath, 12.40 Kedarnath, 12.64 Dayara and 14.28 in Valley of Flowers. Root length was recorded high in Kedarnath (7.50 cm) followed

Table 3 — Site characteristics of selected populations of *Roscoea alpina*

Sites	Altitude (m)	Slope (°)	Latitude	Longitude	Habitat	Threats
Tungnath	3600	20-25	N30°59' 759	E78°27'689	Moist shady sub-alpine slopes with *Rhododendron* scrub	Rhizome used by local inhabitants, flowers offered to temple, grazing
Dayara	3360	20-25	N30°50'118	E78°33'994	Moist shady sub-alpine slopes with *Quercus* spp.	Habitat degradation, over exploitation, commercial development
Valley of Flowers	3248	15-20	N30°34'286	E79°21'486	Open moist meadows	Grazing, rodents consuming rhizome
Kedarnath	3850	20-30	N30°44'753	E79°03'412	Open grassy alpine slopes	Natural calamities, rhizome used by local inhabitants, flowers offered to temple, grazing

Table 4 — Population status of *Roscoea alpina* and assignment of threat categories in Garhwal Himalaya

Sites	Frequency (%)	Density (plant m^{-2})	Abundance	Relative density	Relative dominance	Population estimation (Number of mature individuals)	Extent of occurrence (Number of populations)	Status (IUCN 2001)
Tungnath	70	1.20	1.71	0.70	6.40	134	2	CR*, EN**
Dayara	60	1.00	1.43	0.58	9.20	98	1	CR*, CR**
Valley of Flowers	70	1.40	2.00	0.81	12.67	279	4	EN*, EN**
Kedarnath	60	0.90	1.29	0.52	9.46	184	2	CR*, EN**
Overall status for Garhwal Himalaya								VU*, EN**

*Based on extent of occurrence, **based on number of mature individuals

CR: Critically Endangered, EN: Endangered, VU: Vulnerable

Table 5 — Morphological variations among different populations of *Roscoea alpina*

Sites	Plant height (cm)	Number of leaf	Leaf length (cm)	Rhizome length (cm)	Root length (cm)	Root number
Tungnath	21.70 ± 4.95	2.90 ± 0.74	11.80 ± 2.53	3.80 ± 0.53	6.75 ± 3.03	9.30 ± 4.72
Dayara	18.99 ± 4.24	3.00 ± 0.43	10.50 ± 2.80	4.00 ± 0.88	5.95 ± 2.41	12.64 ± 3.62
Valley of Flowers	21.40 ± 1.54	2.00 ± 0.50	11.41 ± 3.47	3.80 ± 1.10	6.24 ± 1.55	14.28 ± 2.64
Kedarnath	19.44 ± 3.48	2.00 ± 0.12	13.25 ± 3.45	5.20 ± 0.94	7.50 ± 2.54	12.40 ± 1.82

by Tungnath (6.75 cm), Valley of Flowers (6.24) and in Dayara (Table 5).

Discussion

R. alpina was recorded from moist subalpine to alpine slopes under the canopy of timberline trees (*Rhododendron and Quercus species*) in Garhwal Himalaya, Uttarakhand. Earlier study also reported the species in clearings or among low herbaceous plants in *Rhododendron*, *Betula* or conifer forests in short damp grass[8]. The low density and high frequency were recorded in identified populations of *R. alpina* in Garhwal Himalaya. It indicates that the species tends to cover a wide space in a given area but unable to exhibit dense stocking. It may be due to the harvesting of its rhizomes for vitality promoting ayurvedic products particularly for *Chyawanprasha*, since Charak Samhita period of fourth century BC. The plant rhizomes have been uprooted unsustainably and may have resulted in low density in identified populations. The removal of the entire plant (above and below ground part) before maturation not only nullifies the possibility of regeneration through seeds but also finish the possibility to regenerate through rhizome or tuber[29]. In the Indian Himalayan region, over-collection and grazing pressure were the major factors contributing for the low density and continuous decline of the natural populations of rare and threatened medicinal plants[30,31]. Similar observations were reported in other medicinal herbs of Himalaya e.g., *Swertia chirayita*[32], *Aconitum balfourii*[33], *Lilium polyphyllum*[34].

In the majority of natural habitats, *R. alpina* distribution pattern was regular, a common characteristic of species-rich communities in alpine region[35]. This type of distribution can be attributed to underground parts (rhizome, bulb etc.), which bifurcate into 3-5 ramets as age advances. Bulb division has been reported in natural habitats of *L. polyphyllum* which results in the development of young individuals[36]. Data on number of mature individuals and population suggest that the species is threatened in the Garhwal region. Further, we recommend field visits in Kumaon Himalaya to locate more populations of the species. Earlier studies assessed threats for various Himalayan medicinal plants based on quantitative measurements[32,34,37,38]. Threat assessment on regional scale is important because an extinction of a species at a regional scale can aggravate a cascade of extinctions, causing a change in species composition and in ecosystem processes[39,40]. It is also suggested that extinction of a species is the outcome of local extinctions of its populations[41]. Therefore, present assessment will provide baseline information for conservation of the species and protection of wild habitats on a regional scale.

R. alpina plants from Tungnath and Kedarnath population indicate superior morphology. The individuals of these populations may be selected as elite germplasm for future experimental studies. Morphological variations among different populations of *Ksirakakoli* (*Lilium polyphyllum*) was recorded and used for domestication[42]. Research studies on *Angelica glauca* and *A. archangelica* observed morphological features for selection of elite germplasm in Garhwal Himalaya[37]. Specialized adaptation by plant species in alpine habitat to a precise set of environmental characteristics means that they are very vulnerable to all type of environment changes. Thus, while attempting to domesticate this species, it is essential to consider, morphological variations, genetic diversity, secondary metabolites and productivity.

Conclusion

The present study on the availability status, ecological parameters and morphological variations in natural populations will assist to understand the distribution and conservation status of *R. alpina*. The present study recommends locating more populations to develop future conservation strategy for the species. Natural populations were observed for morphological growth and superior germplasm of *R. alpina* was found mostly on moist habitats with slopes. Thus, for the domestication of the species,

moist sites with north-facing slopes would be suitable for better yield of the rhizome. Further, we recommend observing phenotypic traits of the plant after planting in nursery. Medicinal uses reported in literature may provide insights for future research studies to explore essential oil profile, phytochemical constituents and pharmacology of the species.

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Conflict of Interests

Authors declare no conflict of interest.

Author Contributions

Study design and fieldwork: AD, YMB, BPN, MCN; writing the article: AD, VKY, PC, BPN

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