

Conservation status and morphological variations between populations of *Angelica glauca* Edgew. and *Angelica archangelica* Linn. in Garhwal Himalaya

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Natural populations of two species of *Angelica*, viz. *A. glauca* and *A. archangelica* in subalpine and alpine regions of Garhwal Himalaya were surveyed for the determination of threat status and evaluation of germplasm for domestication and cultivation. The study revealed that frequency of both species was more than 50% in nature. However, density of individuals and area occupied were low compared to other species of alpine and subalpine region, indicating habitat loss and heavy exploitation. Status was determined on site-to-site basis as well as for entire Garhwal region of Western Himalaya. Based on species occurrence in selected areas, both species were identified as critically endangered to endangered in different areas. The results also revealed that natural distribution of these species was narrowing down due to habitat destruction. The number of mature individuals was also very low for both species of *Angelica* and therefore, status was again assigned as critically endangered for each site. Immediate remedial measures are needed for the conservation of natural sites to ensure sustainable mode of utilization. Efforts were also made to evaluate germplasm for domestication on the basis of morphological variations and yield of rhizomes under natural conditions as well as on the basis of phenotypic traits.

Keywords: Conservation, domestication, exploitation, habitat, sustainable.

THE high altitude region of Himalaya is a rich source of important medicinal and aromatic plants (MAPs). However, most of these MAPs are experiencing habitat destruction due to over and illegal exploitation and are no longer found in the accessible habitats in large quantities. Since the species of this region are either endemic or prefer specific habitat, many are on the threshold of extinction^{1,2}. There are many species which have become rare in several tracts and are found only in inaccessible hilly areas, while a few others have fallen in the list of endangered species. Recently CAMP, 2003 assessed threat status of western Himalayan species and *Angelica glauca* was assigned the endangered status. This species is widely used in traditional systems of medicine. *A. archangelica* is also found in high altitude regions of Himalaya and used in

cosmetic industry mainly in Europe and used locally as diuretic. Exploitation of these species, especially *A. glauca* from wild is going on and they are facing severe threats. However, quantitative data on natural populations of these species are not available for Garhwal Himalaya.

Angelica glauca Edgew. (vern. Choru, Gandhrayan) belonging to the family Apiaceae is a glabrous rhizomatous, aromatic herb and found between 2600 and 3700 m asl in western Himalaya (Figure 1). Roots of *A. glauca* are used as a spice or condiment, and also as a drug. The odour is characteristically aromatic and pungent with a sweet bitter taste. Roots can be collected and dried during Sept–October. The root is considered as cardio active and stimulant, carminative, expectorant and diaphoretic; it is also useful in constipation. The powdered root is administered with warm water in stomach ailments of children; it also checks vomiting. On steam distillation, the roots yield a pale to brownish yellow essential oil.

Angelica archangelica Linn. (vern. Rickchoru) of the family Apiaceae is an aromatic, stout, perennial herb found at altitudes between 2600 and 3900 m asl in Garhwal Himalaya (Figure 2). The herb, including the fruits and roots, is used for flavouring, and possesses carminative properties. The leaf stalks are employed in confectionery. The root is aromatic and possess diaphoretic and diuretic properties, and is used in flatulent colic. It is sometimes applied externally as a counter-irritant. On steam distillation, the roots yield a light greenish yellow essential oil (0.35–1.0%, dry basis) having strong aromatic odour. The oil has not yet been commercially exploited in



Figure 1. *Angelica glauca* in natural habitat.

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India. In Europe, the essential oil from *A. archangelica* is used in liquors, dental preparations and in high-grade perfumery to impart a musky note, which cannot be distinguished easily from that of true musk. The roots and seeds have mild antiseptic properties and depressant action on the central nervous system.

General information on *Angelica* species is available in the literature³⁻⁶. However, information regarding the status and morphological variations of natural populations is lacking. The present study was made with the following objectives to assess natural population of *Angelica* species in Garhwal, Western Himalaya: (i) The exact status of the species in nature, i.e. availability and occurrence to determine the threat categories, (ii) Population structure and associates of the species in nature, (iii) Morphological variations under different conditions and sites for identification of superior germplasm and strains for domestication, and (iv) selection of elite strains/germplasm for future multiplication on the basis of phenotypic traits. The results will be helpful for future sustainable use of the herbs as medicine. Simultaneously, the goal of protecting natural populations will be achieved by pertinence of suitable conservation and management strategies.

The survey was conducted in high altitude areas of Garhwal Himalaya, Uttarakhand (29°26'–31°28'N and 77°49'–80°6'E), India to identify natural populations. Eight sites were identified as natural habitats of *Angelica glauca* and *A. archangelica* and selected for the study.



Figure 2. *Angelica archangelica* in natural habitat.

Description of each site is given in Table 1. Generally, these sites are under heavy snow cover for 4–6 months during winter although intensity of snow cover varied during the years. Maximum day time air temperature reaches up to 25°C during the summer followed by nearly freezing temperature at night. Precipitation is typically of monsoon type. *A. glauca* prefers moist shady sub-alpine slopes and found mostly in the shady canopies of *Rhododendron companulatum*, *Betula utilis*, *Quercus semicarpifolia* and *Acer* forests. *A. archangelica* is found in shady pockets in inner Himalayan ranges at moist, grassy open slopes and prefers sandy loam and acidic soil mostly on the west aspects.

For population analysis and threat category determination, stands of 100 × 100 m² were identified and marked on each site. Vegetation sampling was conducted through vertical belt transects⁷. Since the distribution range is narrow and topography is diverse, approximately 60 m long and 30 m wide transects were laid across each stand. Transects were divided into three plots of 20 × 10 m size as replicates and ten quadrats of 1 × 1 m size were laid randomly in each plot following Kershaw⁸. Mean values derived from plots of each transect were used for analysis of quantitative parameters of the respective stands. Individuals of all species associated with *Angelica* species were counted in each quadrat. Analytical features for population study such as percentage frequency (% F), density (D plant m⁻²) and total basal cover (TBC, cm² m⁻²) were calculated by using the methods given by Mishra⁹. During the population analysis, some sites where individuals of representative species were very few (1–5) are not considered as stands. However, these individuals were also marked and counted as area of occurrence and for the demographic observations for threat category assessment. For threat assessment, two criteria, i.e. population estimation (density and number of mature individuals) and extent of occurrence (number of populations/plots) were used as per IUCN Red List Categories¹⁰. During the study, only flowering plants were considered as mature individuals and taken further for population estimation. Species having mature individuals <250 was considered as critically endangered, <2,500 as endangered and <10,000 as vulnerable. Similarly, species having single population was categorized as critically endangered, <5 populations as endangered and <10 populations as vulnerable. Furthermore, status was assigned separately for each natural site as well as for entire Garhwal region.

Ten individuals of approximately same age from each stand were sampled randomly for morphological details (plant height, number of leaves, leaf length and width) and for the observation of phenotypic traits during flowering of plants in September. Efforts were made to visit all the sites within 15 days to obtain uniformity in observations. Individual plants were selected on the basis of appearance of flowers as an indication of completion of juvenile growth phase. For belowground biomass estima-

Table 1. Site characteristics of the selected populations of *Angelica glauca* (Ag) and *A. archangelica* (Aa)

Sites	Species	Altitude (m)	Aspect	Slope	Habitat	Dominant species
Bharnala (BH)	Ag	2650–3000	EN	25–30°	Moist shady sub-alpine slopes under canopy of <i>Acer</i> forest	<i>Carex</i> spp., <i>Geranium wallichinum</i>
Tungnath (TN)	—	—	—	—	—	—
	Ag	2950–3200	NW	20–25°	Moist shady sub-alpine slopes, under canopies of <i>Acer</i> and <i>Betula utilis</i> .	<i>Salvia hians</i> , <i>Polygonatum cirrifolium</i> , <i>Teucrium</i> sp.
Kunwari Pass (KP)	Aa	2950–3200	SW	20–25°	Found in shady and moist places of Krumholtz zone	Fern species, <i>Ranunculus hirtellus</i> , <i>Polygonum aviculare</i>
	Ag	2850–3000	NW	20–30°	Moist shady sub-alpine slopes under canopy of <i>Acer</i> forest	<i>Danthonia cachemyriana</i> , <i>Anaphalis</i> spp., <i>Polygonum aviculare</i>
Panwalikantha (PK)	Aa	2850–3000	SW	20–30°	Open grassy slopes in subalpine-alpine	<i>Danthonia cachemyriana</i> , <i>Selinum candolli</i> , Fern species
	Ag	3000–3300	EN	15–20°	Moist shady sub-alpine slopes found mostly under	Fern species, <i>Doronicum roylei</i> , <i>Impatiens thomsonii</i>
Rudranath (RN)	Aa	3000–3300	SW	20–30°	<i>Quercus</i> spp. Shady and moist places in alpine	<i>Danthonia cachemyriana</i> , <i>Anaphalis busua</i> , <i>Polygonum aviculare</i>
	Ag	2800–3000	WS	20–30°	Moist shady sub-alpine slopes, under canopy of <i>Rhododendron campanulatum</i>	<i>Poa annua</i> , <i>Fragaria nubicola</i> , <i>Selinum candolli</i>
Kedarnath (KN)	Aa	2800–3000	NW	20–25°	Open grassy slopes of subalpine-alpine	<i>Poa annua</i> , <i>Fragaria nubicola</i> , <i>Anaphalis busua</i>
	Ag	3500–4000	NW	30–35°	Open grassy alpine slope	<i>Carex</i> , <i>Impatiens</i> , <i>Tanacetum longifolium</i>
Valley of flowers (VF)	Aa	3500–4000	WS	30–40°	Open grassy alpine slopes	<i>Carex</i> , <i>Impatiens thomsonii</i> , <i>Fragaria nubicola</i>
	Ag	2900–3200	NW	20–30°	Open moist meadows and grassy slopes	<i>Polygonum aviculare</i> , <i>Fragaria nubicola</i> , <i>Senecio chrysanthemoides</i>
Dayara (DY)	Aa	2950–3300	WS	25–30°	Open grassy slopes and moist meadows	<i>Polygonum aviculare</i> , Fern species <i>Potentilla fulgens</i>
	Ag	3000–3400	NW	20–30°	Moist shady sub-alpine slopes, under canopies of <i>Quercus</i> spp.	<i>Impatiens thomsonii</i> , <i>Rosa brunonii</i> , <i>Senecio chrysanthemoides</i>
	Aa	3000–3400	SW	20–30°	Open grassy slopes	<i>Fragaria nubicola</i> , Fern species, <i>Tanacetum longifolium</i>

tion, five mature plants were dug out and brought to the laboratory. The underground parts were washed with a fine jet of water. All samples were dried at 80°C until constant weight^{11,12}. Population-wise performance of selected species was observed and germplasm evaluated for the selection of superior germplasm for domestication. Observations on phenotypic trait were also made out. Plants having similar morphological attributes as well as of same age from selected sites were planted at nursery site (2200 m) under similar environment. Observations were carried out for survival, growth and yield parameters. Population performing well during phenotypic traits observation was identified as a source of elite germplasm and recommended for future multiplication of the species for commercial cultivation.

Moist sub-alpine slopes and under canopy of timberline trees are the major habitats of *A. glauca*. Similarly, *A. archangelica* is found mostly in shady habitat in inner Himalayan ranges in moist and open grassy slopes (Table 1). Major topographic features like elevation, aspects and slope condition play a vital role in determining structural characteristic of vegetation¹³. Dominant associates of *A. glauca* at most sites were *Senecio chrysanthemoides*, *Po-*

lygonum aviculare, *Fragaria nubicola* and *Impatiens thomsonii*. *Anaphalis*, *Carex* and ferns were other dominant associates of the species. Likewise, *Polygonum aviculare*, *Fragaria nubicola* and ferns species were dominant associates of *A. archangelica*. Species richness was maximum in Rudranath (RN) population of *A. glauca* and relative density of this species was maximum (3.39) in Dayara (DY) population and minimum (0.41) in RN population. Relative dominance of the species was maximum in Kedarnath (KN) and minimum in Tungnath (TN) population (Table 2). While in *A. archangelica* populations species richness was maximum (16) in KN and minimum (12) in TN. Relative density was maximum (4.44) in TN and minimum (0.50) in Kunwari Pass (KP) population. Relative dominance was maximum in VF and minimum in RN population. Earlier, several workers^{14–16} have reported that species density in high altitude region is very high. However, populations of *Angelica* species showed comparatively low plant density and relative dominance. The valley of flowers (VF) had maximum frequency for both species as this site is a part of Nanda Devi Biosphere Reserve (NDBR). Distribution of *Angelica* species at other sites was also between 50 and 70%, indicating dis-

Table 2. Population status of *Angelica* species and assignment of threat categories in Garhwal Himalaya

Sites	Species	Frequency (%)	Density (plant m ⁻²)	Relative density	Relative dominance	No. of mature individuals	No. of populations	Status
BH	<i>Ag</i>	50	0.7	0.7	7.7	35	1	CE*, CE**
	<i>Aa</i>	–	–	–	–	–	–	–
TN	<i>Ag</i>	60	1.2	2.0	2.9	73	2	EN*, CE**
	<i>Aa</i>	60	1.4	4.4	10.5	84	1	CE*, CE**
KP	<i>Ag</i>	60	0.9	0.6	9.2	86	2	EN*, CE**
	<i>Aa</i>	70	0.9	0.5	20.3	96	2	CE*, CE**
PK	<i>Ag</i>	50	0.8	2.3	6.4	65	2	EN*, CE**
	<i>Aa</i>	60	0.7	0.6	12.2	110	2	EN*, CE**
RN	<i>Ag</i>	60	0.8	0.4	9.2	96	2	EN*, CE**
	<i>Aa</i>	60	0.8	0.7	6.1	163	3	EN*, CE**
KN	<i>Ag</i>	50	0.7	0.5	10.3	31	1	CE*, CE**
	<i>Aa</i>	60	0.8	0.6	9.5	114	2	EN*, CE**
VF	<i>Ag</i>	90	1.5	2.2	8.9	296	4	EN*, CE**
	<i>Aa</i>	100	1.7	3.8	15.3	569	4	EN*, CE**
DY	<i>Ag</i>	60	0.8	3.4	6.4	69	2	EN*, CE**
	<i>Aa</i>	60	0.7	2.0	20.7	168	3	EN*, CE**
Overall status for Garhwal Region, Western Himalaya:							<i>Ag</i>	V*, EN**
							<i>Aa</i>	V*, EN**

*Based on extent of occurrence; **Population estimation.

persed distribution range. Overall density of both species was found between 0.7 and 1.7 plants m⁻².

Owing to anthropological changes in the form of habitat disturbances, over and heavy exploitation of plants in areas of high conservation, the original habitat is degraded into small sized population. In wild habitats at different sites, about 31–296 mature individuals of *A. glauca* were present and distribution was restricted to 1–4 populations (sites of small size). Likewise, *A. archangelica* occurrence was also restricted to 1–4 populations with mature individual population recorded between 84 and 569 at different sites in Garhwal. As per IUCN Red List Categories¹⁰, data on mature individual population and extent of occurrence (population numbers) indicate critically endangered to endangered status for both the species. The rate of depletion of the population is generally faster in small group than in bigger habitat as microhabitats available for the survival are proportionally reduced. Data indicated that although species occurrence is seldom (frequency was > 50% for both species in each site), the area of occurrence is narrowing down with very few mature individuals present (Table 2) and therefore, both the species are categorized as vulnerable on the basis of occurrence and endangered on the basis of population estimation. Therefore, immediate attention is needed to restore the population in natural sites and alternate op-

tions for the commercial exploitation are to be explored to save these two MAPs in Garhwal Himalaya.

Specialized adaptation by plants in alpine habitats to a specific set of environmental characteristics means that they are very susceptible to all sorts of environmental changes¹⁷. Therefore, morphological variation along with genetic diversity and productivity in case of MAPs must be considered during the domestication of these plants. During the study, morphological characters of the species were observed to see the performance and to identify the superior germplasm at different sites. Across the sites, a considerable variation in morphology of *A. glauca* was observed (Table 3). Plants from site VF had greatest plant height (165.67 cm) while plants from KP had lowest plant height (54.8 cm). Leaf area was maximum in plants observed at PK (12.80 × 5.10 cm) and maximum leaves (10) were found in RN site. As noted earlier, the sites on north- and west-facing slopes in alpine regions are relatively shady with little exposure¹¹, having higher moisture^{15,18}, organic carbon and nitrogen contents¹⁴. These observations in nature indicated that the species require these conditions for better growth. Underground biomass also showed considerable variation at different sites. The maximum below-ground biomass was recorded at site DY (18.00 g/plant), followed by site TN (14.35 g/plant) that again corresponds to moist, North-West facing habitats. In addition,

Table 3. Morphological variations among different populations of *Angelica glauca* and phenotypic traits observation in nursery

Sites	Plant height (cm)	No. of leaf	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Rhizome length (cm)	Rhizome dry weight (g/plant)
Populations in wild							
BH	146.3 ± 3.9	7.3 ± 0.6	9.9 ± 2.0	6.5 ± 1.0	3.1 ± 0.6	13.3 ± 0.7	11.2 ± 0.8
TN	118.0 ± 2.8	6.6 ± 0.5	4.5 ± 1.0	9.8 ± 1.9	4.6 ± 1.7	15.9 ± 0.5	14.4 ± 2.7
KP	54.8 ± 22.4	7.0 ± 2.6	7.7 ± 3.9	9.5 ± 2.4	4.4 ± 1.1	12.8 ± 0.4	1.8 ± 1.1
PK	91.7 ± 36.7	7.3 ± 0.6	6.0 ± 2.5	12.8 ± 2.8	5.1 ± 1.1	12.9 ± 0.5	6.5 ± 1.4
RN	149.0 ± 6.5	10.3 ± 1.7	10.8 ± 1.9	7.1 ± 0.6	3.5 ± 0.4	12.3 ± 0.3	3.8 ± 0.5
KN	110.0 ± 5.49	5.5 ± 1.0	9.4 ± 1.7	6.5 ± 0.8	3.3 ± 0.5	11.9 ± 0.4	3.8 ± 0.6
VF	165.7 ± 4.0	8.3 ± 1.6	12.8 ± 0.5	7.7 ± 0.3	4.0 ± 0.2	13.5 ± 1.0	4.6 ± 3.2
DY	154.7 ± 3.5	6.7 ± 0.6	11.8 ± 0.5	7.3 ± 0.5	3.8 ± 0.3	14.2 ± 0.4	18.0 ± 4.8
<i>F</i> value significant at <i>P</i> = 0.05	11.73*	10.00*	13.34*	11.69*	6.33*	15.02*	15.63*
Populations in nursery for phenotypic traits							
TN	54.7 ± 5.5	6.3 ± 1.2	—	8.3 ± 1.5	4.1 ± 0.5	13.5 ± 0.5	15.9 ± 2.2
KP	52.9 ± 2.7	5.0 ± 1.0	—	7.3 ± 1.9	3.8 ± 0.7	10.7 ± 2.2	9.3 ± 1.9
PK	54.1 ± 3.1	6.0 ± 1.0	—	8.8 ± 1.1	4.0 ± 0.4	11.6 ± 1.8	12.0 ± 1.9
BH	56.9 ± 5.0	7.0 ± 0.0	—	10.4 ± 1.5	4.3 ± 0.5	13.5 ± 1.5	14.4 ± 1.7
DY	59.6 ± 6.4	7.0 ± 1.0	—	10.5 ± 2.20	3.6 ± 0.5	11.0 ± 1.7	17.8 ± 2.4
<i>F</i> value significant at <i>P</i> = 0.1	0.92 ns	2.38 ns	—	1.99 ns	0.58 ns	2.13 ns	8.10**

*After completion of second growth year; vegetatively propagated plants through rhizome transplantation; **Significant; ns, non significant.

Table 4. Morphological variations among different populations of *Angelica archangelica* and phenotypic traits observation in nursery

Sites	Plant height (cm)	No. of leaf	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Rhizome length (cm)	Rhizome dry weight (g/plant)
Populations in wild							
TN	107.3 ± 15.5	6.3 ± 1.2	4.8 ± 1.1	9.8 ± 1.0	4.6 ± 1.5	9.5 ± 0.4	1.8 ± 0.5
KP	147.6 ± 4.2	7.0 ± 0.0	8.1 ± 0.6	7.3 ± 0.3	3.1 ± 0.2	9.9 ± 0.4	3.7 ± 0.4
PK	145.0 ± 3.1	8.0 ± 1.0	9.3 ± 0.2	7.0 ± 0.3	3.1 ± 0.2	10.8 ± 0.7	3.6 ± 0.7
RN	147.0 ± 3.6	7.7 ± 1.2	7.4 ± 0.5	6.1 ± 1.4	3.9 ± 2.5	10.1 ± 0.5	6.7 ± 3.4
KN	154.3 ± 5.0	8.7 ± 1.5	10.8 ± 0.5	7.2 ± 0.2	3.1 ± 0.1	10.8 ± 0.4	8.9 ± 4.7
VF	169.0 ± 1.0	8.7 ± 1.5	6.9 ± 0.8	9.3 ± 0.5	5.8 ± 0.4	11.3 ± 0.4	10.1 ± 1.1
DY	152.3 ± 2.5	9.3 ± 0.6	10.5 ± 0.9	6.2 ± 0.5	3.1 ± 0.2	10.7 ± 1.2	7.4 ± 0.8
<i>F</i> value significant at 0.05	23.85*	2.95*	8.25*	166.97*	215.17*	5.72*	5.49*
Populations in nursery for phenotypic traits							
TN	50.2 ± 0.6	5.7 ± 0.6	—	9.9 ± 1.5	4.0 ± 0.6	8.8 ± 2.5	5.2 ± 2.0
RN	54.5 ± 1.9	5.7 ± 0.6	—	9.7 ± 1.4	4.3 ± 0.8	11.3 ± 1.9	9.4 ± 2.2
PK	53.5 ± 5.2	6.0 ± 1.0	—	10.1 ± 1.2	4.3 ± 0.7	8.7 ± 1.7	5.4 ± 1.2
KN	63.2 ± 3.9	6.7 ± 0.6	—	10.3 ± 0.8	4.3 ± 0.5	13.7 ± 1.6	13.2 ± 0.7
DY	64.5 ± 4.0	7.0 ± 0.0	—	10.5 ± 1.0	3.9 ± 0.7	11.2 ± 2.1	11.6 ± 1.3
<i>F</i> value	9.50** <i>P</i> = 0.001	2.75 ns <i>P</i> = 0.1	—	0.16 ns <i>P</i> = 0.05	0.26 ns <i>P</i> = 0.05	3.21 ns <i>P</i> = 0.05	15.86** <i>P</i> = 0.001

*After completion of second growth year; vegetatively propagated plants through rhizome transplantation; **Significant; ns, non significant.

morphological characters showed significant variation on the basis of ANOVA. Plant height significantly varied among different populations ($F = 11.73$, $P = 0.05$, $df = 7$). Similarly, significant variation between populations was also found for rhizome biomass with ($F = 15.63$, $P = 0.05$; $df = 7$) and other characters as well (Table 3), indicating the role of topographic and climatic conditions. However, number of leaves and rhizome length did not show any significant variation in different populations.

In *A. archangelica*, plants from site VF had greatest plant height (169 cm) and leaf area was maximum in plants from TN (9.84×4.64 cm). Maximum leaves were found in DY site (9.3) and minimum (6.3) in TN site (Table 4). Underground biomass also showed considerable variation at different sites. The maximum belowground biomass was recorded at site VF (10.10 g/plant), followed by site KN (8.98 g/plant). Significant variation was found in different morphological characters observed, i.e. plant

height, number of leaf, rhizome length and yield and petiole length with $F = 23.85; 2.94; 5.72; 5.49$ and 8.25 respectively (at $P = 0.05$ and $df = 6$).

Phenotypic traits were observed in *A. glauca* when plants of different natural populations were planted in Pothibasa nursey (Table 3). These rhizomes were planted during October 2003. Morphological parameters were observed at the end of each growing season for two consecutive growth seasons. Tables 3 and 4 show population-wise performance of both *Angelica* species. In *A. glauca*, germplasm collected from DY showed overall better morphological growth and yield of rhizome on dry weight basis (17.83 g/plant) after two years of observations. Similarly, in *A. archangelica*, KN population performed well with maximum biomass of rhizomes (13.23 g/plant). Overall, variation in different parameters between populations revealed that in *A. glauca* only rhizome biomass showed significant variation ($F = 8.10, P = 0.1$) while for *A. archangelica*, plant height ($F = 9.5; P = 0.001$) and rhizome biomass ($F = 15.86; P = 0.001$) had significant variation under phenotypic traits (Tables 3 and 4). Evaluation of germplasm in nature generally provides an idea about suitable climate and selection of habitat/location for domestication and cultivation. However, on the basis of phenotypic traits, elite germplasm can be identified for further crop improvement. On the basis of above observations, it can be postulated that moist location with north-west facing slopes of mountains of Himalaya are better suited for the cultivation of these species and germplasm from DY was identified as elite for *A. glauca* and KN for *A. archangelica*.

The observations on threat status, morphological variation and biomass pattern of *A. glauca* and *A. archangelica* illustrate that although habitats of these species were present in different locations in Garhwal, they are degrading and these species are now restricted to very few sites with comparatively low population and are critically endangered to endangered. If urgent steps for conservation are not taken, both species will be extinct from wild in the near future. Natural populations of both the species are observed for morphological growth and yield of rhizomes. In nature, superior *A. glauca* and *A. archangelica* germplasm was found mostly on moist habitats with rich humus contents. Therefore, for the domestication of these species, moist sites preferably north-facing slopes and germplasm from open meadows would be suitable for better yield of rhizome. Likewise, on the basis of phenotypic trait observations, germplasm of both species from different natural populations was evaluated and elite germplasm was identified for future multiplication and commercial cultivation.

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