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RESEARCH ARTICLE

Effect of Habitat Variability on Phenotypic Characters and Resource Allocation in *Aralia cachemirica* Decne. – An Endemic Medicinal Plant of Kashmir Himalaya

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ABSTRACT

Aralia cachemirica Decne. is an endemic and significant medicinal plant species of Kashmir Himalaya. The present study was carried out to determine the impact of habitat variability on morphological features and resource partitioning of the species under study. The species exhibited great variability in its morphological traits under different environmental conditions. The plants were more vigorous and taller at Ferozpur Nallah site followed by Kashmir University Botanical Garden while Aharbal population was shortest. During the present study, it was observed that partitioning of resources is not uniform among different parts of a plant, much resources were allocated toward the root followed by the shoot then by leaves, and least amount of resources was allocated toward inflorescence among the studied populations. Our results present a detailed account of the variation of phenotypic characters and changes in resource allocation patterns in relation to environmental conditions of this medicinal plant species.

Keywords: *Aralia cachemirica*, environmental conditions, habitat variability, morphological traits, resource allocation

INTRODUCTION

Phenotypic plasticity is the ability of a genotype to exhibit alternative morphological, behavioral, and physiological attributes in response to environmental conditions.[1,2] Plasticity also may play a key role in evolution by governing or modifying developmental pathways.[3] Thus, phenotypic plasticity plays a significant role in creating the phenotypic diversity observed in nature.[2] These morphological variations across different environmental conditions (both biological and non-biological) not only give specific botanical identity to a species but can also disclose interesting features helpful in understanding the series of morphological variations present across different ecological zones. Resource allocation is essential to plant development, yield formation, and tolerance to abiotic and biotic stress.[4]

Aralia cachemirica Decne. commonly known as devils walking stick/Hercules Club and locally known as "khoree" is a clump-forming herbaceous perennial, which is capable of forming upright stems 1–3 m tall with large bright green tripinnate leaves, white flowers, and purple-black fruit. It is found distributed in temperate Himalayas from Kashmir to Sikkim at 2100–4000 m altitude and belongs to the family Araliaceae.[5,6] Various important medicinal properties have been reported by different workers from time to time. Bhat *et al*.[7] reported hypoglycemic activity from the roots of *A. cachemirica*. Anti-inflammatory activity also has been reported in this plant.[7] Furthermore, continentalic acid isolation from *A. cachemirica* and evaluation of its immunomodulatory activity already has been reported. Furthermore,

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continentalic acid has been reported for its analgesic activity,[8,9] growth inhibition and apoptosis induction,[10] antibacterial activity,[11] and anti-inflammatory activity.[9,12,13] *A. cachemirica* has been investigated for essential oil composition from Jammu and Kashmir[14] and Uttarakhand region.[15]

MATERIALS AND METHODS

Study sites

The exploration of different Kashmir Himalayan habitats was carried out to identify specific areas across different ecological conditions covering a wide range of habitats. Various populations were selected on the basis of their accessibility, habitat structure, and plant density for the present studies. The detailed geographic features of these study sites are given in Table 1.

Plant collection

Giving due cognizance to the threat status, healthy and disease free mature flowering plants of Aralia cachemirica were collected quiet judiciously from different study sites in order to avoid variations due to different developmental stages. The specimens were identified and deposited in Kashmir University Herbarium (KASH) under voucher number 2689-KASH.

Species morphology and phenotypic variability

Randomly selected mature plants were tagged in three natural populations and were analyzed for morphological features and phenotypic variability. The morphological traits analyzed include plant height, leaf number, leaf dimensions, flower number, and flower dimensions. The differences in morphological features were analyzed statistically by one-way analysis of variance (ANOVA) within and across different selected populations.

Resource allocation

The resource allocation was estimated by harvesting mature and flowering plants from different populations. Each plant was fragmented into component parts to determine dry weight after oven drying at 80°C for 48 h.[16] The dry mass of these plant parts was compared with each other to estimate resource partitioning in these plant parts.

Statistical analysis

The results were analyzed by one-way ANOVA, using SPSS version 20.0. The data were expressed as mean ± standard deviation and difference between groups considered statistically significant at $P < 0.05$.

RESULTS

Distribution

A. cachemirica Decne. commonly known as devil walking stick/Hercules Club and locally known as "khoree." It is a shrubby herb, 1–3 m tall, found distributed in temperate Himalayas from Kashmir to Sikkim at 2100–4000 m altitude and belongs to the family Araliaceae. In Kashmir valley, it is found growing in Aharbal, Ferozpur Nallah, Sonamarg, Mahadev, Daksum, and Dachigam.

Species morphology

The morphological features of *A. cachemirica* are described in tabulated form [Table 2] and also presented in Figure 1.

Phenotypic variability

The phenotypic variability of *A. cachemirica* recorded in three selected Kashmir Himalayan

Table 1: Geographical coordinates and salient features of the selected sites for *Aralia cachemirica*

S. No.	Study site	District	Altitude (m) amsl	Geographical coordinates	Habitat
1.	Aharbal	Kulgam	2400	33°38.281'N 74°46.653'E	Open, rocky slopes
2.	Ferozpur Nallah	Baramulla	2179	34°02.845'N 074°25.253'E	Rocky, moist, and grassy slopes
3.	Kashmir University Botanical Garden	Srinagar	1595	34°50'N 74°48'E	Moist open field

Table 2: Morphological attributes of *Aralia cachemirica*

Habit	Herbaceous perennial
Root	Very thick, branched
Stem	Upright stems, 1–3 m tall
Leaves	Large bright green tripinnate leaves, imparipinnate. Petiole long; leaflets ovate, apex acuminate, glabrous
Inflorescence	Inflorescence of umbels in axillary or terminal panicles
Calyx	Toothed, persistent
Corolla	Petals ovate
Androecium	Stamens 5, filaments longer than the petals, broader at the base and alternating with the petals
Gynoecium	Styles 5, united at the base, persistent. Ovary 5-locular
Flowering	July–August (September)
Fruit	Fruit a 5-angled drupe, purplish-black
Seed	Kidney shaped, whitish-gray, smooth

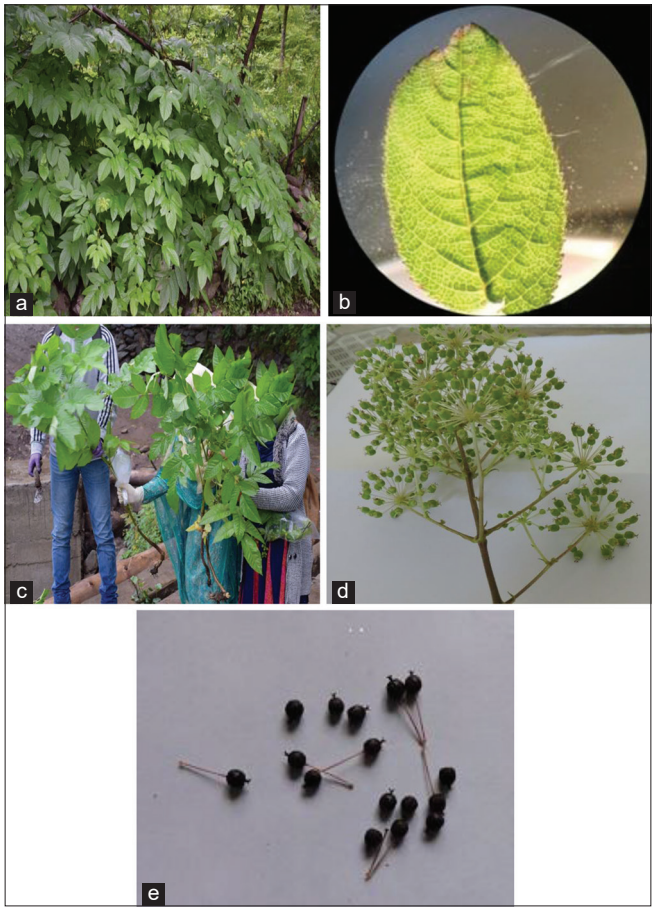

Figure 1: Morphological features of *Aralia cachemirica*. (a) General morphology (b) leaf dentate (c) thick branched root (d) inflorescence umbel (e) fruit globose, purplish-black

populations, namely, Aharbal (2400 m), Ferozpur Nallah (2250 m), and Kashmir University Botanical Garden (KUBG) (1595 m) reveals that the species depict significant variations in different phenotypic traits including plant height, root length, number of leaves per branch, and flower number per plant. The studies also reveal that the species exhibit substantial variation in the phenotypic traits within and across populations under different environmental conditions. The variation in various phenotypic traits of *A. cachemirica* is summarized in Table 3 and Figure 2 and described below:

Plant height

The present study depicted that the plant height ranges from 132 to 155 cm among the different selected populations. The plants growing at Ferozpur Nallah were found to be tallest (155.2 ± 14.30) followed by the plants growing at KUBG (138.2 ± 10.70), while the plants growing at Aharbal site were the shortest (132.8 ± 12.92). The plant height varies significantly ($P \leq 0.05$) across different habitats. The plants growing in shady, rocky, and moist habitats attain vigorous growth as compared to the plants growing in open sunny conditions.

Root length

The root length showed variation among different studied populations. The plants growing at Ferozpur Nallah were found to have the highest root length (33 ± 8.23) as compared to the plants growing at KUBG and Aharbal populations which show the primary root length of 24.5 ± 5.94 and 24.4 ± 2.54, respectively. The difference in root length is significant among Ferozpur Nallah and other two studied populations while KUBG and Aharbal populations did not show any significant difference in the root length.

Number of branches

The number of branches also depicted variation among and within studied populations. The results reveal that the difference in branch number is significant ($P \leq 0.05$) among the studied populations. However, the highest branch number was recorded at Ferozpur Nallah site and the lowest number of branches was recorded at Aharbal site.

Number of leaves

The species exhibit a significant difference in the number of leaves per plant across different

Table 3: Morphological variation in *Aralia cachemirica* across different Kashmir Himalayan populations

Phenotypic traits	Population			F	P
	Aharbal (2400 m asl)	Ferozpur Nallah (2179 m asl)	KUBG (1595 m asl)		
Plant height (cm)	132.8±12.92*	155.2±14.30	138.2±10.70	8.430	0.001
Root length (cm)	24.4±2.54	33±8.23	24.5±5.94	6.667	0.004
Number of branches	2.4±0.51	4±1.33	2.9±0.99	6.626	0.005
Number of leaves	49.5±10.17	64.2±13.18	36.2±9.97	15.607	0.000
Number of umbels	24±3.01	38.8±12.48	29±7.36	7.754	0.002

*Mean±standard deviation; *n*=10

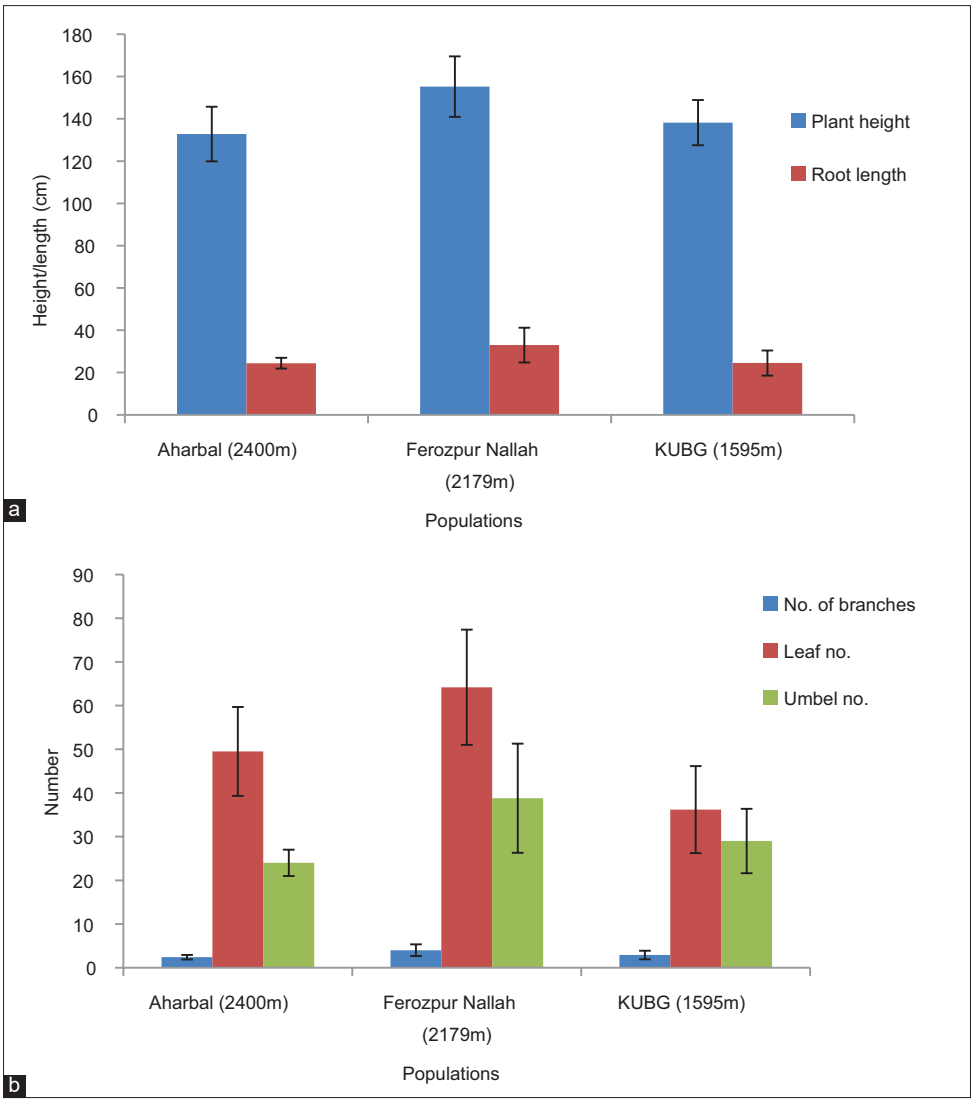

Figure 2: (a and b) Comparison of different phenotypic traits of *Aralia cachemirica* across different study sites

studied populations. The leaf number was highest in the Ferozpur Nallah (2250 m) population (64.2 ± 13.18) followed by the plants growing at Aharbal (2400 m) and KUBG (1595 m) populations which show the number of leaves as 49.5 ± 10.17 and 36.2 ± 9.97, respectively.

Number of umbels

The variability in number of umbels among and within populations was studied in fully mature flowering plants and the results depict significant differences ($P \leq 0.05$). Among the different studied populations, the highest number of umbels was

recorded in Ferozpur Nallah population and lowest in Aharbal population.

Resource allocation

The study of resource allocation to different plant parts in *Aralia cachemirica* was carried out in different populations Ferozpur Nallah, Aharbal and KUBG with varying habitats. The present study revealed that partitioning of resources is not uniform among different parts of a plant, much resources were allocated towards the root (16.62 ± 3.85 g to 21.43 ± 2.34 g) dry weight followed by the shoot (14.37 ± 3.73 g to 18.56 ± 2.86 g) dry weight then by leaves (8.37 ± 1.68 g to 13.65 ± 1.92 g) dry weight and least amount of resources were allocated towards inflorescence (2.31 ± 0.69 g to 6.65 ± 0.95 g) dry weight among the studied populations [Table 4].

The percentage resource allocation also varied significantly among different studied populations. In all the studied populations (Aharbal, Drang, and KUBG), the percentage resource allocation was highest toward root followed by shoot, leaves, and inflorescence, respectively [Table 3 and Figure 3].

The present studies reveal that the plants growing at Ferozpur Nallah population are vigorous having maximum dry weight per plant as compared to

Table 4: Percentage resource allocation to various plant parts in *Aralia cachemirica* across different populations

Plant part (dry wt. [g])	Population		
	Aharbal (2400 m)	Ferozpur Nallah (2179 m)	Kashmir University Botanical Garden (1595 m)
Leaves	8.37±1.68*	13.65±1.92	10.45±1.37
Shoot	14.37±3.73	18.56±2.86	16.29±2.76
Root	16.62±3.85	21.43±2.34	18.32±2.87
Inflorescence	2.31±0.69	6.65±0.95	4.54±0.87
Total resource budget per plant (g)	41.67	60.29	49.6
Above ground total dry wt. (g)	25.05	38.86	31.28
% age resource allocation toward leaves	20.08	22.64	21.06
% age resource allocation toward shoot	34.48	30.78	32.84
% age resource allocation toward root	39.88	35.54	36.93
% age resource allocation toward inflorescence	5.54	11.03	9.15

*Mean±standard deviation

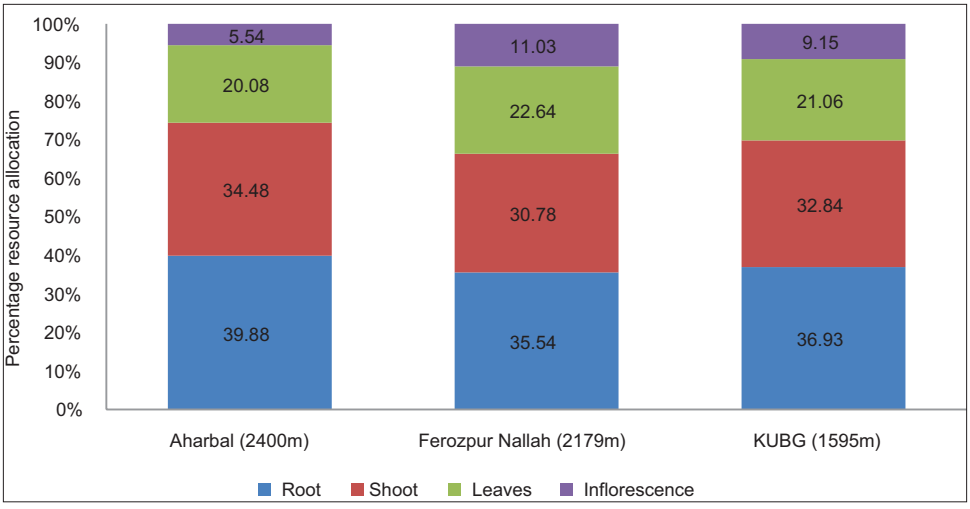

Figure 3: Comparison of percentage resource allocation toward different parts of *Aralia cachemirica* across different populations

the plants growing at rest of the populations. This may be due to the fact that the habitat of Ferozpur Nallah population is much shady, with enough moisture content and grows under shrubbery forests [Table 4].

CONCLUSION

Our results depict a wide range of suitable habitats for the growth of *A. cachemirica* Decne. The species is distributed in the mountain ranges of Kashmir Himalaya ranging in altitude from 2100 to 4000 m asl and grows in the open grassy, moist open field, and moist rocky slopes with great variability in its morphological traits under different environmental conditions. The species exhibit significant phenotypic variability across different populations with varying habitat conditions. The biomass allocations in the species reveal that partitioning of the resources among the different parts of the plant is not even.

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