ISSN 2581 – 4303

Available Online at www.ijpba.info
International Journal of Pharmaceutical & Biological Archives 2019; 10(2):104-110

RESEARCH ARTICLE

Variation of Growth Dynamics and Resource Allocation Patterns of *Dictamnus albus*

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Received: 20 January 2019; Revised: 25 March 2019; Accepted: 10 April 2019

ABSTRACT

Dictamnus albus is a medicinally important plant distributed throughout South and central Europe, temperate Asia, and Himalayas. The present study was devised for the 1st time to understand the variation in growth characteristics and changes in allocation patterns in relation to altitude and habitats of Kashmir Himalaya. The present investigation revealed extensive variability in morphological parameters both within and across the individuals of different populations. Our findings clearly displayed significant divergence among sites which reveal a definite impact of altitude and habitat on morphological and reproductive features of the species under study. Our results are very useful to introduce the species into cultivation and developing strategies for conservation.

Keywords: Altitude, *Dictamnus albus*, habitat, phenotypic variability, resource allocation

INTRODUCTION

Plant life is challenged by myriads of environmental stresses and in response to these stresses, plants alter various characters, namely morphological, biochemical, and anatomical, to adapt in different environmental conditions prevailing across the altitudinal range. The variation in morphological characteristics of plants with changing altitude and habitat indicates plastic and evolutionary changes in these traits which would influence population performance across attitudinally or climatically variable conditions.[1] The reduction in overall plant size is the most conspicuous structural alteration in plants observed along elevational gradients.[2] Phenotypic variability across the geographical range of a species may be a consequence of hereditary differences and the influence of environmental factors. Rainfall levels, environmental temperature, and availability of nutrients can drastically influence the geographic structure of genetic and phenotypic variation between plant populations.[3]

Genus *Dictamnus* is distributed in the temperate regions of the Old World, from N. W. Himalayas east to Japan and westward to C. Asia and S. C. Europe.[4-6] In India, it is represented by only one species *Dictamnus albus*.[4] *D. albus*, perennial herb, commonly known as gas plant or burning bush, is distributed throughout South and central Europe, temperate Asia, and temperate Himalayas.[4] In temperate Himalayas, it often grows on rocky habitats between 2775m and 3000 m.[7] The present study was devised for the 1st time to understand the variation in growth characteristics and changes in allocation patterns in relation to altitude and habitats of Kashmir Himalaya. This study aimed at developing strategies for cultivation and sustainable use of wild populations and to find the environments that are most favorable and productive for the growth of *D. albus*.

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MATERIALS AND METHODOLOGY

Morphological characterization

The study was carried out by selecting mature flowering individuals randomly from each population to observe the various morphological parameters of the species. The populations were analyzed for morphological traits such as plant height, leaf number, leaf dimensions, and floral density and dimensions.

Resource allocation

Mature flowering individuals were harvested from different natural populations for the study of resource allocation in different parts of the plant. The plants were fragmented into component parts to determine dry weight after oven drying for 48 h at 80°C, using electric balance.[8] The dry weight of these plant parts was compared with each other to estimate the allocation of resources in these parts.

RESULTS

The extensive exploration of the Kashmir Himalayan region depicts a wide range of suitable habitats for the growth of *D. albus* prefers both open and partial shady slopes (rocky) ranging in altitude from 1800m to 3000 m asl. The detailed habitat characteristics of both the species are presented in a tabulated form [Table 1]. *D. albu*s grows in Hiller, Sonamarg, Sarbal, Ferozepora, and Gurais areas of J and K state. Of these, three sites of varying habitats and altitudes, namely Hiller, Ferozepora, and Sonamarg, were selected. The salient features of the selected sites are summarized in Table 1. The sites (populations) were selected basis on the basis of accessibility, habitat structure, and plant density. The specimens collected were identified and deposited in Kashmir University Herbarium (KASH) under voucher number 2688-KASH.

Phenotypic variability

D. albus is a perennial herb [Figure 1]. The general morphology of *D. albus* is depicted in Table 2. The phenotypic variability [Figure 2] of *D. albus* exhibits a significant variation within and across populations ($P \leq 0.05$) [Table 3].

Plant height

The present study depicts that plant height ranges from 114.1±15.96 cm to 137.7±15.18 cm. The study revealed that Sonamarg population shows shorter

Figure 1: General morphology of *Dictamnus albus*

Table 1: Salient features of the selected sites of *Dictamnus albus*

Character	Population		
	Hiller	Ferozepora	Sonamarg
Altitude (m)	1863	2183	2814
Latitude and longitude	N33°32'687" E075°12'732"	N34°02'914" E074°25'263"	N34°30'238" E075°29'655"
Climatic zone	Sub-alpine	Sub-alpine	Sub-alpine
Habitat	Partial shady and rocky slope	Shady and rocky slope	Open plain and rocky slope

Table 2: General morphology of *Dictamnus albus*

Habit	Perennial, herb
Root	Taproot, thick, branched
Stem	Erect, herbaceous, aerial, densely branched, hollow, glabrous, lower part green, upper part reddish dotted green
Leaf	Sessile, opposite, pubescent, dotted, elliptic to ovate to lanceolate, serrulate, acute to acuminate
Inflorescence	Flowers light pink; lanceolate bracts; densely glandular long pedicel
Calyx	Petalloids 5, star-shaped, oblong, glandular
Corolla	Petals 5, white striped pink, clawed, glandular in the middle
Androecium	Stamens 10; filaments whitish pink, densely hairy glandular, curved, exserted
Gynoecium	Ovary hypogynous, 5 locular, glandular; style curved, glandular; stigma punctuate
Fruit	Capsule, densely glandular, star-shaped, 5 lobed, each lobe with 2–3 seeded
Seed	Black, subglobose

Table 3: Phenotypic variability in morphological traits of *Dictamnus albus* across different populations in Kashmir Himalaya

Phenotypic traits	Populations			F	P
	Hiller	Ferozepora	Sonamarg		
Plant height (cm)	137.7 ± 15.18*	121.50 ± 9.54	114.1 ± 15.96	7.583	0.002
Root length (cm)	19.8 ± 2.85	21.8 ± 3.64	24.6 ± 2.71	6.046	0.007
Number of leaves	569.2 ± 77.12	504.60 ± 75.75	471.1 ± 69.30	4.524	0.020
Leaf length (cm)	3.27 ± 0.48	2.76 ± 0.27	2.58 ± 0.25	11.011	0.000
Leaf breadth (cm)	0.99 ± 0.35	0.89 ± 0.17	0.64 ± 0.23	4.663	0.018
Number of flowers	33.6 ± 2.98	30.7 ± 5.37	24.3 ± 5.27	10.352	0.000
Length of filament (cm)	3.42 ± 0.07	3.37 ± 0.08	3.32 ± 0.05	4.103	0.028
Length of anther (cm)	0.30 ± 0.00	0.26 ± 0.05	0.20 ± 0.00	28.500	0.000

*Standard deviation

Table 4: Percent resource allocation to various plant parts in *Dictamnus albus* across different populations in Kashmir Himalaya

Plant parts dry wt.	Population			F	P
	Hiller	Ferozepora	Sonamarg		
Root (g)	20.550 ± 7.527	25.458 ± 4.666	31.123 ± 10.645	4.104	0.023
Shoot (g)	10.928 ± 1.954	8.851 ± 1.608	7.665 ± 1.324	10.028	0.001
Leaves (g)	25.380 ± 7.135	22.384 ± 5.543	14.192 ± 7.113	7.609	0.002
Inflorescence (g)	3.667 ± 0.443	2.993 ± 0.468	2.575 ± 0.485	13.987	0.000
Total resource budget per plant (g)	60.525	59.686	55.555		
Above ground total dry wt. (g)	39.975	34.228	24.432		
% age resource allocation toward root	33.95	42.65	56.02		
% age resource allocation toward shoot	18.05	14.82	13.79		
% age resource allocation toward leaves	41.93	37.50	25.54		
% age resource allocation toward inflorescence	6.05	5.01	4.63		

plant height as compared to other populations. The results depict that plant height decreases with the increase in altitude and vary significantly ($P \leq 0.05$) across different populations.

Root length

A negative correlation was observed between root length and plant height while as a direct relation with the altitude and habitat characteristics was recorded in *D. albus*. Since *D. albus* was found to be predominantly present in the rocky habitats, it was observed that more steep the habitat more was the root length. The root length ranges from 19.8±2.85 to 24.6±2.71 cm.

Number of leaves

The present study reveals that the average number of leaves ranges between 471.1±69.30 cm and 569.2±77.12 cm for *D. albus* in all the studied natural populations. The highest number of leaves was recorded in Hiller population followed by Ferozepora and Sonamarg population. The leaf number varied significantly ($P \leq 0.05$) across populations and also a highly positive correlated relationship was observed between the plant height and leaf number.

Foliar dimensions

The plants display significant differences ($P \leq 0.05$) in dimensions of leaves across populations. Leaf dimensions decrease with increase in altitude. The higher altitude populations, i.e. Sonamarg possess least leaf dimensions (2.58±0.25 cm long and 0.64±0.23 cm broad).

Floral characteristics

The plants exhibit significant differences ($P \leq 0.05$) in flower number across populations and decrease with increasing altitude. As far as *D. albus* is concerned, the number of flowers ranges from 24.3±5.27 to 33.6±2.98. The highest number was registered in Hiller population. Furthermore, length of filament and length of anther follow the same trend and vary significantly across populations.

Resource allocation

The present study reveals that partitioning of resources is not uniform among different parts of the species studied [Figure 3]. The selected species showed significant differences in the resource allocation patterns across different populations [Table 4]. A remarkable difference was observed in the total aboveground dry weight biomass and dry weight of different vegetative structures among the plants of studied populations, inhabiting varying habitats, and altitudes. Maximum resource allocation was registered in root (20.550±7.527–31.123±10.645 g), followed by leaves (14.192±7.113 to 25.380±7.135 g), stem (7.665±1.324 to 10.928±1.954 g), and least in case of inflorescence (2.575±0.485 to 3.667±0.443 g).. The total resource budget per plant of low-altitude and high-altitude population varied to a great extent, wherein the values were maximum in low-altitude population. It is observed that with the increase in altitude percentage of resources allocated toward shoot, leaves, and inflorescence decreased while as a reverse trend is observed in case of root.

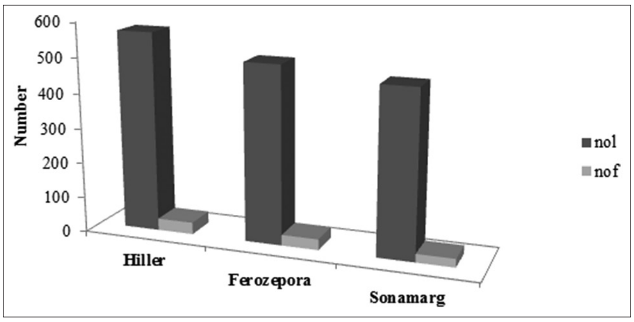

Figure 2: Comparison of morphological characters of *Dictamnuc albus* across different populations (where, ph=plant height; rl= root length; ll= leaf length; l leaf breadth; loa= length of anther; lo length of anther; nol= number of leaves; nof= number of flowers)

DISCUSSION

Phenotypic variability

A change in altitude and habitat can bring myriads of challenges in plant life among which most important is environmental stress such as cold and arid climate, scanty rainfall, high wind velocity, snow storms, blizzards, and high ultraviolet radiations.[9] As plants are immobile, so in order to survive within their natural habitats, these cope up with a variety of stresses by altering their morphological attributes.[10] These variations in plants clearly indicate plastic and evolutionary changes in these characters which would impact population performance across altitudinal or climatically variable conditions.[1] These morphological variations across altitude not only give explicit botanical identity to a species but can also uncover fascinating highlights helpful in understanding the scope of morphological variations present across different ecological zones.

During the present study, variability in phenotypic traits of *D. albus* was analyzed for different populations. The species in response to highly specific ecological environmental conditions developed a spectacular diversity in morphological characters, namely plant height, number of leaves per plant, leaf dimensions, and floral density. This diversity provides a strong edifice at which an ambitious plan for domestication and genetic improvement for commercial exploitation can

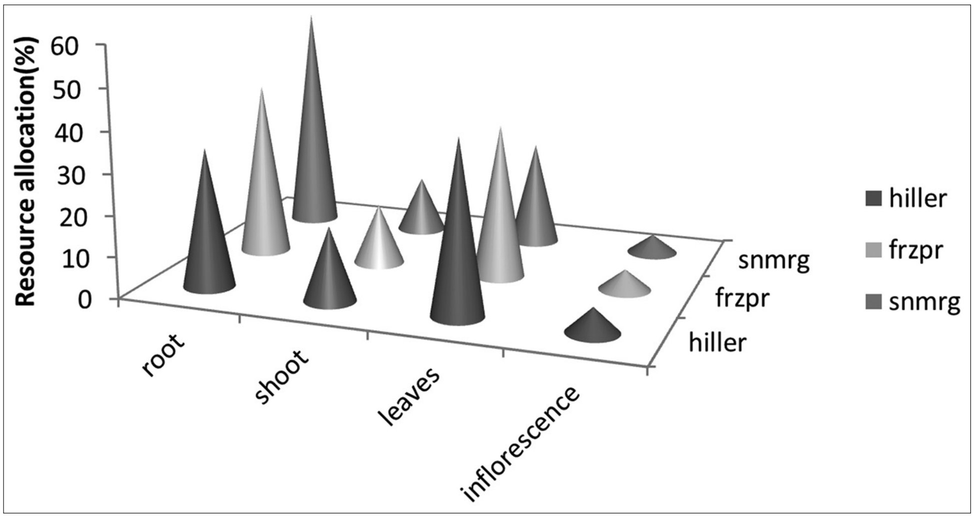

Figure 3: Comparison of resource allocation patterns to various plant parts in *Dictamnus albus* across different populations

be built. The present investigations revealed extensive variability in morphological parameters both within and across the individuals of different populations. The details are as under.

Plant height

The evaluation of plant height is a highly plastic trait in the species under discussion and varies from plant to plant and population to population. The study revealed that plants growing at Hiller show maximum variability in this trait as compared to the other studied populations. A significant decrease in plant height is observed with increase in altitude. This can be ascribed to the severe conditions and the shorter growing season prevalent at higher altitudes. The variations in plant height of any species is by and large supposed to be beneficial for long term survival as it influences most aspects of an individual's ecology.

Our results are in conformity with that of Korner,[11] Willis and Hulme,[12] Baret *et al*.,[13] Shabir *et al*.,[14] and Yaqoob and Nawchoo,[15] who registered a decrease in plant size as an adaptation to increasing altitude. Korner *et al*.[16] inferred that the decrease in overall plant size is the most prominent structural change in plants observed along elevational gradients. At higher altitudes, harsh climatic conditions have a negative impact on the overall growth of a plant;[17,18] hence, low-altitude plants show better phenotypic response as compared to higher altitude plants. The reduction in plant height with the increase in altitude prevents the plants from devastating effects brought about by the prevalence of high-speed winds.[19] At higher elevations, plants amplify supercooling capacity by diminishing cell size and intercellular spaces[20] which eventually result in the overall decreased plant size.

Leaf number and dimensions

The species exhibits significant variability in leaf dimensions and leaf number per plant in different populations along the altitudinal gradient. Among the studied populations, maximum leaf number per plant and highest leaf dimensions, i.e. length and breadth are recorded in plants growing at Hiller as compared to plants growing at higher altitudes in rest of the selected populations. Since plants need to rapidly complete their growing cycle when their growth period is short, it is expected that leaf characters may contrast between the lowland and upland plants as reduction in size is a vital approach employed by plants at high altitude to resist decrease in temperature and reduced nutrient availability. Our results are in accordance with the observations of Woodward,[21] Kao and Chang,[22] Bonan,[23] Bresson *et al*.,[24] and Yaqoob and Nawchoo[15] who reported a decrease in length and breadth of leaves with the rise in altitude. Hovendon[25] predicted that leaf morphology is under strong genetic control; however, Hovendon and Vander Schoor[26] reported that the trends of decreasing leaf length were environmentally controlled rather than genetic.

The present study also depicts that plants growing at high-altitude sites bear thicker leaves as compared to those growing at low altitudes. Korner and Larcher[27] also reported thicker leaves in some high-altitude plants which enable them to have more nitrogen per unit area of leaves as the nitrogen combines with chlorophyll and uses the daylight as the vitality source to carry out basic plant functions including nutrient uptake. Taguchi and Wada[28] opined that increase in leaf thickness at higher altitudes occurs as a response to low temperatures to protect the mesophyll.

Floral density

The plants display significant differences ($P \leq 0.05$) regarding the number of flowers per plant along the altitudinal gradient with the highest number of flowers at the lowest altitude (Hiller). Plants may develop to lessen reproductive costs at energy-limited sites where resource investment in vegetative organs might be crucial for survival.[29,30] The results concur with Johnson and Cook[31] who also reported that plants growing at low altitude produce greater number of flowers as compared to high-altitude plants. This is further in agreement with the fact that sexual reproduction is often small in alpine regions in comparison with the same or closely related species growing in warmer areas.[32-34]

It can be suggested from the present study that the plants growing at low altitudes are comparatively much more diverse and vigorous in respect of the various morphological features. Expectedly, the differences in the altitudinal range are associated with changes in the soil architecture and the microclimate which ultimately affects the overall growth and development of plants.

It is proposed that the heterogeneity of the environmental conditions is the main source of phenotypic variation of *D. albus*. Our observation revealed a wide range of suitable habitats for its growth and development.

Resource Allocation

In presently investigated plant species more resources are allocated towards the root followed by leaves, shoot and inflorescence. Furthermore, with the increase in altitude, percentage of resource allocation towards root increases while as an opposite trend was observed in case of shoot, leaves and inflorescence. The possible reason could be that the high altitudes plants tend to allocate more resources to belowground parts which enables the plant to make the best use of short growing season for their survival. This in accordance Korner [35], who opined that plants growing at high altitude put more investment to enlarge root and allocate more assimilates towards belowground parts to improve restricted nutrient absorption in harsh alpine environments and increases root-zone temperature so as to survive in a windy, cold and barren alpine soils.

CONCLUSIONS

With increased altitude, a significant decrease is found in the phenotypic characteristics of *D. albus*; thus, it seems that these sites endure a larger environmental stress. Increasing altitude resulted in a decrease in the allocation of biomass to reproductive structures in the form of decreasing dry weight. However, future studies should explore the phenotypic variability in more detail in plants growing at contrasting environments.

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