Proceedings of the Pakistan Academy of Sciences: Part B
Life and Environmental Sciences 59(2): 35-47 (2022)

ISSN (Print): 2518-4261; ISSN (Online): 2518-427X
http://doi.org/10.53560/PPASB(59-2)707

Pakistan Academy of Sciences

Research Article

Phenotypic Variability and Resource Allocation in Kashmir Sage (*Phlomis cashmeriana* Royle ex Benth.) in relation to Different Habitats and Altitudes

Roof Ul Qadir[1*], Hanan Javid[1], Gowhar A. Shapoo[2], Bilal A. Wani[1], Junaid A. Magray[1], Irshad A. Nawchoo[1], and Shabana Gulzar[3]

[1]Plant Reproductive Biology, Genetic Diversity and Phytochemistry Research Laboratory, Department of Botany, University of Kashmir, Srinagar, Jammu & Kashmir, India
[2]Plant Tissue culture and Research Laboratory, Department of Botany, University of Kashmir, Srinagar, Jammu & Kashmir, India
[3]Government College for Women, Maulana Azad Road, Cluster University, Srinagar, Jammu & Kashmir, India

Abstract: *Phlomis cashmeriana* Royle ex Benth. commonly known as Kashmir sage is a rare and important medicinal plant growing in Kashmir Himalaya. The current study is the first of its kind, carried out to find the impingement on growth dynamics of the plant under study along various altitudinal inclines and habitats. Extensive field surveys were conducted during the years 2020-2021 to assess the distribution and phenotypic attributes of *Phlomis cashmeriana*. Three natural sites viz, Jawahar tunnel, Hillar naar, Daksum and one control population at KUBG were selected for the present work. Morphological characteristics of species were noticed to be varying extensively under different scopes of environment. Plants thriving at lower altitudes (KUBG) were found to be growing vigorously and taller. However, the opposite scenario was observed in plants growing at higher altitudes (Jawahar tunnel). KUBG and Daksum were reasonably found to be better habitats for the growth of *Phlomis cashmeriana* as revealed by principal component analysis (PCA). Majority of resources were attributed towards the growth of rhizomes followed by leaf, stem, and inflorescences respectively. Variation in reproductive success was also observed along different altitudes ranging from 63.94 % to 53.40 %. The total resource budget per plant also varied among different populations with a maximum in populations growing at low altitude, KUBG (23.73±6.63) and least in populations growing at high altitude J. tunnel (12.94±7.67). We hypothesize that a heterogeneous environment is the primary cause of phenotypic variability across different altitudes, however, the role of other environmental factors should also be taken into consideration.

Keywords: Phenotypic Variability, *Phlomis cashmeriana*, Resource Allocation, Reproductive Success

1. INTRODUCTION

Sessile nature of plants has made it obligatory for them to make fine adjustments genetically or morphologically to varying environmental conditions through phenotypic plasticity within a geographical area [1]. In the present study, we evaluated the information on plant plasticity under changing environmental conditions within a geographical area along different altitudinal gradients. Despite receiving huge attention from ecologists as well as evolutionary biologists the research on the study of phenotypic plasticity and its implication in the changing environment is largely obscure [2]. Quantification of changes involved in the physiognomy of plants on different steep environmental gradients like altitude is rarely being done besides being evident. These changes have resulted in the distortion of the pattern involved in the assimilate investments and thereby affecting the leaf microclimate to which they are exposed [3]. Considering higher altitudes, dramatic variations in abiotic factors take place over small distances, contributing to key

Received: March 2022; Accepted: June 2022
*Corresponding Author: Roof Ul Qadir <rouf0629@gmail.com>

alterations in selection pressures acting on different plant traits [4]. Among different plant species, the response to these selection pressures is significantly varied. So far altitudinal gradients are reckoned they provide profuse experimental prospects for looking into the functional traits accompanying these plants to withstand the implication of the changing environmental conditions [5]. In stressful conditions, for perseverance plants allow morphological and physiological adjustments at higher altitudes such features include dwarfness, habit compaction, small and densely pubescent leaves. In addition to this, physiology of the leaf also changes with altitude [6]. Population divergence is tempted by selection pressure differences forced by different neutral evolutionary processes and ecological environments or both. The change in the phenotypic characters plays an important role in the reproductive behavior of specific plant species [7]. *Phlomis cashmeriana* (Lamiaceae) commonly known as Kashmir sage belongs to the family Lamiaceae and is often found growing in wastelands or on open slopes and blooms in summer [8]. *P. cashmeriana* is a perennial herb native to Afghanistan, Pakistan, Tadzhikistan and the west Himalaya [9]. It has several stems (40-80 cm), simple or branched with a sturdy woody rootstock. Leaves are oblong-lanceolate, leathery, covered with densely whitish trichomes, Inflorescence verticillasters, flowers labiates, and corolla lobes pale purple. Species of this genus have been used for many decades in folk medicine as tonics, wound healers, and stimulants [10]. Some biological and pharmacological activities such as antidiabetic [11], antiulcerogenic, antimicrobial [12], anti-inflammatory, antinociceptive, antifibriel, and immuno-suppressive [13] have also been documented.

2. MATERIALS AND METHODS

2.1 Study Area

The current study was carried out during 2020-2021 across Kashmir Himalaya, India. Extensive and robust field surveys were conducted to assess the distribution and phenotypic attributes of *Phlomis cashmeriana*. It was found growing across diverse habitats, altitudes and areas of Kashmir including (Hillar Naar, Sehpora Dooru Anantnag, Jawahar tunnel, Daksum vailoo, Koot Larnoo, Shatroo, Soaf Shali Kokernag, Adigam Kokernag, Deral Gam Kokernag, Panzgam kokernag, Dandipora Kokernag). Three natural sites viz, Jawahar tunnel, Hillar naar, Daksum were selected based on availability, accessibility and abundance of the population to carry out the present work Besides, one established population at Kashmir University Botanical Garden (KUBG) was taken as control (Figure 1). The characteristic features of selected sites and geo-coordinates (using Garmin GPS etrex 10) were recorded (Table 1). Herbarium specimens from selected sites were submitted in KASH Herbarium under voucher specimens No. 2941, 2942 & 2943). The distribution map and map of selected sites of *P. cashmeriana* is shown in Figure 2 and 3 respectively.

2.2 Morphological Characterization

The research was carried out in three natural habitats and one controlled site (*ex situ* and *in situ*). images were shot with MI note 8 pro camera having a resolution of 64 mega pixels. To observe different morphological features of the species and to record the variability in floral and vegetative properties, twenty full flowering individuals were randomly selected and tagged from each group. Most of

Table 1. Salient features and geo-coordinates of selected study sites for the collection of *P. cashmeriana.*

Study site	Altitude (m-asl)	Latitude and longitude	Climatic zone	Habitat
Jawahar tunnel	2580	33°6'N,75°2' E	Temperate	Sunny open Rocky slope
Hillar Naar	2200	33°5'N,75°18' E	Temperate	Sunny open Rocky slope
Daksum	2000	33°5'N,75°3' E	Temperate	Sunny with Partial shade
KUBG	1595	34°5'N ,74°48' E	Temperate	Moist open field

Fig. 1. Different study sites of *P. cashmeriana*: A) Daksum, B) Hillar Naar, C) KUBG, D) Jawahar tunnel

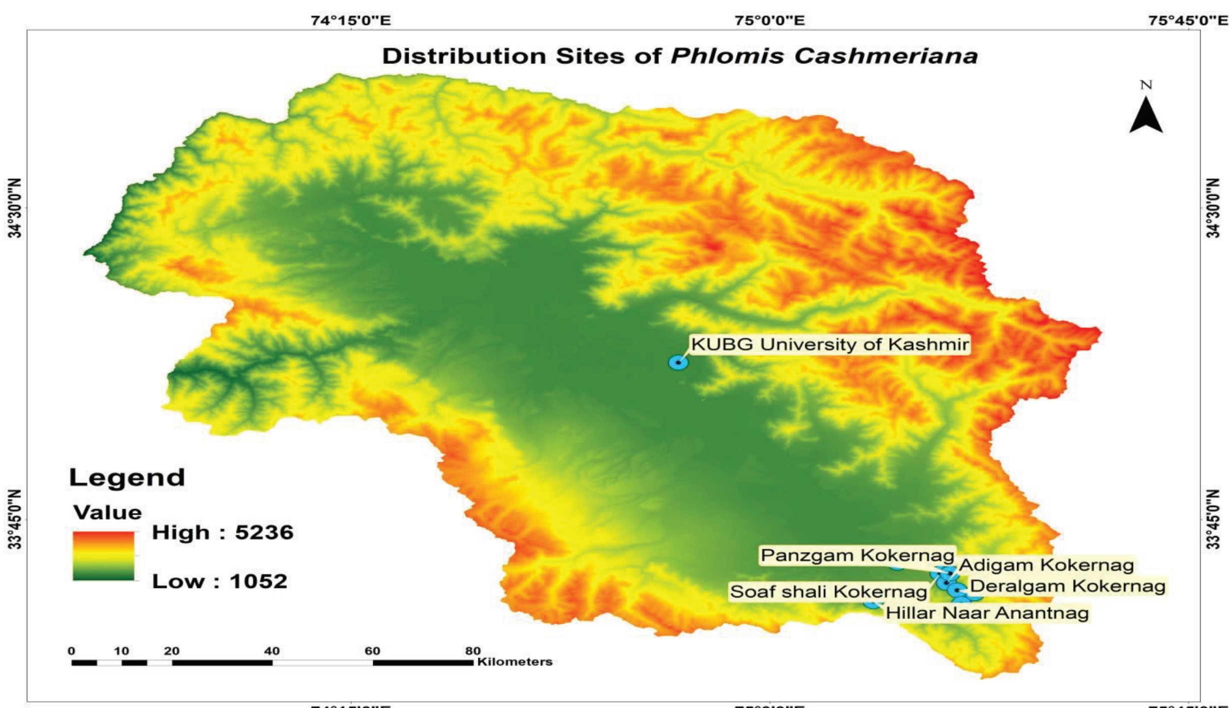

Fig. 2. Distribution map (Asterdem) of *P. cashmeriana*

these characteristics were recorded after the plants were measured *in situ*. All populations were at the flowering stage at the time of collection. To locate the places of improved growth performance for this species, we performed linear regression analysis to establish the link between several morphological features across different altitudes. The morphological features were analyzed using principal component analysis (PCA) with habitat dynamics. It was also used to determine the degree of coherence between several vegetative and reproductive indicators.

2.3 Resource Allocation

Resource allocation pattern in different plant parts was determined by harvesting twenty matures plants from each selected study site. The harvested plant material was partitioned into different parts (Rhizome, Stem, Leaf, and Inflorescence). Fresh weight of every individual plant part from each plant was measured using an electronic weighing balance. After measuring the fresh weight of every plant sample, the plant material was oven-dried using a hot air oven (72 hours at 80 °C) then the dry weight of the plant material was determined following Kawano and Masuda with slight modification [14]. Reproductive effort (RE) was calculated from the estimates of dry weight or biomass allocated to reproductive and vegetative structures following [15,16]

$$\text{Reproductive effort} = \frac{\text{Dry weight of the inflorescence}}{\text{Total dry weight of the above-ground tissues}} \times 100$$

2.4 Reproductive Success

Flower heads were collected from each selected population during the peak flowering season. The number of flowers per head was counted, and the dimension of floral parts includes sepal breadth and length; upper lip (petal) length and breadth; stamen and carpel length and breadth were measured to examine the proportion of variation within and among plants as well as among populations. We determined the percentage seed set of each plant expressed as the ratio of total no. seeds produced to the total no of ovules borne by a plant. Developed seeds and undeveloped seeds were easily distinguished because the developed ones were plump and hard while undeveloped ones were hollow and soft [17].

2.5 Data Analysis

SPSS software (version 20.0) was used to carry out ANOVA to check the difference between different morphological attributes. Tukey's multiple comparisons of means were also used to compare different populations and variations within the individual as well as average means, means were considered to be significant at ≤ 0.05. To carry out linear regression analysis Origin 2021 was used to find out the correlation between different morphological characters along different altitudes. Analysis between different morphological characters with respect to different habitats and to understand the coherence between different vegetative and reproductive parameters principal component analysis (PCA) was also carried out.

3. RESULTS

3.1 Morphological Characterization

During the present study it was found that *P. cashmeriana* prefers open rocky slopes (Table 1). *P. cashmeriana* is an erect, densely woolly perennial herb with a sturdy woody rootstock, stems several, 40-80cm herbaceous, simple or branched, with a white indumentum of readily rubbed off dendroid-stellate hairs. Leaves are oblong-lanceolate, densely white tomentose beneath with dendroid-stellate hairs, above green with scattered irregularly branched dendroid hairs (Figure 4).

The present study revealed a clear-cut difference in morphological traits along different altitudes and habitats (Table 2). It was found that the plant height is maximum at low altitude, KUBG (58.71±13.53 cm) while minimum height was seen in plants growing at Jawahar tunnel (40.6±6.09 cm). Root length and breadth were maximum in plants grown at KUBG (27.5±6.57 & 1.97±0.38 cm) while as a minimum at Jawahar tunnel (12.02±3.02 & 1.53±0.32 cm). Much difference wasn't seen in the number of leaves; maximum leaf no was seen in plants growing at Daksum (25.7±6.68 cm) while a minimum number of leaves were present in plants growing at J. tunnel (18.9±5.93 cm). Maximum variation was seen in basal leaf length and basal petiole length, the plants grown at low altitude

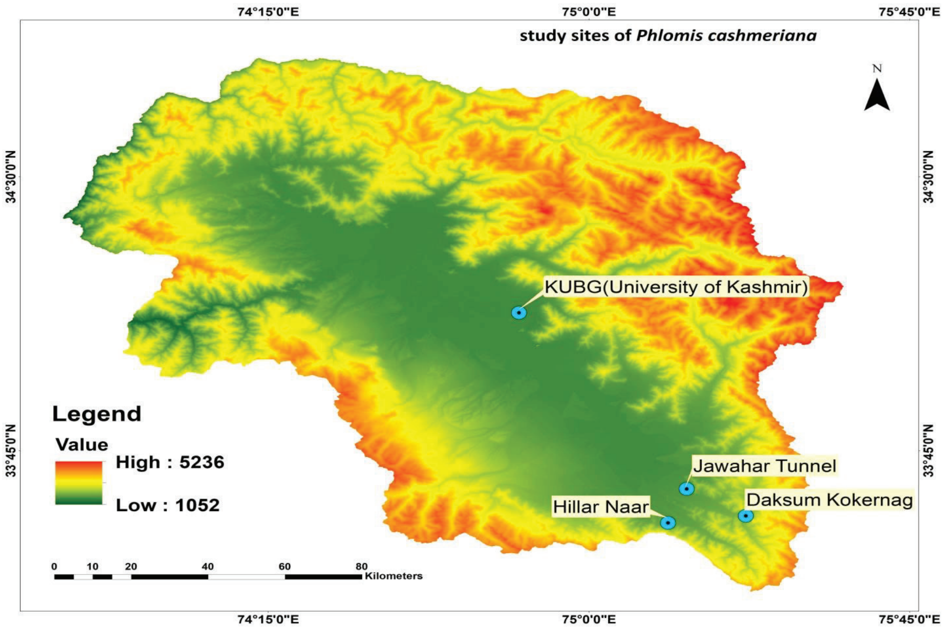

Fig. 3. Location map (Asterdem) of study sites

Fig. 4. (A-F). Morphological features of *P. cashmeriana* (A) Habitat, (B) Rhizome, (C) leaf with petiole abaxial and adaxial view, (D) Inflorescence, (E) Flower, (F) Seeds

Table 2. Variation in different morphological traits (Mean±SD) of *P. cashmeriana* across different study sites (2020-2021)

Plant characteristics	Jawahar tunnel (cm)	Hillar Naar (cm)	Daksum (cm)	KUBG (cm)	*F* value
Plant height	40.6±6.09^{c*}	50.8±3.49^{ab}	53.62±12.80^{ab}	58.71±13.53^{a}	8.027
Rhizome length	12.02±3.02^{b}	16.15±8.64^{a}	19.02±1.76^{b}	27.5±6.57^{a}	9.43
Rhizome breadth	1.53±0.32^{a}	1.67±0.69^{a}	1.8±0.76^{a}	1.97±0.38^{a}	0.651
No. of leaves	18.9±5.93^{a}	19.5±9.00^{a}	25.7±6.68a	23.43±12.50^{a}	1.847
Basal leaf length	9.953±2.65^{b}	11.58±1.05^{ab}	12.62±2.80^{a}	17.22±4.05^{a}	7.789
Basal leaf breadth	3.31±0.40^{b}	3.84±0.50^{a}	4.03±0.48^{a}	5.51±0.97^{a}	6.534
Basal Petiole length	7.48±1.55^{b}	8.43±2.70^{a}	9.16±2.43^{a}	13.78±1.82^{a}	9.231
Apical petiole Length	0.87±0.247^{c}	1.04±0.20^{bc}	1.38±0.36^{ab}	1.56±0.17^{a}	12.295
Apical leaf length	5.75±0.58^{c}	6.78±1.4^{b}	7.60±1.10^{ab}	10.36±0.97^{a}	15.934
Apical leaf breadth	1.87±0.40^{c}	2.18±0.39^{b}	2.47±0.20^{ab}	3.05±0.46^{a}	15.271
Inflorescence length	7.91±3.99^{ab}	6.68±5.54^{a}	13±7.35^{a}	8.42±5.40^{a}	2.820

* Means labeled with the different small letters indicate that they significantly differ from each other among different populations

KUBG show almost twice the length (17.22±4.05 and 13.78±1.82 cm) as compared to plants grown at higher altitude Jawahar tunnel (9.953±2.65 and 7.48±1.55 cm). Maximum number of flowers and flower heads per plant at KUBG was maximum (18.28±3.81 & 4±1.67 cm) respectively while the minimum number was seen in plants growing at Jawahar tunnel (16.6±4.47 & 3.3±1.95 cm) (Table 3). Inflorescence length was maximum in individuals growing at KUBG (8.42±5.40 cm) while a minimum in plants growing at Jawahar tunnel (7.91±3.99 cm). Positive correlation was observed (Figure 5 & 6) between plant height and rhizome breadth (r^2 = 0.01187), plant height and rhizome length (r^2 = 0.10595), plant height and basal leaf length (r^2 =0.11591), plant height and basal leaf breadth (r^2 =0.23675), plant height and apical leaf length (r^2 = 0.22617), plant height and apical leaf breadth (r^2 = 0.43063), plant height and basal petiole length (r^2 = 0.07359), plant height and apical petiole length (r^2 = 0.09965), plant height and number of leaves (r^2 = 0.06787) , plant height and inflorescence length (r^2 = 0.08214), plant height and flower no. (r^2 = 0.00376)

Principal component analysis (PCA) of all morphological characters across the study sites reveals that the major differences between populations were due to size characteristics (axis 1; 91 % of total variance) and separated KUBG and Daksum (with high character values) from the other populations (Figure 7). PCA also revealed that the high altitude populations are non-favorable to most of the vegetative and reproductive traits demonstrating better growth conditions at lower altitudes. Apical leaf length, Apical leaf breadth, Rhizome length, Basal leaf length, Basal leaf breadth, and Basal petiole length were found to be favoring the KUBG population. Leaf number, Apical petiole length, Rhizome breadth, and Plant height were found to be favoring the Daksum population. Thus, the habitat of KUBG and Daksum proved relatively better for the growth of *P. cashmeriana.*

3.2 Resource Allocation

Resource portioning in various parts of plants varies differently as shown in Table 4. The population under study shows great variation in the overall dry weight of the above-ground and dry weight of different vegetative structures of plants growing

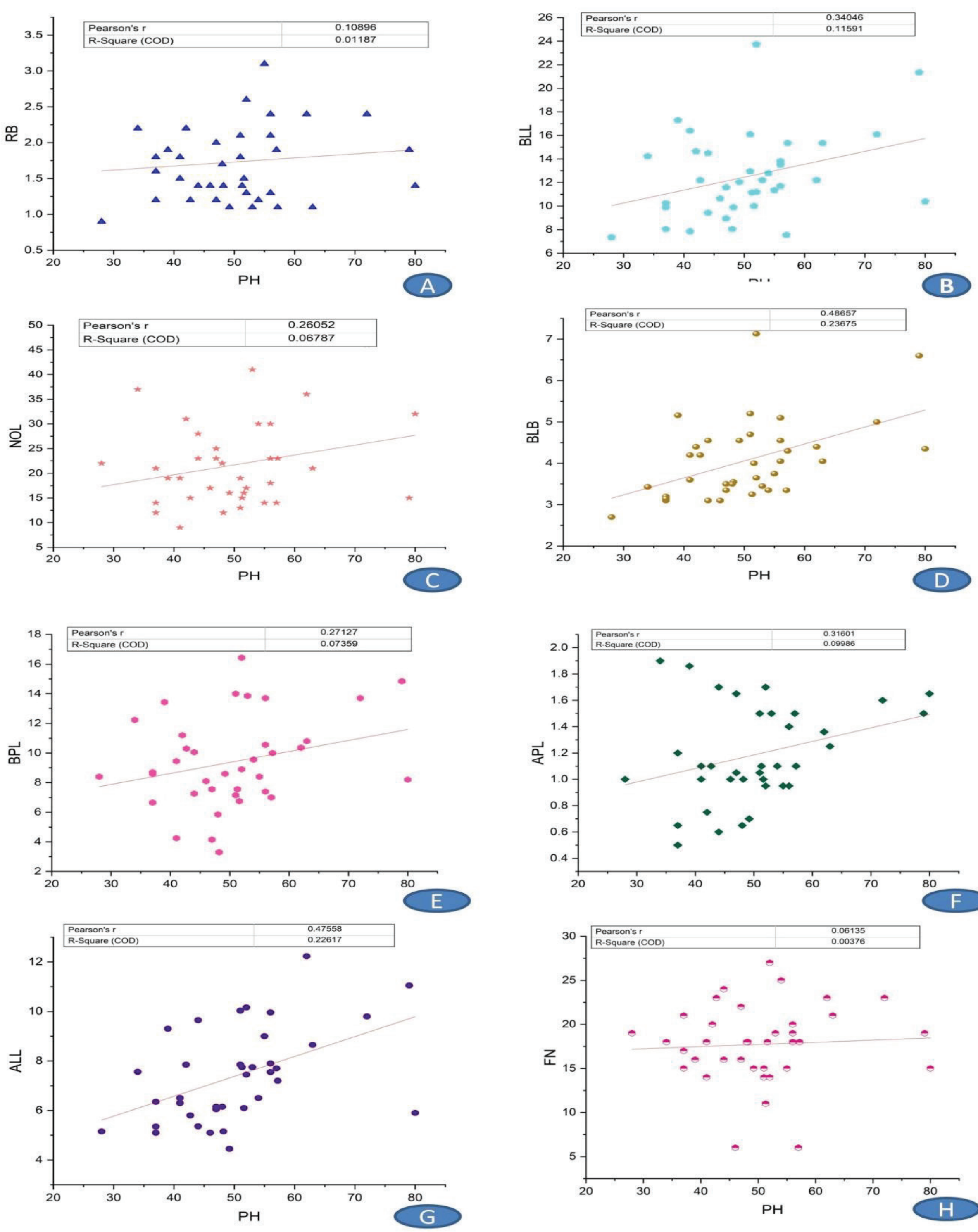

Fig. 5. (A-H) Regression analysis between several morphological features of *P. cashmeriana*

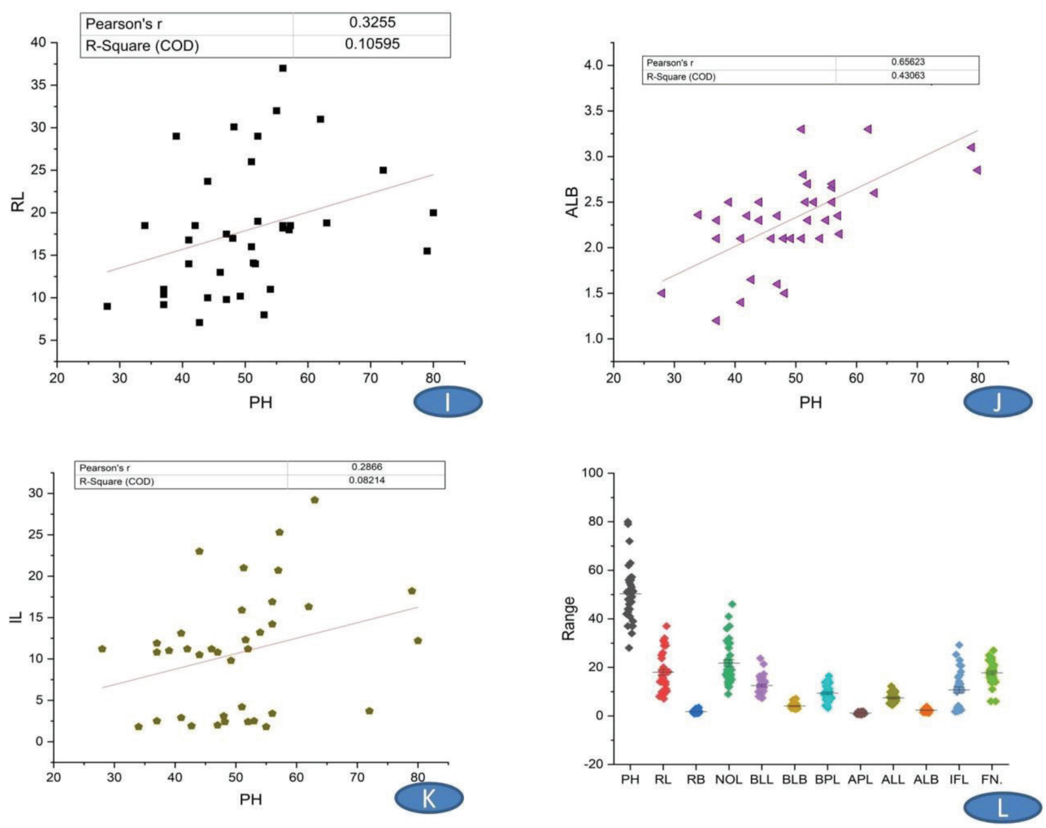

Fig. 6. (I-k) Regression analysis, (L) Range between several morphological features of *P.cashmeriana*

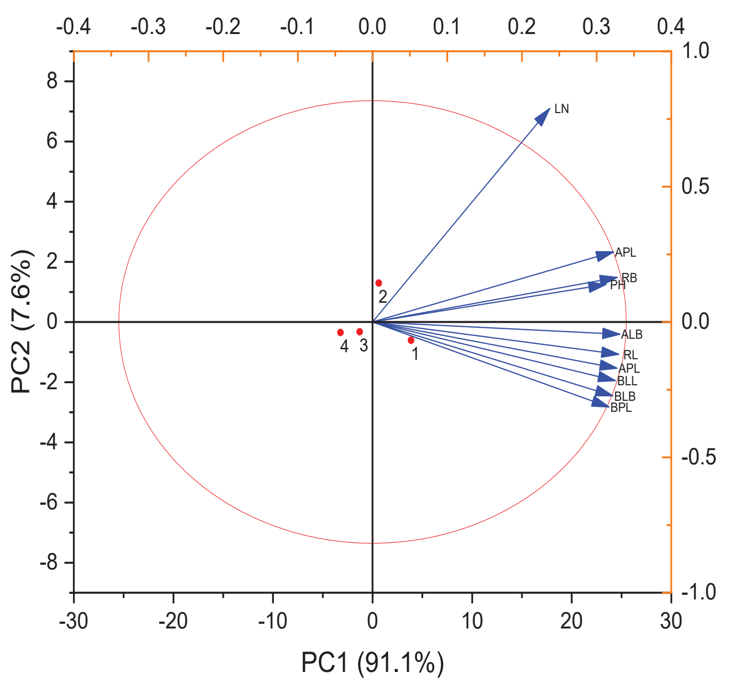

Fig. 7. Principal component analysis (PCA) of different morphological features of *P. cashmeriana* across different study sites. LN – Leaf number, APL – Apical petiole length, RB – Rhizome breadth, PH – Plant height, ALL – Apical leaf length, ALB – Apical leaf breadth, RL-Rhizome length, BLL – Basal leaf length, BLB – Basal leaf breadth, BPL – Basal petiole length; 1-KUBG ,2- Daksum,3- Hillar Naar, 4-. Jawahar tunnel

at different altitudes. The maximum variation can be seen in the overall resource budget and the total dry weight of above-ground plant parts in populations growing at KUBG (23.73±6.63 g) and Jawahar tunnel (12.94±7.67 g) representing minimum and maximum altitude respectively, while the total resource budget for sites Daksum and Hillar was 22.53±9.98 and 17.71±5.45 g. From Table 4 it is also clear that the partitioning of resources shows significant variation between different plant parts. Maximum resources are allocated towards rhizome followed by leaf and stem while minimum resources are allocated towards inflorescence. The maximum values were shown by the population growing at high altitude Jawahar tunnel (68.08±7.60 g) followed by populations present at Hillar and Daksum (48.09±8.59 & 48.10±13.38 g) respectively. While as the least value was shown by the population growing at KUBG (40.25±6.66 g).

3.3 Reproductive Success

Maximum % age reproductive effort per plant was shown by the population growing at high altitudes as compared to the one growing at lower altitudes, values range from 13.64 at Jawahar tunnel to 10.29 at KUBG respectively. From Table 3 it is clear that with the increase in altitude the no. of flowers per flower head as well as no. of flower heads per plant decreases. Maximum number of flowers per flower head and flower heads per plant were seen in KUBG (18.6±3.81 & 4±1.67) and minimum in Jawahar tunnel population (16.6±4.47 & 3.3±1.95) respectively. While as %age seed set also decreases with increase in altitude, highest being shown by population growing at KUBG (63.94 ±9.35) while as a minimum by population growing at J. tunnel (53.40 ±20.58).

4. DISCUSSION

Plants being sedentary possess remarkable phenotypic plasticity giving them an infinite potential for modification of physiological, morphological and reproductive attributes in response to changing environmental conditions. This is one of the dominantly studied plant developmental patterns throughout the globe [18, 19]. During the current study, it is observed that there is a discrete as well as directional vogue towards morphology, structural design, and characters associated with fitness among different surveyed populations of *P. cashmeriana* thriving at various altitudinal ranges. Noteworthy variability in phenotypic characters was documented and a general trend

Table 3. % age seed set (Mean ±SD) and floral dimensions across different study sites

Site	Jawahar tunnel	Hillar naar	Daksum	KUBG	F value
Av. Seeds Produced per flower head	44.4 ±18.45^{b*}	35.5 ±11.46^{a}	47 ±5.51^{a}	81.7 ±21.95^{a}	17.145
Av. Ovules borne	81.2 ±8.65^{b}	63 ±18.31^{a}	80 ±9.26^{a}	126.8 ±23.63^{a}	27.801
% age seed set	53.40 ±20.58^{a}	56.35 ±8.24^{a}	58.75 ±11.10^{a}	63.94 ±9.35^{a}	1.322
Flower no. per flower head	16.6±4.47^{a}	17.6±15.23^{a}	18.28±5.03^{a}	18.6±3.81^{a}	0.323
Flower head per plant	3.3±1.95^{a}	2.8±1.99^{a}	3.9±1.73^{a}	4±1.67^{a}	0.875
calyx length (cm)	1.72±0.20^{a}	1.61±0.18^{a}	1.5±0.22^{a}	1.62±0.13^{a}	2.351
calyx breadth (cm)	0.56±0.27^{a}	0.44±0.10^{a}	0.41±0.05^{a}	0.47±0.08^{a}	1.763
upper lip length (cm)	3.61±0.32^{b}	3.47±0.27^{b}	3.07±0.17^{b}	3.45±0.24^{a}	8.144
upper lip breadth (cm)	2.1±0.22^{b}	1.84±0.21^{b}	2.03±0.34^{b}	2.14±0.14^{a}	8.195
Lower lip length (cm)	3.17±0.36^{a}	3.09±0.19^{a}	2.65±0.32^{a}	3.22±0.20^{a}	1.962
Lower lip breadth (cm)	1.64±0.28^{b}	1.75±0.22^{b}	1.66±0.39^{b}	2.09±0.25^{a}	4.759
Androecium Length (cm)	2.7±0.23^{b}	2.74±0.20^{ab}	2.41±0.45^{ab}	2.87±0.22^{a}	4.116
Gynoecium length (cm)	4.16±0.15^{b}	3.75±0.41^{ab}	3.52±0.30^{a}	3.69±0.33^{a}	9.207

* Means labeled with the different small letters indicate that they significantly differ from each other among different populations

Table 4. Allocation of resources (Mean ±SD) towards vegetative and reproductive parts of *P. cashmeriana* at different sites

Traits	Jawahar tunnel (g)	Hillar naar (g)	Daksum (g)	KUBG (g)	F value
Rhizome	68.08±7.60[a*]	48.09±8.59[a]	48.10±13.38[a]	40.25±6.66[a]	1.904
Leaves	16.03±7.46[c]	29.08±7.45[c]	29.42±8.85[b]	32.53±6.35[a]	7.880
Stem	11.53±2.50[c]	16.50±12.06[bc]	16.51±7.72[ab]	21.05±10.66[a]	82.047
Inflorescence	4.35±2.02[b]	6.31±2.97[b]	5.95±1.99[b]	6.15±2.34[a]	12.520
Total resource budget per plant(gms)	12.94±7.67[c]	17.71±5.45[c]	22.53±9.98[b]	23.73±6.63[a]	22.756
Total reproductive effort per plant (%)	13.64[a]	12.16[a]	11.48[a]	10.29[a]	2.861

* Means labeled with the different small letters indicate that they significantly differ from each other among different populations

of linear decrease in plant traits with increasing altitude was more distinct and pronounced. A great deal of difference was found in plant height as it reduces with increasing altitude. Considerable phenotypic variability has also been found within and across the individuals of different populations of Ajuga bracteosa and Ajuga parviflora growing along different altitudes in Kashmir valley; the morphological characteristics showed both direct as well as a negative correlation with the altitude [20, 21]. Similar findings were revealed by other authors Hadi *et al*. (2022) [22], Korner *et al*. (2003) [23], Wills *et al*. (2002) [24] and Magray *et al*. (2021) [25] being one of the distinguished phenomena towards plant adaptation at increasing altitudes. The said outcome is due to a lower rate of growth as mitigation to stressful conditions and a shorter season for plant growth [26, 27]. The plants gain in such type of phenotypic character comes from evading strong winds blowing at higher altitudes besides enhancing photosynthetic efficiency via maintaining leaves in juxtaposition with warmer soil surface [28]. Besides, Lower mean annual temperature, high-intensity solar radiations, and high-altitude speedy winds limit plant growth and decrease leaf size with increasing altitude are the major reasons explaining this phenomenon. Apart from this decreased leaf size is also responsible for reduced solar radiation absorption which in turn helps in reducing the rate of transpiration and damages caused by high-intensity UV radiations.

The difference in flower number was also observed within the populations growing at different altitudes. The observed trend that plants growing at different altitudes follow suggests that those growing at lower altitudes are more dynamic, show maximum height and are capable of producing more flowers and leaves as compared to the ones growing at high altitudes. This conforms with the results of Johnson *et al*. (1968) [29], and Hickman *et al.* (1975) [30].

In addition to this, the association between the size of the plant and reproductive behavior (flower number); as already reported by Ohlson (1988), Aarssen and Taylor (1992), Kudo (1993) and Clauss and Aarssen (1994) [31-34]. To understand life history operative within a species, it is very important to understand the mechanism operative during resource allocation towards plant parts, within the overall resources allocated to the whole plant, plant size plays a pivotal role, which in turn reflects the potential of a plant to reproduce [35, 36]. *P. cashmeriana* the population under study shows a clear variation in portioning of biomass, as during the current study the population growing at high altitude has biomass allocated towards the stem, inflorescence, and leaves lower as compared to the below-ground part (rhizome). From the above results, it can be concluded that environmental selective forces result in deviation of reproductive strategies also reported by Shabir *et al*. (2013) [37]. Previous studies on some plant species have also proved that reproductive effort reduces considerably as plant size increases [38]. The reproductive effort of the plants growing at high altitudes was more than the plants growing at lower elevations. These findings confirm with Fabbro and Korner (2004) and Molina-Montenegro and Naya (2012), who reported a greater reproductive response with altitude

[39, 40]. Furthermore, the relationship of increased allocation to reproduction (number of flowers) with plant size is consistent with the observations of Aarssenand *et al*.(1992) [32], Clauss *et al*. (1994) [41].

5. CONCLUSION

The current studies reveal that *P. cashmeriana* prefers open rocky steep slopes. Plant species depict a wide range of variability in phenotypic traits along different altitudinal gradients of selected sites. While studying its phenotypic attributes, it was found that the population growing at lower elevations (KUBG) were taller and more vigorous than other studied populations growing at higher elevations. Contrary to plant height, the allocation of resource budget towards different parts showed a great variation, maximum resources were allocated towards rhizome followed by leaf, stem, and inflorescence. Further, reproductive success (fitness) was high in the populations growing at higher elevations as compared to the populations growing at lower elevations. Implying a clear prioritizing of reproduction over growth at high altitudes. This dynamics in both morphological and reproductive traits might be due to the reproductive effort, harsh environmental conditions and the presence of competitive habitat. We concluded that a heterogeneous environment is the primary cause of phenotypic variability in *P. cashmeriana*. Further studies related to the impact of other environmental aspects such as physicochemical properties of soil and climate would help us to understand if there are any other factors responsible for the phenotypic variability across different altitudes.

6. ACKNOWLEDGEMENTS

The first author is highly grateful to the Department of Botany, University of Kashmir for providing lab facilities during this research.

7. CONFLICT OF INTEREST

The authors declare no conflict of interest

8. REFERENCES

1. U. Becker, G. Colling, P. Dostal, A. Jakobsson, and D. Matthies. Local adaptation in the monocarpic perennial Carlina vulgaris at different spatial scales across Europe. *Oecologia* 150: 506–518 (2006).
2. S.Matesanz, E. Gianoli, and F. Valladares. Global change and the evolution of phenotypic plasticity in plants. *Annals of the New York Academy of Sciences* 1206(1): 35–55 (2010).
3. C. Korner, M. Neumayer, S.P Menendez-Riedl, and A. Smeets-Scheel,. Functional morphology of mountain plants. *Flora* 182(5-6): 353–383 (1989).
4. Y. Vitasse, S. Delzon, C. Bresson, R. Michalet, and A. Kremer. Altitudinal differentiation in growth and phenology among populations of temperate-zone tree species growing in a common garden. *Canadian Journal of Forest Research* 39(7): 1259 1269 (2009).
5. C. Korner. The use of 'altitude'in ecological research. *Trends in ecology & evolution* 22(11): 569–574 (2007).
6. J. Oleksyn, J. Modrzýnski, M.G. Tjoelker, R. ytkowiak, P.B. Reich, and P. Karolewski. Growth and physiology of Picea abies populations from elevational transects common garden evidence for altitudinal ecotypes and cold adaptation. *Functional Ecology* 12(4): 573–590 (1998).
7. A.V. Gonzalez, and E. Gianoli.. Morphological plasticity in response to shading in three Convolvulus species of different ecological breadth. *Acta Oecologica* 26(3): 185–190 (2004).
8. I. Calıs, and H. Kırmızıbekmez, Glycosides from Phlomis lunariifolia. *Phytochemistry* 65(18): 2619-2625 (2004).
9. POWO 2022. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet;http://www.plantsoftheworldonline.org/ Retrieved 22 January 2022."
10. I. Limem, H. Harizi, K. Ghedira, and L. Chekir-Ghedira. Leaf extracts from *Phlomis crinite* Cav. subs. mauritanica Mun by affect immune cell functions *in vitro. Immunopharmacology and immunotoxicology* 33(2): 309-314 (2011).
11. P. Sarkhail, S. Rahmanipour, S. Fadyevatan, A. Mohammadirad, G. Dehghan, G. Amin, and M. Abdollahi. Antidiabetic effect of Phlomis anisodonta: effects on hepatic cells lipid peroxidation and antioxidant enzymes in experimental diabetes. *Pharmacological Research* 56(3): 261-266 (2007).
12. N. Wafa, G. Sofiane, and K. Mouhamed. The antioxidant and antimicrobial activities of flavonoids and tannins extracted from Phlomis bovei De Noe. *European Journal Experimental Biolology* 6(3): 55-61 (2016).

13. N.M. AbdEIslam, R. Ullah, J. Ali, and I. Hussain. Analysis of the Fatty acid Composition of Phlomis bracteosa oil by Gas Chromatography-mass spectrometer. *Life Science Journal* 10(7): (2013).
14. S. Kawano, and J. Masuda. The productive and reproductive biology of flowering plants. *Oecologia* 45(3): 307-317 (1980).
15. U. Yaqoob, and I.A. Nawchoo. Impact of habitat variability and altitude on growth dynamics and reproductive allocation in Ferula jaeschkeana Vatke. *Journal of King Saud University-Science* 29(1): 19-27(2017).
16. W.G. Abrahamson, and M. Gadgil. Growth form and reproductive effort in goldenrods (Solidago, Compositae). *The American Naturalist* 107(957): 651-661(1973).
17. R.R. Sokal, F.J. Rohlf, and J.F. Rohlf, biometry: The Principles and Practice of Statistics in Biological Research. 3rd Edition, W.H. Freeman and Co., New York. (1995).
18. C. Parmesan. Ecological and evolutionary responses to recent climate change. *Annual Reviews* 37: 637-669 (2006).
19. G.R. Walther, E. Post, P. Convey, A Menzel. C. Parmesan, T.J. Beebee, and F. Bairlein. *Ecological responses to recent climate change. Nature* 416(6879): 389-395(2002).
20. S. Gulzar, U. Yaqoob, A Hassan. and I. A. Nawchoo, Variation in Growth Dynamics and Reproductive Allocation in Ajuga Species across Different Altitudes. *Herbal Medicines* 3:1 (2017).
21. T.Islam, S. Nissar, N. Majeed, J.A. Magray, I. A. Nawchoo, and B.A. Wani, Impact of habitat variability on phenotypic attributes of Hypericum Perforatum L. along an elevational gradient in Kashmir Himalaya. *Journal of Advanced Applied Scientific Research* 3(1): (2021).
22. A. Hadi, S Singh, I.A. Nawchoo, S. Rafiq, and S. Ali. Impacts of habitat variability on the phenotypic traits of Aconitum violaceum Jacq. ex Stapf. at different altitudes and environmental conditions in the Ladakh Himalaya, India. *Plant Science Today* 9(3): 546-54 (2022).
23. C. Korner, Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems. Springer, Berlin Springer, Berlin, Heidelberg (2003). doi.org/10.1007/978-3-642-18970-8
24. S.G Willis,. and P.E. Hulme. Does temperature limit the invasion of Impatiens glandulifera and Heracleum mantegazzianum in the UK. *Functional Ecology* 16(4): 530-539 (2002).
25. J.A Magray, S.A. Zargar, T. Islam, and I.A Nawchoo. Impact of habitat variability on growth dynamics of Bergenia ciliata (Haw.) Sternb. along an altitudinal gradient in Kashmir Himalaya. *Plant Science Today* 9(1): 144-149 (2021).
26. C.C. Bennington, and J.B. McGraw. Natural selection and ecotypic differentiation in Impatiens pallida. *Ecological Monographs* 65(3): 303-324 (1995).
27. J.P. Grime. Plant strategies and vegetation processes John Wiley and Sons. New York: (1979).
28. C. Korner, and P.M. Cochrane. Stomatal responses and water relations of Eucalyptus pauciflora in summer along an elevational gradient. *Oecologia* 66(3): 443-455 (1985).
29. M.P. Johnson, and S.A. Cook. " Clutch Size" in Buttercups. *The American Naturalist* 102(927): 405-411 (1968).
30. J.C. Hickman. Environmental unpredictability and plastic energy allocation strategies in the annual Polygonum cascadense (Polygonaceae). *The Journal of Ecology* 689-701 (1975).
31. M. Ohlson. Size-dependent reproductive effort in three populations of Saxifraga hirculus in Sweden. *The Journal of Ecology* 1007-1016 (1988).
32. L.W. Aarssenand, and D.R Taylor. Fecundity allocation in herbaceous plants. *Oikos* 225-232. (1992).
33. G. Kudo, Size-dependent Resource Allocation Pattern and Gender Variation of Anemone debilis Fisch. *Plant Species Biology* 8(1), 29-34 (1993).
34. M.J Clauss, and L.W Aarssen. Phenotypic plasticity of size--fecundity relationships in Arabidopsis thaliana. *Journal of Ecology* 447-455 (1994).
35. E.P. Lacey, Onset of reproduction in plants: size-versus age-dependency. *Trends in Ecology & Evolution* 1(3): 72-75. (1986).
36. D.A. Samson, and K.S Werk. Size-dependent effects in the analysis of reproductive effort in plants. *The American Naturalist* 127(5): 667-680 (1986).
37. P.A. Shabir, I.A Nawchoo, and A A. Wani, Floral phenology, secondary pollen presentation and pollination mechanism in Inula racemosa (Angiosperms: Asteraceae). *Journal of Threatened Taxa* 4498-4503 (2013).
38. P.G.L. Klinkhamer, T.J De Jong. and E. Meelis. How to test for size dependent reproductive effort. *American Naturalis*135, 291-300 (1990).
39. T. Fabbro, and C. Korner, Altitudinal differences in flower traits and reproductive allocation. Flora-Morphology, Distribution, *Functional Ecology of*

Plants 199(1): 70-81. (2004).

40. M.A. Molina-Montenegro, and D.E. Naya. Latitudinal patterns in phenotypic plasticity and fitness-related traits: assessing the climatic variability hypothesis (CVH) with an invasive plant species, *PLoS ONE* 7(10): e47620. (2012).
41. M.J. Clauss, and L.W. Aarssen, Phenotypic plasticity of size--fecundity relationships in Arabidopsis thaliana. *Journal of Ecology* 447-455. (1994).