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Research Article

Growth Dynamics and Resource Allocation of *Bistorta amplexicaulis* (D. Don) Greene: An Alteration across Different Habitats and Altitudes

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

[1]Pant Reproductive Biology, Genetic Diversity, and Phytochemistry Research Laboratory, Department of Botany, University of Kashmir, Srinagar, Jammu & Kashmir, India
[2]Government College for Women, Cluster University Srinagar, Jammu & Kashmir, India

Abstract: *Bistorta amplexicaulis* is an essential medicinal plant found in the Kashmir Himalaya. Ethnobotanical studies have revealed that this particular species is used to treat fractures, muscle injuries, heart problems, abnormal leucorrhoea, menorrhagia and inflammation of the mouth and tongue. The current study aimed to determine the variation in growth traits and fluctuations in the allocation patterns with respect to different habitats across the altitudinal gradient. In order to adapt to unpredictable and stressful conditions at higher altitudes, phenotypic plasticity plays a crucial role. Our findings revealed considerable variability in the phenotypic traits, indicating that altitude has a defined effect on this species's morphology and reproductive traits. Low altitude plant populations of Kashmir University Botanical Garden (KUBG), Dara and Tangmarg were more robust and taller (98.4±2.36, 83.58±2.69 and 74.08±1.59 cm, respectively) than the populations of Pissu top and Bangus (23.96±3.38 and 30.43±1.12 cm respectively) at higher altitudes. The habitats of KUBG, Dara, and Tangmarg proved to be substantially better for the growth of *B. amplexicaulis*, as per the Principal component analysis (PCA). The regression analysis demonstrated a negative relation between altitude and plant height. Traits such as leaf length/ breadth, Rhizome length/ breadth and inflorescence length showed a strong correlation with plant height. Our results provide an inclusive description of the phenotypic variability of this significant medicinal plant in response to the habitat variability across different altitudes.

Keywords: Kashmir Himalaya, Phenotypic Variability, Habitat Variability, Altitudinal Gradient

1. INTRODUCTION

An alluring south Asian region- the Kashmir Himalaya is situated at the north-western tip of the Himalayan Biodiversity Hotspot. It harbors around 10,000 plant species, of which 4,000 are endemic, making up about 2.5 % of the global angiosperm diversity [1]. Due to their sedentary nature, plants cannot avoid the vulnerabilities of the environment in which they grow. Therefore, to persist in severe conditions, they must adapt genetically or by phenotypic plasticity [2]. As an adaptation to resource availability, plants can display disparity in morphological characteristics in response to abiotic (temperature, rainfall, and soil) and biotic (grazing and competition) aspects of the environment. The competence of plants to transform their morphology and physiology as a response to inconsistent environmental conditions is called phenotypic plasticity; this phenotypic adaptation is also termed phenotypic accommodation [3]. Phenotypic plasticity plays a crucial role in evolution by adjusting the developmental pathways, thus leading to phenotypic diversity in nature [4]. Phenotypic plasticity has a crucial role in several aspects, such as resource acquisition by plants and differences in the size and positioning of resource-attaining parts (leaves), which are critical to a plant's regulation of resource accessibility.

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*Corresponding Author: Hanan Javid <bhathanan123@gmail.com>

Variability in general growth forms of resource accumulating organs such as tubers, roots, rhizomes, flowers and leaves of a plant are critical to regulate the available resources [5]. Phenotypic plasticity that is environmentally induced in plants is usually measured as a functional response that amplifies fitness in fluctuating environments. If environmental and phenotypic variation within species are correlated, it can be hypothesized that species are phenotypically more variable if they occupy an extensive range of habitats as supported by Sultan (2001) [6]. With increasing evidence from molecular and developmental biology, we have gained an advanced understanding of plasticity methods which are critical for tracking changes in specie distribution, the composition of a community, and the productivity of crops under climate change [7].

Bistorta amplexicaulis (D. Don) Greene (Syn: *Polygonum amplexicaule* D. Don), locally known as "machran chai" belongs to the family Polygonaceae and grows as a medium-sized herb in hilly areas of Kashmir [8]. It is a highly useful medicinal plant, native to China north-central, China south central, Afghanistan China southeast, East Himalaya, Pakistan, Nepal and West Himalaya (POWO). It is a highly useful medicinal plant, native to China north-central, China south central, Afghanistan China southeast, East Himalaya, Pakistan, Nepal and West Himalaya (POWO). *B. amplexicaulis*, a medicinally significant plant, has been used to cure many ailments, such as maintaining normal menstrual flow, reducing stomach pain, treating fractures, rheumatism, osteoporosis, muscle injuries and inflammation of the mouth and tongue [9, 10]. Phytochemical analysis of *B. amplexicaulis* has revealed numerous compounds, including, Friedelin, β–sitosterol, simiarenone, angelicin, psoralen, palmitic acid, quercetin [11] catechin, quercetin-3-O-β-D galactopyranoside, rutin, amplexicine [12]. The current research work aimed to reveal (i) Impact of altitude and habitat variability on the morphological attributes and allocation patterns of *B. amplexicaulis* (ii) to find a suitable habitat for the development, establishment and cultivation of *B. amplexicaulis.*

2. MATERIALS AND METHODS

2.1 Study Area

The Kashmir Himalaya constitutes a distinct biosphere unit in the northern Himalayas due to its bio-geographically important location [13]. The region covers around 15,948 km² and is mountainous for nearly 64 % of its overall size. The region is located between 32º20′ and 34º50' North latitude and 73º55′ and 75º35′ East longitude [14]. Geographically, the region consists primarily of an oblique bowl-shaped valley. The valley is encircled in the south and southwest by the Pir Panjal range of the Lesser Himalaya, and in the north and northeast by the Zanskar range of the Greater Himalaya.

2.2 Survey and Selection of Study Sites

Extended field surveys were conducted during 2019-2021 in varied habitats of Kashmir Himalaya in order to recognize specific areas across diverse geographical conditions. *Bistorta amplexicaulis* was found growing in Dara, Gulmarg, Doodhpathri, Tangmarg, Sinthan top, Aru, Lidderwat, Pissu top, Tarsar, Tosa Maidan, Royelsar, Razdan top, Aharbal, Nilnag, Lolab, Bangus, Reshwar, Margan top, Jawahar tunnel, Ferozpora, Drang, Karnah, Pattan and Duksum (Fig. S1). For the present study, eight natural populations Pissu top (3,286 m asl), Bangus (2866 m asl), Doodhpathri (2,730m asl), Gulmarg (2,657 m asl), Lidderwat (2,634 m asl), Aru (2,417 m asl), Tangmarg (2,158m asl), Dara (2,050 m asl) and one population at Kashmir University Botanical Garden – 1588 m asl (KUBG) (Figure. 1) were selected. The geo-coordinates were taken using Gramin GPS etrex 10. Table 1 depicts the prominent features of the selected sites.

2.3 Morphological Characterization

Twenty mature flowering individuals were randomly selected from the specified populations to observe various morphological parameters. The selected plants were assessed for morphological characteristics such as Rhizome length and breadth, Stem length, basal leaf length and breadth, apical and basal leaf length and breadth, leaf number per plant, number of inflorescences per plant and number of flowers. Populations were selected based on, habitat structure, an abundance of selected plants and ease of access. The specimens from each population were deposited and identified in Kashmir University Herbarium (KASH) under voucher specimens No. 2964, 3749, 4318 and 4319.

Table 1. Habitat features and Geo-coordinates of the selected sites

Study sites	Altitude (m asl)	Latitude (N) and Longitude (E)	Habitat features	Threat
Pissu top	3,286	34°05′02″N 75°26’01’E	Open, dry and rocky slope	Over grazing
Bangus	2866	34°22'14″ N 74°02' 45″E	Open, dry and rocky slopes	Overgrazing, habitat destruction
Doodhpathri	2,730	33°51′24″ N 74°33′51″ E	Open, moist and rocky slope	Overgrazing, habitat destruction
Gulmarg	2,657	34°03′02″ N 74°23′14″ E	Partial Shady, dry and rocky slope	Local use, Habitat destruction and Overgrazing
Lidderwat	2,634	34°06′32″N 75°14′53″ E	Shady slope	Over grazing, habitat destruction
Aru	2,417	34°05′27″ N 75°15′54″ E	Shady slope, moist	Over grazing, habitat destruction
Tangmarg	2,158	34°03′37″ N 74°25′27″ E	Partial shady, moist	Habitat destruction
Dara	2,050	34°04′11″ N 74°54’09″ E	Shady, moist and rocky slopes	Over grazing
KUBG	1,595	34°07′38″ N 74°50′12″ E	Open field, dry	Nil

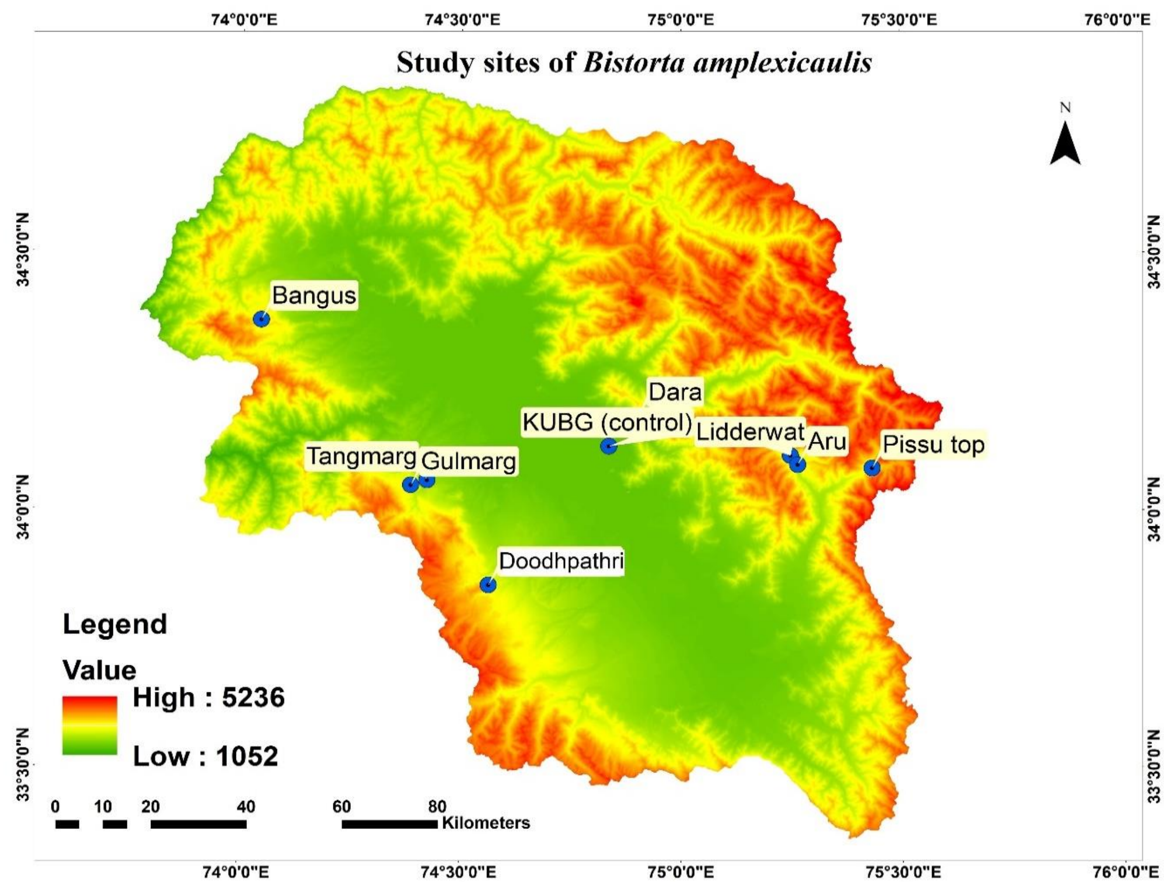

Fig. 1. Map depicting study sites of *B. amplexicaulis* in Kashmir Himalaya

2.4 Resource Allocation

Ten well-developed and flowering plants from the selected study sites were collected for analysing of resource allocation in different plant parts. The selected plants were further split into stem, leaves, rhizome and inflorescence. Freshly collected specimens were weighed and oven dried at 80 °C for 48 h using an electronic balance [15]. Reproductive effort (RE) was calculated from the evaluation of biomass (dry weight) dedicated to reproductive and above ground vegetative structures [16].

$$\text{RE} = \frac{\text{Dry weight of inflorescence}}{\text{total dry weight of the above and below ground parts}} \times 100$$

2.5 Data Analysis

The difference in morphological characters was carried out to test for differences between populations using ANOVA (IBM-SPSS software, version 23). Origin 2021 was used to carry out linear regression between altitude and numerous morphological parameters. Principal component analysis (PCA) was employed to examine morphological features concerning habitat dynamics and comprehend the coherence between various vegetative and reproductive traits.

3. RESULTS

The widespread survey of the Kashmir Himalayas illustrates a wide range of habitats suitable for the growth of *B. amplexicaulis*. The specie grows mainly on rocky slopes (open and partial shady), with an altitudinal range of 1500 m to 3300 m asl (Fig. S2). The morphological features of *B. amplexicaulis* are depicted in Table S1 and also presented in Figure 2. The phenotypic traits of *B. amplexicaulis* studied during the field survey vary substantially, signifying remarkable phenotypic variation between populations across different altitudes (Table 2). The plant height is highest in KUBG (98.54±2.36 cm) and lowest in Pissu top (23.96±3.38 cm). Similarly, Rhizome length and breadth were maximum in KUBG (18.98±1.72 and 2.17±0.31 cm) and minimum in Pissu top (8.66±0.54 and 1.27±0.44 cm). The number of leaves ranged from 3.00±0.67 (Pissu top) to 4.40±0.51 per plant (KUBG). The mean apical and basal leaf length per plant is 4.17±0.72 cm (Pissu top) to 9.62±2.03 cm (KUBG) and 6.51 ± 0.95 cm (Pissu top) to 12.64 ± 2.57 cm (KUBG), respectively. The mean apical and basal leaf breadth per plant ranged from 2.13±0.56 (Pissu top) to 4.57±1.62 (KUBG) and 2.66±0.66 (Pissu top) to 5.38±1.79 cm (KUBG), respectively. Inflorescence length also varied considerably from 2.12±0.43 (Pissu top) to 8.12±0.54 (KUBG) and the number of flowers ranged from 30.4±5.32 (Pissu top) to 95.6±2.99 cm (KUBG) respectively.

The current study demonstrates that resource partitioning is not homogenous amongst different parts of *B. amplexicaulis*. It displayed major differences were displayed in the patterns of resource allocation across the study sites (Table 3). A notable variation was witnessed in the plants across different populations along the altitudinal gradient inhabiting varying habitats with reference to above and belowground dry weight biomass. Maximum resource allocation (dry weight) was exhibited by rhizome (16.92±2.42 to 9.01±1.13 g) followed by the stem (1.85±0.72 to 0.945±0.27 g), leaves (0.98±0.15 to 0.34± 0.14 g) and minimum in inflorescence (0.424±0.06 to 0.19±0.08 g). Significant variation was observed in the resource budget per plant of low and high-altitude populations, as values were maximum at low-altitude populations viz. KUBG, Dara and Tangmarg (19.816±3.4, 18.0±4.60 and 16.2± 2.30 cm respectively) and minimum at high altitude populations viz. Pissu top, Bangus and Doodhpathri (11.36±1.60,11.53±3.69 and 12.38±2.32 cm respectively) as represented in Table 3.

Percent resource allocation followed a distinct trend across all populations with maximum resources allocated to rhizome (87.51±3.76 to 78.52±5.17 %) followed by Stem (9.37±3.29 to 7.00±2.50 %), Leaf (8.46±2.49 to 3.99±1.43 %) and inflorescence (3.85±0.70 to 1.00±0.39 %). The reproductive effort also shows a clear trend as plant populations of lower elevations had lesser reproductive effort compared to the populations of higher altitudes. Reproductive effort of populations from Pissu top, Bangus has maximum percent values (20.27± 0.71, 18.99±9.63 % respectively). In comparison to populations from lower altitudes, which include Tangmarg, Dara and KUBG (11.4±4.7, 9.39±3.77 and 6.9±0.56 % respectively).

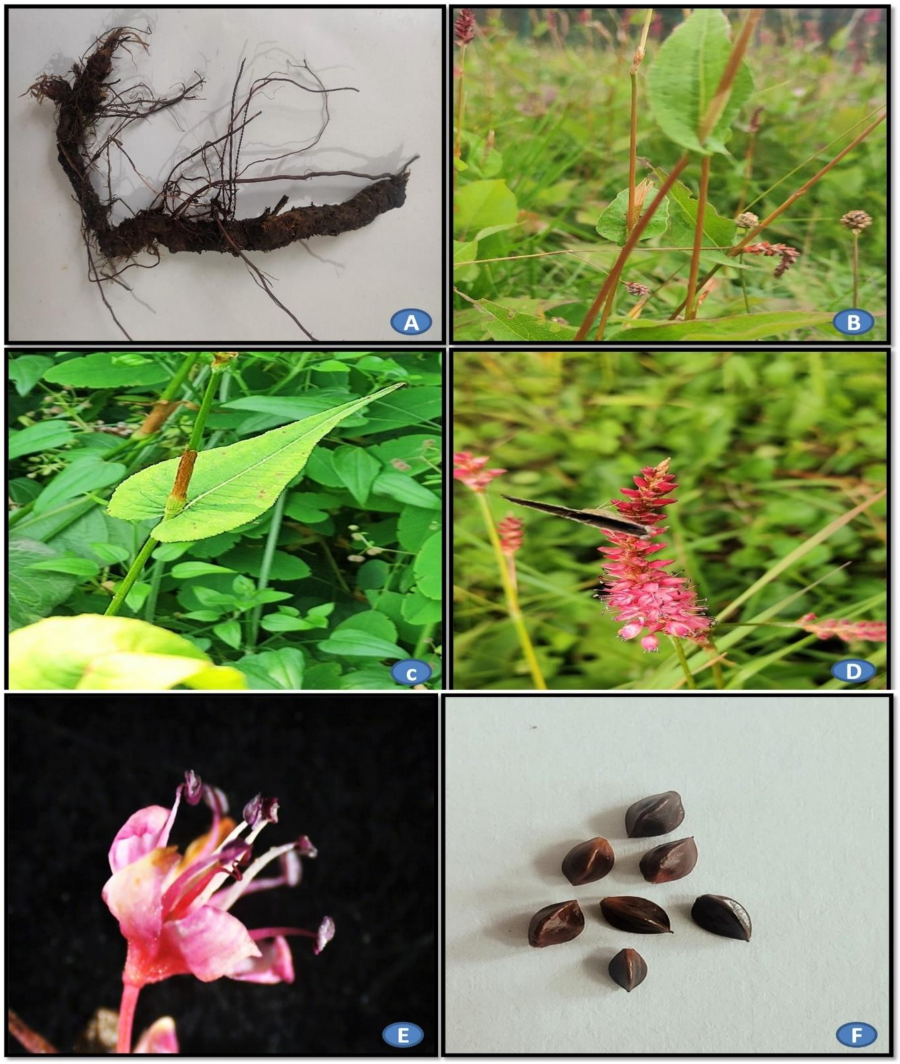

Fig. 2. Morphological features of *Bistorta amplexicaulis* (D. Don) Greene; (A) Rhizome, (B) Stem, (C) Leaf, (D) Inflorescence, (E) Flower, (F) Seeds.

4. DISCUSSION

B. amplexicaulis grows in a wide range of habitats varying from shady slopes, and open plains to rocky and moist slopes from (1585-3300 m asl) in Kashmir Himalaya. Lie *et al*. 2003 [17] indicated a widespread distribution for the species and recorded its distribution in shady grassy places on mountain slopes, grassy slopes in valleys, mountain slopes of forests and on forest margins (1000-3000 m asl). This in turn acquaints us with the fact that the study specie has a broader niche and can show phenotypic plasticity. In the present study we were able to scrutinize significant phenotypic variability and their regression across the populations of different habitats along an elevational gradient (Figure 3). Populations growing at high altitudes (Pissu top, Bangus and Doodhpathri) are comparatively shorter than the populations of low altitudes (Tangmarg, Dara and KUBG). Thus altitude, plant height and other morphological traits are negatively correlated (Figure 4). r^2 values were calculated where altitude and plant height had $r^2 = 0.9218$. Other morphological traits are positively correlated with plant height. The characters include rhizome length ($r^2 = 0.9338$), rhizome breadth ($r^2 = 0.9108$), apical leaf length ($r^2 = 0.9718$), apical leaf breadth ($r^2 = 0.9951$), basal leaf length ($r^2 = 0.9118$), basal leaf breadth ($r^2 = 0.6718$), inflorescence length ($r^2 = 0.9318$). PCA (Figure 5) has shown that high altitudes are disparaging for almost all of the reproductive and vegetative traits of *B. amplexicaulis* demonstrating superior growth conditions at lower altitudes [18]. Increasing altitude causes plants

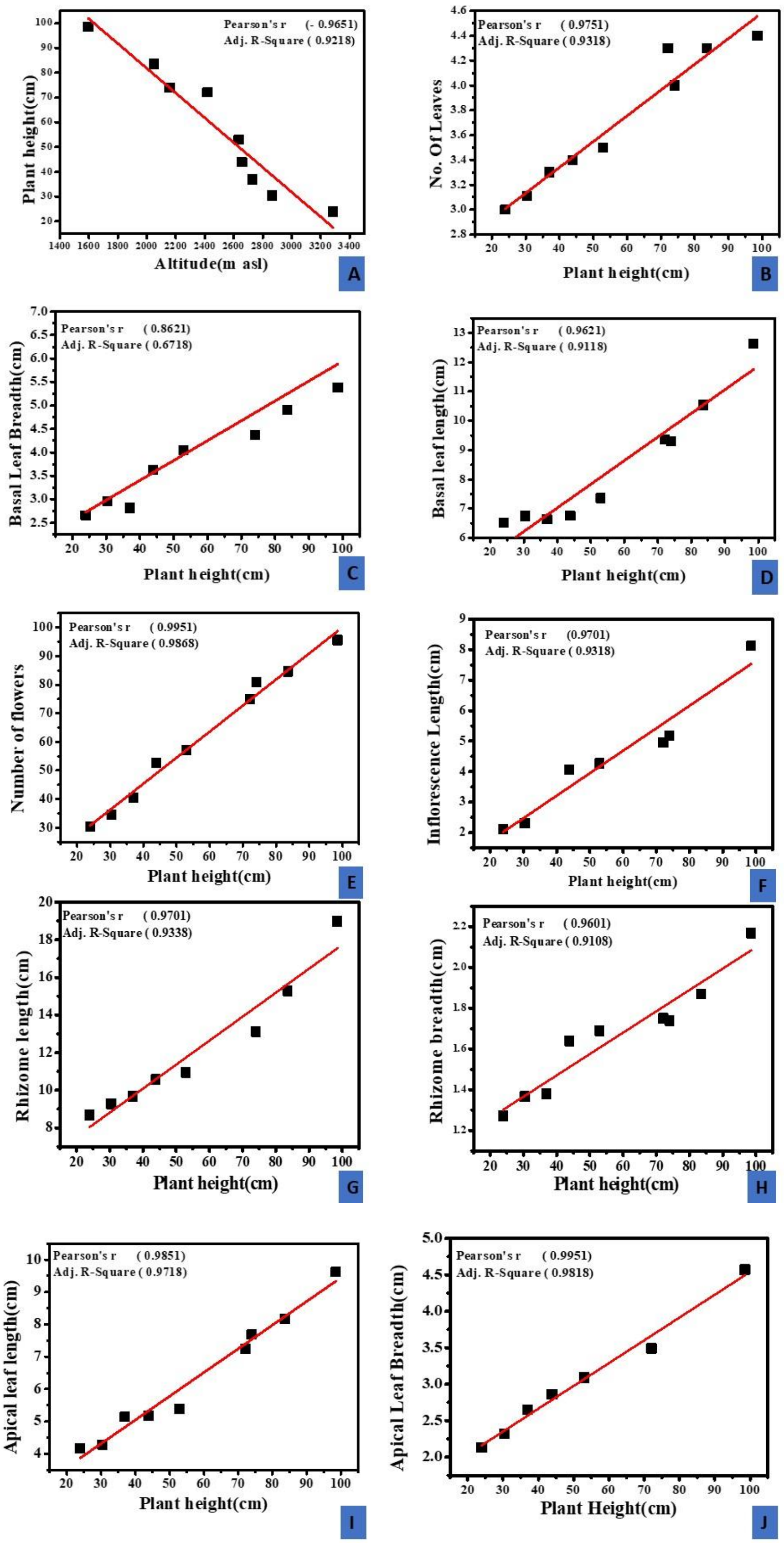

Fig. 3. (A-J) Regression analysis of various morphological traits of *Bistorta amplexicaulis*

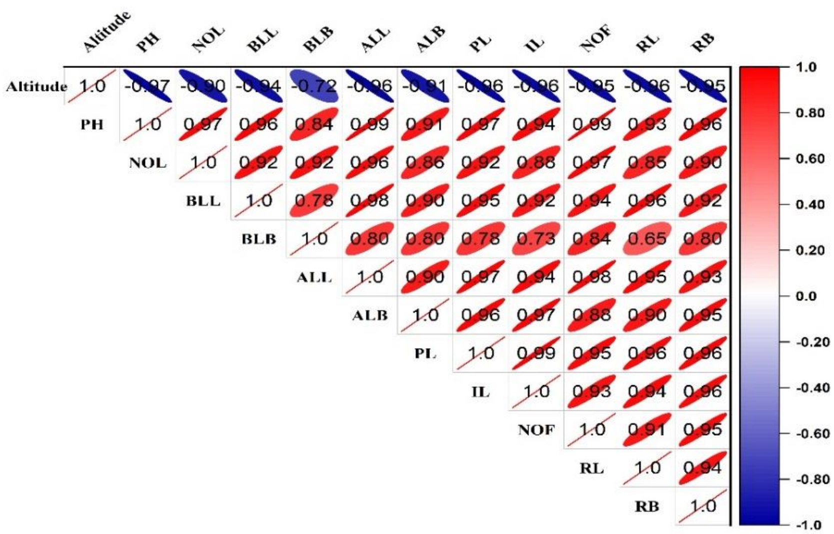

Fig. 4. Correlation plot showing Pearsons correlation coefficient amongst altitude and various morphological traits. PH. Plant height; NOL. Number of leaves; ALL. Apical leaf length; ALB. Apical leaf breadth; BLL. Basal leaf length BLB. Basal leaf breadth; IL Inflorescence length; NOF. Number of flowers; RL. Rhizome length; RB. Rhizome breadth

to grow shorter which can be a survival mechanism to endure harsh climatic conditions such as strong winds, also as leaves remain close to the warmer soil, photosynthetic conditions are amended [19]. At higher altitudes plants intensify super cooling capability by diminishing intercellular spaces and cell size [20]. Which ultimately results in an overall decrease in plant size. This reverse relationship between plant height and increasing altitude, as an adaptation has already been reported by various workers [21-24]. Apart from the severe conditions, plants growing at high altitudes have shorter growing seasons, which are less tall compared to plants at lower altitudes, where the growth period is relatively longer [25, 26].

The most important components of a plant's photosynthetic system are its leaves, which are essential for both plant functioning and enduring environmental adaptability [27]. Essential leaf traits include leaf shape, biomass, and water content [28]. As leaf dry matter content shows the balance between investment in storage and growth, it has frequently been used to forecast growth strategy and responsiveness to environmental perturbations. According to this study, the leaf length and breadth were found to be greatest in plant populations at lower altitudes (Dara, KUBG) and minimum in plants at higher altitudes (Pissu top, Bangus). According to Bresson *et al.* 2011 [29], increasing altitude generally causes a decrease in the length, breadth, and area of leaves. Light is a vitally important limiting factor for plant development and survival at low altitudes [30]. Due to their restricted capacity for photosynthetic activity per unit leaf area, plants that grow in low light intensities would naturally allocate the majority of their biomass to laminas [31, 32]. Large leaves can intercept a significant quantity of light at low light intensities because of their larger foliar display [33].

Understanding the patterns of resource allocation is important for understanding the life history strategies of different plant species. In this study species, allocation of most of the resources is towards the rhizome. After rhizomes, most resources get allocated to the stem followed by leaf and inflorescence across all populations at different altitudes. Even though the relative percent resource allocation follows a similar trend, there is a significant difference in the dry weight biomass amongst the populations at different altitudes. At higher altitudes, relatively more dry mass is accumulated in comparison to low altitude plants. In populations of Pissu top and Bangus the ratio of Dry weight/ fresh weight for rhizomes is 0.616 g and whereas for Dara and KUBG it is

Table 2. Morphological features and their variation (mean ± SD) across different study sites of *B. amplexicaulis*
*Means labelled with the small letters designate that they vary significantly from each other amongst the selected populations (Tukey test: $P \leq 0.05$)
*Mean± Standard Error

Phenotypic traits	Pissu top	Bangus	Doodhpathri	Gulmarg	Lidderwat	Aru	Tangmarg	Dara	KUBG	F valve
Plant height (cm)	*23.96 ± 3.38^{a}	30.433 ± 1.12^{b}	36.93 ± 2.84^{c}	43.89 ± 2.27^{d}	52.29 ± 2.06^{e}	72.08 ± 1.59^{f}	74.03 ± 2.38^{f}	83.58 ± 2.69^{g}	98.54 ± 2.36^{h}	24.938
No. of leaves per plant	3 ± 0.67^{a}	3.11 ± 0.78^{b}	3.3 ± 0.67^{ab}	3.4 ± 0.84^{abc}	3.5 ± 0.52^{abc}	4.3 ± 0.48^{c}	4.00 ± 0.82^{bc}	4.3 ± 0.57^{bc}	4.4 ± 0.51^{c}	0.907
Basal leaf length (cm)	6.51 ± 0.95^{a}	6.744 ± 1.47^{a}	6.636 ± 2.20^{a}	6.755 ± 2.90^{a}	7.36 ± 2.52^{ab}	9.37 ± 2.62^{ab}	9.31 ± 2.16^{ab}	10.54 ± 1.32^{bc}	12.64 ± 2.57^{c}	1.784
Basal leaf breadth (cm)	2.66±0.66a	2.95 ± 1.11^{a}	2.8165 ± 1.00^{a}	3.62 ± 1.03^{ab}	4.05 ± 1.12^{abc}	6.51 ± 2.15^{c}	4.37 ± 0.65^{abc}	4.91 ± 0.731^{bc}	5.38 ± 1.79^{c}	4.557
Apical leaf length (cm)	4.17 ± 0.72^{a}	4.27 ± 1.10^{a}	5.14 ± 1.09^{ab}	5.18 ± 1.11^{ab}	5.39 ± 1.76^{ab}	7.24 ± 2.39^{bc}	7.69 ± 2.13^{cd}	8.17 ± 0.97^{cd}	9.62 ± 2.03^{d}	1.201
Apical leaf breadth (cm)	2.13 ± 0.56^{a}	2.32 ± 0.69^{a}	2.65 ± 0.64^{a}	2.86 ± 1.01^{a}	3.09 ± 1.18^{a}	3.49 ± 1.22^{ab}	3.05 ± 0.55^{a}	3.22 ± 0.52^{ab}	4.57 ± 1.62^{b}	1.393
Inflorescenc e length (cm)	2.12 ± 0.43^{a}	2.31 ± 0.38^{a}	3.88 ± 0.51^{b}	4.07 ± 0.70^{b}	4.27 ± 0.75^{bc}	4.96 ± 0.49^{cd}	5.18 ± 0.89^{d}	5.35 ± 0.37^{d}	8.12 ± 0.54^{e}	13.661
No. of flowers	30.4 ± 5.32^{a}	34.44 ± 3.94^{a}	40.50 ± 3.72^{b}	52.70±3.5c	57.00 ± 4.61^{c}	75.00 ± 3.33^{d}	80.8 ± 3.33^{e}	84.6 ± 2.4^{e}	95.6 ± 2.99^{f}	8.705
Rhizome length (cm)	8.66 ± 0.54^{a}	9.27 ± 1.39^{ab}	9.69 ± 0.54^{abc}	10.56 ± 1.12^{abc}	10.96 ± 0.88^{bc}	11.46 ± 0.95^{cd}	13.12 ± 2.21^{d}	15.99 ± 0.73^{e}	18.98 ± 1.72^{f}	9.497
Rhizome breadth (cm)	1.27 ± 0.44^{a}	1.36 ± 0.15^{ab}	1.38 ± 0.46^{ab}	1.64 ± 0.28^{abc}	1.69 ± 0.58^{abc}	1.75 ± 0.36^{abc}	1.74 ± 0.16^{abc}	1.87 ± 0.221^{bc}	2.17 ± 0.31^{c}	0.5

Table 3. Allocation of resources (mean ± SD) towards different plant parts in *B. amplexicaulis* across different study sites.

Traits	Pissutop	Bangus	Dodhpathri	Gulmarg	Lidderwat	Aru	Tangmarg	Dara	KUBG	F value
Rhizome (g)	*9.012 ± 1.13^{a}	9.19 ± 2.95^{a}	10.23 ± 1.27^{ab}	11.30± 2.19^{ab}	12.15± 1.88bc	12.88± 1.41^{bcd}	14.15 ± 1.06^{cd}	15.40± 1.36^{de}	16.92 ± 2.42^{e}	21.009
Stem (g)	0.945 ± 0.27^{a}	0.97 ± 0.22^{a}	1.04± 0.51^{a}	1.05 ± 0.15^{a}	1.083± 0.47a	1.15 ± 0.45^{a}	1.161 ± 0.50^{a}	1.78± 2.95^{a}	1.85± 0.72a	2.951
Leaf (g)	0.98 ± 0.15^{a}	0.91 ± 0.29^{a}	0.76± 0.37^{a}	0.60± 0.33^{a}	0.61 ± 0.12a	0.68± 0.25^{a}	0.65± 0.28^{a}	0.7± 0.20^{a}	0.83± 0.18^{a}	1.029
Inflorescence (g)	0.424 ± 0.06^{ab}	0.44 ± 0.24^{b}	0.34± 0.18^{ab}	0.32 ± 0.10^{ab}	0.33 ± 0.21ab	0.30± 0.20^{ab}	0.247 ± 0.19^{ab}	0.19± 0.08^{a}	0.197± 0.08^{a}	1.584
Total resource budget per plant (g)	11.13 ± 1.23^{a}	11.53 ± 3.00^{a}	12.38± 1.74^{ab}	13.28± 2.06^{abc}	14.19± 2.31abc	15.02± 1.56^{bcd}	16.21± 1.59^{cd}	18.07± 3.85d^{e}	19.81± 2.65^{e}	4.905
Reproductive effort (%)	20.27 ± 0.71^{c}	18.99± 9.63^{c}	17.17± 7.31^{bc}	16.28± 4.33^{bc}	15.78± 7.81abc	14.20± 7.91^{abc}	11.4± 4.7^{abc}	9.39 ± 3.77^{ab}	6.9± 2.56^{a}	15.288

* Means labelled with the small letters designate that they vary significantly from each other amongst the selected populations (Tukey test: $P \leq 0.05$)
*Mean± Standard Error

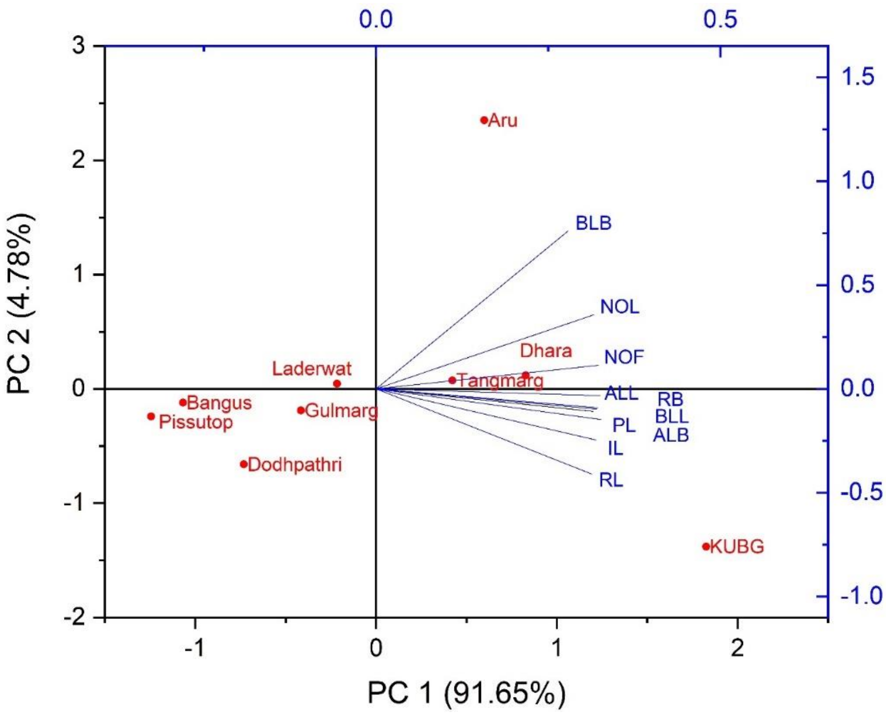

Fig. 5. Principal Component Analysis (PCA) plot of various morphological features of *Bistorta amplexicaulis* across the different study sites.

0.390 g and 0.388 g respectively. A similar trend is followed for stem, leaf and inflorescence. Reproductive effort decreased with decreasing altitude, this is in accordance with various some previous studies [18, 34]. It is also reported that with the increase in plant size, reproductive effort declines [35, 36]. The number of flowers per plant varies significantly ($P \leq 0.05$) along the altitudinal gradient, with lower altitudes having the maximum flowers per plant (Dara, KUBG). In energy-limited environments where survival is the primary concern, resource allocation towards vegetative organs is critical rather than spending resources for the reproductive purposes [37]. The findings support Johnson and Cook's [38] who stated that plants at higher altitudes have lesser flowers than plants growing at lower altitudes. It has also been documented that sexual reproduction in alpine locations is generally low when compared with that of the warmer regions [39].

5. CONCLUSION

It is concluded that environmental heterogeneity is the leading cause of phenotypic variation in *B. amplexicaulis* Our findings demonstrated a diverse variety of favourable environments for the growth of *B. amplexicaulis*. Along an altitudinal gradient, the specie exhibits considerable variability in morphological traits such as stem height, inflorescence length, and leaf and rhizome dimensions. Most of the characters demonstrated a negative correlation with increasing altitude. The most prominent effects were recorded for stem height and leaf dimensions. Given that low altitude population experience less environmental stress, it may be concluded from the current study that these populations were substantially more robust in terms of their morphological characteristics and thus these sites are more suitable for the growth and development of this particular medicinal plant. The total budget (dry weight) showed a negative correlation with increasing altitudes. Further studies related to the effect of other environmental variables such as physicochemical properties of soil and climate (temperature, precipitation and rainfall) would help us to understand if there are any other factors responsible for the phenotypic variability across different altitudes.

6. ACKNOWLEDGEMENTS

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7. CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SUPPLEMENTARY DATA

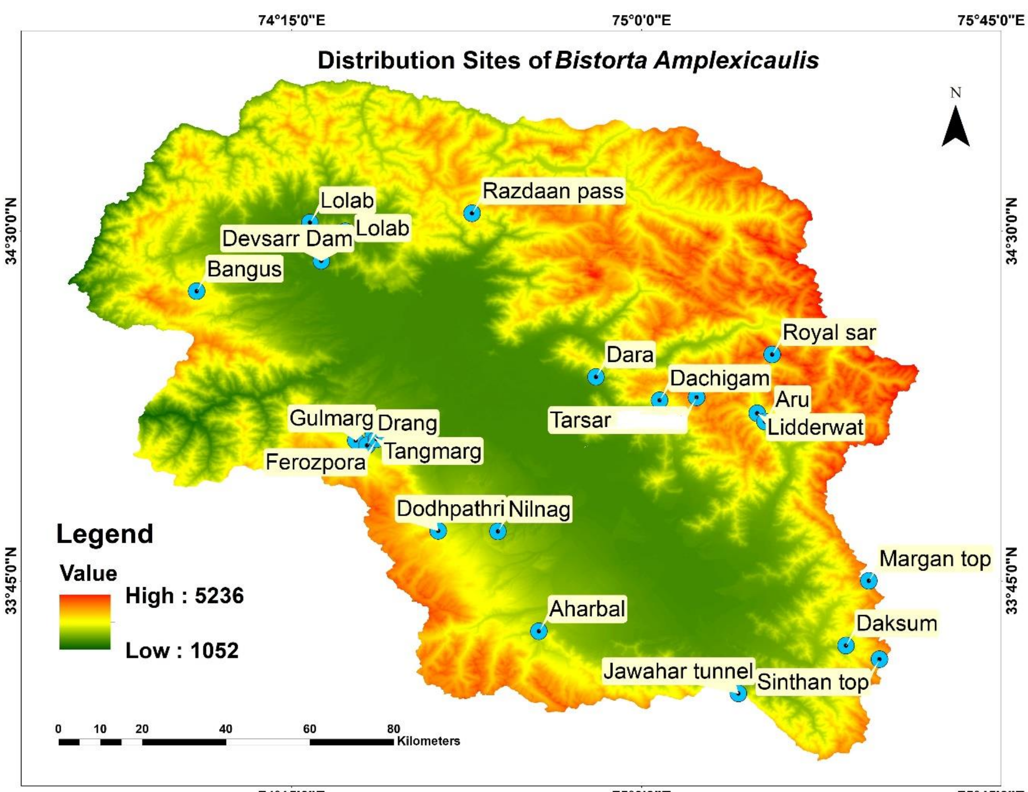

Fig. S1. Map showing distribution sites of *B. amplexicaulis* in Kashmir Himalaya

Fig. S2. Comparative features of different habitats of B. amplexicaulis in Kashmir Himalaya (A) Open, dry and rocky slope (Pissu top) (B) Open, moist and rocky slope (Doodhpathri) (C) Shady slope, moist (Aru) (D) Partial shady, dry and rocky slope (Gulmarg) (E) Partial shady and moist (Tangmarg) (F) Open dry and rocky slopes (Bangus)

Table S1. Different morphological features of *B. amplexicaulis*

Habit	Herbaceous, Perennial
Root	Thick rhizome, with attached fibrous roots.
Stem	Erect 20 - 100 cm, circular in outline
Leaf	Petiolate, lanceolate, Opposite, basal leaves larger (6- 12cm) then apical leaves (4-10 cm), tip acuminate. Leaves are peculiarly stem-clasping (amplexicaule), stipules sheathing giving the stem a jointed appearance at each leaf node.
Inflorescence	Spikes are stalked (2- 9 cm long) rose-red or pinkish in color, narrow, pencil-thin, long-stalked spikes. Flowers are bisexual
Tepals	5, pinkish in colour, proximally connate
Androecium	8 stamens, 5 + 3 arrangement, free, bilobed anthers.
Gynoecium	The ovary consists of three united carpels that form a single locule, which produces only one ovule, ovary superior, basal placentation Styles 3, free; stigmas 3
Fruit	Achene