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BIOMASS ALLOCATION PATTERNS AND THEIR POSSIBLE ROLES FOR ADAPTIVE STRATEGIES IN *BLEPHARIS SINDICA* T. ANDERS – AN ENDANGERED SEROTINOUS MEDICINAL HERB FROM THE INDIAN THAR DESERT

***Purushottam Lal**
Department of Botany, SRRM Govt. College, Jhunjhunu-333001 (Rajasthan), India
**Author for Correspondence: bansiwal.purush@gmail.com*

ABSTRACT
Blepharis sindica T. Anders (Acanthaceae) is an endangered medicinal plant species growing naturally in patchy populations at different parts of the Indian Thar desert. People consume (especially seeds) the species for aphrodisiac and invigorating health benefits. Conspicuous dried and lignified plants in serotinous habit under existing eolian sand burial load reflect species specific adaptabilities to sustain. Plants were found to invest biomass heavily (34.33%) in seed protective features like spike axis, bracts and fruit coats than of actual germplasm (19.15%). Biomass allocation in roots (21.88%) supports both the water absorption from deeper soil layers and to resist uprooting against summer winds to support serotinous habit. Plants were found to invest lowest (8.31%) biomass in foliar system.

Keywords: *Biomass allocation, Adaptive strategies, Serotinous, Medicinal, Eolian, Germplasm*

INTRODUCTION
Despite of hostile ecological conditions, the Indian Thar desert supports several plant species of well documented health benefits (Khan *et.al*., 2003). Arid plants exploit their adaptive features in the most tuned way to survive and reproduce efficiently (Lundholm, 1976; Sen, 1982). Due to ongoing habitat constrains that override species specific life history traits; arid plants have to allocate their biomass more precisely in different body parts to ensure promised future in terms of germplasm production, soil seed pool status and germination efficacies (Poorter and Sack, 2012). Water scarcity and temperature extremities are main physical forces that limit life span of herbs in the arid habitats. Except rainy spells, upper soil layers in deserts remain moisture deficient and plants have to exhibit a particular synchronized growth either as ephemerals or deep rooted annuals/perennials (Charan and Sharma, 2016). During their rapid growth, ephemerals invest more heavily for seed production but annual plants follow specific patterns of biomass allocation for threshold vegetative growth and reasonable seed output. Along with the protection, hard coverings like fruit wall and seed coats increase germplasm durability and the mostly arid plants use this adaptability. Besides dispersed seeds in soil, retaining of germplasm in a protective way by mother plants till upcoming growth season benefits several serotinous herbs (Ezcurra *et.al*., 2020).
Blepharis sindica T. Anders (Acanthaceae) is an endangered medicinal plant species growing naturally in different parts of the Indian Thar desert. Local communities know this species as Billi-khojio/Unt-kantalo/Bhangaro and consume (especially seeds) it for aphrodisiac and invigorating health benefits (Bhandari, 1990; Singh *et al*., 1996; Khare, 2007). Mature plants found to attain a shoot height up-to 55cm during growth season, *i.e.* June-July to December-January. Till the next growing season, the lignified dried plants of previous year remain deep rooted at sandy habitats by holding the germplasm within attached spikes (serotiny habit) and experience the eolian sand burial constrains during successive summer months (Lal *et al*., 2014 & 2020). Unburied capsules are the only source to disperse seeds by explosive mechanism after the mother plants get moistened during initial monsoon showers. Hygroscopic hairs coated membranous seed coats enable the dispersed seeds to imbibe and germinate quickly on moistened soil surfaces.

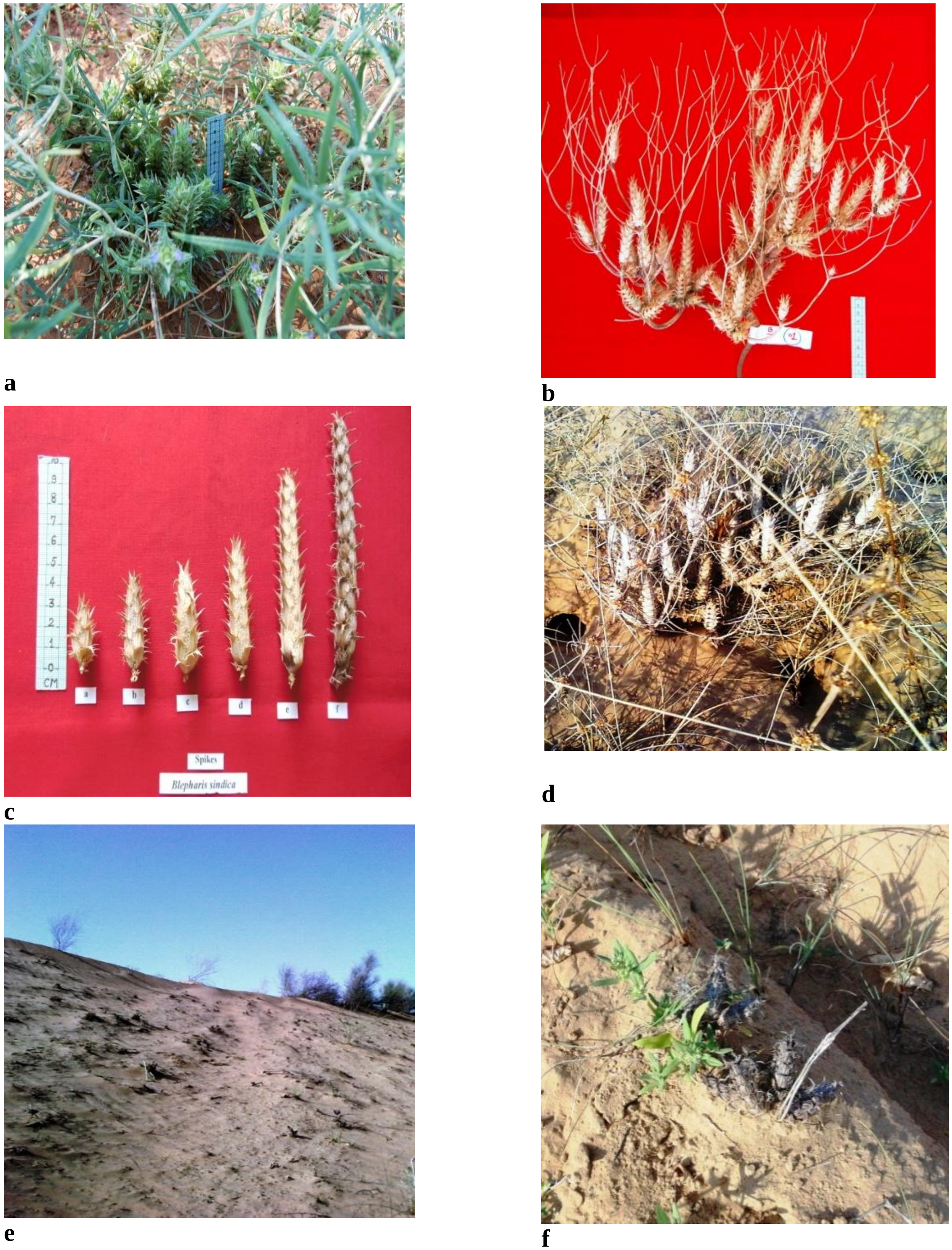


Fig.1 *B. sindica*: A fully developed plant with spikes on lower nodes (a), dried plant bearing capsule loaded spikes reflecting the serotiny habit (b), mechanically separated spikes of different sizes (c), dried plant of previous growth season rooted at sandy habitat (d), sand buried dried plants in summer season (e) and characteristic appearances- Billi-khojio (like cat's claw) given by brown-black colored spikes of buried plant of previous season (f).

Serotinous holding of germplasm within attached spikes, efficacy of seed release during initial rains and seedling establishment are the most vital strategies that limit the size of local patchy populations of this species (Narita and Wada, 1998; Bhatt, *et.al*., 2017).

Serotiny related seed release abilities, eolian sand burial load on dried plants, high predation probabilities of dispersed seeds and excessive moisture availabilities during seedling establishment are the previously reported threats working for the population decline in this species (Mathur, 2014, Lal, *et. al.*, 2020). To withstand against the existing ecological stresses, *B. sindica* plants might have to use their body parts in a precise adaptive way. How far the morphological features of different body parts stand favorably for the species is not yet known. In the present study, an attempt has been made to analyze fractionated biomass contribution in different body parts of *B. sindica* plants. Furthermore, the observed patterns of biomass allocation were interrelated with known adaptive strategies for the species. In essence, the study correlates the biomass allocation strategies with adaptive features of the species under the life threatening conditions of the Indian Thar desert.

MATERIALS AND METHODS

Regular field studies and samplings were carried out during January 2022 to January 2024 from natural habitats of *B. sindica* populations at different localities in arid parts of the Indian Thar desert, *viz.* Shyampura village (28.16’18” N, 74.53’54” E), Buntia village (28.21’11” N, 75.00’45” E), Rashidpura village (27.42’49” N, 75.04’53” E) and Malsisar village (28.22’11” N, 75.18’37” E). Patchy populations at these localities were used to collect plant samples (fresh and dried). Leaf samples (fresh) were collected during September-October (midst of the growth season) from randomly selected 30 plants at each locality. Only 12 leaves per plant were plucked (from second, third and fourth nodes of each plant) and used to estimate leaf dry weight (using oven drying method) values. Total leaves per plant were counted manually (un-plucked) and used to calculate per plant average values of number and dry weights of leaves. Fully dried plants (randomly selected 20 plants from each population in January each year) were used to estimate various parameters (dry sample based). Shoot length and number of spikes (per plant) were calculated directly from 20 rooted plants per population while only 10 plants per population were uprooted to estimate root length and weight values of root, shoot and spikes per plant. Separation of spikes, capsule fruits and seeds (from uprooted plants only) was carried out mechanically by using forceps and pliers. 30 spikes per population were selected (of short, medium and long sizes) to estimate number and weight of seeds. Length and weight values were estimated using graph sheets and single pan digital balance, respectively. Samples from different populations were treated as a single unit and estimated values of all parameters for both seasons were pooled to calculate per plant mean values. Obtained data (triplicate samples x 2 growth seasons) were analyzed statistically as per the methods of Gomez and Gomez (1984). Prior to monsoon showers, unused germplasm (dried plants with attached spikes and separated spikes) was distributed back at the sampling localities to help new germination.

RESULTS AND DISCUSSION

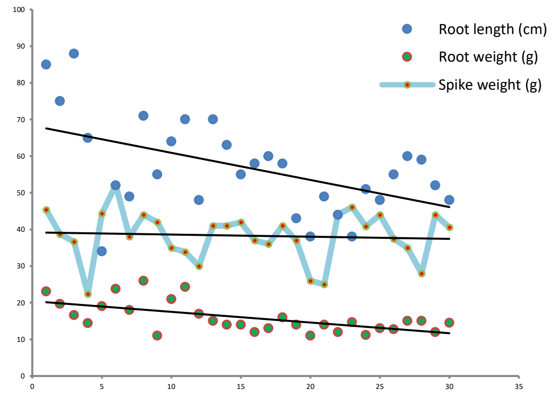
Mean values of different parameters found associated with *B. sindica* plants during the present study are given in Table1. Mean height value was calculated 87.03cm; 65.30% of it’s in the form of root axis (56.83cm) and the remaining 34.70% as shoot length (30.20cm). Sampled plants exhibited greater deviation (SD = ±12.94) for their root lengths in comparison to shoots (SD = ±5.75). Root weight mean value was measured 15.92g while the above ground plant parts were weighted with mean value of 56.85g. As fractions of the shoot part, leaves were found with mean weight of 6.05g, stem and branches for 11.88g and the spikes for 38.92g. Among the above ground body parts, spikes exhibited the highest deviation (SD = ±6.13) for mean weight and leaves with lowest (SD = ±1.32) deviation. Number of spikes and seeds per plant were observed with mean values of 36.60 and 1159.53, respectively. Weight of total seeds per plants was calculated 13.94g with standard deviation value of ±4.11.

Table 1. Various parameters (mean values based on six replicates of both growing seasons) associated with plants of *B. sindica* collected during 2022 and 2023.

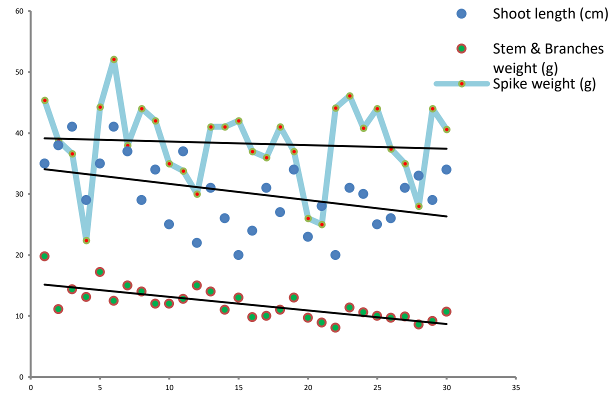
Parameter	Mean Value	SD	CD
Root length (cm)	56.83	± 12.94	0.2207*
Shoot length (cm)	30.20	± 5.75	1.0106*
Root weight (g)	15.92	± 4.15	0.1148#
Stem and branch weight (g)	11.88	± 2.58	0.3219*
Leaves weight (g)	6.05	± 1.32	2.0013*
Spike weight (g)	38.92	± 6.13	0.4007#
Total weight (gm)	72.77	± 10.13	2.3163#
Spikes per plant	36.60	± 3.52	0.6119*
Seeds per plant	1159.53	± 3.08	0.3018*
Weight of total seeds per plant (g)	13.94	± 4.11	2.3191#
Root weight as percentage of plant weight (%)	21.88	± 0.03	0.4065*
Stem and branches weight as percentage of plant weight (%)	16.32	± 0.02	1.2891#
Leaf weight as percentage of plant weight (%)	8.31	± 0.01	0.1172*
Spike weight as percentage of plant weight (%)	53.48	± 0.05	3.2251#
Total seed weight as percentage of plant weight (%)	19.15	± 2.14	1.1083#
Spike axis, bracts and fruit coat weights as percentage of plant weight (%)	34.33	± 1.71	0.4327*

*(# = Significant at $p<0.05$ and * = non-significant at $p<0.05$)*

Mean values for weight of different plant parts were expressed as percentage of the total body weight. Data revealed that 21.88% of the body weight was found to exist as root biomass while the remaining (78.12%) biomass as above ground (shoot) parts fractioned further for stem and branches (16.32%), leaves (8.31%) and spikes (53.48%). Seeds represented 19.15% fraction of the body weight while sterile and protective parts within spikes (like spike axis, bracts and fruit coats) exhibited 34.33% fraction. Data indicates that plants were found to invest heavily for spikes (53.48%) in relation to other parts. 35.81% weight of the spikes were reported to exist as seeds while non-seed parts as remaining 64.19%.
Graphical presentations of observed correlations among different parameters (Fig 2.) revealed that root length values positively depend on root weight values. Longer roots showed stronger dependency on their weight values in compare to shorter ones (Fig 2: a). In arid areas, annual plants are reported with large roots to reach deeper moist soil layers. At their natural growing sites, dried plants of *B. sindica* remain rooted till next growing season with their un-dispersed germplasm protected within clustered, compact, spiny and lignified spikes. For efficient water absorption during growing season and to stand rooted in dried form at sandy areas (facing heavy soil shifting in summer months), deeper roots seems to be more favorable for the species. Present findings indicate that plants allocate more biomass (dry weight) for larger roots for such adaption. Shoot length and shoot (excluding spikes) weight values also reported with strong positive correlation (Fig 2: b). Among the sampled plants from different local populations, shoots were found invariably shorter than roots. It further favors the heavy biomass input for roots rather than shoots. Morphological observations of the green (during growing seasons) and dried plants revealed that clustered spikes located at lower nodes (only few, short and light spikes on upper nodes) form a concentrated biomass for above ground body parts (Fig 1: a & b). Stem and branches were reported to becoming thinner and lighter (due to fistular nature) towards the upper nodes. Leaves were found with smallest biomass share in the entire plant body.



a



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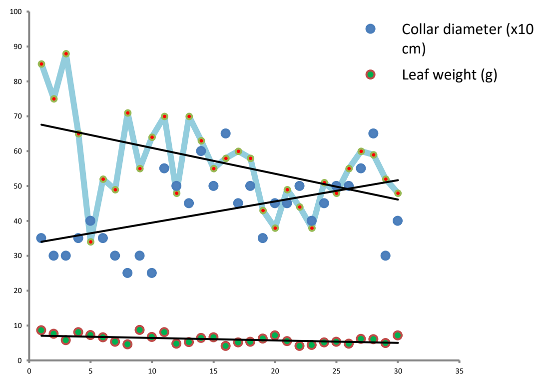

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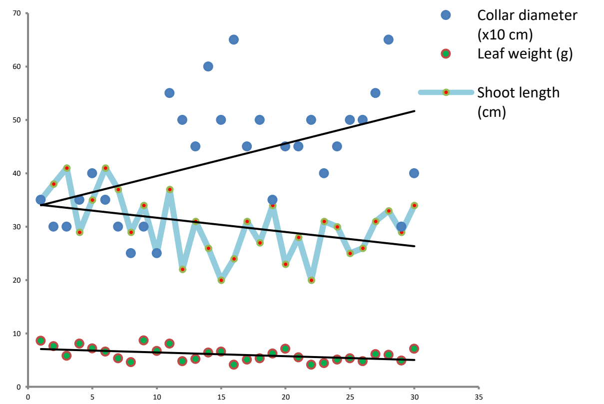

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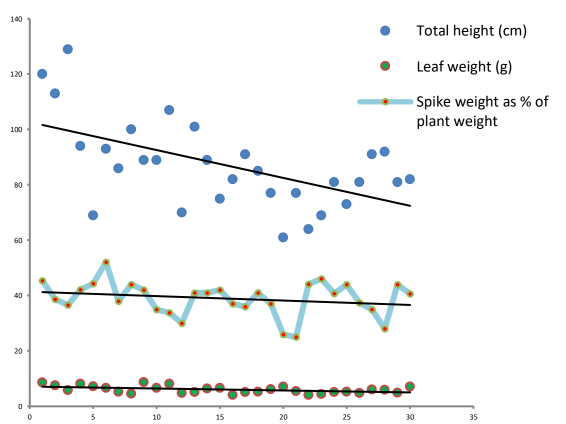

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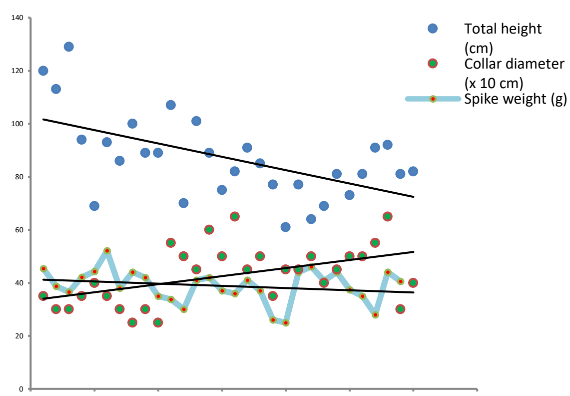

f

Fig. 2. Corelations among various parameters associated with *B. sindica* plants: Spike weight with root length and root weight (a), spike weight with shoot length and weight of stem and branches (b), root length with collar diameter and leaf weight (c), shoot length with collar diameter and leaf weight (d), spike weight as percentage of plant weight with total height and leaf weight (e) and spike weight with total height and collar diameter (f). Data are mean values (30 plants in triplicate for growing seasons, 2022 and 2023).

These findings indicate that upper parts of the shoot system are lighter in weight (with less biomass input) and seems to primarily assist for photosynthetic efficiency. Lower parts of the shoots are heavier with high biomass input in form of thick lignified stem and numerous spikes at lower nodes. Biomass concentration limited to lower nodes of the shoots seems to reduce wind driven uprooting probabilities of the dried plants and supports serotiny habit in the species. The above findings are in agreement with Tonnabel, *et.al*, 2012, who observed heavy biomass allocation in basal body parts for serotiny features in fire-prone areas.

Collar diameter values were observed in negative correlation with that of root and shoot lengths (Fig 2: c, d & f). Within the plant axis length, contributions made by roots were calculated as 88.18% more than of shoots (Table 1) which suggests that the plants with reduced collar diameter produced longer roots. Small standard deviation (SD=±1.11) for collar diameter further indicates that long rooted plants have to invest additional biomass beyond the required amount for a minimal collar diameter. The necessity of a minimal collar diameter supports the role of lignified and woody collar for serotiny habit. The vernacular name- Billi-khojio (like cat's claw) stands for the typical appearance given by "collar cling spikes" turned brown-black at sandy habitat in the area (Fig 1: f).

Spike weight values were observed with negative correlation with root and shoot lengths. Spikes were lighter in taller plants as they seems to invest excess biomass in stem and branches by cutting down their input for spikes (Fig 2: a, b & e). During field visits, taller plants were observed with comparatively few small sized spikes scattered till upper nodes while short sized stout plants having several longer spikes in dense clusters restricted to lower nodes. These observations suggest that taller plant size is attained at a cost of spike mass. Average number of spikes and seeds per plant were calculated 36.60 and 1159.53, respectively. Spike weight values as percentage fraction of the plant weight were observed with a mean of 53.48% that indicates a heavy biomass allocation for spikes in relation to other parts. 64.19% fraction of the spike weights was reported to existing as various spike parts like lignified spike axis, bracts and fruit coats which ensures the serotiny and germplasm protection. Seeds were found to represent 19.15% fraction of the plant weight and being assisted by 34.33% fraction of the plant weight for serotiny and protective features.

CONCLUSION

Serotiny habit in *B. sindica* plants reduces the seed predation possibilities and ensures the germplasm availability to sustain local populations in the naturally growing areas. As a species specific adaptation, *B. sindica* dried plants withstand against eolian sand burial load by adjusting biomass allocation. Plants were found to allocate highest biomass in spikes to prioritize serotinous need. Biomass allocation values for protective and supportive structures stood approximately twice to that of actual seeds. Up-to 22% biomass allocation for longer roots enables plants to absorb water from deeper soil layers as well to resist uprooting in support to serotinous habit. Likewise high seed output, investing more to protect seeds looks highly important for the species under prevailing ecological conditions at the natural habitats. Further studies about habitat specific topographic, meteorological and perpetuation success may provide more clues about the life adjustment efforts existing in the species.

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