J. Indian bot. Soc. (2023)
https://doi: 10.5958/2455-7218.2022.00109.7

e-ISSN:2455-7218, ISSN:0019 - 4468
www.indianbotsoc.org

RESEARCH ARTICLE

Biomass allocation strategy of an invasive alien weed H*yptis suaveolens* (L.) Poit.: Implication for its sustainable management

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Abstract: Biomass allocation is a necessary plant-trait associated with invasiveness of an alien weed. Present work aimed at understanding the invasibility of a tropical American weed *Hyptis suaveolens* L. in Indian dry tropics. Plant traits of this weed at mature stage (shoot length, basal diameter; number of leaves, branches, inflorescences, nodes; biomass of leaf, stem, branch and reproductive components and their mass fractions) and soil characteristics were investigated. Highest aboveground biomass was allocated to stem (42.5%) followed by reproductive part (29.5%), leaf (19.7%) and branch (8.3%). Mean phenotypic plasticity index of biomass fraction traits was relatively higher compared to plant-level morphological traits, indicative of differential biomass allocation strategy as an invasive trait in this weed; where relatively higher reproductive allocation and lower weight of seeds could be attributed to its expansionist invasive character. Thus, the study has implication for sustainable management of *Hyptis suaveolens* in India.

Keywords: *Hyptis suaveolens*, Biomass-allocation, Invasiveness, Plant-traits

Introduction

Hyptis suaveolens (L.) Poit. (family Lamiaceae), native of tropical America, commonly known as Pignut or Bushmint, is considered as a highly noxious invasive weed, reported across several natural ecosystems in tropics and sub-tropics (Raizada 2006, Padalia *et al*. 2014). This weed in India has been reported from Vindhyan region, North-East India, Deccan Peninsula and Andaman and Nicobar Islands (Sharma *et al*. 2017) and Telangana region (Suthari *et al*. 2016). It is basically a pan-tropic, annual and aromatic herb that grows luxuriantly in the months of July-November, along the railway tracks, roadsides and wastelands (Mudgal 1997). This dicotyledonous plant is reported to be of immense medicinal value as it contains essential oils, alkaloids, flavonoids, phenols, saponins, terpenes and sterols (Ziegler *et al*. 2002) with antiplasmodial (Chukwujekwu. *et al.* 2005), anticonvulsant, antirheumatic (Akah and Nwambie 1993), antiinflammatory antinociceptive (Santos *et al*. 2007), antiulcerogenic, carminative and lactagogue properties. Several workers reported its use in various treatments like uterine affections, parasitical cutaneous diseases and gall bladder infections (Ahmed *et al*. 1994, Khare 2007, Koche *et al*. 2010).

Hyptis suaveolens is presently recognised as an aggressive weed invading new environments in Indian dry tropical regions particularly in an around urban and peri-urban ecosystems in Meerut–Saharanpur region including certain protected sites, such as, historically important Hastinapur Wildlife Sanctuary. Such invasive weeds have been observed to expand their area of influence in the anthropic regions through phenotypic plasticity and allelopathic influence (Gupta and Narayan 2010, 2011, 2012, Aggrawal and Narayan 2017). While phenotypic plasticity of an invasive weed can be considered to be a characteristic of adaptational and competitive value for growth and establishment in new environments, its allelochemical potential can be attributed to the chemical nature of the compounds released in soils that may concomitantly impact the survival of the plants or communities in the vicinity.

On the one hand, this weed has been reported to emerge as an important botanical invader in diverse location in the Vindhyan dry deciduous forest, significantly causing alteration in the composition of plant species in Vindhyan

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Received : 1 September 2022 Accepted : 3 October 2022 Published online : 31 December 2022

plateau (Sharma *et al.* 2009). On the others, it has also been reported to significantly impact the floristic composition and soil characteristic across the peri-urban ecosystems in the north western region of India (Sharma *et al*. 2017). There is virtually no ecological investigation on *Hyptis suaveolens* with respect to understanding its invasiveness in rapidly urbanising national capital region (NCR) of Delhi which has witnessed accelerated massive developmental activities in the last 2-4 decades.

The present ecological investigation was undertaken in the urban region of Meerut in NCR to understand its biomass allocation strategy at mature stage, as allocational plasticity is considered as an important trait to adapt to new environment and to invade new areas through its plasticity.

With this focus, the major objective of the present study was to assess the dry matter allocation pattern of *Hyptis suaveolens* to its above ground plant components *viz*. leaf, stem, branch and reproductive parts in relation to soil characteristic.

Materials and methods

Plant species

Hyptis suaveolens

It is a rampant, annual herbaceous weed. Stem of this plant is well-branched, woody, extremely hairy, cubic shape and green or reddish-green in nature, extending up to normally 1-1.5 metre in length. Hairy petiolate leaves are simple, opposite, decussate and ovate or slightly cordate in shape. 2-5 flowers appear in a small cyme which is light purple or pinkish in colour. The calyx is 5mm long and campanulate. The fruit held within the calyx divides into two nutlets, each of which contains a single seed which is about 1.2-2 mm long, dark-brown in colour and slightly notched at the end.

Study area

The present study was carried out at Sanjay Van (28°56'48.07" N lat. and 77°40'26.15" E long.) which was protected during the study period in National Capital Region of Delhi at Meerut, located in western Uttar Pradesh, India. Several annual and perennial exotic weeds are abundant here. Of these, *H. suaveolens* weed has assumed considerable significance on account of its rapid colonizability and ability to occupy new environments impacting the soils and diversity structure of plant communities in the vicinity.

The climate of the study area is semi-arid having three seasons- rainy (Jul-Sep), winter (Nov-Feb) and summer (Mar-Jun).

Biomass sampling

One hundred twenty five mature plant individuals of *H. suaveolens* (hereafter referred to as *Hyptis*) in the seed-developing phase were collected from its different colonies at the study site during late October. Of this eighty randomly selected healthy individuals were investigated for estimation of the biomass in different plant components. The entire plants were harvested by detaching them from their stem base with the help of a sharp knife. Their shoot length (cm), basal diameter (cm), number of leaves, branches, nodes, and inflorescences were recorded. All plant individuals were brought to lab, separated into leaf including petiole, stem, branch and reproductive (inflorescence/flowers/seeds). All separated plant components were placed in oven at 80°C for 48 hr and their dry weights measured. The mass fraction of the separated plant parts i.e. leaf mass fraction (LMF), branch mass fraction (BMF), stem mass fraction (SMF), and reproductive mass fraction (RMF) were estimated as the biomass of each part relative to the total aboveground biomass (AGB). Biomass of each seed was estimated on the basis of dry weight of randomly selected 1000 seeds.

Soil analysis

Four surface soil samples (0-5cm) were randomly collected from different locations of the study site during late October. These samples were air-dried and sieved by 2 mm sieve. Physico-chemical characteristics estimated in this study included soil moisture content, pH, conductivity and total organic Carbon (Walkley and Black 1934).

Plasticity indices and statistical analysis

The degree of plasticity among mature individuals (in reproductive phase) was compared by estimating the plasticity index (PI_v) for each trait (Valladares. *et al*. 2006). The index extreme range includes zero (no plasticity) and one (maximum plasticity). It is evaluated as the difference between the maximum and minimum values of the trait divided by the highest value at a site (Gupta and Narayan 2012). The mean plasticity index for plant-traits of *Hyptis suaveolens* was evaluates by averaging all variables. Pearson-product moment correlation coefficients were generated to evaluate the linear association between thratis and aboveground biomass of the plant individual across the study site. The statistical and graphical analyses were done with the SPSS software (version 25).

Results

Plant traits

The adult individuals of *Hyptis* on mean basis had a shoot length of about 117 cm and basal diameter of 0.74 cm (Table 1). The number of leaves and inflorescences were quite comparable. However, in terms of differential biomass investment, much larger investment was recorded in reproductive component (3.8 g/adult individual) compared to the leaf component (2.5 g/adult individual). Biomass of each seed averaged to 5.7 mg indicative of its light weight. The mean AGB of an adult *Hyptis* plant individual was recorded to be 12.9 g. Of this, the major contribution (6.5 g/adult individual) was made by its support structure (stem and it branches). This is evident from the mass fractions of the plant organs that occurred in the order SMF>RMF>LMF>BMF. This plant had about ten branches on an average. Number of leaves per plant averaged to 166 with mean total leaf biomass value of 2.51 g indicating mean leaf biomass of 15.1 mg per leaf.

Table 1: Plant level traits (Mean±S.E.) of adult individuals of *Hyptis suaveolens* (n=80) in a dry tropical urban ecosystem in India.

Traits	Mean±S.E.
Number of leaves (LN)	166.20±12.81
Number of branches (BN)	9.85±0.67
Number of Inflorescences (IN)	160.40±13.73
Number of Nodes (NN)	20.05±0.50
Shoot length (SL) (cm)	116.58±2.41
Basal diameter (BD) (cm)	0.74±0.02
Leaf biomass (LB) (g)	2.51±0.19
Branch biomass (BB) (g)	1.31±0.16
Reproductive biomass (RB) (g)	3.81±0.27
Stem biomass (SB) (g)	5.18±0.28
Aboveground biomass (AGB) (g)	12.83±0.78
Leaf mass fraction (LMF)	0.19±0.008
Branch mass fraction (BMF)	0.08±0.007
Reproductive mass fraction (RMF)	0.29±0.008
Stem mass fraction (SMF)	0.42±0.012

Investigation of biomass allocation strategy of the adult individuals of this weed to different above-ground plant components indicated the maximum allocation to stem (42.55%), followed by allocation to reproductive parts (29.47%), leaf (19.65%) and branch (8.32%) (Figure 1).

Study site soils were slightly basic to acidic with 1.7% organic carbon and 7.8% moisture content (Table 2).

Relationship among various plant traits

Varying strength and nature of the interrelationship was recorded among plant growth and biomass characteristics (not shown in Table). Of these, the significantly interrelated BN, IN, LB, BB, RB and SB had strong and positive correlations with AGB. LN showed significant positive correlation ($p<0.01$) with IN besides LB. LB also had positive correlation with LN, IN and BB. In contrast to these positively related traits, LN, IN, LB, IB, LMF, BMF and RMF showed significant negative correlations with SMF ($p<0.01$).

Plasticity indices

The plasticity indices (PIv) for morphological plant traits ranged from 0.52 to 0.94 and for plant-level organal biomass fraction traits 0.81 to 0.99 (Table 3). The estimated mean phenotypic plasticity of biomass fraction traits (PIv 0.86) was higher than plant-level morphological traits (PIv 0.77) recorded at the study site. Plasticity indices for SL, BD and NN were lower than LN, BN, IN, LMF, BMF, SMF and RMF.

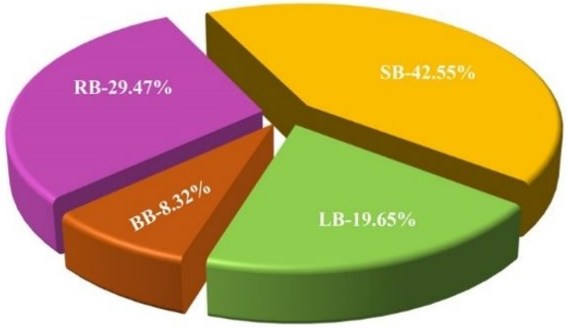
Table 2: Physico-chemical characteristics of soils at the study site.

Soil Characteristics	Mean±S.E.
Moisture content (%) (winter soil)	7.83±0.96
pH	8.07±0.18
Conductivity (mS)	0.20±0.01
Total Organic Carbon (%)	1.77±0.16

Table 3: Plasticity indices of different plant-traits (morphological and organal biomass fraction) in adult individuals of an exotic weed *Hyptis suaveolens* in a dry tropical urban ecosystem (Refer Table 1 for codes)

Plant-level traits			
Morphological		**Biomass fraction**	
LN	0.89	**LMF**	0.82
BN	0.92	**SMF**	0.83
IN	0.94	**BMF**	0.99
NN	0.67	**RMF**	0.81
SL	0.52	-	-
BD	0.65	-	-
Mean value	**0.77**		**0.86**

Figure 1: Biomass allocation strategy of adult plant individuals of exotic invasive weed *Hyptis suaveolens* to different plant components in a dry tropical urban ecosystem in India.



Discussion

Phenotypic plasticity can be considered as a potential mechanism for colonisation success in novel environments (Lehmann and Rebele, 2005). Investigation of biomass compartmentalisation in adult individuals of *Hyptis* in its sites of dominance indicated that the invasibility of this weed could be attributed to significantly higher reproductive biomass allocation (30%), which is higher than that by even *Chenopodium murale* (27%) (Table 4) which has been suggested to rapidly turn into an aggressive invader in Indian dry tropical anthropo-ecosystems (Gupta and Narayan 2012). This trait also highlights its rapid expanding capability in new environments through prolific seed production, which is lighter in weight (5.35g/1000seeds), an invasive character most suitable for wide dispersal and rapid colonisation (Parker. *et al*. 2003)**.** In adult stage, this studied invasive weed differentially allocated less than one-fifth of its AGB to photosynthetic leaf tissues reflecting a remarkable shift in biomass investment strategy at maturity. On the other hand, at this mature adult growth stage >50% stem allocation recorded in the present study is higher than common weeds including *Chenopodium murale* but lower than *Ageratum conyzoides* (Table 4). Its higher stem allocation is indicative of its strategic establishment effort in new environments. More than half of its AGB investment to support structure *viz.* stem and branch, in addition to exhibiting perennial tendency in the investigated region, also allows it to outcompete the neighbouring plants in the vicinity through adverse shading effect and enhanced ability to exploit the aboveground resources e.g. CO_2, solar energy etc. through the leaves located on stem (mean shoot length 117 cm) and branches. In fact, in relatively resource-rich soils, as apparent in the present investigated dry tropical study site (soil organic carbon 1.77%) in comparison to other dry tropical site soils (Gupta and Narayan 2006, 2010, Aggrawal and Narayan, 2017) the competition for above ground resources comes into the major play (Poorter and Nagel 2000). Ontogeny and soil resource states are often

Table 4:. Comparison of biomass allocation to aboveground plant components by some invasive alien weeds across various anthropo-ecosystem in Indian dry tropics

Plant species	Stem (%)	Leaf (%)	Reproductive part (%)	References
Parthenium hysterophorus	46.5	46.5	7.0	Gupta, 2008
Achyranthes aspera	46.5	45.4	8.1	Gupta, 2008
Cassia obtusifolia	46.7	41.1	12.2	Gupta, 2008
Sida cordifolia	39.0	37.0	24.0	Singhal and Narayan, 2014
Sida acuta	38.0	49.0	13.0	Singhal and Narayan, 2014
Ageratum conyzoides	61.1	12.6	26	Chaudhary. *et al*., 2015
Chenopodium murale	46.2	26.4	27.4	Gupta and Narayan, 2012
Hyptis suaveolens	50.9	19.6	29.5	Present study

reported to impact dry matter allocation strategy of a plant species (Maron *et al*. 2004). High plasticity indices for leaf and reproductive organ in the investigated plant species reflected high phenotypic plasticity of this weed, which is considered an important characteristic that facilitates invasibility (Gupta and Narayan 2012). Forty one functional groups of different classes of compounds are reported to be present in studied weed where 95% of functional groups were reported in reproductive components (Lomas *et al*. 2022). This is indicative of various allelochmeical compounds present in this invasive alien plant components (Sharma. *et al*. 2019).

Conclusion

Expansionist nature of the invasive alien weed in Indian dry tropics could be attributes to its relatively high biomass allocation strategy to reproductive parts and the perennial tendency of this annual weed is indicated by highest stem allocation.

Acknowledgments

We acknowledge our sincere thanks to the University Grant Commission, New Delhi, for providing financial support in the form of JRF/SRF to the first author.

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