



Research Article

The morphological traits variation and inter relationships of understorey species of Sal (*Shorea robusta*) forest of north-eastern Uttar Pradesh, India.

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Received: 02/12/2018; Revised: 03/15/2018; Accepted: 03/25/2018

Abstract: Measurements of plant traits are required for evaluating community structure and its ecological responses to varying environmental conditions. The grouping on the basis of functional traits of plants has strong predictive power of important ecosystem responses to environmental perturbation. The morphological traits and their interrelationship among associated species have been analyzed to understand the quantitative variation within regional sal dominated forests. Data for five morphometric traits *viz.*, plant height, leaf length, leaf width, flower size and fruit size, were observed for 193 woody (tree, shrub and liana) species belonging to 56 families within understorey of sal forest. Forty-one families were polytypic in nature. One-way ANOVA was used to detect how variation among all the traits was distributed among habit groups. A significant positive relationship was noticed between plant height and each of the leaf length, leaf width and fruit size. Of the different morphometric traits observed only plant height and fruit size showed wider variation among three life-form categories. Overall, our results suggest that measurement of plant morphometric characters are the major drivers of understory sal associates of the region. Hence, the morphological traits of sal associates should be carefully considered in framing the management and conservation strategy of regional sal forests.

Key words: Sal associates, Morphometric characters, Plant traits, Life form, Habit groups

Introduction

The functional composition of ecosystem has been found to be consistently associated with certain plant functional types and functional richness rather than the species richness (Diaz and Cabido 2001). Various plant functions have strong impacts on ecosystem processes (Cornelissen *et al.*, 1996) and these processes have a strong relationship with various plant traits with respect to their vegetative growth, reproductive strategy and nutrient use efficiency. Traits that determine how a species respond to a disturbance or change in environment (functional response traits) may differ from those that determine how that species affect ecosystem properties (functional effect traits, Lavorel *et al.*, 1997, Walker *et al.*, 1999). A functional group constitutes a set of species that have similar effect on a specific ecosystem process or similar responses to environmental conditions. When many traits are considered simultaneously a plant community can be characterized by the distribution and abundance of its phenotypic traits yielding a functional perspective on the plant community (Doledec and Chessel 1994).

The most favoured plant functional traits are those that are also relatively easy and inexpensive to measure for large numbers of plant species. They are called soft traits (Hodgson *et al.*, 1999) and can

be measured with fair degree of precision (Hendry and Grime 1993, Westoby 1998, Cornelissen *et al.*, 2003). The Inter-specific correlations among traits are the result of the adaptive outcome of natural selection. A particular combinations of traits may be depends over others combination (Lord *et al.*, 1995, Westoby *et al.*, 2002, Wright *et al.*, 2005). A morphological trait like plant height associated with the plant competitive vigour, fecundity and regeneration time after a disturbance (Cornelissen *et al.*, 2003).

Leaf size also linked with plant size, twig size, and architecture. Species with larger leaves tend also to have less frequent branching and to bear larger fruits than species with smaller leaves (Corner's Rules, Corner 1949, Cornelissen 1999, Westoby and Wright 2003). Fonseca *et al.*, (2000) observed 1000-fold variation in leaf size among sets of co-occurring species and suggested that there must be additional costs and benefits associated with variation in leaf size. Other theoretical relation of leaf size with environmental factors and evolutionary approach has been developed by Givnish (1978, 1987), Cornelissen (1999), Gregory-Wodzicki (2000). Morphological traits of reproductive parts of the plants also play an important role in dynamics of plants populations

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because variation in floral morphology is of crucial importance to broadening our understanding of the mechanisms underlying angiospermic evolution. Wright *et al.*, (2007) found an expected relationship among fruit size with plant height and leaf size. A number of studies on plant functional approach are available in India with reference to interrelationship among seed dynamics (Murali 1997), phenotypic traits (Sagar and Singh 2003) and functional trait analysis of liana community in tropical dry evergreen forest (Vivek and Parthasarathy 2015).

However, the functional aspect of morphological traits has been rarely attempted. The plant species content of north-eastern Uttar Pradesh is quite well known through taxonomic and phytosociological studies since 1960s (Srivastava 1976, Pandey and Shukla 2003, Shukla 2009, Srivastava *et al.*, 2015). The grouping on the basis of functional characteristics of plants has strong predictive power of important ecosystem responses to environmental change. We measured five morphological trait attributes of understory woody plants of sal forest. These are maximum plant height, leaf length, leaf width, flower size and fruit size. These traits are also ecologically important traits which reflect their significance in the variation and evolution of focal traits.

Materials and Methods

The forested landscape of north-eastern Uttar Pradesh includes 366 species under 83 families. Data for five morphometric traits *viz.*, plant height, leaf length, leaf width, flower size and fruit size, were observed for 193 woody (tree, shrub and liana) species belonging to 56 families within understory of sal forest. Plant heights (m) were measured with the help of clinometer as the maximum height for each species during field survey. At least 10 separate individuals of a species were used for measurement of height. For leaf trait measurement 20 leaves were taken from 10 non-damaged and mature individuals of a species. We measured leaf length (cm) and leaf width (cm) with simple measuring scale. Leaf length was the maximum length of frond excluding petiole. Leaf width was measured as the maximum diameter of the imaginary circle that can be fitted anywhere in the leaf (Westoby 1998, Cornelissen *et al.*, 2003). For flower size (cm) we measured fully opened, intact flowers with simple scale as the measure of the length of the corolla or perianth followed by Osunkoya (1996). Flower size was grouped into three categories: small (< 2 cm), medium (2-5 cm) and large (> 5 cm). For this trait we measured 3 flowers from each inflorescence of 10 different individuals of each species. Fruit size expanse was measured by multiplying its maximum length and width, accommodating the bias caused by long and linear fruits (Carpenter *et al.*, 2003). The data were analyzed using each species as an independent observation. The G-test for goodness of fit was

used to test for association between the distribution of flower size categories under habit groups and also with polytypic families. One-way ANOVA was used to detect how variation among all the traits was distributed among habit groups. Bivariate trait correlations, across all species were based on a data set of \log_{10} -transformed values. Relationship strength was quantified using regression coefficient (R^2) and P values; relationship slope were described by their model II regression that means standardized major axes (SMA/MA). The data were computed by PAST 3.14 (Hammer 1999- 2012). A critical probability level of $p = 0.05$ was used in hypotheses testing.

Results

Morphometric plant traits *viz.* plant height, leaf length and width, flower size and fruit size of 193 understory plant species belonging to 56 families of sal forest was analyzed. Forty-one families were polytypic in nature. Tree species were quite greater in number followed by lianas and shrubs. These understory species harbor quite large proportion (63%) of small sized flowers followed by medium sized ones. Fewer than 9% of understory plants had large size flower (Fig. 1).

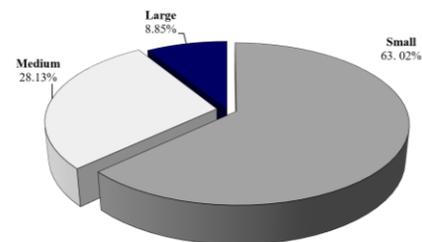


Fig. 1. The percent number of understory species falling within three different flower size groups.

The distribution of flower size was more or less uniform among the three habit groups (Fig. 2) with no significant relationship between the two variables, the flower size and plant height ($\chi^2 = 1.31$, $df = 4$, $P = 0.85$). The flower size was quite variable and significantly different among polytypic families (Fig. 3), ($\chi^2 = 116.02$, $df = 80$, $P = 0.006$). Monotypic families showed no such wide variations.

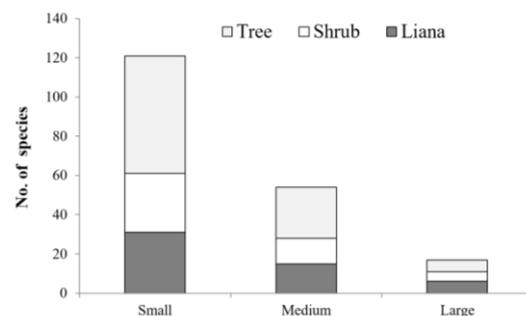


Fig. 2. The number of understory species within three different flower size groups.

Among the polytypic families, Asteraceae, Leeaceae, Poaceae, Samydicaceae, Arecaceae, Celastraceae, Ehretiaceae, Lauraceae, Santalaceae and Ulmaceae mostly possessed small - sized flowers in general. While, 4 families namely, Convolvulaceae, Acanthaceae, Myrtaceae and Santalaceae constituted understory species with medium - sized flowers. The understory species of family Caesalpiniaceae showed greater number of large – sized flowers

(Fig. 3). The fruit size (length × width) was less than 0.1 cm² in *Adenostema viscosum* Forst., *Colebroakia oppositifolia* Sm. Exot., *Embelia ribes* Burm.f., *Callicarpa macrophylla* Vahl., *Mikania cordata* Burm.f., *Wendlandia heynei* (R. & S.) Santapau, *Wendlandia puberula* DC. Prodr. and *Eupatorium odoratum* Linn. The species such as *Haplophragma adenophyllum* Wall. and *Oroxylum indicum* (Linn.) showed fruits large than 100 cm².

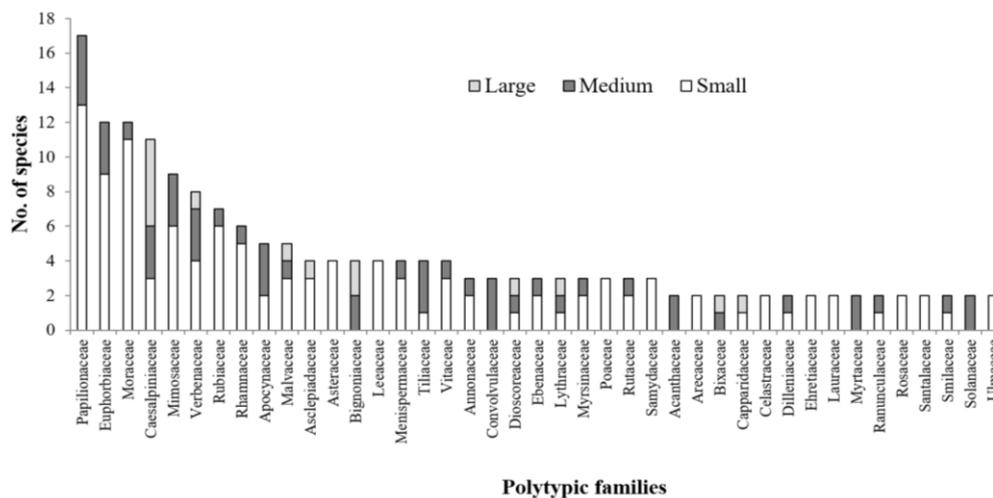


Fig. 3. The number of understory species under polytypic families showing different flower size within forested landscape of north-eastern Uttar Pradesh.

Table 1. Relationship between different traits of understory plants of sal forests of north-eastern Uttar Pradesh.

Trait variables#	R ²	t	P	Regression model*
Plant height				
Leaf length	0.025	2.23	0.026	$y = 0.479 + 0.556x$
Leaf width	0.045	2.98	0.003	$y = - 0.137 + 0.809x$
Flower size	0.007	1.21	0.226	
Fruit size	0.039	2.81	0.005	$y = - 9.564 + 11.43x$
Leaf length				
Leaf width	0.591	16.56	<0.0001	$y = - 0.470 + 1.073x$
Flower size	0.001	0.58	0.562	
Fruit size	0.003	0.76	0.445	
Leaf width				
Flower size	0.019	1.93	0.054	
Fruit size	0.0005	0.31	0.75	
Flower size				
Fruit size	0.132	5.39	<0.0001	$y = - 0.293 + 4.134x$

#Trait variable are measured in centimeter (cm), except plant height (m) and flower size (cm²). * The model is based on standardized major axis (SMA/MA) regression and is only shown for significant relation. Significant probability levels are shown in bold. All traits were log₁₀-transformed prior to analysis. N = 192.

The relationships among the various morphometric traits are shown in (fig. 4-7) and (Table 1). A significant positive relationship was noticed between plant height and each of the leaf length, leaf width and fruit size. These trait associations were albeit quite weakly related (Fig. 4a, b, d and table 1) but the leaf length and leaf width showed strong and positive correlation (R² = 0.59, P < 0.0001, (Fig. 5a, Table 1). Flower size and fruit size also showed strong positive association (R² = 0.13, P < 0.0001, (Fig. 7, Table 1). Thus, only 13% change in the fruit size was statistically affected by flower size. Correlation between plant height and

flower size, leaf length and flower size and with fruit size (Fig. 5 b,c) and that between leaf width and flower size and the fruit size was quite weak (Fig. 6a, b). The mean values of five functional traits of the three habit groups are shown in (Table 2). Of these, plant height (F value = 55.88, P < 0.0001) and fruit size showed significant variation among the three habit groups (F value = 4.44, P = 0.01). Further the mean difference of leaf length (P = 0.57), leaf width (P= 0.08) and flower size (P = 0.78) among different habit groups were non-significant (Table 2).

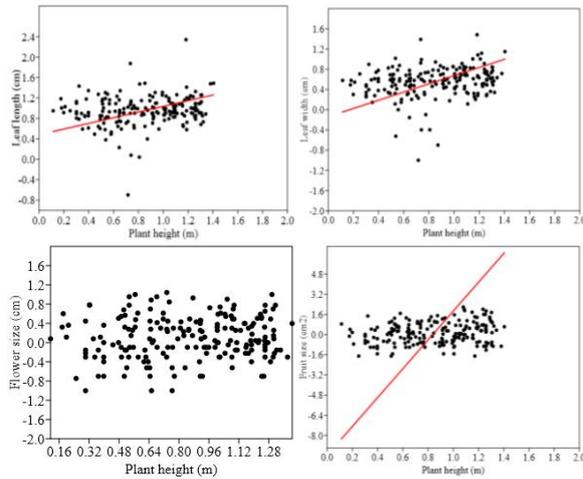


Fig. 4. Relationship between plant height with leaf length (a), leaf width (b), flower size (c) and fruit size (d)

Among 193 woody understorey species within forested landscape of north-eastern Uttar Pradesh. Each data point represents \log_{10} -transformed value for a species. Regression statistics are given in Table 1. The straight line indicates significant association. The Standardized major axis (SMA/MA) slopes (and 95% confidence interval) of significant traits are as follows: (a) leaf length: 0.556 (−0.924, 1.012), (b) leaf width: 0.809 (−0.428, 1.325), (d) fruit size: 11.43 (−10.577, 16.035).

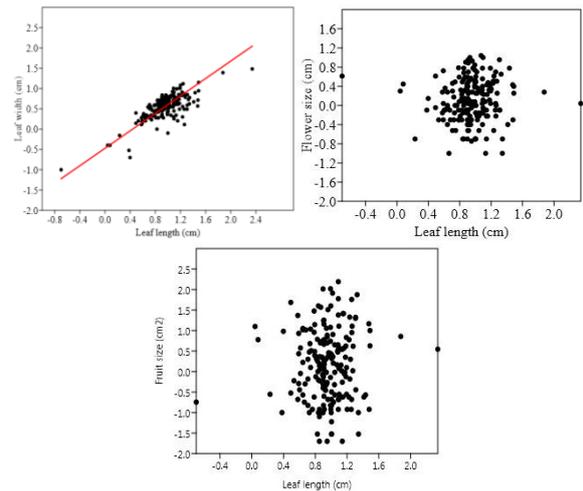


Fig. 5. Relationship between leaf length with leaf width (a), flower size (b) and fruit size (c).

Each data point represents \log_{10} -transformed value for a species. Regression statistics are given in Table 1. The straight line indicates significant association. The SMA slopes (and 95% CI) of significant trait are as follows: (a) leaf width: 1.073 (0.832, 1.222).

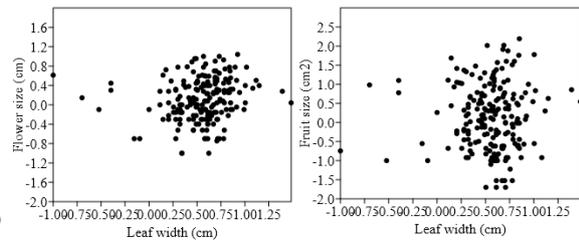


Fig. 6. Relationship between Leaf width with flower size (a) and fruit size (b).

Each data point represents \log_{10} -transformed value for a species. Regression statistics are given in Table 1. The lack of straight line indicates non-significant association.

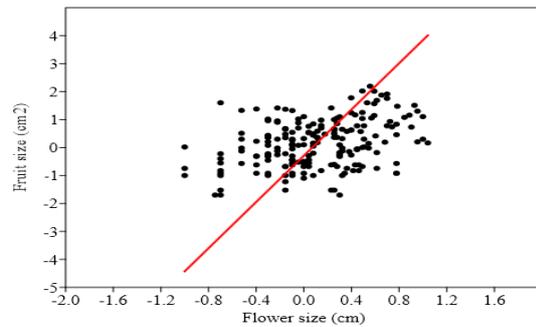


Fig. 7. Relationship between flower size with fruit size.

Each data point represents \log_{10} -transformed value for a species. Regression statistics are given in Table 1. The straight line indicates significant association. The SMA slopes (and 95% CI) are as follows: (a) leaf width: 46.534 (−312.65, 609.38).

Table 2. The Mean \pm S.E. values with their ANOVA test between plant functional traits of sal forest of north-eastern Uttar Pradesh.

Functional traits	Tree	Shrub	Liana	F	P
Plant height	12.11 \pm 0.57 ^{b,c}	3.18 \pm 0.50 ^{a,c}	9.11 \pm 0.75 ^{a,b}	55.88	<
Leaf length	12.68 \pm 2.35	9.52 \pm 0.76	11.62 \pm 1.48	0.56	0.57
Leaf width	4.48 \pm 0.37	3.57 \pm 0.28	5.02 \pm 0.52	2.50	0.08
Flower size	1.92 \pm 0.19	1.14 \pm 0.35	2.13 \pm 0.31	0.24	0.78
Fruit size	11.98 \pm 2.69 ^d	2.81 \pm 1.08 ^d	5.25 \pm 1.19	4.44	0.01

Similar letters in the row indicates significant variation ($P < 0.05$) among tree, shrub and liana after Bonferroni's multiple comparison test.

Discussion

The morphological traits and their interrelationship among understorey species have been analyzed to understand the quantitative variation within regional sal dominated forests. Trait-based approaches have been increasingly adopted to disentangle the different processes in community ecology (Kraft et al., 2008, Messier et al., 2016). The patterns of trait variation can be observed at different ecological scales or for different regions (Roche et al., 2004, Hulshof and Swenson 2010, Messier et al., 2010, Auger and Shipley 2013, Kang et al., 2014).

The understorey vegetation of the regional sal forest was studied to investigate the trait relationship among the species of this stratum. A greater proportion of species exhibited small-sized flowers. It may be due to the fact that flower visitors are showed to the wide array of unspecialized flowers within the community (Bawa *et al.*, 1985). These unspecialized flowers may partly be attributed to the scarcity of larger unspecialized insects. Such cases have been reported from Hawaii, New Zealand and Australia (Lloyd 1985). The observation suggested that the relationship between that plant height and flower size, leaf length and flower size, leaf length and fruit size, leaf width and flower size and leaf width and fruit size are orthogonal and the orthogonality of these morphometric parameters indicate that the dimensions among different parameters convey essentially different information (Ackerly 2004). Despite this, several quite consistent and positive but mostly weak relationships were found between plant height and each of leaf length, width and flower size and fruit size in regional sal forest. However, a strong positive relationship was evident between leaf length and leaf width as also reported elsewhere (Valencia *et al.* 2016). Leaf size and its interspecific variation is important in terms of leaf energy and water balance since it is connected with climatic variation.

A tendency for larger species to have larger fruit was observed in the region and has also been recognized by several workers (Leishman *et al.*, 2000, Moles *et al.*, 2004, Wright *et al.*, 2007). It is unclear why larger species tend to have larger fruits while, logically, there must be a physical constraint whereby small plants could not support large fruits. (Cornelissen 1999 and Wright *et al.*, 2007) reported positive correlation between leaf size and fruit size while, in the present forest such relationship was not noticed. It may be due to the fact that the dimensions of leaves and fruits were limited only to their maximum length and width. Our data concur with Osunkoya (1996) in that, there is significant positive correlations between fruit size and flower sizes. Whitney and Rudgers (2009) also observed similar results for 472 plant species from three flora of USA. Plant height was associated with the competitive vigour, fecundity and regeneration time of the plant species after a disturbance (Cornelissen *et al.*, 2003). Generally, shade – tolerant species invest more in lateral expansion of the crown, thus, increasing light interception under shaded conditions. Whereas light – demanding species invest more in height growth to avoid being shaded neighbours (Shukla and Ramakrishnan 1986). The qualitative analysis and the relationship among ecologically important morphological plant traits provides better understanding of morphological trait variation of species of understorey of regional sal dominated forests.

Acknowledgments

We are thankful to the Head, Department of Botany, DDU Gorakhpur University, Gorakhpur for providing laboratory facilities and forest officers of Gorakhpur Forest Division for their active cooperation in the field. The authors are thankful to Prof. (Dr.) Hatice Nurhan Büyükkartal for their comments and suggestions.

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Cite this article as:

Satish Kumar Rai, Ravindra P. Shukla and Sanjay Kumar Pandey. The morphological traits variation and interrelationships of understorey species of sal (*Shorea robusta*) forest of north-eastern Uttar Pradesh, India. *Annals of Plant Sciences* 7.4 (2018) pp. 2178-2184.

 <http://dx.doi.org/10.21746/aps.2018.7.4.18>

Source of support: Department of Botany, DDU Gorakhpur University

Conflict of interest: Nil