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Research Article

Variations in functional leaf traits of trees and shrubs in the semi-arid regions of Haryana, India

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Abstract
The concept of functional diversity is critical in the field of forest ecology as it helps determine trends in community structure and worldwide change by examining variations in functional traits among plants. Functional traits like leaf traits, stem traits, root traits etc., are characteristics of a species that incorporate its ecological and evolutionary history and can be used to predict both its response and impact on ecosystem function. During the present study, six functional leaf traits viz., leaf size (LS), specific leaf area (SLA), leaf dry matter content (LDMC), leaf nitrogen content (LNC), leaf phosphorus content (LPC), and leaf nitrogen to phosphorus ratio (N:P) were evaluated for a variety of trees and shrubs in the forests of semi-arid regions of Haryana, India i.e., Site I-Dulana (Mahendergarh), Site II-Kheri Batter (Charkhi Dadri) and Site III-Asalwas Dubia (Bhiwani). Functional leaf trait values showed a significant variation. LS was reported to be positively correlated with SLA(0.39) and N:P(0.11) while negatively correlated with LDMC(-0.26) LNC(-0.29) and LPC(-0.16). The selected plant species displayed a negative but weak correlation between SLA and LNC(-0.05) whilst a strong positive correlation between Nitrogen (N) and Phosphorus (P)(0.36). All three Sites had the value of N:P ranging from 12.58 to 65.69, thus exhibiting P limitation. The present study advances the field of functional ecology in Haryana's tropical dry forests significantly. This is also crucial to forecast community formation trends and characterize the contributions of different species to ecological processes.

Keywords: Community structure, Ecosystem functions, Functional diversity, Functional leaf traits

INTRODUCTION

Among the concerns impacting the ecosystem of planet Earth that has received the most research and discussion in recent years are alterations in nutrient cycling, global warming and climate change (Zandalinas *et al*., 2021) that necessitate a thorough knowledge of the linkages among both environment and plants. Functional traits (FTs) are characteristics that integrate a species' ecological and evolutionary history of predicting its reaction and influence on ecosystem functioning. Therefore, one of the fundamental problems in plant biology, agricultural science, and ecology is identifying the links between leaf attributes. Thus, FTs studies have sparked a surge of interest in ecological and ecophysiological research in current years(Osnas *et al.*,2018).

Functional diversity is a key concept in functional ecology that describes the importance, distribution, and relative frequency of FTs in a particular ecosystem. They can be categorized according to their usefulness in a specific approach (Cornelissen *et al.,* 2003), i.e., intact plant traits (e.g. growth forms, plant height), stem traits (thickness of bark), below ground traits (specific root length) and Functional Leaf traits (e.g. Leaf tensile strength, SLA, LDMC, LNC, etc.).

Changes in ecological factors may significantly influence trees' drought survival mechanisms, changing the species diversity of communities with water-limited tropical dry forests (TDF) (Sullivan *et al*., 2020). Ecosystem functioning can be predicted by trait composition and environmental factors, although these correlations differed depending on the functions that were measured (Zirbel *et al*.,2017). PFTs is now a primary focus in plant ecological studies. Because of its accessibility, leaf attributes are the most intensively researched traits and the analysis of their differences among plants can forecast trends in community struc-

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ture and changes at the global level. The characteristic information regarding PFTs is urgently needed at both local and global scales to perform successful restoration against the effects of climate change (Garnier *et al.,* 2016).

The construction of a comprehensive database for PFTs is now a primary focus in plant ecological studies since it aids in interpreting and modelling biodiversity in future and current ecosystems (Westoby, 1988; Keddy, 1992). Leaf functional trait (LFT) display successful ecological plant strategies as the leaves are exposed to diversified environmental conditions and leaf traits enable plants to survive in severe conditions (Cochrane *et al.,* 2016).

Despite such huge studies carried out in the direction of functional ecology around the world, only a few studies have been reported in the tropical dry deciduous forests of India (Dubey *et al.,* 2017; Ratnam *et al.,* 2019; Dhiman *et al.,* 2021; Kaushik *et al.,* 2022). Hardly any attention has been given to investigating the functional diversity of plant species in Haryana's dry deciduous forests. No such research has been observed in the literature from the selected area. Ecosystem services and functional diversity are closely associated, as any changes in PFTs affect the environmental services that particular vegetation delivers (de Bello *et al.,* 2010). Furthermore, investigating LFTs at the regional scale is critical for gaining a better understanding of trait-environment interactions at the global level and developing predictive models. So, the present study aimed to investigate the functional diversity of trees and shrubs species in three tropical dry deciduous forests of southern Haryana State, namely Kheri Batter (Charkhi Dadri), Asalwas Dubia (Bhiwani), and Dulana (Mahendergarh).

MATERIALS AND METHODS

Study site

Haryana (29° 3' 56.7828'' N and 76° 2' 25.7892'' E) is part of the Indo-Gangetic plain and is located in the northwest of India. It is mainly an agricultural state with a geographical area of 80% under agriculture while only 3.62% area under forests. Forests of Haryana are mainly of three types, according to Champion and Seth (1968); Tropical Dry Deciduous Forests, Subtropical Pine Forests and Tropical Thorn Forest.

The present study was carried out in the Tropical dry deciduous forests of the three different districts of southern Haryana viz; Dulana (Mahendergarh)- site I, Kheri batter (Charkhi Dadri)- site II, and Asalwas dubia (Bhiwani)- site III (Fig. 1). In southern Haryana, the canopy cover was about fully deciduous in dry seasons and was often broken and disturbed by anthropic activi-

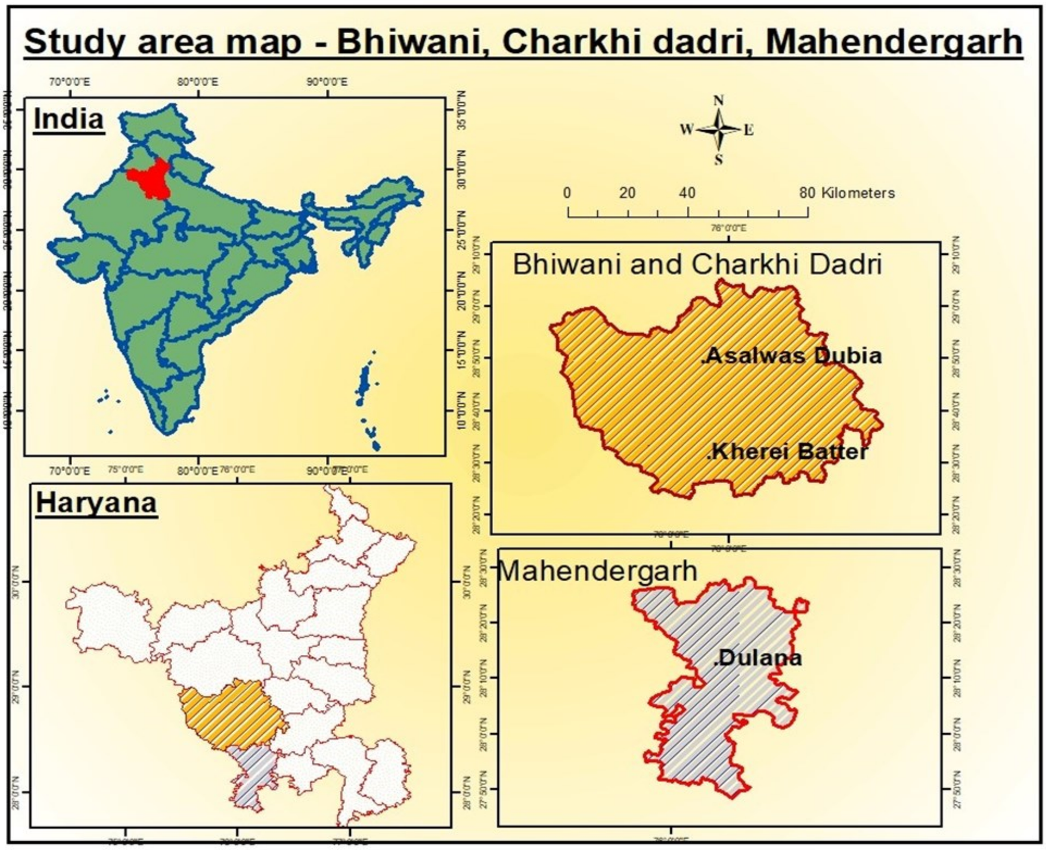

Fig. 1. *Showing the location of the selected forest sites in the selected districts of Haryana*

ties. The sites were selected on the basis of field observations and the type of flora present. All three forests are in southern Haryana but differ in their abiotic conditions and floristic composition. The average annual rainfall and temperature of Mahendergarh were 500mm and 26.4°C, respectively, with vast sandy and alluvial tracts. However, the mean annual temperature of Charkhi Dadri ranged from 16°C- 37°C with extreme seasonal variations in monthly rainfall. Other than this, Bhiwani's average annual temperature and rainfall were 25.2°C and 533mm respectively. The forests selected for the functional trait analysis are representatives of the tropical dry forests in southern Haryana.

Sampling of plants and leaf traits analysis

A total of 15 plots were selected randomly on the three sites and the leaf samples were collected from each plot from the encountered species of Trees and Shrubs. Five leaves were plucked from the adult plants carefully to avoid the leaves having effects of pathogen attacks or herbivore symptoms. The fresh leaves were put inside sealed plastic bags to avoid excessive water loss and carried to the laboratory in the ice box to test leaf traits. Fresh weight (FW) of each turgid leaf was taken and the leaves were placed further in the oven for 48hrs at 60°C temperature. The leaf area or leaf size (LS) was measured using Systronics Leaf Area Meter 211. The specific leaf area (SLA) was deliberated as the ratio of leaf size ((mm^2)/DW (mg), while leaf dry matter content (LDMC) was estimated as the ratio of DW (mg)/FW (mg). Leaf phosphorus content (LPC) was estimated by Vandomolybdo phosphoric acid yellow color method (Jackson, 1973). Leaf nitrogen content (LNC) was calculated by Khjeldal method using Kel -plus nitrogen analyzer (Bremner and Mulvaney, 1982).

Statistical analysis

Pearson correlation was executed on the data for statistical analysis, and a histogram was prepared using R Studio.

RESULTS

Interspecific leaf trait analysis can result in a variety of consequences. Plants with similar habits (Trees or Shrubs) that live in close proximity to each other may have radically diverse features. During the present study, 6 trees and 5 shrubs were reported from Site-I, 9 trees and 6 Shrubs from Site-II, while 10 Trees and 7 Shrubs were reported from Site-III. Functional leaf trait values showed a significant variation for different plant species within the same site and among different sites. The highest Leaf size (LS) among tree species was obtained for *Acacia nilotica* (723.1 mm^2/mg), *Ficus bengelensis* (12333.3 mm^2/mg) and *Morus alba* (9559.4 mm^2/mg) in the forests of Site-I, Site-II and Site -III, respectively (Tables 1-3). Whereas, in the case of shrub species *Calotropis procera* obtained the maximum value for LS on all the three sites selected during the study (Site-I=8890.4 mm^2/mg, Site-II=7946.6 mm^2/mg, Site-III=8266.1 mm^2/mg). Other than this, the maximum value for Specific leaf area (SLA) at Site-I, II and III was observed for *A. nilotica* (18.07 mm^2/mg), *F. religiosa* (19.94 mm^2/mg), *M. alba* (37.63 mm^2/mg) in case of trees and *Parthenium hysterophorus* (18.64 mm^2/mg), *C. procera* (12.96 mm^2/mg) and *Abutilon indicum* (16.78 mm^2/mg) for shrubs respectively.

Across all three study sites, the maximum values of leaf dry matter content (LDMC) were observed for *A, leucophloea* (486.3 mg/g), *Azadirachta indica* (401.8 mg/g) and *Salvadora oleoides* (451.6 mg/g) for trees on Site I, II and III respectively.

While for shrubs, the maximum values of LDMC on Site-I, II and III were obtained for *Ziziphus nummularia* (483.33 mg/g), *A. indicum* (394.06 mg/g) and *Solanum viarum* (552.4 mg/g) respectively. The leaf nitrogen content (LNC) value for trees varied from 24.5 to 48.4 mg/g, while for shrubs it ranged from 11.2 to 43.4 mg/g on the selected study Sites. The highest value of LNC for trees on Site- I and II was recorded for *Albizia lebbeck,* i.e., 48.4mg/g and 36.9mg/g, respectively, while on Site-III *A. indica* (44.4mg/g) had the maximum LNC value. Whereas, among shrubs, maximum LNC was recorded for *P. hysterophorus* (29.6 mg/g), *Maytenus emarginata* (41.3mg/g) and *A. indicum* (43.4 mg/g) on Sites- I, II and III respectively (Table 1-3). Other than this, the value of LPC on the three study sites varied from 0.6 to 1.7 mg/g and 0.59 to 0.95 mg/g for trees and shrubs, respectively. The maximum value of LPC among tree species was observed for *A. leucophloea* on all three Sites (1.7 mg/g on Site I, 0.86 mg/g on Site - II and 0.87 mg/g on Site- III). In the case of shrubs, the maximum value for phosphorus was noted for *A. indicum* (0.8 mg/g) on Site-I, while for *M. emarginata* (0.95 mg/g, 0.91mg/g) on Site- II and III. Consequently, the N:P value for all the plant species varied from 12.58 to 40.34 for Site- I, 35 to 51.37 for Site -II and 26 to 65.69 for Site –III.

The Pearson correlation was determined for the six leaf attributes throughout the study, and a histogram was prepared using R Studio (Fig. 2). It showed that LS was positively correlated with two traits i.e., SLA (r = 0.39) and N:P (r = 0.11) while, negatively correlated with other three traits i.e., LDMC (r = -0.26), LNC (r = -0.29), LPC (r = -0.16). Other than this, a negative correlation was observed between SLA and LDMC (r = -0.23). Similarly, a negative but weak correlation was seen between SLA and LNC (r = -0.05) but a very significant positive correlation was observed between LNC, LPC and N:P.

DISCUSSION

Table 1. Functional leaf traits of plant species (trees and shrubs) in the tropical dry deciduous forests of Dulana (Site-I), District Mahendergarh, Haryana

S.No.	Plant name	Family	LS (mm^2)	SLA (mm^2/mg)	LDMC (mg/mg)	LPC (mg/g)	LNC (mg/g)	N:P
	Trees							
1	*Albizia lebbeck*	Fabaceae	317.4	9.335	216.56	1.2	48.4	40.34
2	*Acacia leucophloea*	Fabaceae	432.2	4.856	486.3	1.7	36.2	21.29
3	*Acacia nilotica*	Fabaceae	723.1	18.07	291	0.9	27.3	30.33
4	*Azadirachta indica*	Meliaceae	712.5	8.28	419.5	0.7	32.9	47
5	*Prosopis juliflora*	Fabaceae	282.5	14.69	346.3	1.25	42.3	33.84
6	*Salvadora oleoides*	Salvadoraceae	446.2	4.09	365.7	0.8	28.4	35.5
	Shurabs							
1	*Abutilon indicum*	Malvaceae	1186.2	12.10	343.85	0.93	28.7	30.86
2	*Calotropis procera*	Asclepiadaceae	8890.4	11.83	135.07	0.9	24.9	27.66
3	*Parthenium hysterophorus*	Asteraceae	1286.7	18.64	242.1	0.75	29.6	39.46
4	*Solanum viarum*	Solanaceae	693.3	9.142	290.54	0.89	11.2	12.58
5	*Ziziphus nummularia*	Rhamnaceae	590.6	10.18	483.33	0.69	24.5	35.50

LS- Leaf Size, SLA-Specific Leaf Area, LDMC-Leaf Dry Matter Content, LPC- Leaf Phosphorus content, LNC- Leaf Nitrogen Content, N:P- Ratio of leaf nitrogen and phosphorus content.

More and more research has shown that functional diversity, rather than species diversity-determines, how well ecosystems function (Naeem *et al.,* 1994; Tilman *et al.,* 1997; Loreau *et al.,* 2001; Díaz *et al.,* 2007; Fornara and Tilman, 2008). Thereby, for understanding forest ecosystem processes, determining the functional trait composition of forests is currently emphasized more than evaluating species richness (Díaz and Cabido, 2001; McGill *et al.,* 2006; Roscher *et al*., 2012). Functional traits offer the capacity to characterize how community functional composition responds to environmental gradients and influences ecological processes and service delivery. Research into leaf characteristic variability might help predict the effects of management and restoration initiatives on a regional and global scale. The functional trait technique can help with the creation of models that show the relationship between traits and species responses to management and restoration initiatives. Plant functional features have already been studied in the context of ecosystem restoration and management (Sandel *et al.,* 2011; Lavorel *et al.,* 2011; Roberts *et al.,* 2010; Gondard *et al.,* 2003). The leaf traits evaluated in this study were shown to have a substantial correlation with one another. The same method of plant functional ecology was integrated with floristic investigations to gain a better knowledge of forest traits and processes in the Central Highlands of Chiapas State, Mexico (Bolom-Ton, 2016).

During the current investigation, the LS of plant species varied from 193.3 mm^2 for *Prosopis juliflora* to 12333.3 mm^2 for *Ficus bengelensis* in the selected forests (Table 2). In areas of Tropical dry deciduous forests small-sized leaves and lobbed leaves are several strategies that enhance the ability for heat dissipation and are more advantageous than leaves with high leaf area due to high solar radiations and dry environment (Peguero-Pina *et al*., 2020). Other than this, the value of SLA for trees varied from 4.09 to 18.07 mm^2/mg, 4.15 to 19.94 mm^2/mg and 1.559 to 37.63 mm^2/mg on the three study sites, i.e., Site-I, site-II and Site-III respectively. On the other hand, for shrubs, the value of SLA ranged from 9.142 to 18.64 mm^2/mg, 6.4 to 12.96 mm^2/mg and 8.81 to 16.78 mm^2/mg for the three sites, i.e., Site-I, II and III respectively (Table-1,2,3). So, the shrub species were observed to have a high value of SLA in comparison to tree species. This can be supported by the results of Ordonez *et al.* (2010) and Gong *et al.* (2020), who also reported low value of SLA for trees than shrubs during their study of soil and climate effects on key leaf traits in northeastern China.SLA is one of the most commonly used key characteristic leaf traits affected by growth environments. Species with typically low specific leaf area values are geared for the conservation of acquired resources due to their large dry matter content, high concentrations of cell walls and secondary metabolites, and high leaf and root longevity. Due to their high dry matter content and secondary metabolites, species with low specific leaf area values are orientated towards conserving acquired resources. Low

Table 2. Functional leaf traits of plant species (trees and shrubs) in the tropical dry deciduous forests of Kheri Batter (Site-II), District Charkhi Dadri, Haryana

S. No.	Plant name	Family	LS (mm^2)	SLA (mm^2/mg)	LDMC (mg/mg)	LPC (mg/g)	LNC (mg/g)	N:P
	Trees							
1	*Acacia leucophloea*	Fabaceae	387.8	4.357	342.3	0.86	30.1	35
2	*Albizia lebbeck*	Fabaceae	486.7	15.20	326.5	0.75	36.9	49.2
3	*Azadirachta indica*	Meliaceae	744.3	8.45	401.8	0.67	32.9	49.10
4	*Dalbergia sissoo*	Fabaceae	1320.6	11.89	346.8	0.66	24.5	37.12
5	*Ficus bengelensis*	Moraceae	12333.3	7.613	347.1	0.6	26.3	43.83
6	*Ficus religiosa*	Moraceae	7220	19.94	329.9	0.65	26.6	40.92
7	*Morus alba*	Moraceae	9286.3	13.41	372.4	0.7	30.1	43
8	*Prosopis juliflora*	Fabaceae	193.3	6.04	240.6	0.85	36.4	42.82
9	*Salvadora oleoides*	Salvadoraceae	423.9	4.15	344.59	0.75	27.3	36.4
	Shrubs							
1	*Abutilon indicum*	Malvaceae	1198.2	12.86	394.06	0.8	41.1	51.37
2	*Carissa spinarum*	Apocynaceae	812.3	9.23	331.4	0.79	38.2	48.35
3	*Calotropis procera*	Asclepiadaceae	7946.6	12.96	147.6	0.8	35.7	44.62
4	*Maytenus emarginata*	Celesrtaceae	671.1	11.09	212.6	0.95	41.3	43.47
5	*Parthenium hysterophorus*	Asteraceae	1108.2	12.45	297.6	0.71	28.4	40
6	*Ziziphus nummularia*	Asteraceae	576.6	6.40	338.3	0.59	27.3	46.27

Abbreviations used: LS- Leaf Size, SLA-Specific Leaf Area, LDMC-Leaf Dry Matter Content, LPC- Leaf Phosphorus content, LNC- Leaf Nitrogen Content, N:P- Ratio of leaf nitrogen and phosphorus content.

-SLA leaves are thick and dense, making them physically more resilient and much less appealing to herbivores than high-SLA leaves (Cornelissen *et al.,* 2003); as a result, they are less inviting to herbivores. Low SLA levels, on the other hand, are linked to relatively significant leaf investors. Furthermore, these leaves have a tendency to be longer-lived, which might contribute to longer plant lifespans on their own (Grime *et al.,* 1997). A study in Sonebhadra district of Uttar Pradesh concluded that species in resource-rich environments, on the other hand, are more likely to have a higher SLA than those in resource-stressed contexts (Chaturvedi *et al.,* 2011). The present study observed low SLA for *Acacia leucophloea* on Site-I(Table 1) and Site II (Table 2) while for *Salvadora oleoides* on Site-III (Table 3), thus acting more efficiently than plants with high SLA viz; *Parthenium hysterophorus* on Site-I, *Ficus religiosa* on Site-II and *Morus alba* on Site-III.

The value of LDMC ranged from 124.2 to 486.3 mg/g, which was more or less similar to the results of Himanshi *et al.* (2021), who observed the value of LDMC ranging from 150.6 to 467.4 mg/g during their study in the forests of Morni Hills, Panchkula. In the case of LDMC, tree species exhibited higher value than shrub species on all three sites, also supported by Akram and Zhang (2022). LDMC is thought to be a marker of a plant's resource usage strategy since it falls somewhere between two functional extremes, quick consumption and broadening at one end and systematic resource conservation inside well-protected tissues at the other.

The variation trend observed here is associated with the acquisition-conservation trade-off (Wright and Westoby, 2001) that confirmed the importance of LDMC as a useful indicator of differential functional strategies. The results of the present study are in accordance with the hypothesis of Poorter and Garnier (1999) and Wright and Westoby (2001), where forests at Site-III have a predominant resource-acquisition strategy and low LDMC and have less water use efficiency. Whereas forests at Site-I have a predominant conservative strategy with a high value of LDMC and high water use efficiency. LDMC or Tissue density positively correlates with leaf life span (Chaturvedi *et al.,* 2011). Leaves having high LDMC are relatively resistant to physical strains like wind and herbivory (Coley, 1983) due to their physical toughness than leaves with low value of LDMC. Present study shows high value of LDMC for *Acacia leucophloea*, *Ziziphus nummularia* for Site-I(Table 1), *Azadirachta indica*, *Abutilon indicum* for Site-II(Table 2) and for *Salvadora oleoides* and *Solanum viarum* for Site-III (Table 3).

Subsequently, foliar nutrients such as nitrogen and phosphorus are considered the main limiting factors for plant growth because they are integral parts of plants, helping in their life-sustaining processes. The potential of plants for fast development under productive conditions and the ability to sustain output under a restricted supply of nutrients are strongly related to high N and P leaf concentrations. High leaf N and P concentrations enable the plant to grow rapidly under productive environments (Westoby *et al.,* 2002). The value of LNC for the current study ranged from 11.2 to 48.4 mg/g for Site-I, 26.3 to 41.3 mg/g for Site-II and 5.6 to 44.4 mg/g for Site-III. The obtained values are more or less similar to the results of Powers and Tiffin (2010) who observed the LNC value to be ranging from 11.7 to 36.3 mg/g in the Costa Rican Dry forests. Other than this, LPC values for tree species ranged from 0.7 to 1.7 mg/g for Site-I, 0.6 to 0.86 mg/g for Site-II and 0.6 to 0.87 mg/g for Site-III. This is also comparable to the values of LPC obtained by Powers and Tiffin (2010) for the dry forest trees, i.e., 0.6 to 2.0 mg/g.

LNC and LPC are critical for plant growth and development since they offer data on essential characteristics such as the pace of relative growth and exchange of gases via leaves (Santiago and Wright, 2007). Cornelissen *et al.* (2003) used N:P ratio as a tool to determine whether the supply of N or P in ecosystems is far more limiting for carbon cycling pathways. Along with this, according to the fertilization experiments of Güsewell (2004), a value of N:P less than 10 shows Nitrogen limitation, while a value of N:P greater than 20 represents Phosphorus limitation for most of the plant species.

As all three Sites have the value of N:P ratio >10 thus, there is no Nitrogen limitation observed. This shows that the plant species under investigation are using nitrogen significantly, allowing them to maintain nitrogen stability. Consequently, the plant species also showed N:P ratio of more than 20. Thus, as per Güsewell *et al.* (2004), the plant species exhibited a strong phosphorus limitation. The P limiting conditions have been seen to enable more species to coexist than N limitation (Olde Venterink, 2011).

During statistical analysis, the results of the present work showed a weak but negative correlation between SLA and LNC as per the findings of Garnier *et al.* (1997) who recorded this type of relation for annuals in Mediterranean old fields. Likewise, among three tropical dry deciduous forests selected, SLA of Trees and shrubs were found to be weakly but negatively correlated with LPC. Santiago and Wright (2006) reported same type of correlation during their study in the tropical forests of Central panama. In some other studies also, SLA is reported to be associated with LNC and LPC (Garnier *et al.,*1997; Lambers and Poorter, 1992).

A strong positive correlation between LNC and LPC was observed in the present study, also reported in several investigations (Cramer and Leemans, 1993; Wright *et al.,* 2001; Güsewell, 2004). The present research findings follow Wu *et al.* (2012), where a posi-

Table 3. Functional leaf traits of plant species (trees and shrubs) in the tropical dry deciduous forests of Asalwas Dubia (Site-III), District Bhiwani, Haryana

Sr No.	Plant name	Family	LS (mm^2)	SLA (mm^2/mg)	LDMC (mg/mg)	LPC (mg/g)	LNC (mg/g)	N:P
	Trees							
1	*Acacia leucophloea*	Fabaceae	386.4	5.944	367.2	0.87	35.0	40.22
2	*Acacia nilotica*	Fabaceae	744.4	19.08	261.7	0.7	24.4	34.85
3	*Ailanthus excels*	Simaroubaceae	3587.5	5.588	389.5	0.8	35.7	44.62
4	*Albizia lebbeck*	Fabaceae	398.4	9.265	349.2	0.85	38.5	45.29
5	*Azadirachta indica*	Meliaceae	748.7	8.88	397.4	0.65	42.7	65.69
6	*Ficus religiosa*	Moraceae	7289.9	13.52	235.1	0.65	27.3	42
7	*Melia azadirachta*	Meliaceae	710.1	2.99	302.2	0.66	44.4	67.27
8	*Morus alba*	Moraceae	9559.4	37.63	408.6	0.6	28.7	47.83
9	*Prosopis juliflora*	Fabaceae	207.3	2.727	280.4	0.84	42.3	50.35
10	*Salvadora oleoides*	Salvadoraceae	488.2	1.559	451.6	0.73	25.2	34.52
	Shrubs							
1	*Abutilon indicum*	Malvaceae	1057.2	16.78	183.6	0.9	43.4	48.22
2	*Calotropis procera*	Asclepiadaceae	8266.1	11.14	124.2	0.65	38.5	59.23
3	*Carissa spinarum*	Apocynaceae	495.2	8.81	418.0	0.8	38.4	48
4	*Maytenus emarginata*	Celesrtaceae	744.7	12.05	193.8	0.91	40.2	44.17
5	*Parthenium hysterophorus*	Asteraceae	1266.7	16.66	247.5	0.65	27.3	42
6	*Solanum viarum*	Solanaceae	693.9	4.391	552.4	0.6	15.6	26
7	*Ziziphus nummularia*	Asteraceae	602.3	8.989	394.11	0.7	29.4	42

Abbreviations: LS- Leaf Size, SLA-Specific Leaf Area, LDMC-Leaf Dry Matter Content, LPC- Leaf Phosphorus content, LNC- Leaf Nitrogen Content, N:P- Ratio of leaf nitrogen and phosphorus content.

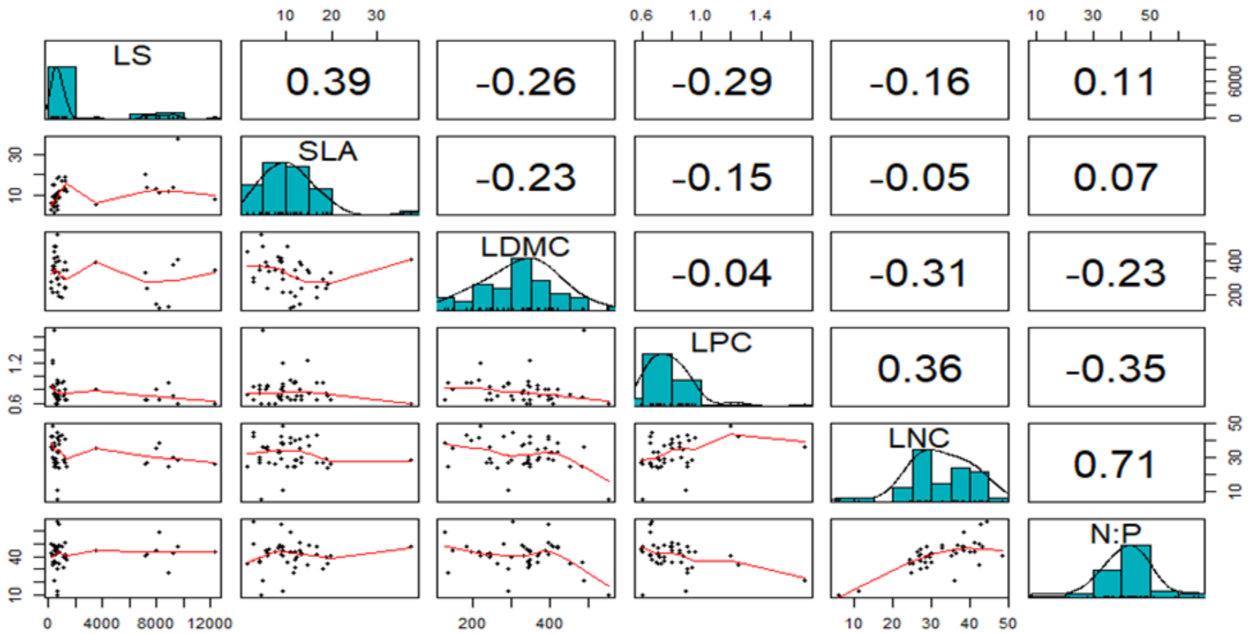

Fig. 2. *Relationship between the functional leaf traits of trees and shrubs species in the tropical dry deciduous forests of Southern Haryana*

tive correlation was observed between Leaf N and P concentrations, while LPC and Leaf N:P ratio was negatively correlated across all three Sites, significantly. Besides this, LNC showed a strong positive correlation with N:P ratio. Thus, the present research is a very significant step taken in the direction of functional diversity of Southern Haryana, as these forests are devoid of such research. It is a marked initiative for further work. The confirmatory results have important implications for understanding plant characteristics, nutrient cycling, herbivore patterns and resource acquisition strategies of plants in forests of Southern Haryana.

Conclusion

Several trait-based investigations carried out in the different ecosystems worldwide emphasize how crucial it is to determine how functional traits affect ecological processes in forest ecosystems. The present study observed a strong positive correlation between LNC and LPC and LNC showed a strong positive correlation with N:P in TDDFs of Kheri Batter (Charkhi Dadri), Dulana (Mahendergarh) and Mandhana (Bhiwani). The SLA of Trees and shrubs was weakly but negatively correlated with LPC on all three selected sites. It can be anticipated that no plant species show nitrogen limitation, thus, making significant use of nitrogen, allowing them to maintain nitrogen stability. The present study showed substantial implications for the use of functional characteristics in the monitoring of forest ecosystems. It could be used to discuss ecosystem functioning changes and gauge the recovery of various ecological processes. Along with this, a more accurate assessment of functional trajectories and the restoration of ecological functions may be possible by using functional traits to assess forests undergoing restoration.

Conflict of interest

The authors declare that they have no conflict of interest.

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