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Comparative Analysis of Leguminous and Non-Leguminous Tree Species in Terms of Leaf Chemistry and Nutrient Cycling

MANISHA PRAGYA AND PURABI SAIKIA*
Department of Environmental Sciences, Central University of Jharkhand, Ranchi-835205, India
Email: manisha.pragya2dec@gmail.com, purabi.saikia@cuj.ac.in
***Corresponding author**

ABSTRACT

The present study aimed to analyse the rhizospheric soils of leguminous (*Dalbergia sissoo,* and *Tamarindus indica*), and non-leguminous (*Mangifera indica,* and *Ficus benghalensis*) tree species and their leaf pigment concentration in a natural forest of Ranchi in pre-monsoon (February 2020), and post-monsoon (November 2019) seasons. Soil nutrient status was better during the post-monsoon season, while leaf pigment concentration was higher during the pre-monsoon season. Again, soil nutrient status was better in rhizospheric soils of legumes as compared to the non-legumes. SOC (%) was quite high in the rhizospheric soil of leguminous trees that ranged from 0.75-0.86 % during pre-monsoon, and 0.88-0.92% during post-monsoon seasons. The highest SOC (%) was found in rhizospheric soils of *D. sissoo* (0.92±0.04), lowest BD (1.08±0.11 gm cm^{-3}) in rhizospheric soils of *M. indica,* while AN (kg ha^{-1}), and TKN (%) both were highest in rhizospheric soils of *T. indica* (AN: 470.68±50.53, TKN: 0.42±0.09) during post-monsoon season. On the other hand, pigment concentration (mg gm^{-1}) including chlorophyll a, b, total chl, and total carotenoids were highest in leaves of *M. indica* (Chl A: 1.15±0.04, Chl B: 0.82±0.01, total Chl: 1.71±0.04, and total carotenoids: 30.61±0.87) in pre-monsoon season. Rhizospheric soil nutrient status of legumes was better during both the pre-and post-monsoon seasons in comparison to non-legumes. Leguminous tree species are very important from an ecological point of view in terms of their nutrient recycling efficiency and photosynthetic ability. Therefore, it can be suggested for afforestation, and social forestry programs for sustainable ecological development as they can easily grow under natural conditions without any extra care.

Key words: Soil organic carbon, Total Kjeldahl nitrogen, Chlorophylls, Carotenoids, Legumes, Non-legumes

INTRODUCTION

Legumes (Fabaceae) have been demonstrated as the third most species-rich angiosperm family (Edwards et al. 2006) with *ca*. 19,400 species belonging to 730 genera (Lewis et al. 2005). It is cosmopolitan in distribution found in diverse habitats from tropics to arctic zones, from the seashore to alpine habitats, and in rainforests, mangroves, peat swamp forests, seasonal forests, savannas, and deserts (Prado and Gibbs 1993, Pennington et al. 2000, Prado 2000). It has an unusual flower structure, podded fruit, and the ability of 88% of species to fix atmospheric nitrogen (Saikia et al. 2020). Legumes support important ecosystem services through their ability to fix atmospheric N_2 by means of symbiotic relationship with bacteria, cyanobacteria, and actinomycetes (Franche et al. 2009, Sprent 2009), and make it usable for the other non-leguminous plant species. Legumes are important all over the tropics as a source of protein-rich food, timber, fuelwood, charcoal, forage, fodder, green manure, biofuel, and bio-pesticides (Hughes and Styles 1989). The facilitative effects of N-fixers on non-N-fixers are vital for the community development and net primary productivity of forest ecosystems (Siddique et al. 2008). Higher amounts of N in soil and litter under leguminous plants due to their deciduous nature instigate major soil microbial activities in natural forests (Allison et al. 2006). A wide variety of N-fixers colonize in the root surface of non-leguminous plants without forming any altered structures are known as associative symbiosis (Elmerich and Newton 2007). In the symbiotic association between legumes and rhizobial endosymbiont bacteria have the ability to supply nitrogen (N) to plants through biological nitrogen fixation (BNF) (Maroti and Kondorosi 2014). During the process of Legumes-*Rhizobia* interactions, nodules are formed that provide a proper environment for bacterial nitrogen fixation as it restricts the free flow of oxygen which is considered as an inhibitor of the BNF enzymatic process (Dixon and Kahn 2004). The increased anthropogenic N-deposition has strong effects on the

N-dynamics, N-runoff, litter decomposition, and soil enzymatic activities of forests (Chen and Mulder 2007). Symbiotic nitrogen fixers are most abundant in arid biomes with alkaline soils and high maximum temperatures (Steidinger et al. 2019). Leguminous tree species that are abundant in subtropical forests may be a critical regulator of soil nutrient dynamics because of their potential for symbiotic N-fixation (Xia and Wan 2008, Gei and Powers 2013). Irrespective of their ability to fix atmospheric N_2, most of the members of this family have higher foliar nitrogen (Fyllas et al. 2009) as compared to non-leguminous plants (Powers and Tiffin 2010). More significant levels of soil organic carbon under N-fixing trees have been credited to their higher development rates and ensuing higher carbon contributions to the soil through litter and root exudates (Saikia et al. 2020). Deep-rooted perennial legumes reduce the risk of groundwater contamination by nitrate (NO^{3-}), or the development of dryland salinity, due to their ability to grow and extract water throughout the year (Angus et al. 2001, Lefroy et al. 2006). N-fixers play a vital role in the facilitation of non-N fixing plants as they acquire fixed atmospheric nitrogen through the decomposition of litters and dead roots (van Kessel et al. 1994). Nitrogen concentration per unit leaf mass for N-fixing plants in natural ecosystems is universally greater (43-100%) than that of non-N fixing plants (Taylor and Ostrowsky 2019). N fixing plants are very important in a global context due to their N input and their role in the global carbon cycle (Sprent and Parsons 2000). Legumes play a critical role in natural ecosystems, agriculture, and agroforestry, through their ability to fix atmospheric N through symbiosis, and make them excellent colonizers in low-N environments (Graham and Vance 2003). The association of NF bacteria with various non-leguminous plants emphasizes their potential to promote host plant growth and yield (Bhattacharjee et al. 2008). Under higher N supply, there is a minor difference between leguminous, and non-leguminous plants in terms of PME (phosphomonoesterase) activities and grasses may have higher PME activity than that of legumes but, under low inorganic P and N supply, leguminous plants have a higher root PME activity than other non-leguminous plants (Venterink 2011). The number of ammonia and organic acid producers in legumes nodules was higher than in roots (Kumar et al. 2013). Non-leguminous species have shown higher efficiency for nitrogen resorption and lower efficiency for phosphorus resorption, while leguminous species have shown lower efficiency for nitrogen resorption and higher efficiency for phosphorus resorption (Singh 2015). However, legumes are often recalcitrant to regeneration and transformation (Iantchev et al. 2013). Leguminous plants have a significant effect on the amount of nitrogen in the soil (van Kessel and Hartley 2000). Thus, the cultivation of leguminous crops might reduce the utilization of nitrogen-based fertilizers (Al-Mujahidy et al. 2013). There were higher levels of soil carbon and nitrogen under N-fixing trees compared to non-N-fixing trees and the inclusion of N-fixers may help to increase soil carbon and nitrogen, but the response may be site- and species-specific (Hoogmoed et al. 2014). Plantation of N-fixing tree species in degraded areas caused by soil erosion, urbanization, industrial, construction, and mining activities have the potential to recover soil organic matter, restore biodiversity, and other ecosystem goods and services (Chaer et al. 2011). Plant association with BNF is highly desirable in non-leguminous plants and leguminous plants from ecological and economic perspectives. Therefore, the present study aimed to determine the physico-chemical properties (bulk density, available nitrogen, TKN, and soil organic carbon) of rhizospheric soil during pre-monsoon and post-monsoon seasons under legumes (*Dalbergia sissoo,* and *Tamarindus indica*), and non-legumes (*Mangifera indica,* and *Ficus benghalensis*) and also their leaf chemistry (chlorophylls and carotenoids) to determine their ecological efficiency.

STUDY AREA

The present study was conducted in the natural forest located at Brambe, Ranchi, 25 km away from Ranchi city, in the State of Jharkhand, eastern India (Fig. 1). Ranchi, the capital city of Jharkhand, The Ranchi district lies in 23.13°N to 23.21°N latitude, 85.51°E to 85.54°E longitude, and with altitude range varies from 400 to 700 m above mean sea level (MSL). The climate of Ranchi is considered as Cwa

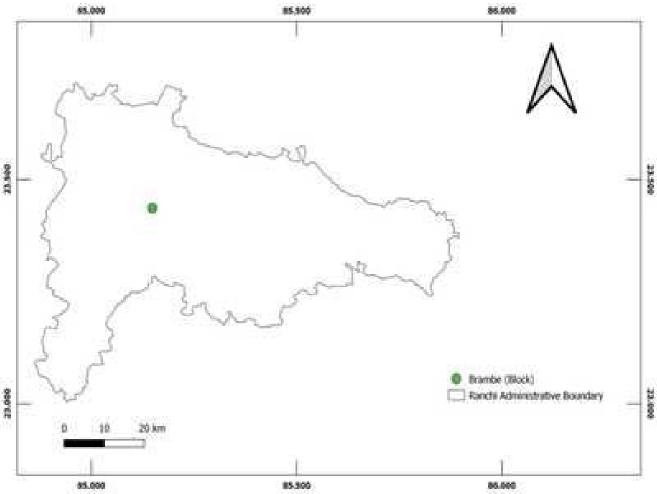

Figure 1. Map of the study site (Brambe, Ranchi, Jharkhand).

(Subtropical humid) according to the Köppen-Geiger climate classification. Winter temperatures range from 5°C to 25°C, and summer temperatures vary from 20°C to 42°C, and cumulative annual rainfall is 1400 mm yr^{-1}. The State of Jharkhand is known for its rich forests and mineral wealth. Jharkhand is rich in tropical moist deciduous, and tropical dry deciduous forests and dominant tree species like *Shorea robusta*, *Madhuca longifolia*, *Tamarindus indica*, *Butea monosperma*, *Mangifera indica*, and *Zizyphus jujuba*.

MATERIALS AND METHODS

Field Sampling (Soil and Leaf Sample Collection) and Sample Preparation

Random sampling has been conducted during the post-monsoon (November 2019) and pre-monsoon (February 2020) seasons, and four surface soil samples of 0-15 cm depth from the rhizospheric zone within one m peripheries from tree trunk were collected in zipper bags from each four selected trees with the help of cylindrical metallic soil cores. Hence, 16 soil samples were analysed during the pre-monsoon season and 16 samples were analysed in the post-monsoon season. For the collection of leaf samples two leguminous trees (*Dalbergia sissoo* and *Tamarindus indica*), and two non-leguminous trees (*Mangifera indica* and *Ficus benghalensis*) were selected according to the availability in the fields. Randomly selected 20 mature leaves from each of the four selected individual trees were collected for further analysis of pigment concentration.

Soil samples were air-dried, ground with mortar and pestle, and removed all the unwanted particles by sieving them through 2 mm mesh. Again, keep it in the zipper bag, labelled with a marker pen to avoid inter-mixing of samples, and stored in a wind-free, dark place. For the analysis of bulk density, soil core samples were directly dried inside in a hot air oven at 105°C till constant weight was achieved. Physico-chemical analysis of the collected soil samples was carried out by standard methods as given in Table 1.

For the leaf pigment analysis, freshly collected leaves were used. For the determination of chlorophyll and carotenoids, ~0.5 mg of fresh leaf samples were weighed for individual plant species in triplicates and crushed in 10 ml of 80% chilled acetone with the help of mortar and pestle in a dark room. Liquid extract was poured off from the mortar and 05 ml extract was created by adding acetone to the centrifuge. The extract was centrifuged at 500 rpm at 10°C for 15 minutes. For spectrophotometer calibration (*i.e.,* then set the absorbance to zero), 80% acetone was used as blank. The cuvette was rinsed with 80% acetone before taking supernatant. The supernatant was taken in cuvette and absorption was measured at wavelength 663 nm, 545 nm, and 480 nm by UV-visible spectrophotometer. Formulas used for the determination of chlorophylls and carotenoids are given in Table 1.

RESULTS AND DISCUSSION

Physico-Chemical Properties of Rhizospheric Soils of Legumes and Non-Legumes

Bulk density (BD) of mineral soils ranges from 1.0 to 1.8 gm cm^{-3} and root growth is restricted in soils with a bulk density higher than 1.60 gm cm^{-3} (Russell 1977). The present study recorded higher BDs (gm cm^{-3}) of rhizospheric soils during the pre-monsoon season, *i.e.*, ranging from 1.19±0.31 SE (*Ficus benghalensis*) to 1.62±0.06 (*Tamarindus indica*) while, it was ranged from 1.08±0.11 (*Mangifera indica*) to 1.51±0.05 (*T. indica*) in post-monsoon season (Fig. 2). The BD of rhizospheric soils of *T. indica* (1.62 gm cm^{-3}) was slightly higher than the range of favourable plant growth. Generally, low BDs in soils indicate high organic matter content, good granulation, high infiltration, and good aeration,

Table 1. Methods used for the various physicochemical analysis of soil and chlorophylls and carotenoids analysis of leaf samples.

Parameters	Formula used	Methods
Bulk density (BD)	$BD = (W_1 - W_2)/(V\ gm\ cc^{-1})$	Soil core method (Singh, 1988)
Soil organic carbon (SOC)	$SOC = ((B-T) * 0.5 * 0.003 * 100)/Sample\ wt.$ where, B = amount of ferrous ammonium sulphate used for blank reading, T = amount of ferrous ammonium sulphate used for soil actual titrant reading, 0.5 = Normality of ferrous ammonium sulphate.	Walkley and Black (1934) Wet-oxidation process as modified by Allison (1965)
Total Kjeldahl Nitrogen (TKN)	*TKN (%) = (14 * Normality of acit* actual titrant value * 100)/Sample wt.*	TKN method (Kjeldahl, 1883)
Available Nitrogen (AN)	AN (kg ha^{-1}) = *(14 * Normality of acid * actual titrant value * 2.20 * 10^{6})/sample wt. * 100*	
Chlorophylls	$Chl\ A\ (mg\ g^{-1}) = (12.7 * OD_{663}) - (2.63 * OD_{645}) * (V/100) * wt.$ $Chl\ B\ (mg\ g^{-1}) = (2.9 * OD_{645}) - (4.68 * OD_{663}) * (V/100) * Wt.$	
Total carotenoids (TC)	$TC\ (mg\ g^{-1}) = (4.695 * OD_{480} - 0.268) * Chl\ A \pm B$ where, v = volume of acetone (10 ml), OD = absorption at wavelength 663 nm, 645 nm, 480 nm, Wt= weight of sample (0.5gm)	

resulting in a good rooting medium (NRC 1981). In the present study, BDs were lower in rhizospheric soils of non-legumes *i.e., M. indica* (pre-monsoon: 1.19 gm cm^{-3}, and post-monsoon: 1.08 gm cm^{-3}), and *F. benghalensis* (pre-monsoon: 1.28 gm cm^{-3}, and post-monsoon: 1.19 gm cm^{-3}) that may be due to their continuous organic matter supply to the soil throughout the years because of their evergreen growth habit, that ultimately facilitates better root growths. Organic matter is very important in tropical soils as it plays a crucial role in soil formation and maintenance of soil structure, fertility, nutrient status, and water availability (Craswell and Lefroy 2001, Six et al. 2002). The availability of higher concentrations of nutrients in the course of ecological succession promotes an increase in the number of tree species (Francis and Read 1994, Davidson et al. 2004). Soil organic carbon (SOC) is a heterogeneous material that can be separated into light and a heavy fraction (Janzen et al. 1992, Gregorich and Ellert 1993). The light fraction mainly consists of botanical relics and is more responsible for cropping practices than the heavy fraction (Biederbeck et al. 1994, Gregorich et al. 1994). SOC (%) was quite high in the studied forests, ranging from 0.92±0.04 in *D. sissoo* during the post-monsoon season to 0.19±0.04 in *F. benghalensis* during pre-monsoon season (Fig. 3). Again, it was higher during the post-monsoon season (0.92±0.04 to 0.40±0.02) as compared to pre-monsoon season (0.86±0.02 to 0.19±0.04) may be due to the maximum leaf shedding during post-monsoon seasons, as well as higher decomposition rate after heavy monsoon showers. Rhizospheric soils of legumes had higher SOC (%) (0.75±0.05 to 0.92±0.04) as compared to non-legumes (0.19±0.04 to 0.52±0.04) may be due to the deciduous nature of legumes. SOC, and AN used to increase during forest development and succession process (Brown and

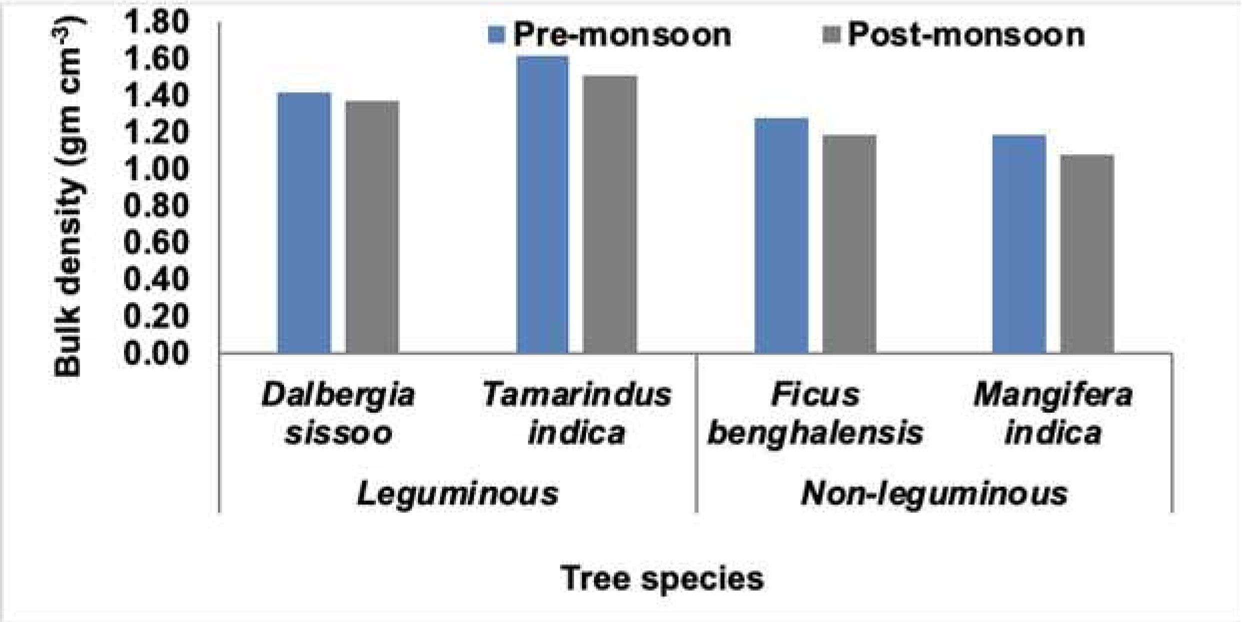

Figure 2. Bulk density (gm cm^{-3}) of rhizosphere soils of leguminous, and non-leguminous tree species during pre- and post-monsoon seasons

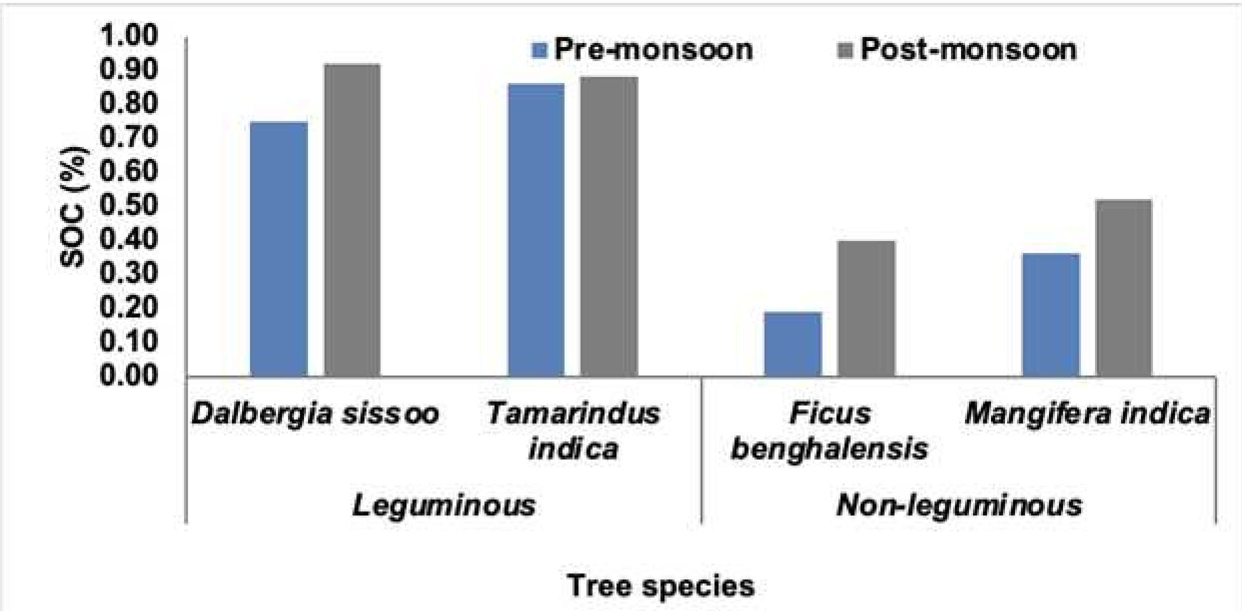

Figure 3. SOC (%) of rhizosphere soils of leguminous and non-leguminous tree species during pre- and post-monsoon seasons

Lugo 1990, Feldpausch et al. 2004). Legumes are unique plants as they contribute many different functions and ecosystem services that are of great value for agriculture and society (Crews and Peoples 2004, Peoples et al. 2009).

Total Kjeldahl Nitrogen (TKN) is the total concentration of organic nitrogen and ammonia. TKN (%) was also high in the studied forest, *i.e.* ranged from 0.42±0.09 in *T. indica* (legume) during the post-monsoon season to 0.07±0.01 in both the non-legumes during pre-monsoon season as legumes used to fix the atmospheric nitrogen through the biological nitrogen fixation process. TKN was quite higher during the post-monsoon season as compared to the pre-monsoon season (Fig. 4) as the studied legume species had shed their leaves during the post-monsoon season. Soil nitrogen increase is very much

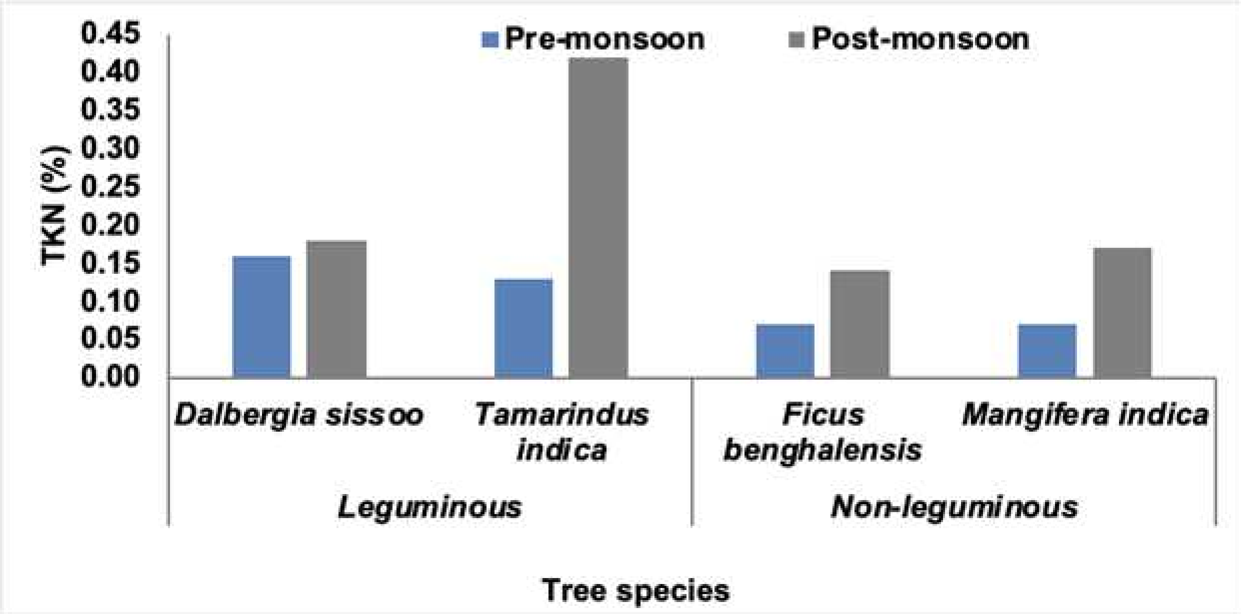

Figure 4. TKN (%) of rhizosphere soils of leguminous and non-leguminous tree species during pre- and post-monsoon seasons

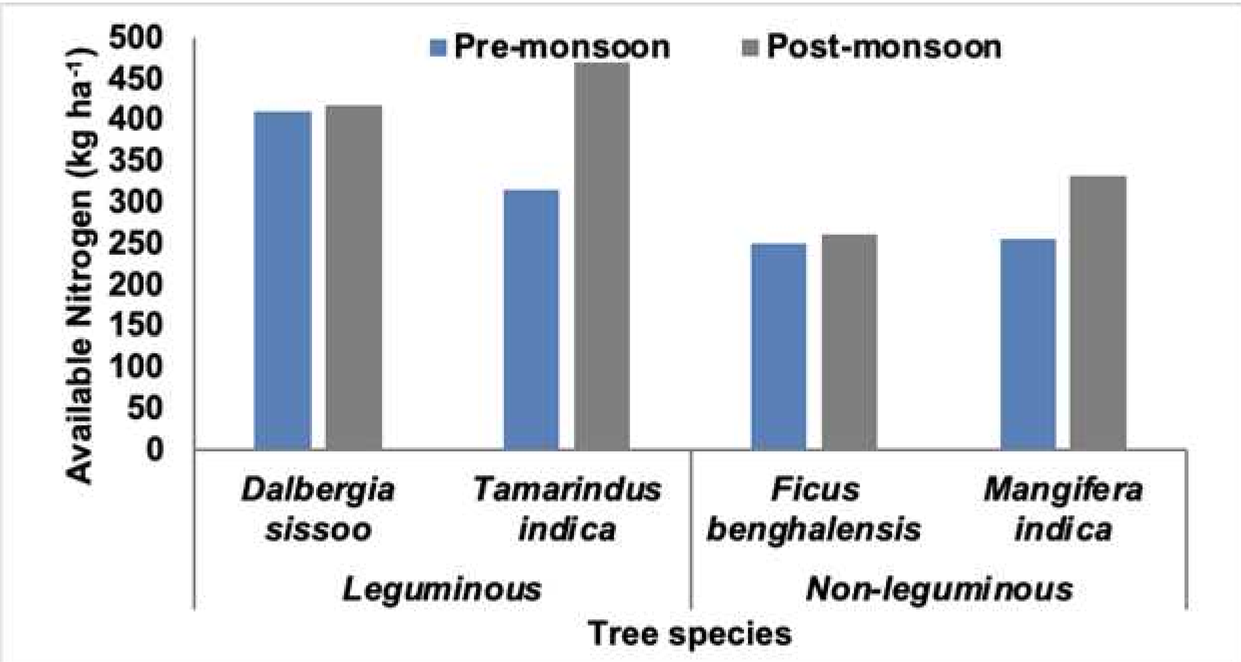

Figure 5. Available nitrogen (kg ha^{-1}) of rhizosphere soils of leguminous and non-leguminous tree species during pre- and post-monsoon seasons

essential in the rehabilitation of degraded land (Francis and Read 1994). In rhizospheric soil of legumes, TKN concentration ranged from 0.04 gm kg^{-1} in *Prosopis glandulosa* to 1.68 gm kg^{-1} in *Dalea spinosa* as both were capable of symbiotic N-fixation (Allen and Allen 1981). The most important forms of available nitrogen (AN) are $NH_4^{\pm}$, NO_3^-, and certain simple organic compounds, principally those containing free amide or amino groups that can be readily absorbed by plant roots. Nitrites are a minor source of available nitrogen. Processes that supply available nitrogen to the soil are (1) organic matter, (2) fertilizer additions, (3) symbiotic fixation, (4) non-symbiotic fixation, (5) rainfall. Although plants can usually utilize any of these nitrogen forms, there are numerous exceptions (Arnon 1937, Bonner 1946, Ghosh and Burris 1950). Similarly, AN (kg ha^{-1}) was also higher in the studied forest, and it was quite higher in rhizospheric soils of legumes (ranged from 470.68±50.53 to 316.28±54.87) as compared to rhizospheric soils of non-legumes (ranged from 331.30±48.45 to 250.16±29.71). Like SOC and TKN, AN was also higher during the post-monsoon season as compared to the pre-monsoon season (Fig. 5). The carbon-nitrogen (C/N) ratio of soil is related to the patterns of nitrogen immobilization and mineralization during organic matter decomposition by microorganisms (Swift et al. 1979). The reported range of C/N ratio of deciduous forests is 11.5 to 22.2 (Yamakura and Sahunalu 1990). The present study recorded a very poor C/N ratio 2.10 to 6.62 (Table 2) may be due to the variations in sampling season. It indicates the decomposition rate in terrestrial ecosystems (Jordan 1985) and used to be decreased as decomposition proceeds (Swift et al. 1979). C/N ratio is negatively correlated with the rate of nitrogen mineralization in decomposition (Tsutsumi 1987a). It also depends on the nitrogen contents of the litter itself (Jordan 1985, Swift et al. 1979) and local variations in soil conditions according to the topography and parent material (Tsutsumi 1987b).

Leaf Pigment Concentration of Legumes and Non-Legumes

Unlike the soil physicochemical properties of rhizospheric soil, the leaf pigment concentration of legumes and non-legumes were higher during the pre-monsoon season as compared to the post-monsoon season (Table 3). In pre-monsoon season, chl a was highest in *M. indica* (1.15±0.04 mg gm^{-1}), and lowest in *F. benghalensis* (0.57±0.05 mg gm^{-1}), while in post-monsoon season, chl a was highest in *D. sissoo* (0.42±0.11mg gm^{-1}), and lowest in *F. benghalensis* (0.01±0.001 mg gm^{-1}) (Fig. 6). The decreasing order of chl a was *M. indica* > *D. sissoo* > *T. indica* > *F. benghalensis* in pre-monsoon season, while the decreasing order of chl b was *M. indica* (0.82±0.01 mg gm^{-1}) > *D. sissoo* (0.47±0.06 mg gm^{-1}) > *F. benghalensis* (0.42±0.06 mg gm^{-1}) > *T. indica* (0.41±0.27 mg gm^{-1}). A higher pigment concentration of *M. indica* as compared to *D. sissoo* was also reported by earlier workers (Giri et al. 2013). Like, chl a, chl b was also extremely less in the post-monsoon season (Fig. 7). The present study recorded a very less chl a/ chl b ratio (ranging from 0.18 in *M. indica* to 1.90 in *T. indica* during pre-monsoon season) as it ranged from 1.43-7.07 in natural forests (Li et al. 2018). The lowest chl a/ chl b ratio in *M. indica* as well as in *F. benghalensis* as compared to deciduous tree species (legumes) as evergreen trees has a lower chl a/ chl b ratio as compared to deciduous trees (Li et al. 2018). Chlorophyll a is bluish-green, while chlorophyll b is a yellowish-green pigment. Chl a is usually three times higher as compared to chl b in leaf tissues of higher plants (Palta 1990). The present study also reported a higher concentration of chl a as compared to chl b, and chl a is up to two times (1.90) higher than chl b. Total chlorophyll and carotenoids were quite higher in the pre-monsoon season as compared to the post-monsoon season. The decreasing order of total chlorophyll and carotenoids were *M. indica* (total chl: 1.71±0.04 mg gm^{-1}, total carotenoids: 30.61±0.87 mg gm^{-1})> *D. sissoo* (total chl: 1.07±0.10 mg gm^{-1}, total carotenoids: 19.45±1.86 mg gm^{-1})> *T. indica* (total chl: 0.97±0.30 mg gm^{-1}, total carotenoids: 16.62±7.46 mg gm^{-1})> *F. benghalensis* (total chl: 0.83±0.08 mg gm^{-1}, total carotenoids: 14.41±1.88 mg gm^{-1}) in pre-monsoon season (Figs. 8 and 9).

CONCLUSION

Forests are among the most complex ecosystems in the world, and the world's forests hold importance for all of their inhabitants as well as for the overall health of the planet. Forests contain a greater range of biodiversity than any other terrestrial ecosystems on earth. In the comparative analysis of leguminous (*D. sissoo* and *T. indica*), and non-leguminous (*M. indica* and *F. benghalensis*) tree species in terms of leaf chemistry, and nutrient cycling in natural forest of Brambe, Ranchi in pre-monsoon and post-monsoon seasons provides an important insight on the present ecological status of natural forest. Rhizospheric soil nutrient status was better during both the pre- and post-monsoon seasons of legumes as compared to non-leguminous tree species. While legumes can add in better soil nutrient status, non-legumes have better photosynthetic abilities. Therefore, it can be suggested that mixed vegetation of both legumes and non-legumes aid in better ecosystem productivity.

Table 2. Physico-chemical properties of rhizospheric soil of leguminous and non-leguminous tree species during pre-monsoon and post-monsoon seasons

Species type	Species name	Seasons	BD (gm cm^{-3})	SOC (%)	TKN (%)	C/N ratio	AN (kg ha^{-1})
Leguminous	*Dalbergia sissoo*	Pre-monsoon	1.42±0.03	0.75±0.05	0.16±0.02	4.69	410.64±21.73
		Post-monsoon	1.37±0.01	0.92±0.04	0.18±0.03	5.41	418.91±24.65
	Tamarindus indica	Pre-monsoon	1.62±0.06	0.86±0.02	0.13±0.02	6.62	316.28±54.87
		Post-monsoon	1.51±0.05	0.88±0.03	0.42±0.09	2.1	470.68±50.53
Non-leguminous	*Ficus benghalensis*	Pre-monsoon	1.28±0.03	0.19±0.04	0.07±0.01	2.71	250.16±29.71
		Post-monsoon	1.19±0.03	0.40±0.02	0.14±0.02	2.86	261.51±25.40
	Mangifera indica	Pre-monsoon	1.19±0.31	0.36±0.04	0.07±0.01	5.14	255.61±29.91
		Post-monsoon	1.08±0.11	0.52±0.04	0.17±0.01	2.89	331.30±48.45

Table 3. Leaf pigments concentration of leguminous, and non-leguminous tree species during pre-monsoon, and post-monsoon seasons

Species type	Species name	Seasons	Chl a (mg gm^{-1})	Chl b (mg gm^{-1})	Chl a/b	Total Chl (mg gm^{-1})	Total Carotenoids (mg gm^{-1})
Leguminous	*Dalbergia sissoo*	Pre-monsoon	0.84±0.06	0.47±0.06	1.79	1.07±0.10	19.45±1.86
		Post-monsoon	0.42±0.11	0.30±0.05	1.40	1.08±0.28	0.06±0.002
	Tamarindus indica	Pre-monsoon	0.78±0.07	0.41±0.27	1.90	0.97±0.30	16.62±7.46
		Post-monsoon	0.31±0.24	0.17±0.12	1.82	0.12±0.02	0.012±0.002
Non-leguminous	*Ficus benghalensis*	Pre-monsoon	0.57±0.05	0.42±0.06	1.36	0.83±0.08	14.41±1.88
		Post-monsoon	0.01±0.001	0.004±0.001	1.25	0.10±0.002	0.01±0.001
	Mangifera indica	Pre-monsoon	1.15±0.04	0.82±0.01	0.18	1.71±0.04	30.61±0.87
		Post-monsoon	0.08±0.01	0.06±0.02	1.33	0.12±0.02	0.01±0.001

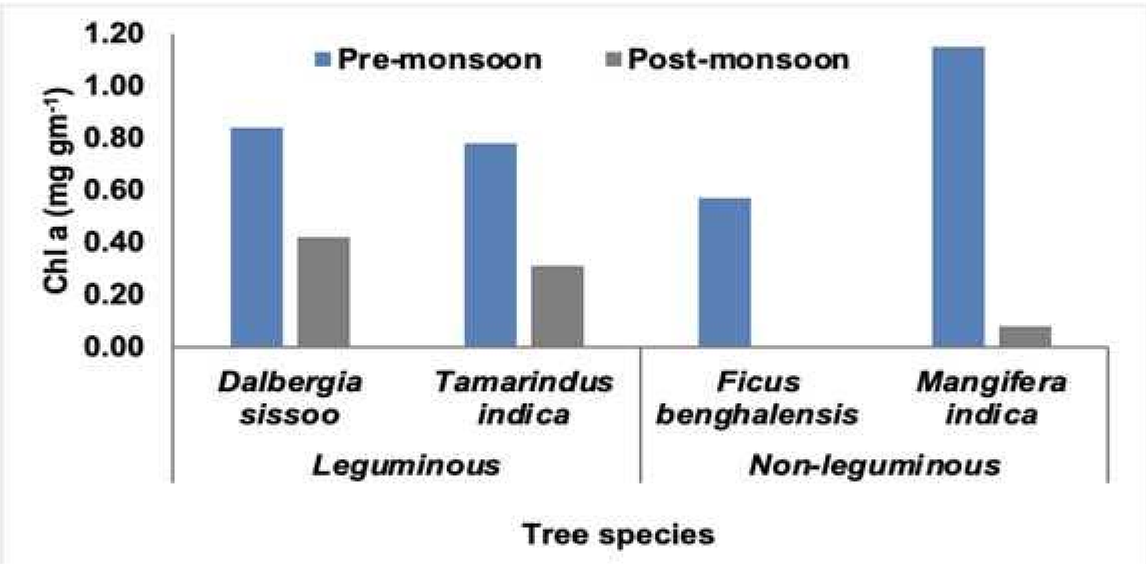

Figure 6. Chlorophyll a (mg gm^{-1}) in leaves of leguminous and non-leguminous tree species during pre- and post-monsoon seasons

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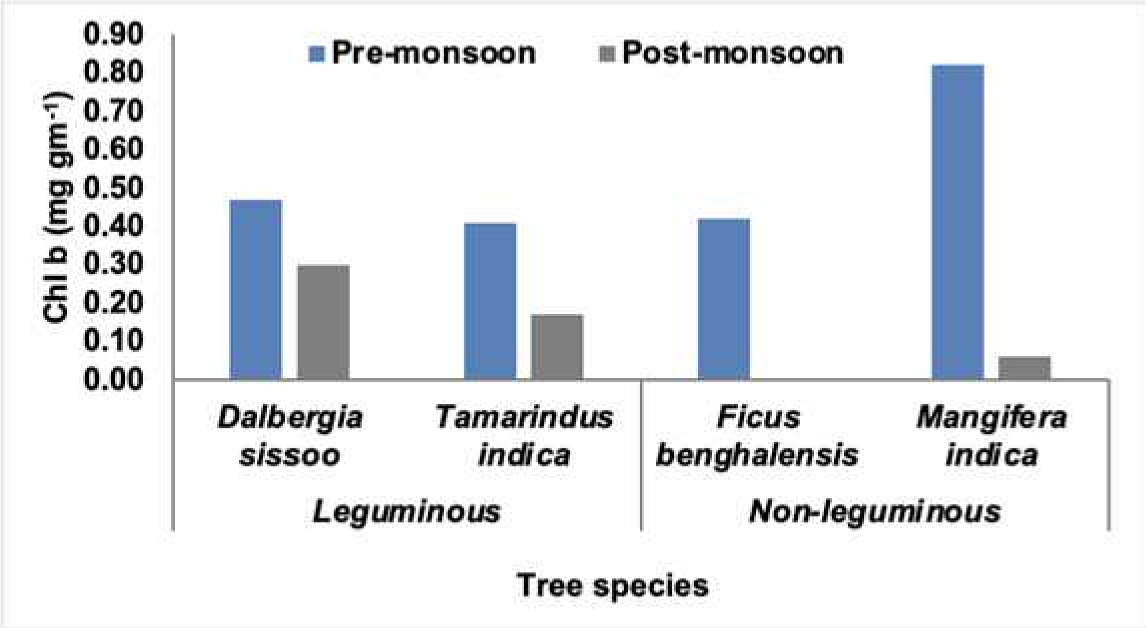

Figure 7. Chlorophyll b (mg gm^{-1}) in leaves of leguminous and non-leguminous tree species during pre- and post-monsoon seasons

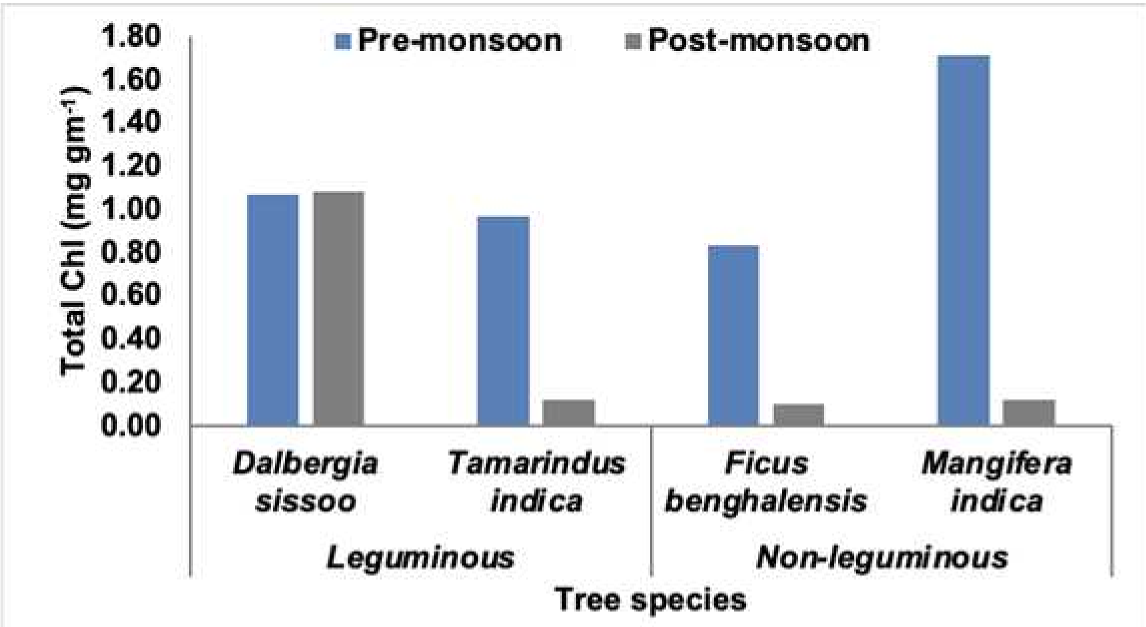

Figure 8. Total chlorophyll content (mg gm^{-1}) in leaves of leguminous and non-leguminous tree species during pre-and post-monsoon seasons

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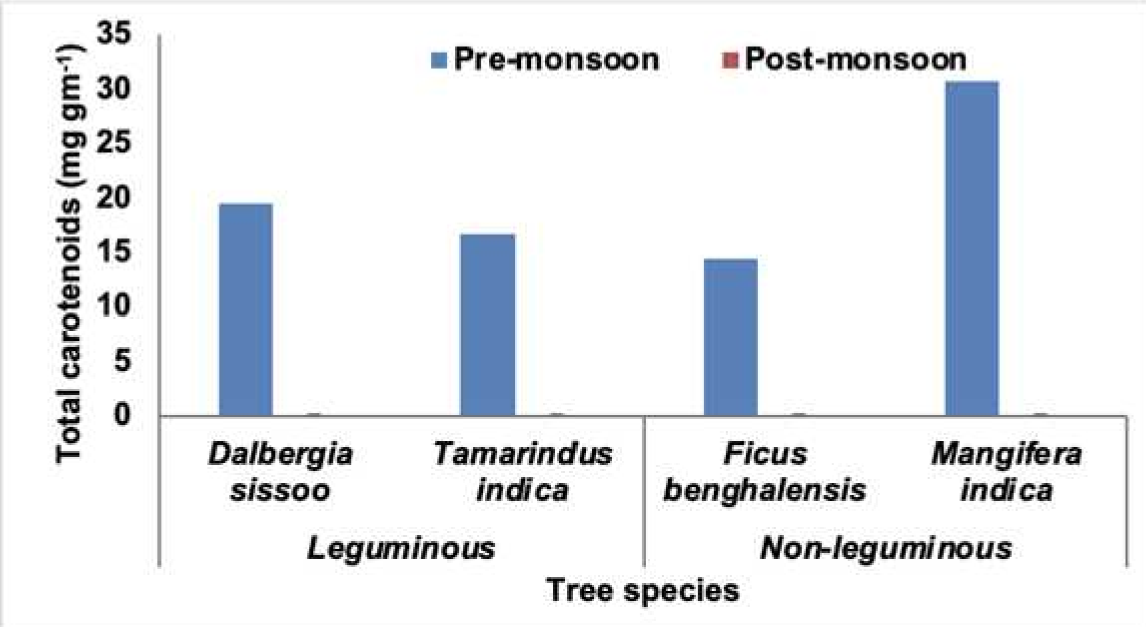

Figure 9. Total carotenoid content (mg gm^{-1}) in leaves of leguminous and non-leguminous tree species during pre- and post-monsoon seasons

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