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Consequence of *Butea monosperma* plantation on the nutrient cycling in a semiarid grazingland, Rajasthan, India

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SUMMARY

In this study, monthly changes in concentrations of various nutrients (N, P, K, Na, Ca and Mg) and their uptake, accumulation, transfer and release in both plant components and soil were studied in grazingland under *Butea* plantation and in the open grazingland in the semi-arid region of Udaipur, Rajasthan, India. At both sites, the maximum concentration of all nutrients was recorded in the live shoot, followed by dead shoot, below ground and litter. The average nutrient accumulation in the plant parts as well as in the soil was in the order of N > Ca > K > Na >Mg >P. Among the sites, the nutrients concentration in plant components and the uptake from the soil were significantly higher (P<=0.001) in the *Butea* plantation site than in the open grazingland. The soil moisture content also showed significant increase under *Butea* plantation than in the open grazingland. Of the total uptake, about 85% of nutrients, were transferred to above ground plant parts and very little was transferred to below ground parts. At both sites, the nutrients return to the soil through root was lower than that of litter disappearance. The study reveals that *Butea* trees can increase the nutrient content of understorey grasses by their rapid leaf turnover and decomposition of nutrient rich litter, which can result in significant increase in soil fertility.

Key words : Nutrient dynamics, Litter disappearance, Open grazingland, Plantation, Root disappearance, Semi-arid region

Establishment of suitable tree species in the degraded grasslands is one of the ways to improve grassland productivity. However, they may have both positive as well as negative effects. Low herbaceous productivity, under tree canopies than the open grasslands have been reported by Fernando and James (2006), whereas in other instances higher grassland productivity under canopies has been observed by Kai (2000). The increase in productivity of understorey vegetation under plantation depends upon the nature of the tree species selected. The choice of species may affect understorey colonization in several ways as tree species will differ in their canopy architecture and influence the understorey light, temperature and humidity regimes; rates of leaf litter production, decomposition and litter chemistry (Sharma *et al*. 2002); and influence on soil biological activity and other aspects of soil fertility. Lodhiyal *et al.* (2000) studied the importance of trees in creating horizontal structure and influencing the dynamics of Shisham forests in central Himalaya, India. The functioning of most forest ecosystems, particularly in regard to primary production, is generally influenced by the availability of nutrients, and this in turn depends on their distribution and rates of cycling. The concentration of nutrients within any part of the ecosystem usually depends upon a functional balance within the system. Nutrient accumulation and the transfer of nutrients between vegetation and soil have been assessed in dry tropical deciduous forests, Rajasthan, India by Nirmal Kumar *et al.* (2008) and Nirmal Kumar *et al.* (2009).However, contribution of lower layer has not been explored so far in this area. Hence, the present study deals with the effects of *Butea* plantation on nutrient dynamics and soil fertility of the grazingland in the semi-arid environment.

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Study site:

The study was conducted in Chitravas forest areas (23^0 03" N latitude, 69^0 30" E, longitude; altitude 579.4 m above the mean sea level) at the Udaipur district in the state of Rajasthan which is 85 km away from the Udaipur city (Fig.1). The climate of the study area is semi-arid. There are three distinct seasons per year; winter (November to February), summer (April to mid June), and rainy season (mid-June to mid September). The climate is tropical with maximum of 45.3^0C and minimum of 28.8^0C during summers. Winters are little cold with

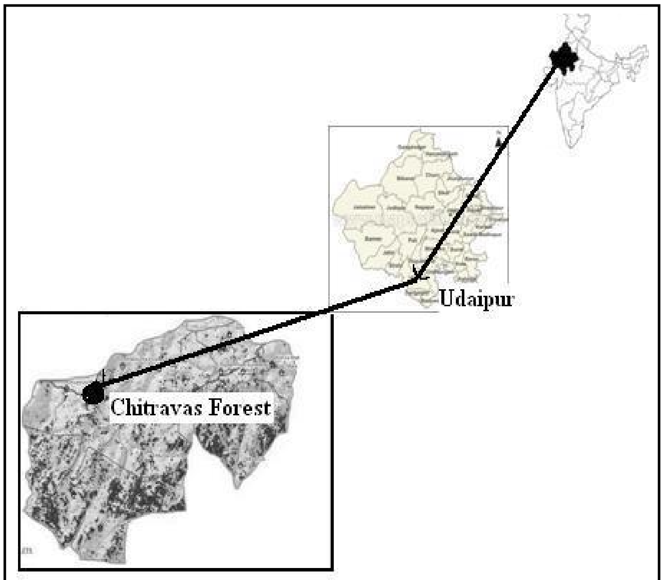

Fig. 1 : Study site

the maximum temperature rising to 26.8^0 C and the minimum dropping to 2.5^0 C. Annual rainfall during the study period was 300 mm and the relative humidity ranged between 21% and 73%. The soil is alluvial, reddish brown, to deep medium black and loamy with rocky beds.

The plantation system, where the sampling done, was composed of 15 years old *Butea monosperma* trees with the associated herbaceous vegetation mostly dominated by *Cassia tora*, with the density of 100 trees per hectare. The mean dbh of *Butea monosperma* was 15 cm and range between 15-20 cm. The trees were spaced at 3 m in a grid pattern. Whereas the adjacent open grazingland, dominated by *Cassia tora*, was considered as control. *Acaranthus aspera* and *Blepharis maderaspatensis* were the codominants in the open grazingland, while *Boerhavia diffusa* and *Cassia occidentalis* were the co-dominants in the *Butea* plantation system. Both the plantation system and the open grazingland were protected from grazing during the study period from January to December, 2008. The laboratory analysis was conducted at the Department of Environmental Science and Technology, ISTAR, Sardar Patel University, Vallabh Vidyanagar.

MATERIALS AND METHODS

Sampling of vegetation and soil:

The biomass was estimated by harvest method (Haring *et al.*, 2007). The sample was harvested at monthly intervals from 10 randomly laid quadrate plots of 0.5 m^2. Litter was collected from each harvested plot. The above ground materials were separated into live shoot, standing dead and litter. From the harvested quadrat, the belowground biomass was estimated by excavating 25 x 25 x 30 cm monolith from three randomly laid quadrats. The roots were separated by washing the soil with tap water using 2 mm sieve. All samples were oven dried at 60^{0}C to constant weight and weighed. A portion of dried samples was powdered and used for nutrients analysis and its concentration. The soil samples were collected separately on each sampling month from three different places by digging pits of 25 x 25 x 30 cm at the experimental site. The samples were dried, sieved (2 mm) and used for nutrients analysis and its quantification. Soil moisture was determined by gravimetric method. The total nitrogen (N) was determined by micro- Kjeldahl technique; Phosphorus (P) was estimated by phosphomolybdic blue colorimetric method, and potassium (K) and sodium (Na) by flame photometry. Calcium (Ca) and magnesium (Mg) were determined by EDTA titration method, (Maiti, 2003 and Narwal *et al.*, 2007).

Nutrient transfers between soil and vegetation compartments:

The nutrient storage was calculated by multiplying concentration of respective nutrients (mg g^{-1})with biomass (gm^{-2}). The nutrient content per gram dry weight of soil was multiplied by the bulk density to obtain its storage in soil (g m^{-2} per 30 cm depth).The annual mean nutrients concentration in live shoot and root were multiplied, respectively with annual net aboveground and belowground production values, to obtain the estimates of aboveground and belowground nutrient uptake. Nutrient release from litter was calculated by multiplying the annual mean nutrient concentration in litter with the quantity of litter that disappeared. Similarly, nutrient transfer from below ground parts to their disappearance were calculated by multiplying the annual mean nutrient concentration of root with the value of dry mass of root that disappeared during the year (Gregory *et al.*, 2006). Dry matter production and its transfers between vegetation compartments were calculated following balance sheet approach of Pandey *et al.* (2007).

Statistical analysis:

Student "t" test and one way ANOVA was used to test significant differences between the sites.

RESULTS AND DISCUSSION

The results obtained from the present investigation are presented below:

Nutrient concentration in plant components:

The monthly changes in N, P, K, Ca and Mg

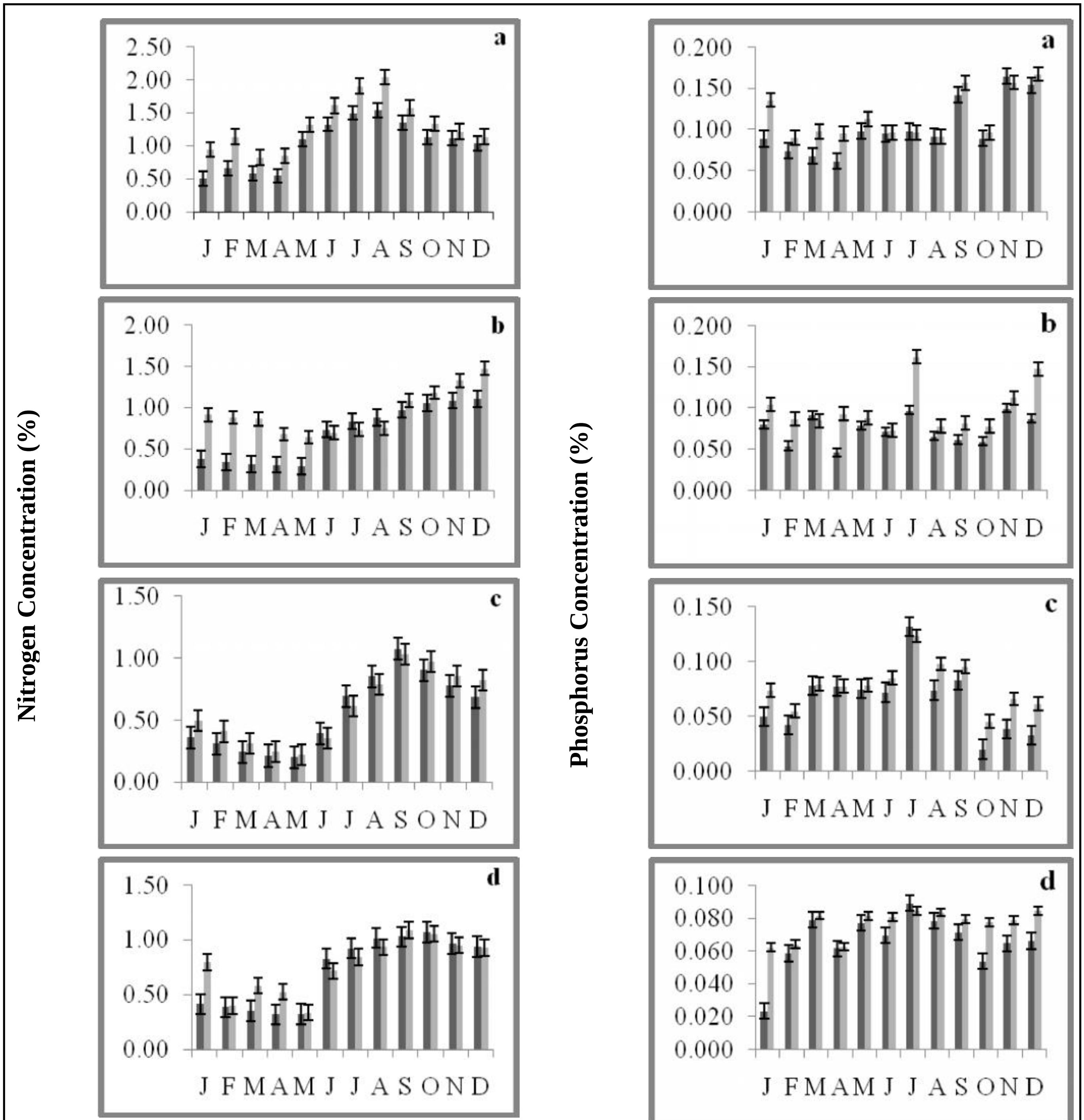

Fig. 2 : Monthly changes in N and P concentrations in live shoot (a), standing dead (b), litter (c), and below ground (d) of the vegetation in open grazingland (☐) and grassland under *Butea* plantation (▩)

concentrations in vegetational components of the open grazinglands and the grassland community under Butea plantation system are shown in the Fig. 2, 3 and 4. Maximum concentration of all the elements was recorded in the live shoots followed by dead shoots, below ground parts and litter. Concentration of N in the live shoots showed one peak in August in both the communities. It ranged between 0.5% (January) and 1.55% (December) in the open grazingland and 0.82% (August) and 2.04% (December) in the plantation site. N concentration in the below ground parts was maximum in September in the grassland community under Butea plantation system. Phosphorus concentration was lowest among the nutrients studied. The relative proportions of various elements

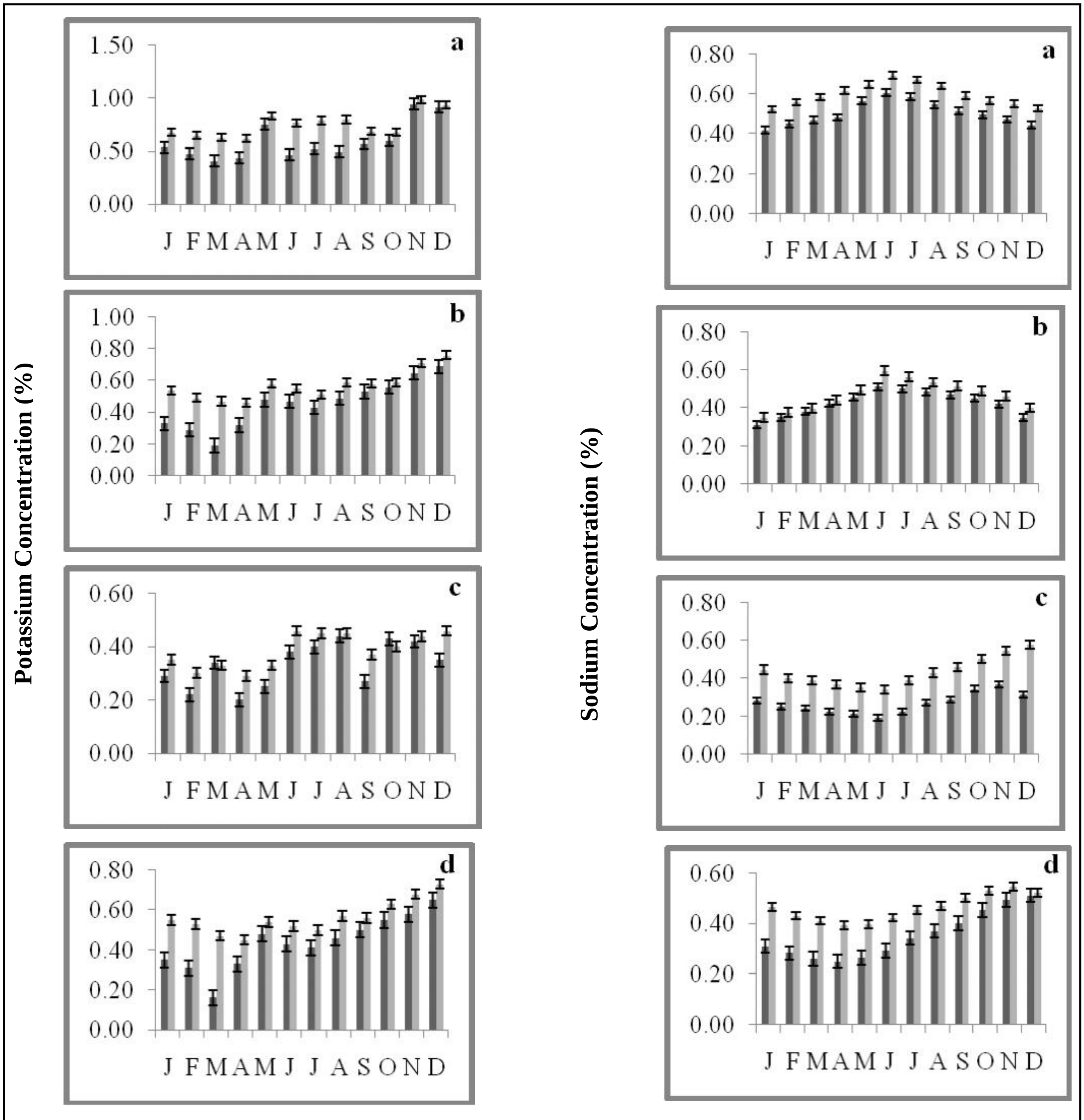

Fig. 3 : Monthly changes in K and Na concentrations in live shoot (a), standing dead (b), litter (c), and below ground (d) of the vegetation in open grazingland (☐) and grassland under *Butea* plantation (▪)

differed considerably in different plant components. Significant increase (P<=0.001) in nutrients concentration in plant components was observed in the grazingland under Butea plantation than in the open site. At both the sites, the average nutrient concentration in the plant components were in the order of N>Ca>K>Na>Mg>P.

Nutrient concentration in soil:

Table 1 shows the conspicuous seasonal variations of soil nutrients concentration and moisture content during the study period. Among the five elements, concentration of N was the highest and that of P the lowest. Analysis of variance showed that there was a significant difference in the nitrogen concentration between the sites

Table 1 : Seasonal variation in soil nutrients concentration (0-30 cm depth) and soil moisture content (± SE) in the open grazingland (A) and the grazingland under *Butea* plantation (B)

Season	Summer		Monsoon		Winter	
	A	B	A	B	A	B
Nitrogen (%)	0.062	0.117	0.076	0.113	0.094	0.122
Phosphorus (%)	0.007	0.012	0.008	0.013	0.0094	0.014
Potassium (%)	0.005	0.0097	0.0079	0.0132	0.0087	0.0142
Sodium (%)	0.005	0.0064	0.0058	0.0078	0.0088	0.0102
Calcium (%)	0.015	0.021	0.017	0.023	0.026	0.032
Magnesium (%)	0.008	0.022	0.0091	0.024	0.0107	0.033
Moisture (%)	3.05±0.13	4.75±0.19	3.35±0.09	5.3±0.18	7.45±0.19	9.7±0.09

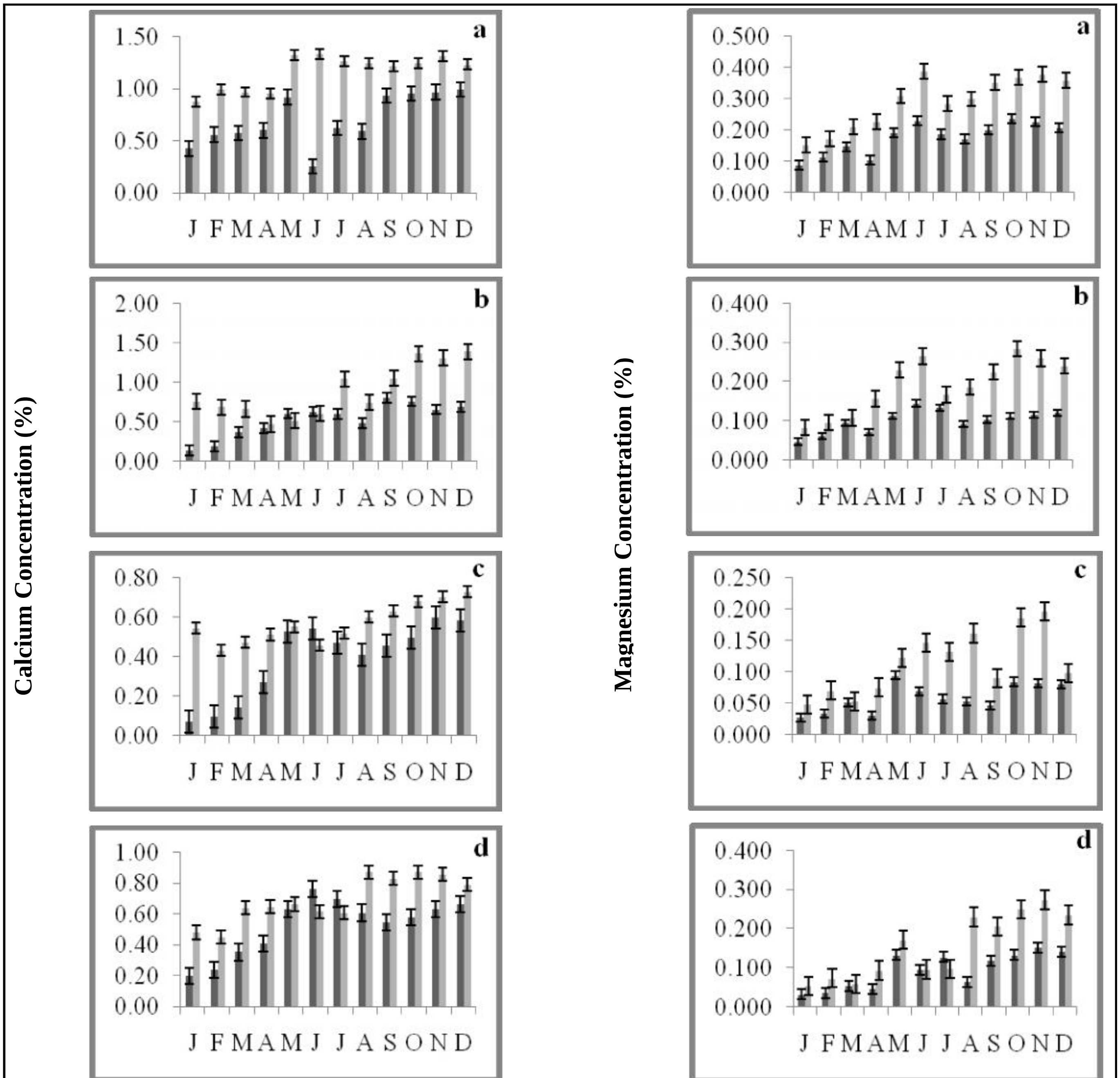

Fig. 4 : Monthly changes in Ca and Mg concentrations in live shoot (a), standing dead (b), litter (c), and below ground (d) of the vegetation in open grazingland (☐) and grassland under *Butea* plantation (▩)

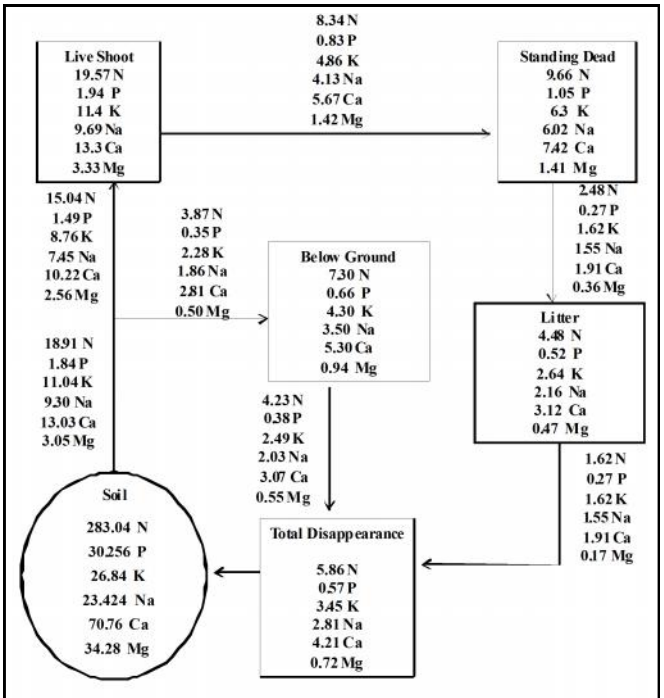

Fig. 5a : Mean storage (g m^{-2}) and annual uptake, transfer and release (g m $^{-2}$ yr^{-1}) of nutrients in the open grazingland. Values in compartments are storage and those on arrows are flux rates

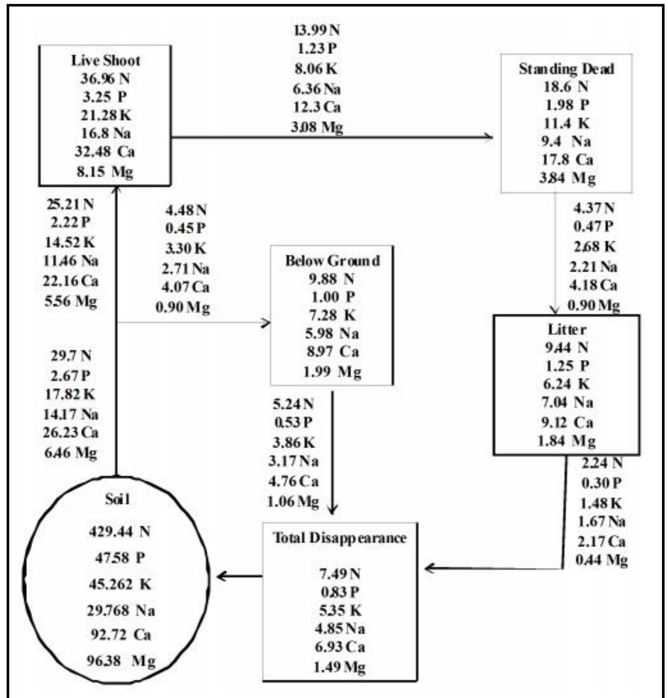

Fig. 5b : Mean storage (g m^{-2}) and annual uptake, transfer and release (g m^{-2} yr^{-1}) of nutrients in the grassland under *Butea* plantation. Values in compartments are storage and those on arrows are flux rates

($P<=0.001$). The soil nutrients were higher during winter followed by summer and rainy season. At both the sites, the nutrient concentration in the soil was in the order of N>Ca>K>Na >Mg>P. At both sites, the soil moisture content was in the order of winter> monsoon>summer. The soil moisture content also showed significant increase ($P<0.05$) in the grazingland under Butea plantation than in the open grazingland.

Annual uptake, transfer and release of nutrients:

Fig. 5a and b show the uptake, transfer and release of nutrients in the grazinglands. In the open grazingland , the annual uptake of N, P, K, Na, Ca and Mg by vegetation was 18.91, 1.84, 11.04, 9.30, 13.30 and 3.05 g m^{-2} yr^{-1}, respectively, while in the plantation site, the corresponding values were 29.7, 2.67, 17.82, 14.17, 26.23 and 6.46 g m^{-2} yr^{-1}. Of the total uptake 85% of nutrients were transferred to the live shoot and very little and rest was transferred to the below ground parts. The return of all nutrients to soil through litter and roots was much lower than their uptake. At both the sites, the nutrients returned to the soil through roots were lower than the litter. The uptake of the nutrients was significantly higher in the grazingland under plantation than in the open grazingland.

The greater concentration of all elements occurred in the live shoot followed by dead shoots, below-ground parts and litter at both the sites,. Similarly, Karunaichamy and Paliwal (1995) observed that the above ground live shoots contain higher percentage of nutrient concentration than the other plant components. The decline in concentration of nutrients from live shoot to dead shoot is a common phenomenon in temperate as well as tropical grasslands (Lechmere-Oertel *et al.*, 2008). This decline could be attributed to the withdrawal of nutrients from the shoot during senescence, weathering, leaching and microbial activity. Results of large number of studies revealed that nutrient concentration in below ground part is generally lower than the live shoot both in temperate (Agrawal, 1988; Ohlson and Malmer, 1990) and tropical grasslands (Billore and Mall, 1976; Chadurvedi *et al.*, 1988) which substantiate current findings. The annual uptake of nutrients in both the grazinglands were in the order of N>Ca>K>Na>Mg>P. The amount of nitrogen stored in the plant components was higher than the other nutrients. These differences might be attributed to their relative requirements in the metabolic processes, or to their relative availability in the ecosystem (Raghubanshi, 2008).

The nutrient concentrations in the plant components were significantly higher in the *Butea* plantation site than in the open grazingland. Similar increase in nutrient concentration under tree canopies was also reported by

Kay and Leonard (1980) in California and by Wilson *et al.* (1990) in Australia. The higher concentration of nutrients in the plant components resulted from higher nutrient content of the soil. Under canopy the soil moisture status is increased, which increases the moisture content of the surface litter, litter break down and mineralization of organic matter (Fernando and James, 2006).

The uptake of nutrients was higher in the grassland under Butea plantation than in the open grazingland. This might be due to lower nutrient concentration in the open grazingland and also due to litter decomposition and types of micro organisms. Singh *et al.* (2000) emphasized that the plantation system promotes nutrient cycling by taking up soil nutrients through tree roots and recycling them as litter, and root residue and helping to synchronize nutrient release with grass requirements. The nutrients return to the soil through litter disappearance was lower than that of root disappearance. Eastham (1988) observed that the evapotranspiration losses from pasture were highest under open area and decreased as the pasture was more shaded by the tree canopy. Because of low evapotranspiration rates, the soil moisture increased under canopy, which would improve the nutrient uptake from soil. Agarwal (1988) studied the level of fertility under different plantations and the soil under open field conditions and he observed that soil profile below *P. cineraria* contains comparatively higher organic matter, total nitrogen, available phosphorus, soluble calcium, low pH, available micro nutrients and better mechanical composition of soil up to 120 cm depth. The soil fertility is maintained through decomposition of roots of trees and crops and litterfall, which in sequence increase organic matter and biological activity of the soil by enhancing soil nutrient status.

In the present study the increase of nutrients under canopies might be due to the nutrient input by tree litter. Samarakoon *et al.* (1990) reported that shaded grasses have higher concentrations of N, P, K, Ca, Mg, Cu and Zn than un-shaded grasses. In contrast to these results, Suresh and Vinaya Rai (1987) observed the inhibitory effect of certain tree species on the surrounding vegetation through production of chemical inhibitors like phenolic compounds. The allelochemicals that are released through root exudates and leaf leachates in the Eucalyptus plantation reduces the NPP and nutrient content of the grazingland in the semi-arid region (Kailash Paliwal and Meenakshi Sundaravalli, 1998). The selection of overstorey tree species can exert a significant influence on the subsequent plant growth. The present study reveals that the tree species such as *B. monosperma* can increase the nutrient content of understorey grasses by their rapid leaf turnover and decomposition of nutrient rich litter, which can result in significant increase in soil fertility.

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