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IMPACT OF LEAF CHEMICAL QUALITY INDICES OF DIFFERENT TREE SPECIES ON SOIL MICROBIAL BIOMASS AND N-AVAILABILITY IN A WHEAT MICROCOSM

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ABSTRACT

Leaves of tropical multipurpose tree species (5 N-fixing, 5 non-N-fixing and combinations of 5 N-fixing species with a non-N-fixing) were incorporated in soil to evaluate effects on soil microbial biomass and N-availability of wheat in a pot experiment under dryland conditions. Soil microbial biomass and N-availability are closely linked to the productivity of an ecosystem. High quality leaves of N-fixing tree species had higher N content, and lower polyphenol (PPL) and lignin (LIG) contents (resulting in lower LIG/N, PPL/N and LIG + PPL/N ratios) than low quality leaves of non-N-fixing species. Combination treatments showed intermediate values of different parameters. Application of high quality leaves caused maximum rise in microbial biomass C and N and available-N in soil; the increase was minimum with low quality leaves and intermediate with combined treatment. Among N-fixing species, *Dalbergia sissoo, Cassia fistula* and *Prosopis cineraria* leaf applications showed greater increase in microbial biomass C (128-147% over control) and N (174 - 228%). Strong correlations between LIG + PPL/N ratio of leaves with MBC and MBN of wheat suggests that the ratio can be used to screen multipurpose tree species for use as soil amendment.

Key words: Microbial biomass C and N, *Cassia fistula*, *Dalbergia sissoo*, High quality resource, Low quality resource, *Prosopis cineraria*.

INTRODUCTION

The search for self–sustaining, low-input and energy efficient agricultural system is now a major concern of the researchers and policy makers especially in tropical dryland tracts which account for ca. 68% arable land in India. Sustainable agriculture must focus on biological soil fertility management, relying on a careful synchronization of crop nutrient needs with the availability of those nutrients in the soil[1,2]. The declining trends of

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organic matter content in tropical cultivated soils have necessitated to look for other alternatives such as the application of multipurpose tree leaves, which may serve a dual role as a fertilizer and a source of organic matter. The importance of leguminous trees for soil management has been emphasized in context of application of green leaves to soil as fertilizer[3]. The suitability of leaf materials as a source of N, may depend to a great extent on its decomposition rate, accumulation of N in soil microbial biomass, and N-mineralization rate in relation to the crop demand. Microbial biomass, a small but active fraction of soil organic matter (1-5% by weight), serves as a reservoir of plant available nutrients[4] and generally microbial biomass is closely linked to the primary productivity of an ecosystem[5]. Though many studies on leaf/litter decomposition and nutrient release of tropical agroforestry/multipurpose tree species are available[6,7], there is lack of studies evaluating the impact of tree leaves on soil fertility indicators. There is a need to screen tropical multipurpose tree species whose leaves can be used as a source of soil amendment; both singly and in combination, particularly in dryland cultivated regions.

The present study aims to evaluate the effect of addition of high and low resource quality leaves on key soil fertility indicators; Soil microbial biomass and available-N of wheat in a pot experiment.

EXPERIMENTAL

Materials and methods

The study was carried out in the Botanical Garden of Department of Botany, BHU (25° 18'N and 83°1' E, 76 m, above sea level). The soil of the study site belongs to the order Inceptisols, sub-order orchrepts, sub-group udic ustocrepts. The fine loamy, mixed, hyperthermic soil neutral to slightly alkaline reaction[8].

The experiment was designed with leaves of ten tree species used as soil amendments. Amongst the test tree species, 5 were symbiotic N-fixing and 5 non-N-fixing species. The N-fixing species were: *Dalbergia sissoo* Roxb. (Papilionaceae), *Bauhinia variegata* Linn. (Caesalpiniaceae), *Cassia fistula* L. (Caesalpiniaceae), *Prosopis cineraria* (Linn.) Druce (Mimosaceae) and *Casuarina equisetifolia* J. R. Forst and G. Forst (Casurinaceae). The non-N-fixing species were: *Sapindus emarginatus* Vahl (Sapindaceae), *Terminalia chebula* Retz. (Combretaceae), *Eucalyptus globulus* Labill. (Myrtaceae), *Madhuca indica* Gmel. (Sapotaceae) and *Holarrhena antidysenterica* (Roth) A. DC (Apocynaceae). Fresh leaves of these species were collected, air dried, and cut into small (~2 cm) pieces. The substrate in which the test crop, wheat (*Triticum aestivum*, var. HUW 533), was grown comprised field soil. Chopped leaves of 10 above mentioned species and a combination series of five N-fixing species each with non-N-fixing *Terminalia chebula* were incorporated within 0-5 cm deep soil. In all, there were 16 treatments (10 different species + 5 N-fixers with non-N-fixer + control). For each treatment 10 pots were set up. Seeds of the test crop were sown in pots in December 2003 and the crop was harvested after 120 days in April 2004. All pots were placed in an experimental area, which was covered with 3 cm mesh nylon net.

Air-dried tree leaves were finely powdered and the initial chemical composition was determined in triplicate. Carbon and total N content in leaves was determined by ignition method[9] and microkjeldahl method[10], respectfully. Lignin content (Klason lignin) was estimated[11]. Extractable polyphenols were determined by Folin-Denis method[12]. For the estimation of microbial biomass and available N, soil samples were collected at seedling and maturity stages of crop. Fresh moist soil, subjected to chloroform fumigation-extraction, was used to estimate microbial biomass. Microbial biomass C was measured[13] and Microbial biomass N was estimated by using microkjeldahl digestion procedure[14]. Nitrate-N was measured by the phenol disulphonic acid method[10]. Ammonium-N was extracted with 2 M KCl and analysed by the phenate method (APHA 1995)[15].

Treatment mean values were compared using least significant difference (LSD) range test procedure at the 5% level of significance. Correlation between was calculated by using SPSS / PC + software.

RESULTS AND DISCUSSION

Leaves of N-fixing tree species showed lower LIG/N (2.6-10.7), PPL/N (1.0-2.0) and LIG + PPL/N (3.6-12.1) ratios (Table 1). Non-N-fixing species leaves showed distinctly lesser N content but greater lignin and polyphenol contents; therefore, these species showed higher LIG/N (6.3-14.1), PPL/N (1.2-9.2) and LIG + PPL/N (10.4-22.5) ratios. The C/N ratio of N-fixing species leaves (15.8-26.1) was lower than the C/N ratio of non-N-fixing species (23.6-35.7). Combining low N containing *T. chebula* leaves with N-fixing tree leaves provided intermediate values of different parameters. The leaf chemical quality of tree species studied was comparable with characteristics reported in several other multipurpose tree species[16]. The leaves of N-fixing species, therefore, represented potentially rapidly mineralizing high quality resource, and the leaves of non-N-fixing species constituted low quality resource.

Table 1: Leaf quality indices and correlation coefficients (r) of different tree species with soil microbial biomass (MBC, MBN) and available-N; All correlations are significant at $p < 0.01$; for parameter abbreviation see text.

Leaf of tree species	Leaf quality indices			
	C/N	LIG/N	PPL/N	LIG + PPL/N
N-fixing-species				
B. variegata	20.6	8.3	1.9	10.2
C. equisetifolia	26.1	10.7	1.4	12.1
C. fistula	18.6	3.1	1.8	4.6
D. sissoo	15.8	2.6	1.0	3.6
P. cineraria	16.4	4.0	2.0	5.9
Non-N-fixing-species				
E. citriodora	25.2	14.1	5.1	19.2
H antidysentrica	23.6	5.8	4.6	10.4
M. indica	35.7	13.3	9.2	22.5
S. emarginatus	24.2	9.2	1.2	10.4
T. chebula	25.2	6.3	6.2	12.5
Combined species*				
B. variegata+	22.8	7.4	3.9	11.3
C. equisetifolia+	25.6	8.4	3.9	12.3
C. fistula+	21.4	4.4	3.7	8.1
D. sissoo+	21.5	4.5	3.5	7.9
P. cineraria+	19.9	4.8	3.7	8.5
LSD ($p < 0.05$)	*0.47*	*0.72*	*0.34*	*0.77*

Cont…

Leaf of tree species	Leaf quality indices			
	C/N	**LIG/N**	**PPL/N**	**LIG + PPL/N**
Soil characteristics				
MBC (µg g^{-1}.)	-0.73	-0.73	-0.63	-0.80
MBN (µg g^{-1}.)	-0.81	-0.78	-0.69	-0.86
Available-N	-0.80	-0.73	-0.72	-0.84

*N-fixing species combined with *T. chebula*; n = 45

In all treatments, the soil microbial biomass C and N increased at the maturity stage of wheat (Fig. 1). The increase in microbial biomass towards maturity stage is probably related to the greater nutrient availability in soil due to decreased crop demand and considerable pre-harvest root mortality and decomposition[17]. The mean microbial biomass C of five N-fixing species treatments (291 µg g^{-1}) was ca.108% higher than the control and the mean of non-N-fixing leaf treatments was 36% greater than control. The mean microbial biomass N showed greater increase (ca. 150% increase relative to control with N-fixing species; ca. 50% increase only with non-N-fixing species). When the non-N-fixing species leaves were combined with low quality *T. chebula* leaves, the mean microbial biomass C and N levels increased 78% and 100%, respectively. Greater increase in the amount of microbial biomass due to N-fixing species leaf application indicates predominant role of N derived from tree leaf decomposition in promoting microbial growth in soil. Substantially greater microbial biomass enhancement with N rich leaves of *D. sissoo, C. fistula* and *P. cineraria* (MBC, 128 - 147%; MBN, 174 - 228% over control) supports the above contention. Evidently, microbial biomass N was more strongly correlated with all leaf quality parameters than biomass C (Table 1). Besides, biomass N and available-N exhibited comparable correlations with different leaf quality parameters.

Soil available-N (NH_4-N + NO_3-N) concentrations were greater at crop maturity stage in all treatments (Fig. 1), and NH_4-N comprised of 78-82% of available N (data not shown). Greater soil N release occurred in N-fixing species treatments, indicated by 111% greater soil available N concentration than in control (cf. 33% and 67% greater N concentrations in non N-fixing and combined treatments). Addition of *D. sissoo, C fistula* and *P. cineraria* leaves showed >120% increase in soil available N over control, along with greater increase in microbial biomass.

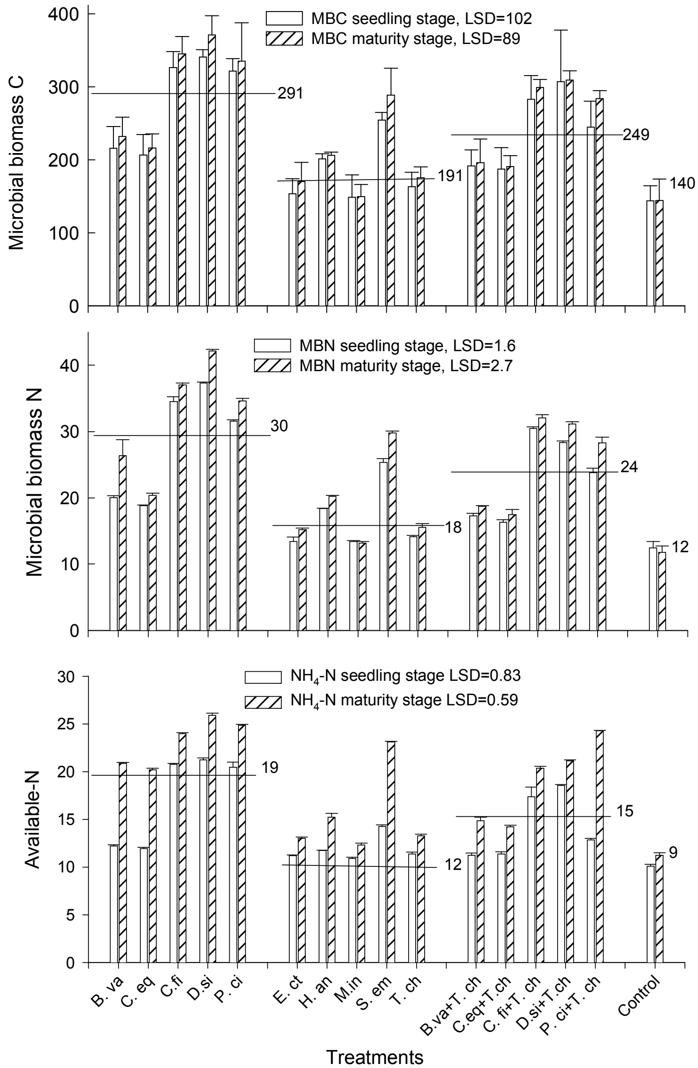

Figure 1. Microbial biomass C, N and available-N (µg g^{-1}) at wheat seedling (open bar) and maturity (hatched bar) stages in soil amended with different tree leaves (N-fixing, non-N-fixing and combined species, sequenced as in Table 1); Horizontal lines show mean values for the three groups; vertical lines over the bars show SE of mean; LSD across treatments is shown at $p < 0.05$.

It seems that profuse nutrient release from decomposing leaves of such species not only met the microbial demand but was accumulated in plenty in soil. In non-N-fixing species treatments (excepting *S. emarginatus*) the available N levels remained marginally (ca. 33%) greater than in control. Since incorporation of high quality tree leaves in soil leads to an early net release of N, such leaf resources may serve as major source of nitrogen to meet the immediate requirements during vegetative and reproductive growth phases of quick maturing crops. The addition of poor quality resource results in fierce competition between microbes and crops for available N, with major portion being immobilized by the former; thereby drastically reducing N availability to the crop in the short term[1]. Very rapid mineralization has been reported from residues of high quality *Sesbania sesban* and low mineralization from low quality residues of *Grevillea robusta*[18]. When mixed with *T. chebula*, *D. sissoo* and *C. fistula* treatments showed ca. 77-80% increase over control, but in case of combined input with *P. cineraria* the increase was much smaller. Combined high + low quality resources (with the three legumes studied presently) showing slower N release can be more suited as N source for slower maturing crops having longer life span, or for the succeeding crops.

There is a need to assess the indicator value of chemical composition of added leaf material accurately to anticipate crop growth and yield enhancements. N concentration and C/N ratio have traditionally been used to assess decomposition and nutrient release potential of organic inputs in natural ecosystems. More recently, lignin and polyphenol contents and their ratios (LIG/N, PPL/N, LIG + PPL/N) have been evaluated for the same purpose[18], though less frequently. Strong correlations found in this study between LIG + PPL/N ratio of incorporated tree leaves with microbial biomass and available N in soil indicate the regulatory effect of interactions among leaf constituents on soil nutrient availability that is directly related to crop growth. Thus, LIG + PPL/N ratio can be used as a tool to screen leaf of potential tree species for crop fertilization.

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