International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 3 Number 4 (2014) pp. 830-842**
http://www.ijcmas.com

Original Research Article

Variation in wheat yield, microbial biomass and N-availability in tropical dry land agroecosystem: Impact of application of different tree leaves

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A B S T R A C T

Keywords

Cassia fistula
Dalbergia sissoo
High quality resource
Low quality resource
Prosopis cineraria
Wheat yield

Tree leaves of some species can serve as sources of fertilizer for nutrient supply, especially nitrogen (N). In this study, leaves of selected tropical 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, N-availability and on yield of wheat in a pot experiment under dryland conditions. High quality leaves of N-fixing tree species had higher N content, 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%). The application of tree leaves resulted in N concentration rise in wheat components, the increase being greater with N-fixing species. Yield and N-uptake of wheat were regulated by soil nitrogen availability which in turn was related to microbial biomass. Direct application of high quality N-fixing tree species leaves, may serve as short-term

Introduction

To fulfill the demand of world growing population in changing climate, without increasing cultivated area have been increasingly recognized. Such endeavors are rendered difficult in developing countries of South Asia including India where land degradation has become a major problem (*Semwal et al.*, 2003). In India, especially in tropical dryland tracts (no irrigation available, depending on natural rainfall only) which account for ca. 68% arable land, the search for low-input and energy efficient agricultural system is now a major concern of the researchers and policymakers. Low input sustainable agriculture relying on a careful synchronization of crop nutrient needs with the availability of those nutrients in the soil (*Sarrantonio*, 2003; *Kundu* et al., 2007). The scarcity of traditional organic inputs and declining trends of organic matter content in tropical cultivated soils have necessitated looking for other options such as the application of tree leaves which may serve a dual role as a fertilizer and as 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 (*Chirwa* et al., 2003; *Silva Matos* et al., 2011). The suitability of leaf materials as a source of nitrogen (N), a critical nutrient often in short supply 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 (*Smith and Paul*, 1990), and generally microbial biomass is closely linked to the primary productivity of an ecosystem (*Piao* et al., 2000).

Chemical quality of tree leaves (like C, N, lignin, tannin or soluble polyphenol etc.) regulates decomposition rate and nutrient availability which together affects the crop productivity. High nitrogen, low lignin and low polyphenol contents are making high quality residues which decompose rapidly (*Haynes*, 1986). *Vityakon* et al. (2000) showed that variation in lignin, polyphenol and C/N ratios in different residues like groundnut, *Sesbania rostrata* stover, rice straw, *Tamarindus indica* and *Dipterocarpus tuberculatus* affects nitrogen release patterns and dynamics of microbial biomass. They stated that N concentration is the most significant factor influencing N release while extractable polyphenols exhibited a significance influence on N release.

Many studies on leaf/litter decomposition and nutrient release of tropical agroforestry/multipurpose tree species are available (e.g. *Byard* et al., 1996; *Lehman* et al., 1995; *Mwiinga* et al., 1994; *Palm* et al., 1997), Fewer studies evaluate the impact of tree leaves on soil microbial biomass, availability of nutrients and the yield of major cereal crops (e.g *Mafongoya* et al., 1996; *Tian* et al., 1993; *Anthofer* et al., 1998; *Akkaya* et al., 2006). Leaf quality may affect availability of nutrients and productivity of crops; while increasing nitrogen concentration promotes nutrient release, increasing lignin and polyphenol concentrations decrease it. There is a need to screen tropical multipurpose tree species whose leaves can be used as a source of soil amendment, particularly in dryland cultivated regions. The present study aims to evaluate the effect of addition of high and low quality multipurpose tree species leaves on key soil fertility indicators and biological productivity including yield of wheat in a pot experiment maintained out doors under dryland cropping conditions. This study addressed the following questions: (1) What is the impact of soil incorporation of selected tree species leaves on N-availability and microbial biomass, a biological indicator of the fertility of soil? (2) Whether the chemical quality of incorporated tree leaves is reflected on available-N and grain yield?

Materials and Methods

Study site

The study was carried out in the Botanical Garden of the Department of Botany, Banaras Hindu University (25° 18’N and 83°1’ E, 76 m, above sea level). The region has a tropical sub-humid seasonal climate with a warm-rainy season (July-September), a cool-dry winter (November-

February), and a hot-dry summer (April-June); October and March constitute transitional months between the seasons.

The experiment was designed with leaves of 5 symbiotic N-fixing and 5 non-N-fixing multipurpose tree species, used alone and in combination, as soil amendments. 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 & 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). Mature green leaves of these species were collected in November 2003, air dried in the laboratory and cut into small (≤2 cm) pieces.

Experimental set up

Upper layer (0-10 cm) of loam soil collected from a cultivated field (belongings to the order Inceptisols, sub-order orchrepts, sub-group udic ustocrepts, *Srivastava and Singh*, 2002) was broken thoroughly to remove root fragments, sieved through 2 mm mesh, thoroughly mixed and filled in 160 clay pots (each 30 cm diameter, 25 cm height). The soil characteristics were: (mean±SE): pH 7.3±0.1; maximum water holding capacity 51.2±0.2% (by brass cup, *Piper*, 1966); organic carbon (by dichromate oxidation, *Kalembasa* and *Jenkinson*, 1973) 7870±150 μg g^{-1}, total nitrogen (by micro-kjeldahl, *Jackson*, 1973) 770±3 μg g^{-1} soil. Pre-weighed chopped leaves of 10 abovementioned species and a combination series (five N-fixing species each with the non-N-fixing *Terminalia chebula*) were incorporated within 0-5 cm depth soil in pots. In all there were 16 treatments (10 different species + 5 N-fixing with non-N-fixing species + control). Single species leaves were applied @ 280 g m^{-2} (2800 kg ha^{-1}), and combined leaves @ 140 g m^{-2} each. Depending upon the nitrogen content, the applied leaves of N-fixing trees represented the addition of 54-84 kg N ha^{-1} (c.f. recommended dose being 60-80 kg N ha^{-1} in dryland agriculture). For each treatment 10 pots were set up.

Seeds of the test crop wheat (*Triticum aestivum*, var. HUW 533) were sown in pots in December 2003 (cool dry winter) and the crop was harvested after 120 days in April 2004. Four equidistant plants were raised in each pot. Barring occasional light rain spells of winter, the pots received (usually at 10-15 days interval) just enough water to maintain ca. 8-12% gravimetric soil moisture (approximating winter soil moisture range in cultivated drylands). Hand weeding was done once every month. All pots were placed in an open experimental area, covered with 3 cm mesh nylon net at top (2.5 m height) and sides to prevent litter blown from external sources or bird herbivory. The pots were randomly arranged in treatment blocks, which were spatially rotated every ten days. Periodically three pots per treatment were removed for soil and plant samplings.

Chemical analysis

Air-dried tree leaves were milled and passed through 1 mm mesh screen and the initial chemical composition was determined in triplicate. Carbon content in leaves was determined by ignition method

(*McBrayer* and *Cromack*, 1980). The total N content was estimated by the microkjeldahl method (*Jackson*, 1973). For estimating lignin content (*Klason* lignin) the initial leaf samples were digested in hot sulphuric acid, and the acid insoluble residue obtained by filtration was dried and weighed (*Effland*, 1977). Extractable polyphenols were determined by Folin-Denis method (*Anderson* and *Ingram*, 1993).

For the estimation of microbial biomass and available N, soil samples were collected from three pots per treatment, two times, at seedling and maturity stages of wheat crop. Fresh moist and sieved (2 mm mesh) soil, subjected to chloroform fumigation-extraction, was used to estimate microbial biomass. Microbial biomass C was measured by determining the organic C in K_2SO_4 extracts of fumigated and non-fumigated soil samples by dichromate digestion, as described by *Vance* et al., (1987). Microbial biomass C (MBC) was estimated from the equation: MBC = 2.64 Ec, where Ec is the difference between the amount of organic C extracted from K_2SO_4 extract of fumigated and non-fumigated soils, and 2.64 is the relationship between microbial biomass C as fumigation incubation method and amount of C extracted by 0.5 M K_2SO_4 after chloroform treatment. Another portion of K_2SO_4 extract was used to determine biomass N, estimated as total N using microkjeldahl digestion procedure (*Brookes* et al. 1985). Microbial biomass N (MBN) was computed from the equation: MBN = En / 0.54, where En is the difference between the amount of N extracted by K_2SO_4 extract of fumigated and non-fumigated and 0.54 is the fraction of biomass N extracted after chloroform fumigation. In another lot of fresh field moist and sieved soil, NO_3-N was measured by the phenol disulphonic acid method, using $CaSO_4$ as the extractant (*Jackson*, 1973), and NH_4-N extracted with 2 M KCl was analysed by the phenate method (*APHA*, 1995). The sum of NO_3-N and NH_4-N provided an estimate of available N.

The crop biomass was estimated at seedling, grain-forming and maturity stages (40, 80 and 120 days after sowing) (data not shown). The retrieved plant biomass was separated into shoot and root components. Further, the fraction of shoot representing grain yield was separated. All separated plant biomass components were oven dried at 80°C and weighed. N concentrations in finely powdered biomass were determined by microkjeldahl methods (*Jackson*, 1973). The N-uptake of wheat was calculated by multiplying the productivity of different plant parts with their N concentrations.

Statistical analysis

Treatment mean values were compared using least significant difference (LSD) range test procedure at the 5% level of significance. Correlations between different crop productivity and soil fertility parameters were calculated by using SPSS/PC+ software.

Results and Discussion

Leaves of N-fixing tree species showed higher N content (2.2-2.8% excepting *C. equisetifolia*), lower polyphenol (PPL, 2.4-5.7%) and lignin (LIG, 6.8-18.4%) contents, resulting in 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 (1.3-1.9%) than N-fixing species but greater lignin (11.2-26.9%) and polyphenol (8.8-12.1%, excepting *S.emarginatus*) 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). The two species groups showed overlapping ash and water-soluble compound contents. 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 (reflected by N, lignin and polyphenol contents and the ratios integrating these parameters) was comparable with characteristics reported in several other multipurpose tree species (e.g. *Dalbergia sissoo, Albizzia lebbek, Alnus nepalensis, Ficus roxburghi* etc.) by *Semwal* et al., (2003). Several studies suggest that plant materials with N >1.7%, lignin < 15%, polyphenol < 3% and C/N ratio < 20 generally mineralize rapidly in soil, while those exceeding these limits initially immobilize N (*Palm* et al., 1997). 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.

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 (*Singh and Singh*, 1993; *Kushwaha* et al., 2000). 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. Although the quantity of microbial biomass is mainly related to C inputs, other mitigating factors can regulate the growth and activity of the native microflora (*Smith and Paul*, 1990). The variation in the level of microbial biomass is dependent on the decomposition rate of the organic input (*Sarrantonio*, 2003). 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 2). 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 2.7 times increase in soil available N over control, along with greater increase in microbial biomass. In non-N-fixing species treatments (excepting *S. emarginatus*) the available N levels remained marginally (ca. 1.3 times) greater than in control. Since incorporation of high quality tree leaves in soil leads to an early net release of N, such leaf resources (e.g. *D. sissoo, C. fistula* and *P. cineraria*) 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 (*Myers* et al., 1994). Very rapid mineralization has been reported from residues of high quality *Sesbania sesban* and low mineralization from low quality residues of *Grevillea robusta* (*Nyberg* et al. 2002). When mixed with *T. chebula, D. sissoo* and *C. fistula* treatments showed ca. 1.8 times 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.

The addition of tree leaves to soil resulted in N concentration rise in wheat components, the increase being maximum with N-fixing species leaves (Table 3). Considerably higher N concentration was recorded in all parts of wheat in *D. sissoo* and *C. fistula* treatments. Total N uptake of wheat crop (the amount of N associated with crop productivity) in N-fixing species leaf treatments exceeded the uptake in non-N-fixing species leaf treatments (excepting *S. emerginatus*). *Ashraf* et al., (2004) also formed greater N-uptake in rice treated with leguminous *Sesbania* residue than with maize residue. Of the total N uptake, panicle accounted for 21-33%, shoot 57-66% and root 9-14% in different treatments.

The application of N-fixing tree leaves increased wheat yield 1.8 to 3.3 times (mean 2.8 times) and when combined with non-N-fixing *T. chebula* leaves the yield increased 1.5 to 2.6 times (Fig. 2). *D. sissoo*, *C. fistula* and *P. cineraria* leaves, applied alone as well as in combination with *T. chebula,* showed relatively higher wheat yield than other species. Barring *S. emarginatus* treatment, application of non-N-fixing species leaves alone showed small yield increase.

Fast decomposing, N rich leaf-material of *Leucaena leucocephala* and *Gliricidia sepium* (both N fixing legumes, containing >4% N in leaves) increased growth (ca. 3 times) and yield (ca. 2 times over control) of maize (*Kamara* et al., 2000). Comparable enhancements in crop productivity and grain yield obtained in this study due to incorporation of N-fixing tree leaves showing relatively lesser N content (especially *D. sissoo, C. fistula* and *P. cineraria*, 2.2-2.8% N) may be a consequence of better temporal synchronization between wheat demand and N availability in soil, reflected by greatly increased accumulation of N in the wheat biomass (Table 3).

Table.1 Chemical characteristics of tropical tree leaves used in the experiment; for abbreviations of constituents see text

Leaf of tree species	C (%)	N (%)	PPL (%)	LIG (%)	C/N ratio	LIG/N ratio	PPL/N ratio	LIG+PPL/N ratio
N-fixing-species								
Bauhinia variegata	44.5	2.2	4.2	17.9	20.6	8.3	1.9	10.2
Cassurina equisetifolia	44.8	1.7	2.4	18.4	26.1	10.7	1.4	12.1
Cassia fistula	46.7	2.5	4.5	7.7	18.6	3.1	1.8	4.6
Dalbergia sissoo	40.9	2.6	2.6	6.8	15.8	2.6	1.0	3.6
Prosopis cineraria	46.4	2.8	5.7	11.0	16.4	4.0	2.0	5.9
Non-N-fixing-species								
Eucalyptus citriodora	48.1	1.9	9.8	26.9	25.2	14.1	5.1	19.2
Holarrhena antidysentrica	45.4	1.9	8.8	11.2	23.6	5.8	4.6	10.4
Madhuca indica	46.9	1.3	12.1	17.5	35.7	13.3	9.2	22.5
Sapindus emarginatus	41.2	1.7	2.0	15.9	24.2	9.2	1.2	10.4
Terminalia chebula	46.7	1.8	11.5	11.6	25.2	6.3	6.2	12.5
Combined species								
B. variegata + T. chebula	45.6	2.0	7.8	14.8	22.8	7.4	3.9	11.3
C. equisetifolia + T. chebula	45.7	1.8	6.9	15.0	25.6	8.4	3.9	12.3
C. fistula + T. chebula	46.7	2.2	8.0	9.7	21.4	4.4	3.7	8.1
D. sissoo + T. chebula	43.8	2.0	7.1	9.2	21.5	4.5	3.5	7.9
P. cineraria + T. chebula	46.5	2.3	8.6	11.3	19.9	4.8	3.7	8.5
LSD	*0.48*	*0.07*	*0.99*	*2.22*	*0.47*	*0.72*	*0.34*	*0.77*

Table.2 N concentration (mg g^{-1}) and total N uptake (g m^{-2} $crop^{-1}$) in wheat grown in soil amended with tree leaves. LSD is shown at $p<0.05$

Treatments	N concentration			Total N uptake
	Panicle	Shoot	Root	
N-fixing-species				
Bauhinia variegata	7.7	6.1	4.8	6.38±0.42
Cassurina equisetifolia	7.4	5.8	4.3	5.78±0.18
Cassia fistula	10.4	8.0	6.7	12.15±0.11
Dalbergia sissoo	10.8	8.0	6.9	13.39±0.23
Prosopis cineraria	9.3	7.8	6.3	9.74±0.04
Mean	**9.1**	**7.1**	**5.8**	**9.49**
Non-N-fixing species				
Eucalyptus citriodora	6.3	4.4	3.0	3.47±0.06
Holarrhena antidysentrica	7.2	5.5	4.1	5.22±0.05
Madhuca indica	5.9	3.8	2.5	2.85±0.03
Sapindus emarginatus	8.1	6.9	5.5	7.54±0.31
Terminalia chebula	6.7	4.8	3.2	4.24±0.11
Mean	**6.8**	**5.1**	**3.7**	**4.66**
Combined species				
B. variegata + T. chebula	7.1	5.1	3.6	4.54±0.05
C. equisetifolia + T. chebula	7.0	4.9	3.5	5.00±0.27
C. fistula + T. chebula	8.2	7.2	5.7	7.70±0.15
D. sissoo + T. chebula	8.9	7.5	5.3	8.10±0.06
P. cineraria + T. chebula	7.8	6.5	5.2	7.03±0.25
Mean	**7.8**	**6.2**	**4.7**	**6.47**
Control	5.6	3.2	2.3	2.10±0.07
*LSD***	*0.4*	*0.2*	*0.3*	*1.2*

Table.3 Correlation coefficients (r) showing relationships of soil microbial biomass (MBC, MBN) and available-N with (a) chemical quality of added tree leaves and (b) wheat yield and crop N uptake

All correlations are significant at p<0.01(n=45); for parameter abbreviation see text.

Parameters	Soil characteristics		
	MBC	MBN	Available-N
Leaf quality			
LIG	-0.65	-0.70	-0.64
PPL	-0.54	-0.60	-0.64
C/N	-0.73	-0.81	-0.80
LIG/N	-0.73	-0.78	-0.73
PPL/N	-0.63	-0.69	-0.72
LIG + PPL/N	-0.80	-0.86	-0.84
Yield	0.89	0.99	0.98
Crop N uptake	0.98	0.95	0.98

Microbial biomass C, N and available N showed significant negative relationship with C, lignin, polyphenol and with their ratios whereas N showed positive relationship with microbial biomass C, N and available N. C/N, lignin/N, polyphenol/N and lignin+polyphenol/N ratios also showed negative relationship with crop yield and N uptake. Yield was more strongly negatively correlated with lignin+polyphenol/N ratio than with lignin and polyphenol contents alone. N concentration and C/N ratio have traditionally been used to assess decomposition and nutrient release potential of organic inputs in natural ecosystems (*Frankenberger* and *Abdelmagid*, 1985). More recently lignin and polyphenol contents and their ratios (LIG/N, PPL/N, LIG+PPL/N) have been evaluated for the same purpose (*Nyberg* et al., 2002), though less frequently. It has been shown that N release from decomposing leaf materials is strongly affected by their initial N, lignin and polyphenol contents (*Palm* et al., 1997). N release from leaf material is considerably reduced at high lignin concentrations, which is known to be a recalcitrant substance, being greatly resistant to microbial decomposition. Polyphenols act as bactericides (*Tian* et al., 1992); therefore, higher polyphenol content can slow down the decomposition of leaves by lowering the activity of microorganisms and enzymes. Most interactions during early stages of decomposition are believed to be due to polyphenols and interactions due to lignin occurs later (*Rayner*, 1994).

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.

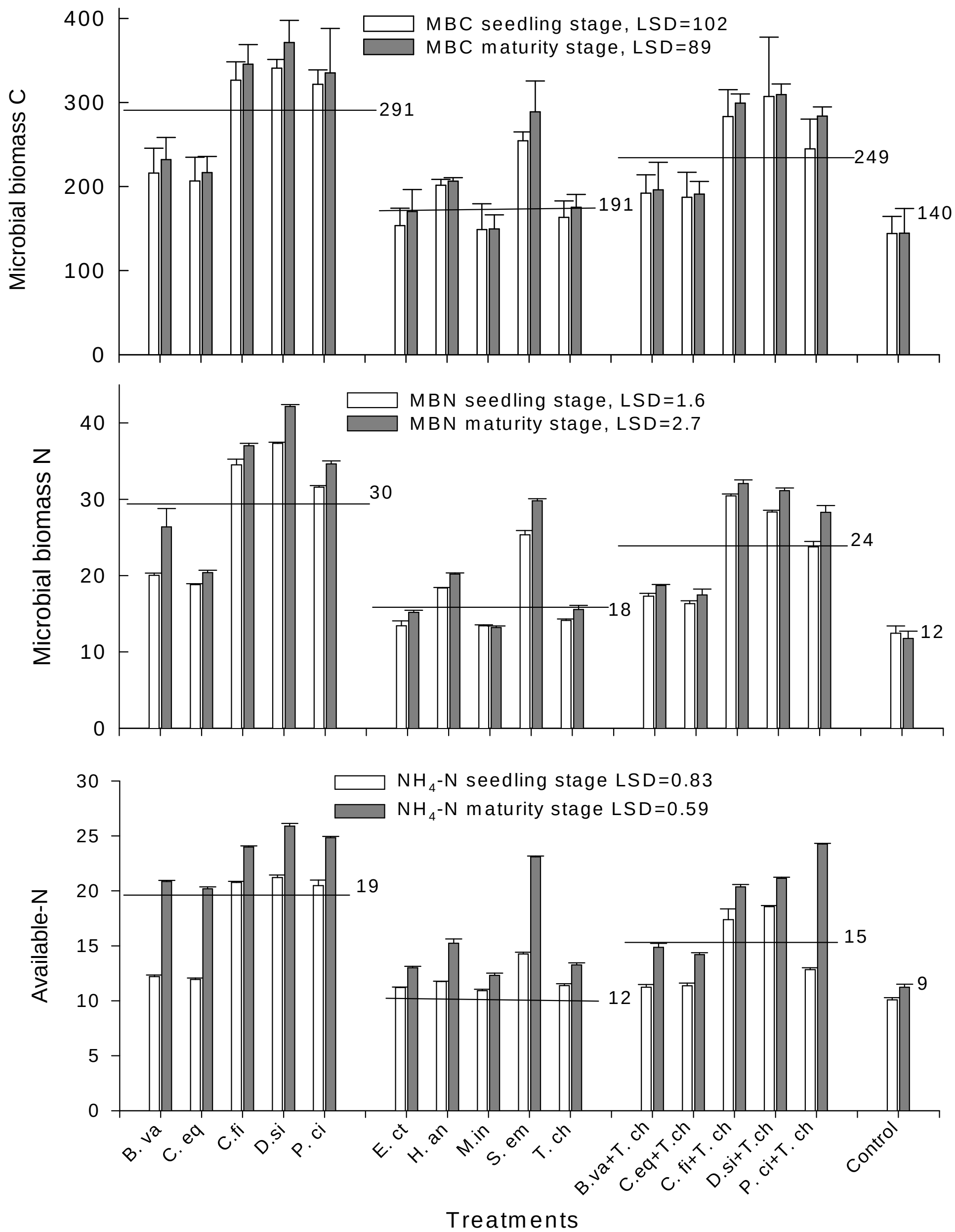
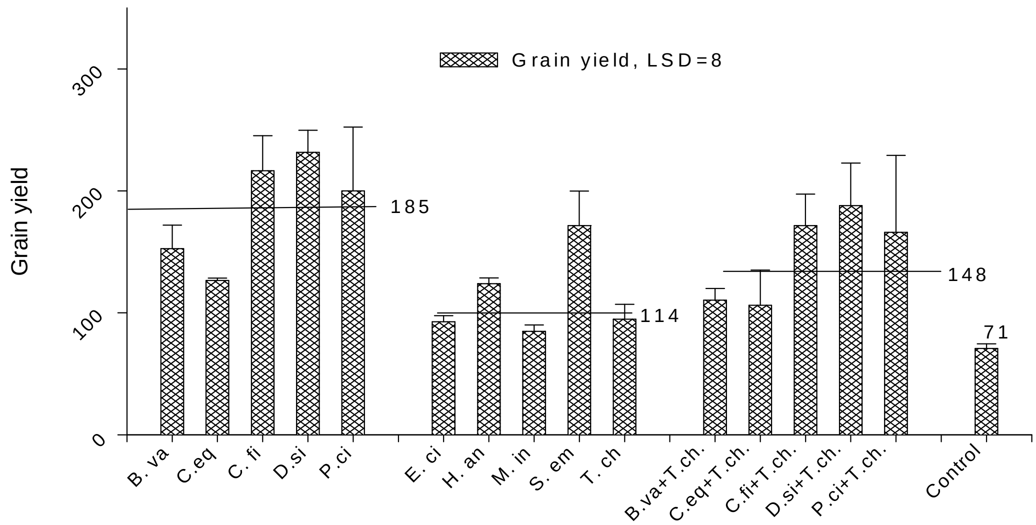


Figure.2 Effect of soil incorporation of different tree leaves (N-fixing, non-N-fixing and combined species, sequenced as in Table 1) on grain yield of wheat; horizontal lines show mean values for the groups; vertical lines on the bars show SE of mean; values are expressed as g m^{-2} $crop^{-1}$; LSD across treatments is shown at $p<0.05$.



Sholiahah et al., (2012) reported N, lignin and polyphenol contents are the residues quality factors that govern N mineralization. *Loranger* et al., (2002) have reported negative correlations between mass loss of decomposing organic matter and lignin content, polyphenol content and LIG+PPL/N ratio in tropical forests. *Silva* et al., (2008) also showed lignin/N and lignin+polyphenol/N ratios have significant correlation with decomposition rate and nitrogen release by comparing ten species. 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 and crop growth. Thus, LIG+PPL/N ratio in leaf should serve as a useful index in screening of potential tree species for crop fertilization.

It is concluded that direct incorporation of leaves of N-fixing multipurpose trees (e.g. *D. sissoo*, *C fistula* and *P. cineraria*) will significantly enhance microbial biomass and nitrogen availability in soil, which in turn will improve wheat productivity in a short term. To promote long term, gradual impact the combined application of N-fixing and non-N-fixing tree leaves may be justified. For mass screening of multipurpose tree species, to assess their effect on soil quality and crop growth, the LIG+PPL/N ratio of leaves can serve as a reliable index.

Acknowledgement

The authors thank the Head and the Programme Co-ordinator, Centre of Advanced Study in the Department of Botany for providing laboratory and library facilities. Ministry of Environment and Forests, New Delhi, India provided financial assistance to the project which included a Research Associateship to RS.

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