EXCELLENT PUBLISHERS

International Journal of Current Research in Biosciences and Plant Biology

ISSN: 2349-8080 Volume 2 Number 2 (February-2015) pp. 67-73

www.ijcrbp.com

Original Research Article

Variation in Total Biological Productivity and N Uptake of Tropical Rice Crop Due to Application of Different N Rich Tree Leaves as Soil Amendments

Rajani Srivastava*

Environmental Science and Technology, IESD, RGSC (Barkachha), Banaras Hindu University, Mirzapur-221 005, India

**Corresponding author.*

Abstract

High N containing tree leaves can serve as sources of fertilizer for nutrient supply, especially nitrogen (N). In this study chopped leaves of three N rich tropical tree species, *Dalbergia sissoo*, *Cassia fistula* and *Azadirachta indica* alone and in combination with low quality wheat straw (WS) were incorporated in soil to evaluate its effects on N uptake and rice total biological productivity (including grain yield) under dryland condition. *D. sissoo*, *C. fistula* and *A. indica* leaves have low lignin+polyphenol/N ratio (LIG+PPL/N, 4.5-12.4) compared to combined treatments. The N concentration in rice components increased in all treatments, maximum concentration being recorded in fertilizer treatment followed by *D. sissoo* leaf treatment. In various treatments, ANP and BNP of rice ranged between 490-1114 g m^{-2} $crop^{-1}$ (cf. 422 g m^{-2} $crop^{-1}$ in control) and 88-226 g m^{-2} $crop^{-1}$ (cf. 79 m^{-2} $crop^{-1}$ in control), respectively (Table 2). Range of grain yield in different treatments was 134-238 g m^{-2} $crop^{-1}$ (cf. 104 m^{-2} $crop^{-1}$ in control). Among all treatments, after chemical fertilizer treatment, application of *D. sissoo*, *C. fistula* and *A. indica* tree leaf alone showed substantially higher rice productivity than others. Strong correlation in this study between LIG+PPL/N ratio to total crop productivity (including grain yield) reflect the regulatory effect of leaf constituent interactions on nutrient availability and crop growth. Thus, it is recommended that for soil fertility amelioration geared to sustainable high rice productivity in tropical dryland agroecosystem, the ecological soil fertility manipulation by application of high quality tree leaves holds great potential.

Keywords

Azadirachta indica

Cassia fistula

Dalbergia sissoo

LIG+PPL/N ratio

Soil sustainability

Introduction

In recent years ‘Green revolution’ has begun slowing down and in some regions rice and wheat yields have either remained stagnant or even declined (Ramesh et al., 2005), besides causing several environmental health problems (Aulakh et al., 2001). Green manure not only serves as a source of current nutrients but it also enhances the overall and long-term fertility of soil (Palm and Sanchez 1991). Leaves of multipurpose tree species constitute valuable resources, which are potential source of green manure (Srivastava and Singh 2013). Nutrient release from green manure is important for tropical crops, where subsistence agriculture is wide spread and use of inorganic fertilizer is limited (Palm et al., 1997). However, there is paucity of organized information on the use of leaves from natural and agroforestry ecosystems as detritus and nutrient sources in agroecosystems.

It is hypothesized that variation in quality and quantity of organic matter (crop residue and external inputs) added to soil affect crop productivity by regulating soil fertility through nutrient availability. The tropical dryland agroecosystems (rainfed only), accounting for 68% arable land in India and having no access to irrigation, are characterized by low crop productivity due to water and nutrient scarcity (Ghoshal and Singh, 1995). Since only about 38% food grain is produced from dryland areas (Singh and Venkateswarin, 1999), tremendous possibilities exist for the enhancement of crop production in these extensive drylands, through measures aimed at improvement of soil fertility by incorporation of organic residues.

The current emphasis on promotion of multipurpose tree plantations on vacant lands and agroforestry practices opens new avenues for organic material supply. In this respect the evaluation of the impact of high N containing multipurpose tree leaves on soil fertility assumes significance. The aim of present study was to assess the effect of N-rich multipurpose tree leaves, added alone (high quality) or in combination with wheat straw (low quality), on soil fertility and productivity and yield of rice, grown as test crop in dryland conditions.

Materials and methods

Study site

This work was carried out in the Botanical Garden of Department of Botany, Banaras Hindu University (25° 18'N and 83°1' E, 76 m, above sea level). This region has a tropical sub-humid seasonal climate, showing 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 seasons. The long-term average annual rainfall is about 1100 mm. The soil of the study site belongs to the order Inceptisols, sub-order orchrepts, sub-group udic ustocrepts (Srivastava and Singh, 2002). The topsoil is loamy, neutral in reaction, with 0.79% organic C and 0 0.08% total N.

Experimental design

The experiment was designed with nitrogen rich leaves of three multipurpose (high quality resource) tree species, collected during November when the canopy is fully developed. These species were: *Dalbergia sissoo* (Papilionaceae), *Cassia fistula* (Caesalpinaceae), *Azadirachta indica* (Meliaceae). Following treatments using leaves of following trees, alone or in combination with wheat straw (low quality resource), were tried with rice (*Oryza sativa*, var. NDR 97) as the test crop during rainy season: (1) *D. sissoo*, (2) *C. fistula*, (3) *A. indica*, (4) wheat straw (5) *D. sissoo* leaves + wheat straw, (6) *C. fistula* leaves + wheat straw, (7) *A. indica* leaves + wheat straw, (8) Fertilizer (urea) (9) Control. All leaf materials were collected in November; air dried in the laboratory and cut into small (~2 cm) pieces.

The soil used as substrate for the test crop collected from cultivated field in the Botanical Garden was broken thoroughly and sieved through a 2 mm sieve to remove root fragments and other undecomposed litter. The sieved soil, thoroughly mixed 5-6 times to homogenize it well, was used to fill up pots (each 30 cm diameter, 25 cm height). The chopped leaves of tree species (alone and in combination with chopped wheat straw) were mixed well within 0-5 cm soil depth. Fertilizer was also similarly mixed with soil. Both leaves and fertilizer were applied in calculated quantities to supply 80 kg N $ha^{-1.}$ In combination treatments, wheat straw and leaves were applied @ 40 kg N ha^{-1} of each. For each treatment 15 pots were set up. Rice seeds were sown in pots in July 2005, four plants were maintained per plot, and the crop was harvested in November. The pots received natural rainfall only, all pots were placed in an open experimental plot that was covered with nylon net (3 cm mesh, 2.5 m height) at top and sides to prevent litter blown from external sources or the bird herbivory. The pots were randomly arranged in treatment blocks, which were spatially rotated every ten days. Five pots per treatment were sampled each time.

Chemical analysis of tree leaves

The initial chemical composition of air-dried milled tree leaves 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, Effland, 1977) the leaf samples were digested in hot sulphuric acid, and the acid insoluble residue obtained by filtration was dried and weighed. Extractable polyphenols were determined by Folin-Denis method (Anderson and Ingram, 1993). Their ratios are used in this paper.

Crop productivity and N-uptake

The crop biomass was estimated at seedling, grain-forming and maturity stages (40, 80 and 120 days after rice sowing). Wheat plants were carefully removed from the pots and the roots were washed with a fine jet of water over a three sieves assembly (2 mm, 0.5 mm and 0.2 mm mesh). The plant biomass was divided into aboveground shoot and belowground root components. At maturity the fraction of aboveground biomass representing grain yield was separated. All plant biomass components were separately oven dried at 80°C and weighed.

N concentrations in the biomass components were determined by the microkjeldahl method (Jackson, 1973). Total net productivity was calculated as the sum of aboveground net productivity (ANP) and belowground net productivity (BNP). The ANP and BNP of wheat plants were derived from the maximum aboveground and belowground biomass values recorded at maturity and grain-forming stages, respectively. 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 and correlations were done by using SPSS / PC+ software.

Results and discussion

Leaves of all species showed high N concentration and low values of various ratios (C/N, 14.9-19.5; LIG/N, 2-4.3; LIG+PPL/N, 4.5-12.4) (Table 1). Combined inputs (leaf+wheat straw) were characterized by lower N concentration and higher ratios (C/N, 22.5-26.5; LIG/N, 7.6-9.9; LIG+PPL/N, 11.2-16.3). Wheat straw treatment showed maximum C/N and LIG+PPL/N ratios. Palm et al. (1997) reported that plant materials with concentrations of N >1.7%, LIG <15%, PPL <3% and C/N ratio <20 generally mineralize rapidly in soil, while those exceeding these limits initially immobilize N. While rapidly mineralizing species are high quality resources, the slow mineralisers are low quality resources.

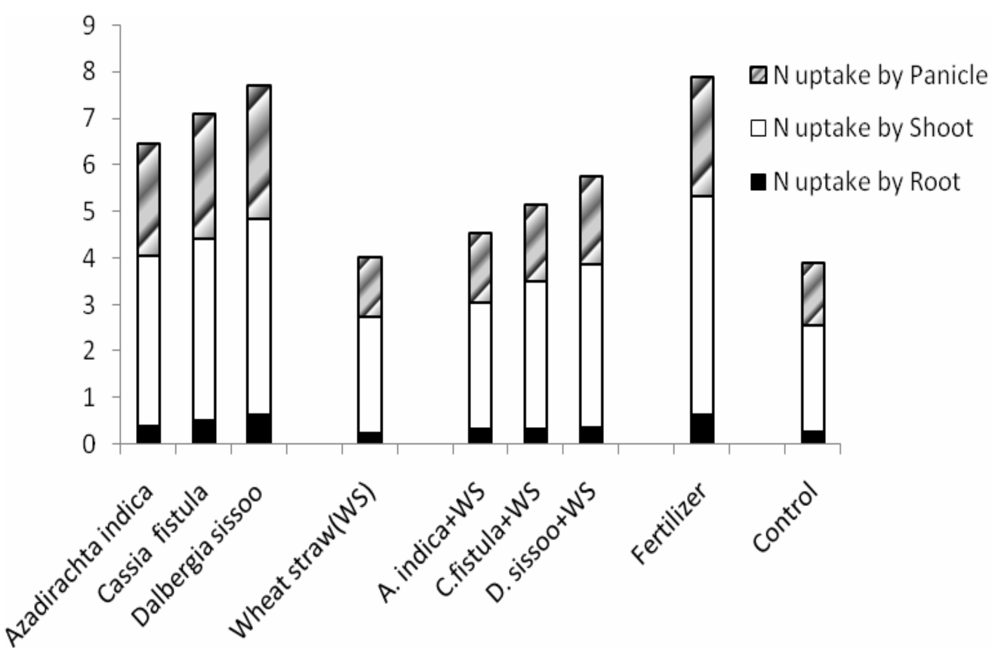
The leaves of N rich tree species studied here were categorized as high quality, wheat straw as low quality and N rich species and wheat straw as medium quality resources. The resource quality of soil amendments significantly affects nutrient availability (especially of N) by regulating mineralization rate. Mineralization is rapid and high from high quality residue (low ratio of PPL+LIG/N) and slow and low from low quality residues (high ratio of PPL+LIG/N) (Nyberg et al., 2002).

Table 1. Quality indices ratios of different tree leaves, wheat straw and their combinations.
LSD (p<0.05) compares values in column.

Species	C/N ratio	LIG/N ratio	PPL/N ratio	LIG+PPL/N ratio
Azadirachta indica	19.5	4.3	3.5	12.4
Cassia fistula	17.0	3.1	1.7	7.4
Dalbergia sissoo	14.9	2.0	0.9	4.5
Wheat straw(WS)	77.6	19.7	3.8	22.1
A. indica + WS	26.5	9.9	3.7	16.3
C. fistula + WS	24.4	8.6	2.5	13.1
D. sissoo + WS	22.5	7.6	1.8	11.2
LSD	*2.4*	*2.8*	*0.2*	*2.3*

High N containing tree leaf materials resulted in increased N-mineralization rate or available-N, but this effect was lowered in presence of high concentration of polyphenols and lignin in the decomposing material. Polyphenol is widely known as disinfectant and acts as bactericide, lowering the activity of microorganisms and slowing down the decomposition processes (Tian et al., 1992). Phenolic compounds are known to bind mineralized-N in the nitro- and nitroso- form in soil humus. Lignin is a recalcitrant substance, resulting in slow mineralization of lignin-bound nitrogen. In the present study, the incorporation of N rich tree leaves (*D. sissoo, C. fistula* and *A. indica*), representing rapidly mineralizing high quality resources, compared to combination treatments where added material decomposed slowly, support the above contention. Nutrients in excess of crop demand may be lost through leaching or volatilization (Myers et al. 1994). Synchrony between nutrient mineralization rate and crop demand is desirable. On the other hand, combination of high+low quality resources (tree leaves + wheat straw) showing delayed release of N can be more suited as N source for slow maturing crops having longer maturation time. Although combination treatments show marginally lesser rice productivity, nevertheless, these treatments offer the advantage of long term nutrient enhancement in soil, which may profitable for succeeding crop. Thus, *D. sissoo, C. fistula* and *A. indica* tree leaf alone seem to be more appropriate for current crop productivity and soil fertility whereas these tree leaves combined with wheat straw may be more beneficial for next crop. In case of crop N-uptake, maximum concentration of N was recorded in the shoot followed in decreasing order by paicle and root. The N concentration in rice components increased in all treatments, maximum concentrations being recorded in fertilizer treatment followed by *D. sissoo* leaf treatment. The application of tree leaf alone and in combination with wheat straw distinctly increased N uptake (N associated with rice productivity) of rice (Fig. 1).

Fig. 1: Total N uptake (g m^{-2} crop^{-1}) in rice crop grown in soil amended with different leaf materials alone and in combination with wheat straw.



Of the total uptake 31-38% was reflected in panicle, 54-62% in shoot and 6-8% in root in different treatments. Phongpon and Mosier (2003) also reported maximum N uptake in fertilizer treatment followed by compost and straw treatment. Similar report is also given by Nyberg et al. (2002), where he emphasized that to achieve synchrony with crop demand caution is needed in management as large amounts of N mineralized within a few days after application. Tree leaves+wheat straw treatment may be useful in context of long-term sustainability of soil. Tree leaf inputs have been show to improve physico-chemical properties and crop yield (Tian et al., 1992). But there is scarcity of information on effect of tree leaf alone and in various combinations on total biological productivity and soil fertility in tropical dryland agroecosystem. Comparable enhancement in crop productivity (3 times cf. control) and grain yield (2 times cf. control) was observed by Kamara et al. (2002) by using high N containing, fast decomposing *Leucaena leucocephala* and *Gliricidia sepium* as high quality resources.

In various treatments, ANP and BNP of rice ranged between 490-1114 g m^{-2} $crop^{-1}$ (cf. 422 g m^{-2} $crop^{-1}$ in control) and 88-226 g m^{-2} $crop^{-1}$ (cf. 79 m^{-2} $crop^{-1}$ in control) (Table 2). Range of grain yield in different treatments was 134-238 g m^{-2} $crop^{-1}$ (cf. 104 m^{-2} $crop^{-1}$ in control). Among all treatments, after chemical fertilizer treatment, application of *D. sissoo*, *C. fistula* and *A. indica* tree leaf alone showed substantially higher productivity than others. On an average, TNP in high quality, N rich tree leaf treatment exceeded over control 111% whereas combination with wheat straw treatment showed only 36% increase. There was slightly increase in BNP/ANP ratio in tree leaf with wheat straw treatment (mean 0.22 in single tree leaf treatments; mean 0.25 in combined treatments, 0.21 in fertilizer and 0.22 in control treatments).

Table 2. Effect of soil incorporation of different leaf materials alone and in combination with wheat straw, sequenced as in Table 1; on aboveground net productivity (ANP), belowground net productivity (BNP) and grain yield of crop (g m^{-2} $crop^{-1}$); LSD is shown at p<0.05.

Species	ANP	BNP	Grain yield
Azadirachta indica	810	155	179
Cassia fistula	906	176	203
Dalbergia sissoo	1073	226	229
Wheat straw(WS)	490	88	134
A. indica + WS	597	118	152
C. fistula + WS	666	131	157
D. sissoo + WS	732	143	168
Fertilizer	1114	109	238
Control	422	79	104
LSD	*60*	*17*	*17*

Table 3. Correlation coefficients showing relationships between rice productivity and chemical quality of tree leaves incorporated in soil.

Leaf quality	Rice productivity			
	ANP	BNP	TNP	Grain yield
C/N	-0.77**	-0.74**	-0.78**	-0.75**
LIG/N	-0.81**	-0.78**	-0.83**	-0.78**
PPL/N	-0.52**	-0.49**	-0.53**	-0.50**
LIG + PPL/N	-0.84**	-0.81**	-0.86**	-0.81**
Units: Rice productivity components g m^{-2} $crop^{-1}$; Significant at the 0.01 level.				

In tree leaf with wheat straw treatment there was slightly increase in BNP/ANP ratio noted. Increase in BNP compared to ANP is another important aspect in the functioning of agroecosystems because most of the ANP is harvested but bulk of BNP remains within the soil. Under rotation cropping subsequent crop gains due to prolonged nutrient release from the decomposing dead root mass of preceding crop (Singh and Shekhar, 1989). Variation in N availability and crop productivity in amended soil might due to variation in chemical composition of added leaves. There is a need to assess the indicator value of chemical composition of added material in affecting crop growth and yield. N concentration and C/N ratio have long been used to assess the decomposition and nutrient release potential of organic input in agroecosystems. But now it has been shown that N release is strongly related to lignin and polyphenol content (Palm, 1995). Lignin reduces the rate of N mineralization from decomposing plant materials by forming lignoprotein complexes (Frankenberger and Abdelmagid, 1985), but how polyphenol inhibit decomposition is not clear (Oglesby and Fownes, 1992). Soluble phenols may precipitate proteins, thereby inhibiting microbial/enzyme activities essential for N mineralization. In this study lower availability of N to rice crop in tree leaf+wheat straw (high quality+low quality) treatment may be due to higher lignin and polyphenol contents. However, amongst various parameters, lignin+polyphenol/N account for maximum variation in available N and crop productivity. Handeyanto et al. (1994) and Dinesh et al. (2001) also found LIG+PPL/N to be a better index for predicting N mineralization in soils than lignin/N and polyphenol/N ratio. Strong correlation in this study between LIG+PPL/N ratio to crop productivity (including grain yield) reflect the regulatory effect of leaf constituent interactions on nutrient availability and crop growth.

Conclusion

It is evident that incorporation of leaves of N-fixing multipurpose trees (e.g. *D. sissoo* and *C fistula*) will significantly improve the biological basis of soil fertility and rice productivity in a short term in tropical dryland conditions. For assessing the effect of tree leaves on soil quality and rice productivity, LIG+PPL/N ratio can be used as an index for screening of large number of multipurpose tree species and other materials used as soil amendment. Thus, it is recommended that for soil fertility amelioration geared to sustainable high rice productivity in tropical dryland agroecosystem, with least dependence upon chemical fertilizer input, the ecological soil fertility manipulation by application of high quality tree leaves holds great potential.

Acknowledgement

We thank the Head and the Programme Co-ordinator, Centre of Advanced Study in the Department of Botany for providing laboratory and library facilities.

References

Anderson, J.M., Ingram, J.S.I., 1993. Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International, Wallingford, UK.

Aulakh, M.S., Khera, T.S., Doran, J.W., Bronson, K.F., 2001. Managing crop residue with green manure, urea, and tillage in a rice-wheat rotation. Soil Sci. Soc. Amer. J. 65, 820-827.

Dinesh, R., Suryanarayana, M.A., Nair, A. K., Chaudhuri, S.G., 2001. Leguminous cover crop effects on nitrogen mineralization rates and kinetics in soil. J. Agron. Crop Sci. 187, 161-166.

Effland, M.J., 1977. Modified procedure to determine acid insoluble lignin in wood and pulp. Technical Assoc. Pulp Indust. (TAPPI) 60, 143-144.

Frankenberger, W.T., Abdelmagid, H.M., 1985. Kinetic parameters of nitrogen mineralization rates of leguminous crops incorporated into soil. Plant Soil 87, 257-271.

Ghoshal, N., Singh, K.P., 1995. Effect of farmyard manure and chemical fertilizer on total net production, yield and root necromass in a dryland rice-lentil agroecosystem. Trop. Agric. 72, 225-230.

Jackson, M.L., 1973. Soil chemical Analysis. Prentice-Hall, Inc. Englewood, Cliffs, New Jersey, 485 p.

Kamara, A. Y., Akobundu, I.O., Sanginga, N., Jutzi, S.C., 2000. Effect of mulch from selected multipurpose trees (MPTs) on growth, nitrogen nutrition and yield of maize (*Zea mays* L.). J. Agron. Crop Sci. 184, 73-80.

Mayer, R.J.K., Palm, C. A., Cuevas, E., Gunatilleke, I.U.N., Brossard, M., 1994. The synchronization of nutrient mineralization and plant nutrient demand. In: The Biological Management of Tropical Soil Fertility (Eds.: Woomer, P.L., Swift, M..J.). Wiley, Sussex. pp. 1-116.

McBrayer, Jr. J.F., Cromack, K., 1980. Effect of snow-pack on oak-litter breakdown and nutrient release in a Minnesota forest. Pedobiol. 20, 47-54.

Nyberg, G., Ekblad, A., Buresh, R., Högberg, P., 2002. Short-term patterns of carbon and nitrogen mineralization in a fallow field amended with green manures from agroforestry trees. Biol. Fertil. Soils 36, 18-25.

Oglesby, K.A., Fownes, J.H., 1992. Effects of chemical composition on nitrogen mineralization from green manures of seven tropical leguminous trees. Plant Soils 14, 127-132.

Palm, C.A., 1995. Contribution of agroforestry trees to nutrient requirements of intercropped plants. Agroforest. Syst. 30, 105-124.

Palm, C.A., Sanchez, P.A., 1991. Nitrogen release from the leaves of some tropical legumes as affected by their lignin and polyphenol contents. Soil Biol. Biochem. 23, 83-88.

Palm, C.A., Mayers, R.J.K., Nandwa, S.M., 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. In: Replenishing Soil Fertility in Africa (Eds.: Buresh, R.J., Sanchez, P.A., Cathoun, F.). SSSA Special Publication no. 51. Soil Science Society of America, American Society of Agronomy, Madison, Wis. pp. 193-217.

Pongpan, S., Moiser, A.R., 2003. Effect of rice straw management on nitrogen balance and residual effect of urea-N in an annual lowland rice cropping sequence. Biol. Fertil. Soils 37, 102-107.

Ramesh, P., Singh, M., Rao, A.S., 2005. Organic farming: Its relevance to the Indian context. Curr. Sci. 88, 561-568.

Singh, H.P., Venkateswarin, B., 1999. Turning grey areas green. *The Hindu Survey of Indian Agriculture*, 1999. The Hindu, Chennai, India. pp. 25-27.

Singh, K.P., Shekhar, C., 1989. Concentration and release patterns of nutrients (N, P and K) during decomposition of maize and wheat roots in a seasonally-dry tropical region. Soil Biol. Biochem. 21, 81-85.

Spedding, T. A., Hamel, C., Mehuys, G. R., Madramootoo, C.A., 2004. Soil microbial dynamics in maize-growing soil under different tillage and residue management systems. Soil Biol. Biochem. 36, 499-512.

Srivastava, R., Singh, K.P., 2002. Variations in soil organic C and N storage due to cultivation practices in the Gangetic plain, India. Int. J. Ecol. Environ. Sci. 28, 193-199.

Srivastava, R., Singh, K.P., 2013. Implications of multipurpose tree leaf application on wheat productivity in dry tropics. J. Forest. Res. 24 (4), 777-782.

Tian, G., Kang, B.T., Brussaard, L., 1992. Effects of chemical composition of N, Ca, and Mg release during incubation of leaves from selected agroforestry and fallow plant species. Biogeochem. 16, 103-119.