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Effect of Tree Prunings on Soil Fertility and Crop Yield in Alley Cropping System

M. A. Haque, M. I. Ali and M. K. Khan
Division of Soil Science, Bangladeh Institute of Nuclear Agriculture,
P.O. Box-4, Mymensingh, Bangladesh

Abstract: The study was conducted to find the impact of incorporation of green prunings from *Samanea saman* and *Dalbergia sissoo* in alley cropping system on soil fertility and subsequently yields of rice and wheat. Three treatments used were, 100 kg N ha^{-1} from ^{15}N ammonium sulphate, 80 kg N ha^{-1} provided through prunings either from *D. sissoo* or *S. saman* plus 20 kg N ha^{-1} from ^{15}N ammonium sulphate. Grain and straw yields of rice were increased by 23.8 and 32.1%. $\%^{15}N$ atom excess (a. e.) and percent nitrogen derived from fertilizer were higher in treatment receiving 100% chemical fertilizer compared to those with tree prunings. Nitrogen contribution of tree prunings to rice yield was 51.3% in *D. sissoo* and 54.1% in *S. saman*. The positive effect of pruning was observed in P and K uptake by rice grain and straw. Residual effect of added prunings in succeeding wheat crop was also noticed for both in *D. sissoo* prunings (11.7%) and *S. saman* prunings (11.3%). In wheat crop , $\%^{15}N$ (a. e.) and %Ndff were higher in 100% chemical fertilizer treatment compared to the residues of those with tree prunings. Nitrogen availability from the residues of tree prunings for wheat crop was 17.72 to 22.54%. P and K uptake in wheat were also more in previously tree pruning treated plots, as compared to the untreated ones. Improvement of soil fertility were observed due to application of tree prunings. Total N, available P, K and organic C were increased, resulting in good soil health, due to prunings.

Key words: Agroforestry practices, nutrient uptake, ^{15}N, soil fertility, rice, wheat.

Introduction

Due to absence or high cost of mineral fertilizers, croping systems in the tropics rely to a greater extent on the use of plant residues to maintain soil fertility (Vanlauwe *et al.*, 1997). At present, trees are being an important component of the traditional farming systems in the tropics because of their environmental and economic benefits. Chaphale and Badole, (1999) reported that incorporation of glyricidia leafy foliage increased inorganic C, total N, available NPK, water holding capacity and decreased the bulk density of soil. They also recorded significantly higher rice grain and straw yields over control. In alley cropping systems, crops are grown between hedge rows of preferably N_2 fixing trees or shrubs which are regularly pruned to reduce crop tree competition for water, nutrients or light (Kang *et al.*, 1981). Nitrogen released from plant residues and not taken up by the growing crops are not necessarily lost from the alley cropping system, but may be recovered by the hedge row trees or immobilized in the soil organic matter pool for the benefit of future crops (Vanlauwe *et al.*, 1998). In agroforestry systems, N can be fixed from the atmosphere through N_2 fixation or recovered from the soil in or below the crop root zone by deep-rooting perennial species (Vanlauwe *et al.*,1996). *Samanea saman* and *Dalbergia sissoo* can fix atmospheric N_2 upto 66 and 48%, respectively (Haque *et al.*, 1997). Organic matter supplied through agroforestry system is a major cause of soil fertility improvement and there is a direct relation between organic matter level and soil biological activity since humus is the substrate for soil fauna (Haque *et al.*, 1999). Under such circumstances, the objectives of the present study were to findout the impact of freshly added prunings of two leguminous tree crops viz, *S. saman* and *D. sissoo* on soil fertility specially on N, P, K and organic matter changes in soil and consequently on the yields of rice and wheat.

Materials and Methods

6 field experiments were conducted for 3 consecutive years from 1997-98 to 1999-2000 at the Bangladesh Institute of Nuclear Agriculture Farm, Mymensingh, Bangladesh with aus rice and subsequent wheat crop. The soil at the experimental field was silt loam in texture containing 6.4 g kg^{-1} organic carbon, 0.5 g kg^{-1} total N, 11 mg kg^{-1} available P, 0.12 cmol(+)kg^{-1} K, 8.9 cmol(+)kg^{-1} CEC and 7.3 pH. Three treatments were used for the transplanted aus rice which are as follows:

- T_1- Without trees on the alleys and no prunings, only 100 kg N ha^{-1} from labelled ammonium sulphate (^{15}N 1% atom excess).
- T_2- 80 kg N ha^{-1} tree prunings from *Dalbergia sissoo* planted on the alley + 20 kg N ha^{-1} from labelled ammonium sulphate (^{15}N 10% atom excess)
- T_3- 80 kg N ha^{-1} tree prunings from *Samanea saman* planted on the alley + 20 kg N ha^{-1} from labelled ammonium sulphate (^{15}N 10% atom excess)

The same plots were used for wheat crop in *rabi* season to assess the residual effects of tree prunings. For wheat crop T_2 and T_3 each received 75 kg N ha^{-1}, while T_1 received the recommended fertilizer rate of 100 kg N ha^{-1}. Two multipurpose legume trees, *S. saman* and *D. sissoo* were transplanted on the border of grain crops on January 1997. The tree spacing was maintained at 2 × 2m^2 on the border around the grain crop plot of 4 × 4m^2. The experiment was laid out in a Randomized Complete Block Design (RCBD). After one year growth of trees, side branches were pruned and specified amount of fresh prunings (4.75 t ha^{-1} from *S. saman* containing 4.2% N and 5.5 t ha^{-1} from *D. sissoo* containing 3.1% N) were applied to grain crop plots before two weeks of transplanting of rice seedlings. During the first year, rice crop received the prunings from the same trees grown elsewhere. The prunings were incorporated into the soil and irrigated the plots to accelerate the decomposition. Rice seedlings (var. BR-24) were transplanted in grain crop plots in May every year. Row to row and plant to plant distances were maintained at 20 x 15 cm^2. Aus rice was harvested on August every year. Then wheat (var. Kanchan) was sown on November in each year. Ammonium sulphate enriched with 10% and 1% ^{15}N a. e. were applied in the isotope subplots of rice in two equal splits. The first split was applied at 15 days after transplanting and second split was applied at 45 days after transplanting of aus rice. Other fertilizer applications (20 kg P ha^{-1} and 30 kg K ha^{-1} from triple super phosphate and muriate of potash, respectively) and agronomic practices were followed as recommended for the area. Wheat was harvested in March each year. Grain and straw yields along with other agronomic parameters such as plant height, panicle length, number of grain per panicle and tillers per hill (data not shown) were recorded. Grain and straw samples were ground separately and stored for determination of total N and ^{15}N a. e. The total N was determined by Kjeldahl method (AOAC, 1980) and the ^{15}N /^{14}N ratio was determined using emission spectrometer. The percent nitrogen derived from the fertilizer was estimated following the deduction of Fried and Dean (1976). P and K contents were also determined from rice and wheat grain and straw following digestion with nitric-perchloric acid system and measuring P colorimetrically and K using flame photometer. The data were subjected to statistical analysis and the significance of the mean differences was determined by Duncan's new multiple range test (Gomez and Gomez, 1984).

Results and Discussion

Yield of rice crop: Grain and straw yields of rice in successive 3 years are presented in Table 1. Both grain and straw yields were significantly influenced by the treatments. The maximum grain (4110 kg ha^{-1}) and straw (6142 kg ha^{-1}) yields of rice were recorded in treatment T_3 followed by T_2 (3853 kg ha^{-1}grain and 5838 kg ha^{-1} straw yields). While the minimum grain and straw yields (3111 kg ha^{-1} and 5134 kg ha^{-1}) were recorded in T_1. This yield trend was recorded in each of the three years. The increase in grain yields over the treatment T_1 were 23.8% in T_2 and 32.1% in T_3. Chaphale and Badole (1999) reported that glyricidia foliage incorporated @ 5 t ha^{-1} in rice gave 14.16% and 19.33% more grain and straw yields, respectively over control. Zhongze *et al.* (2000) reported that 60 kg N ha^{-1} from tree prunings incorporated with 40 kg N ha^{-1} of ammonium sulphate corn grew well and the grain yield was increased by 11.6% as compared to that fertilized with 100 kg N ha^{-1} ammonium sulphate. Sisworo *et al.* (2000) observed that on 100% alley cuttings, the upland rice yield showed results nearly as good as for 100% urea. This means that N from the alley cutting were quite enough to produce high yields. These findings corroborate the present study.

Nitrogen parameter for rice crop: Nitrogen contents, %^{15}N a. e., %Ndff, total N uptake, fertilizer N uptake, percent fertilizer N recovery and %N contribution of prunings to rice production are presented in Tables 2 and 3. The maximum fertilizer N uptake (23.62 kg ha^{-1}) was recorded in treatment T_1 followed by the treatment T_3 (4.27 kg ha^{-1}) while the minimum was in T_2 (3.72 kg ha^{-1}). The highest fertilizer N recovery was observed in T_1 (23.62%) followed by T_3 (21.35%). Fertilizer N recovery by rice was higher in T_1 where 100 kg N ha^{-1} was applied through inorganic ammonium sulphate than two pruning treatments (T_2 and T_3). Medhi and De Datta (1996) observed that recovery of applied N (grain + straw) at harvest ranged from 42% for the *Sesbania rostrata* green manuring to 45% for prilled urea in transplanted rice. In the present study fertilizer recovery was low by rice crop because of heavy rainfall in the monsoon season which may be attributed to the loss of fertilizer N (Patwary *et al.*, 1987). Substantial N contribution of tree prunings were observed to rice yield. The highest % N contribution of prunings was recorded in T_3 treatment (54.10%) followed by T_2 treatment (51.3%). Residue quality was shown to have a major impact on the dynamics of applied residue N in alley cropping systems and it is an important factor in deciding which residue-supplying plant species to integrate into similar cropping systems (Vanlauwe *et al.*, 1998).

P and K availability from prunings for rice crop: P and K contents and uptake by rice crop are presented in Table 4. The maximum P content in both grain (2.2 g kg^{-1}) and straw (0.8 g kg^{-1}) of rice were observed in treatment T_2 followed by treatment T_3 (2.0 g kg^{-1} in grain and 0.7 g kg^{-1} in straw) and the minimum in treatment T_1 (1.7 g kg^{-1} in grain and 0.6 g kg^{-1} in straw). Similar trend was observed in P uptake by rice crop. The highest total P uptake was recorded in treatment T_2 (12.24 kg ha^{-1}) followed by treatment T_3 (11.66 kg ha^{-1}) and the lowest in treatment T_1 (8.05 kg ha^{-1}). P uptake by rice crop was enhanced from both the added prunings as compared to the full chemical fertilizer treatment. The maximum K content in rice grain was observed in treatment T_2 (1.5 g kg^{-1}) followed by treatment T_3 (1.3 g kg^{-1}) and the minimum in treatment T_1 (1.1 g kg^{-1}). A similar trend of K content was recorded for rice straw. The maximum K uptake by rice crop was noted in treatment T_3 (70.5 kg ha^{-1}) followed by T_2 (68.37 kg ha^{-1}) and the lowest in treatment T_1 (56.4 kg ha^{-1}).

Yield of wheat crop: Residual effects of added tree prunings on wheat yield for three consecutive cropping cycles are presented in Table 5. The effects of the prunings were not much prominent for wheat grain and straw yields. There were, however, a slight difference in yield of both grain and straw between treatments T_2 and T_3 while the difference was rather spectacular from that of T_1 although the treatments were not statistically significant. There was thus a clear indication that pruning had marked residual effect. The average increase of grain yield in T_2 and T_3 (each received only 75% N) were 8.48 and 5.16 %, respectively over the treatment T_1 (received 100% N). Higher yield in prunings treated plots receiving less N dose might be due to better moisture conservation, slow but constant release of N and possibly increased availability of other nutrients. Saleque *et al.* (1991) observed that the rice straw applied previously along with chemical fertilizers significantly increased the grain yield of rice.

N availability from residual prunings to wheat Crop: Nitrogen content, %^{15}N a. e, %Ndff, total residual fertilizer N uptake, % residual fertilizer N utilization and %N contribution from residual prunings to wheat yield are presented in Table 6. %^{15}N excess and %Ndff were maximum in both grain and straw in treatment T_1. The highest residual fertilizer N uptake was recorded in treatment T_1 (5.27 kg ha^{-1}), followed by treatment T_2 (0.51 kg ha^{-1}) and the lowest in treatment T_3 (0.45 kg ha^{-1}). Maximum residual fertilizer N was utilized in treatment T_1 (5.27%) followed by treatment T_2 (2.58%) and minimum in treatment T_3 (2.26%). The N contribution from residual prunings to wheat yield was 22.54 and 17.72 % in T_2 and T_3, respectively. Saleque *et al.* (1991) observed that the residual N resulting from rice straw accounted for about 10 kg N ha^{-1} absorbed by the rice crop.

P and K availability from residual prunings to wheat crop: P and K contents and uptake in wheat crop are presented in Table 7. The highest P content in both wheat grain (3.5 g kg^{-1}) and straw (0.6 g kg^{-1}) were observed in treatment T_2 followed by treatment T_3 (3.3 g kg^{-1} in grain and 0.5 g kg^{-1} in straw) and the lowest in treatment T_1 (2.9 g kg^{-1} in grain and 0.4 g kg^{-1} in straw). The maximum total P uptake was observed in treatment T_2 (16.15 kg ha^{-1}) followed by the treatment T_3 (14.42 kg ha^{-1}) & the minimum in treatment T_1

Table 1: Grain and straw yields (kg ha^{-1}) of rice as influenced by tree prunings

Treatments	1997-98		1998-99		1999-2000		Average yield		% increase over control	
	Grain yield	Straw yield	Grain yield	Straw yield	Grain yield	Straw yield	Grain yield	Straw yield	Grain	Straw
T_1	3092 c	5464 b	3210 b	5113 b	3032 c	4825 b	3111	5134	-	-
T_2	4165 b	6389 a	3698 a	5976 a	3695 b	5150 ab	3853	5838	23.8	13.7
T_3	4386 a	6719 a	4018 a	6256 a	3925 a	5450 a	4110	6142	32.1	19.6
$(P_{0.05})$	*	*	*	*	*	*				

Values sharing same letter(s) do not differ at 5% level.

Table 2: Nitrogen content and uptake, % ^{15}N excess, % Ndff and fertilizer N uptake in rice grain and straw as affected by different treatments (average of 3 yrs.)

Treatments	N (g kg^{-1})		%^{15}N excess		%Ndff		Total N uptake (grain + straw) (kg ha^{-1})	Total Fert. N uptake (grain + straw) (kg ha^{-1})
	Grain	Straw	Grain	Straw	Grain	Straw		
T_1	9.7	4.9	0.41	0.34	45.19	37.06	55.32	23.62
T_2	11.0	5.2	0.55	0.40	5.74	4.12	72.73	3.72
T_3	11.3	5.7	0.58	0.42	6.00	4.39	81.46	4.27

Table 3: Nitrogen recovery from fertilizer and nitrogen contribution of prunings to rice yield as influenced by different treatments (average of 3 yrs.)

Treatment	Total-N uptake by grain + straw (kg ha^{-1})	Total fert. N uptake by grain + straw (kg ha^{-1})	Percent fert. -N recovery	N-uptake from soil (kg ha^{-1})	N-uptake from soil + prunings (kg ha^{-1})	N-uptake from prunings (kg ha^{-1})	% N contribution of prunings to rice yield
T_1	55.32	23.62	23.62	31.7	--	--	--
T_2	72.73	3.72	18.55	--	69.01	37.31	51.3
T_3	81.46	4.27	21.35	--	77.20	43.77	54.10

Table 4: P and K contents and uptake in rice crop as influenced by different treatments

Treatments	P (g kg^{-1})		Total P uptake (kg ha^{-1})	K (g kg^{-1})		Total K uptake (kg ha^{-1})
	Grain	Straw		Grain	Straw	
T_1	1.7	0.6	8.05	1.1	11.0	56.40
T_2	2.2	0.8	12.24	1.5	12.2	68.37
T_3	2.0	0.7	11.66	1.3	12.0	70.50

Table 5: Residual effect of added prunings on wheat yield (kg ha^{-1})

Treatments	1997-98		1998-99		1999-2000		Average yield		% increase over control	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	3375	5500	3335	5679	3223	5269	3311	5483	----	----
T_2	3625	6250	3576	6040	3575	6081	3592	6124	8.48	11.7
T_3	3500	6125	3495	6135	3450	6056	3482	6105	5.16	11.3
$(P_{0.05})$	NS	NS	NS	NS	NS	NS				

NS: Non significant

Table 6: Residual N contribution of added prunings to wheat yield (average of 3 yrs.)

Treatment	N (g kg^{-1})		%^{15}N excess		%Ndff		Total residual fert. N uptake (grain + straw) (kg ha^{-1})	% Residual fert. N utilization	% N contribution from residual prunings to wheat yield
	Grain	Straw	Grain	Straw	Grain	Straw			
T_1	19.6	4.8	0.065	0.023	7.13	2.50	5.27	5.27	---
T_2	21.2	5.7	0.059	0.016	0.60	0.16	0.51	2.58	22.54
T_3	20.5	5.5	0.055	0.017	0.56	0.17	0.45	2.26	17.72

Table 7: P and K contents and uptake in wheat crop as influenced by different treatments

Treatments	P (g kg^{-1})		Total P uptake (kg ha^{-1})	K (g kg^{-1})		Total K uptake (kg ha^{-1})
	Grain	Straw		Grain	Straw	
T_1	2.9	0.4	11.46	2.8	11.2	68.03
T_2	3.5	0.6	16.15	3.6	11.7	84.01
T_3	3.3	0.5	14.42	3.5	11.5	81.71

Table 8: Total N, available P, K and organic carbon content in soil at post harvest of rice and wheat (average of 3 yrs.)

Treatment	Rice				Wheat			
	N (g kg^{-1})	P (mg kg^{-1})	K cmol(+)kg^{-1}	O.C (g kg^{-1})	N (g kg^{-1})	P (mg kg^{-1})	K cmol(+)kg^{-1}	O.C (g kg^{-1})
T_1	0.50	10.0	0.11	6.4	0.50	10.0	10.5	6.1
T_2	0.76	12.5	0.14	8.3	0.66	11.5	0.13	8.2
T_3	0.63	12.0	0.13	7.9	0.63	11.3	0.12	7.8

Initial nutrient contents: Total N 0.5 g kg^{-1} available P 11 mg kg^{-1}, available K 0.12 cmol(+)kg^{-1} and organic C 6.4 g kg^{-1}

(11.46 kg ha^{-1}). Similar trends were also observed in K content and uptake in wheat.

Fertility status in soil at post harvest of both rice and wheat crop: Total N, available P, available K and organic C contents in soil after harvest of rice and wheat crop averaging for three crop cycles are presented in Table 8. It can be noticed that pruning treatments have markedly improved the level of N, P, K and organic C in soil, the contents being greater in *D. sissoo* prunings treated plots than in *S. saman* prunings treated plots and the lowest in plots received 100% chemical fertilizer. The residual effects of tree prunings on soil fertility level also was more pronounced with prunings incorporation from *D. sissoo* than those from *S. saman*.. Althrough a positive improvement in soil fertility was observed from the application of tree prunings. Miah *et al.* (1997) observed that three multipurpose tree legumes inter cropped with upland rice and mungbean showed positive changes in fertility except soil pH and exchangeable Mg. They recorded an increase in organic C by 9%, total N by 11.6%, available P by 11.2% and exchangeable K by 10.6% . These results are in good agreement with the present study. It may be concluded that the incorporation of prunings from *D. sissoo* and *S. saman* in an alley cropping system is highly beneficial in improving soil fertility and sustaining grain crop productivity.

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