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Research paper

Impact of alley cropping system on soil fertility

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Abstract

A field experiment was conducted to investigate the effect of pruned materials of two hedgerow species on wheat production and soil nutrient changes at different nitrogen levels in the research farm of the Bangabandhu Shiekh Mujibur Rahman Agricultural University (BSMARU) during November 2012 to March 2013. The design of the experiment was split plot, where two multipurpose tree species (MPTS) namely *Gliricidia sepium* and *Leucaena leucocephala* were arranged in main plots and five different doses of nitrogen (0, 25, 50, 75 and 100 % of recommended dose) with pruned materials were distributed to sub plots. Alley widths of both tree species were 6.0 meter. There were also control plots where full dose of recommended nitrogen was applied but no pruned material (PM) was incorporated. The soil chemical properties in the alleys consisting of *G. sepium* and *L. leucocephala* responded differently. Positive changes in the soil fertility in terms of soil pH, organic C, total N, available P, available S and exchangeable Ca, Mg, K and CEC of the top soil layer were observed in alley cropping system. Pruned materials application substantially reduced the nitrogen requirement for wheat production and 50 % Nitrogen fertilizer could be saved through pruned materials application. Among the tree species *G. sepium* seemed to be superior over *L. leucocephala* in building soil health.

Keywords: *Alley Cropping; Hedgerow; Pruning; Soil Fertility; Ph.*

1. Introduction

Bangladesh is a small deltaic country with a large population of 161 million with cultivable land of 8.44 million ha is being used for agricultural purpose which has low productivity due to the poor soil health. Due to intensive cultivation, soil fertility is reducing rapidly, and consequently reducing the crop yield. As a result, the natural soil ecosystem has rapidly degrading and farm agro-ecosystem losing its integrity and health as well as polluting the environment. The organic matter content which is an indicator of soil health is depleted to less than critical value of 1 percent (Hossain and Kashem, 1997) in most of the areas (about 60 percent) of cultivable land during the last 20-25 years. Now-a-days, alley cropping is considered as an ideal technology for sustainable crop production where agricultural crops are grown in the inter-space between rows of planted shrubs/tree species, preferably legumes, which are periodically pruned to minimized tree-crop competition for growth resources such as water, nutrient and light (Tossah et al., 1999). Pruned materials are applied in soil for releasing nutrients to improve the growth and development of associated crops through improving the physiochemical characteristics of soils (Miah, 1993). In addition, fast growing leguminous trees/shrubs species are grown because it usually recycles nutrients, contribute biological nitrogen fixation (Kang et al., 1994). Among the evaluated tree species for alley cropping *Gliricidia sepium* and *Leucaena leucocephala* are the two most suitable species which are used in alley cropping in many parts of the world. These two species biologically fix N, can be established easily by direct seeding, withstand repeated pruning, produce large amounts of biomass. Any nitrogenous fertilizer saving by maintaining the crop productivity through alley cropping system would be immense value particularly for the resource poor farmers of Bangladesh. This information will help the farmers for reducing their production cost. Eventually, it will be considered as suitable technology both economically and environmentally.
In view of the above circumstances, a study was undertaken with the following objectives:
To examine the soil fertility status influenced by alley cropping system.

2. Materials and methods

2.1. Description of experimental site and duration

The experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMARU) research farm of the Department of Agroforestry and Environment, Gazipur.

2.2. Soil

The experimental soil was originally shallow red brown terrace under Salna Series (Brammer, 1978) in Madhupur Tract (AEZ 28).

2.3. Experimental design and treatment

The experimental was laid out in a split-plot design, with three replications. Tree species were arranged in main plots and different doses of nitrogen were distributed into sub plot. Tree species used in main plots were as follows:
Factor A: Two tree species with control

- *Gliricidia sepium (G. sepium)*
- *Leucaena leucocephala (L. leucocephala)*
- Control (Without tree species)

Factor B: Nitrogen levels (5)

- N0 (zero dose of N) + Pruned materials (PM)
- N25 (25% of recommended N dose) + PM
- N50 (50% of recommended N dose) + PM
- N75 (75% of recommended N dose) + PM
- N100 (100% of recommended N dose) + PM

The alley width was 6.0 m. Every alley was divided into 15 unit plots comprising three replications and five levels of nitrogen. The unit plot length was 5 m. So, total area of a unit plot was 6m x 5m.
There were a control treatments which received recommended nitrogen dose but no pruned material was used for growing crops to compare the results with crop yields under alley cropping system. Urea was used as the source of different nitrogen doses.

2.4. Soil sample collection and chemical analysis

Soils from different positions were collected before starting of the experiment and immediately after harvesting of the crops from N_0+ PM, N_{25}+ PM, N_{50}+ PM, N_{75}+ PM, N_{100}+ PM treated plots. Before starting the experiment, soil samples were collected from different part of the alley of the experimental field and then mixed together to make composite samples. Immediately after crop harvest, the soil samples were collected from N_0, N_{25}, N_{50}, N_{75} and N_{100} plus pruned materials added plots. In each case, soil samples were taken from the 0-15 cm depth. The collected soil samples were then air dried, ground, sieved and used for chemical analysis. Chemical analysis was done for pH, organic carbon, total nitrogen, available phosphorus, available sulfur, exchangeable calcium, magnesium, potassium and cation exchange capacity (CEC). The above analyses were done using the following methods:

2.4.1. Soil pH

Soil pH was measured using glass electrode pH meter as described by Jackson (1985). Soil-water mixture was made in the ratio of 1: 2.5.

2.4.2. Organic carbon

Organic carbon was estimated using wet oxidation method.

2.4.3. Total nitrogen

Total nitrogen was measured using micro-kjeldahl method following H_2SO_4 digestion and steam distillation with NaOH. Ammonia thus collected in boric acid was determined by titration with 0.02 N H_2SO_4.

2.4.4. Available phosphorus

Available phosphorus was measured using Molybdenum Blue method at 710 nm by Double Beam Spectrophotometer.

2.4.5. Exchangeable K and Ca

Exchangeable K and Ca were measured using Atomic Absorption Spectrophotometer. Solution of 1M ammonium acetate was added to air dried soil and allowed to stay overnight. The supernatant was repeatedly collected to allow the exchangeable cations to be exchanged from the soil particles with NH_4^+ cations. The absorbance were measured at wavelength of 766.5 nm for K, 422.8 nm for Ca and 285.2 nm for Mg respectively by Atomic Absorption Spectrophotometer.

2.4.6. Available sulfur (ppm)

Available sulfur was determined turbidimetrically as barium sulfate. The method was that of Chesin and Yien (1951).

2.4.7. Cation exchange capacity (CEC)

Ammonium acetate solution was added to air dried soil and allowed to stay overnight. After centrifugation, the supernant was decanted and this was repeated to allow the exchangeable cation to be exchanged from the soil particles with NH_4^+ cation. The soil was washed with 80% ethanol. Then 1 M NaCl was added with soil and washed for 5 times and was centrifuged. After treating, with 1 M NaCl solution the supernant was collected and allowed to distillation and titration.

2.5. Statistical analysis

The data relating to growth yield and yield contributing characters of wheat and tree performance were subjected to analysis of variation (ANOVA) with the help of computer “MSTATC” program. Analysis of variance was done according to Gomez and Gomez (1984).

3. Results and discussion

3.1. Total nitrogen in soil

Nitrogen, the most limiting nutrient for crop production did not vary in soils with the tree species planted (Figure 2). However, total soil nitrogen in *L. leucocephala* alley was found slightly higher than G. sepium alley, which might be due to higher leaf nitrogen content in *L. leucocephala*.

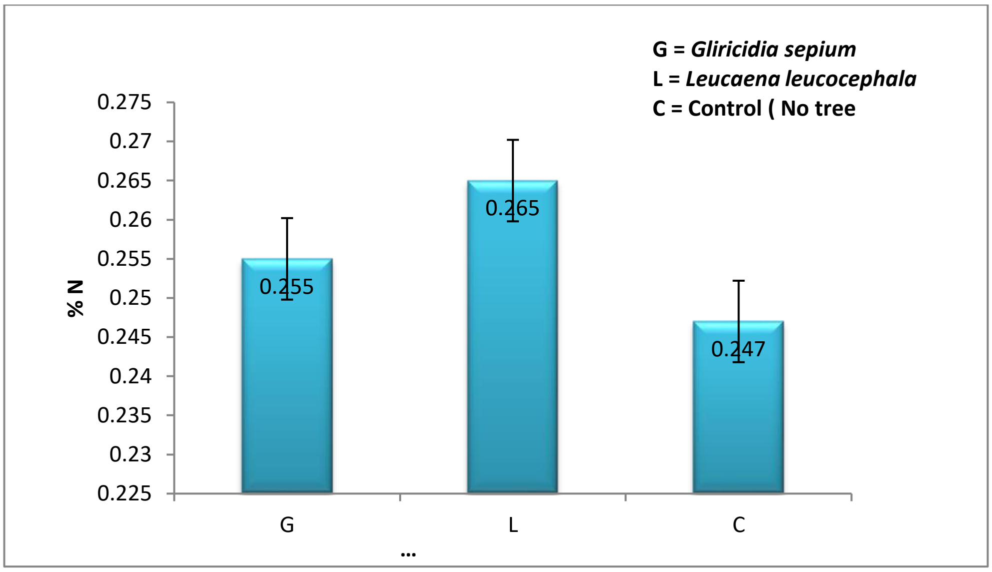

Fig. 1: Nitrogen Status in Alley Cropping Systems as Influenced by Tree Pruned Materials of Two Different Tree Species after Harvesting of Wheat.

The effect of nitrogen fertilizer plus pruned materials application and the interaction of nitrogen fertilizer and tree species did not show significant effects. In general, highest soil nitrogen (0.263%) was found in N_{100}+PM and N_{75}+PM and the lowest (0.242%) was found in N_{25}+PM (Fig.3).

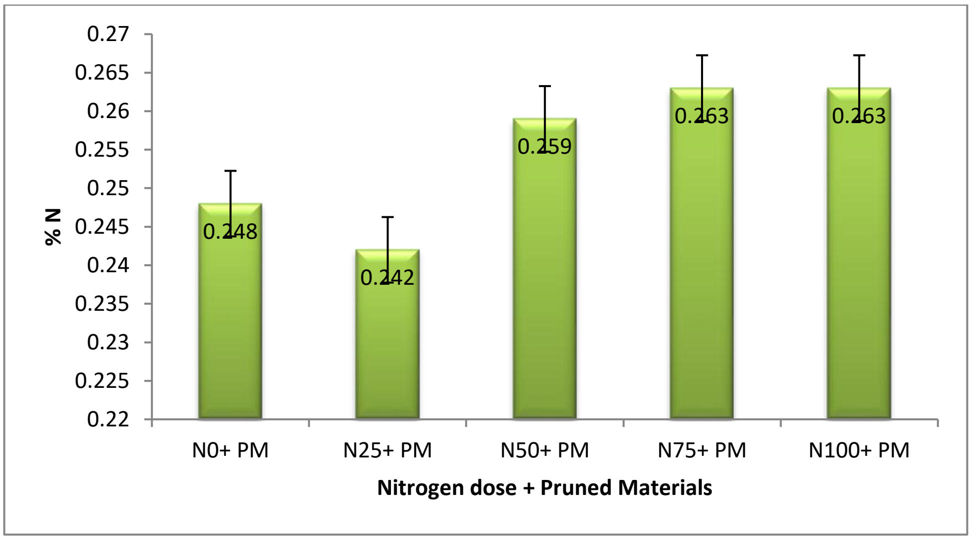

Fig. 2: Nitrogen Status in Alley Cropping Systems as Influenced by Tree Pruned Materials of Two Different Tree Species Along with Different N Doses after Harvesting of Wheat.

In case of interaction of nitrogen fertilizer and tree species (Table 1) the highest soil nitrogen (0.269%) was found in N_{50}×LL, N_{75}×LL and N_{25}×GS and the lowest (0.231%) was found in N_{100}×C combination.

Table 1: Nitrogen Status in Alley Cropping Systems as Influenced by Tree Pruned Materials of Two Different Tree Species Along with Different N Doses after Harvesting of Wheat

Treatment	Total N (%)
Nitrogen × tree species	
N_0×GS	0.249
N_{25}× GS	0.269
N_{50}×GS	0.250
N_{75}×GS	0.240
N_{100}× GS	0.265
N_0×LL	0.240
N_{25}×LL	0.250
N_{50}×LL	0.269

N_{75}× LL	0.269
N_{100}×LL	0.255
N_0× C	0.240
N_{25}× C	0.240
N_{50}× C	0.240
N_{75}× C	0.240
N_{100}×C	0.231

In a column, means followed by a common small letter are not significantly different at the 5% level by DMRT.
GS = *Gliricidia sepium*, LL = *Leucaena leucocephala*

N_0=0% Nitrogen, N_{25}=25% Nitrogen, N_{50}= 50% Nitrogen, N_{75}= 75% Nitrogen and N_{100}= 100% Nitrogen.

The interaction effect of nitrogen fertilizer and tree species on soil nitrogen was found the significantly highest (0.18%) when nitrogen fertilizer was applied at the rate of 75 kg N ha^{-1} in *L. leucocephala* alley, which is still low in terms of soil fertility ranking (BARC, 2005). Nitrogen loss from the soil environment is very high through different pathways like denitrification, ammonia volatilization, nitrate leaching etc. Therefore, enrichment of soil with nitrogen and storing for long time is not possible. Judicious and balanced application of nitrogen as per crop requirements is always advisable for better utilization of nitrogen in crop production. Increased N content of the surface soil with leguminous trees was reported by Getahun and Jama (1989).

3.2. Soil pH

The soil P^H did not vary among the treatments (Table 2). Incorporating the pruning materials slightly increased the soil p^H. Among the treatment, the highest soil p^H was recorded in GS+N_0 (6.6) and the lowest was in CC+N_0 (5.7). The increased soil p^H by *G. sepium* may be explained by its faster leaf decomposition (Miah et al. 1997) and higher foliar Ca levels. Similar increase in soil p^H under *G. sepium* was observed by other scientists (Miah 1993, Gavine 1989, Alla-Krah and Sumberg 1987, Onim et al. 1990).

3.3. Organic carbon

Changes in organic carbon as a result of different treatments showed that soil organic carbon content in the control plot was slightly lower, but higher in all other plots (Table 2). The highest amount of organic carbon was recorded in GS+N_{100} (1.4%) and GS+N_{25} (1.4%). The lowest amount of organic carbon was found in CC+N_{25} (1.1). Alla- Khra and Sumberg (1987) found 1.59% organic carbon with *G. sepium* compared to 1.13% without *G. sepium*. Miah et al. (1997) found 0.983% organic carbon with *G. sepium* compared to 0.847% without *G. sepium*.

3.4. Available P

Available phosphorus means the portion of the total soil phosphorus which can be utilized by plants and that can be extracted by dilute acid solution. Most of the natural ecosystem, P level of soil is low. But soils with tree species showed increased available P content. Among the all treatments, the highest available P was obtained from GS+N_0 (7.01 ppm) and the lowest was obtained from CC+N_0 (5.00 ppm).

Table 2: Soil $P^{H,}$ Organic Carbon & CEC Status in Alley Cropping Systems as Influenced by Tree Pruned Materials of Three Different Species Along With Different N Doses after Harvesting of Wheat

Treatment	PH	Organic C (%)	CEC (MEQ/100g)
GS + No	6.6	1.2	13.46
GS + N25	6.2	1.4	14.28
GS + N50	6.1	1.3	14.56
GS + N75	6.2	1.3	13.46
GS + N100	6.4	1.4	14.28
LL + No	6.2	1.2	13.18
LL + N25	6.3	1.2	13.73
LL + N50	6.2	1.3	14.01
LL + N75	6.0	1.3	14.56
LL + N100	6.0	1.2	13.18
CC + No	5.7	1.3	11.54
CC + N25	5.8	1.1	12.66
CC + N50	5.9	1.3	12.63
CC + N75	6.2	1.3	10.71
CC + N100	5.8	1.2	12.36

3.5. Exchangeable K

The exchangeable K content showed an irregular fashion however it was lower in control treatment compared to agroforestry treatments (Table 11). Crop removal and losses through runoff may be attributed the lowest exchangeable K in control plot moreover no K added to this plot through pruned materials, whereas, the increase in exchangeable K in plots with tree species was probably due to the return of K via tree pruning and leaf litter fall to the soil surface (Miah et al., 1997). Results showed that the highest K content was found in GS+N_{25} (0.22 meq/100g) & GS+N_{50} (0.22 meq/100g) and the lowest was found in CC+N_{25} (0.12 meq/100g). Increased exchangeable K was observed under *G. sepium* by Gonzal and Raros (1987). The present findings are in agreement with that of Gonzal and Raros, (1987), Lasco (1991), and Miah et al. (1993).

Table 3: Soil Available P, Exchangeable Bases (K & Ca) & S Status in Alley Cropping Systems as Influenced by Tree Pruned Materials of Three Different Species Along with Different N Doses after Harvesting of Wheat

Treatment	Available P (ppm)	Exchangeable bases (meq/100g)		S (ppm)
		K	Ca	
GS + N_o	7.01	0.18	5.48	9.36
GS + N_{25}	6.64	0.22	6.14	12.98
GS + N_{50}	6.81	0.22	5.37	11.17
GS + N_{75}	6.67	0.20	6.27	11.77
GS + N_{100}	6.56	0.20	5.72	10.87
LL + N_o	6.78	0.16	5.41	9.66
LL + N_{25}	6.64	0.17	5.34	9.96
LL + N_{50}	7.85	0.15	4.65	12.08
LL + N_{75}	7.30	0.19	4.58	11.47
LL + N_{100}	6.48	0.19	4.71	11.77
CC + N_o	5.00	0.15	5.30	9.06
CC + N_{25}	5.25	0.12	4.99	10.87
CC + N_{50}	5.25	0.16	4.78	8.15
CC + N_{75}	5.58	0.12	4.78	7.25
CC + N_{100}	5.08	0.16	4.58	12.68

3.6. Exchangeable Ca

The exchangeable Ca contents of soil showed an increasing trend in all agroforestry treatments (Table 11). Among the treatments, the highest amount of exchangeable Ca was found in GS+N_{75} (6.27 meq/100g) and lowest was recorded in CC+N_{100} (4.58 meq/100g). The overall exchangeable Ca value was higher in *G. sepium* tree species followed by *L. leucocephala*. Similar results regarding increase of soil Ca in agroforestry systems have been reported in other experiments (Miah et al. 1997, Lal 1989, Onim et al. 1990, Soriano 1991).

3.7. Cation exchange capacity

The variations of CEC of the soil before and after the experiment were not so distinct (Table 11). The CEC in control plot decreased slightly, but increased in all other treatments. However, the overall highest CEC was observed under G. sepium (13.46, 14.28, 14.56, 13.46 and 14.28 meq/100g in GS+N_0, GS+N_{25}, GS+N_{50}, GS+N_{75} and GS+N_{100} treatments respectively) and the lowest was recorded in control plots (11.54, 12.66, 12.63, 10.71 and 12.36 meq/100g in CC+N_0, CC+N_{25}, CC+N_{50}, CC+N_{75} and CC+N_{100} treatments respectively).

3.8. Sulfur

Among all the treatments overall higher amount of S was observed under G. sepium (9.36, 12.98, 11.17, 11.77 and 10.87 meq/100g in GS+N_0, GS+N_{25}, GS+N_{50}, GS+N_{75} and GS+N_{100} treatments respectively) and lower amount was recorded in control plots (9.06, 10.87, 8.15, 7.25 and 12.68 meq/100g in CC+N_0, CC+N_{25}, CC+N_{50}, CC+N_{75} and CC+N_{100} treatments respectively).

4. Conclusion

Accomplishing the present investigation, it may be concluded that In this alley cropping system the soil properties in the top layer changed in a positive direction in respect of soil pH, organic carbon, total N, available P, available S, exchangeable K, Ca and CEC compared to control. The degree of suitability of the two tree species in terms of crop productivity and soil properties may be ranked *as Gliricidia sepium* > *Leucaena leucocephala*.

5. Conflict of interest statement

All the authors do not have any conflict with respect to research, authorship or publications of this article.

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