ISSN-1991-3036 (Online) & ISSN-2075-1621 (Optical)
Int. J. Sustain. Crop Prod. 5(2):21-27(May 2010)

PERFORMANCE OF GROWTH AND SOIL PROPERTIES CHANGE BY FOUR MULTIPURPOSE TREE SPECIES IN ALLEY CROPPING SYSTEM

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Accepted for publication on 12 May 2010

ABSTRACT

Ahmed S, Hasan S, Chowdhury AHMRH, Chowdhury AKMMA, Hossain MA (2010) Performance of growth and soil properties change by four multipurpose tree species in alley cropping system. *Int. J. Sustain. Crop Prod.* 5(2), 21-27.

The experiment was carried out at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) research farm, Gazipur during the period from November 2002 to April 2003 to evaluate the changes of soil properties at different nitrogen levels in alley cropping system. The experiment was conducted in a split plot design with three replications. Four tree species namely, *Gliricidia sepium, Indigofera tysmanii, Leucaena leucocephala* and *Cassia siamea* were arranged in the main plots while five nitrogen doses (0, 25, 50, 75 and 100% plus pruned material) were distributed to sub-plots. In the control plots, recommended N doses were used but no pruned materials were incorporated. The growth performance of four MPTS after pruning at different intervals showed that *Gliricidia sepium* maintained its superiority over the other tree species in terms of both tree height and number of branches per tree at all the measurement dates. The maximum amount of fresh pruned materials were produced and added to the soil by *Gliricidia sepium* (10.63 t ha^{-1}) which was followed by *Indigofera tysmanii* (10.48), *Cassia siamea* (7.73 t ha^{-1}) and *Leucaena leucocephala* (5.88 t ha^{-1}) species, respectively. Soil properties such as organic C, total N, available P, exchangeable K and Ca, CEC and S were 25.00, 31.25, 16.69, 53.26, 38.87, 15.35, and 19.75 percent higher in alley cropped plots over their initial values. Among the alleys consisted of four tree species, all the three vegetables performed better in *G. sepium*, which was followed by *I. tysmanii*, *L. leucocephala* and *C. seamia* alleys. This increased performance has been mostly due to the contribution of alley cropping system.

Key words: *alley cropping system, growth, soil properties change, MPTS*

INTRODUCTION

Different agro-eco systems describe Bangladesh as a plain alluvial land with a considerable area of high land, which is characterized by low soil fertility and poor productivity. Farming of these regions mostly depends on rainfall, which is highly variable in frequency and distribution. For this reason, the yield is low and fluctuates from season to season as well as from year to year. Besides, there are marginal land, char land and degraded land, which are mostly subjected to low nutrient status and soil erosion. So, it is necessary to develop sustainable farming system, which will ensure crop productivity as well as maintaining soil fertility. Alley cropping is an agroforestry practice intended to place trees within agricultural cropland systems. In this system, arable crops are grown in between the hedges of woody shrubs and tree species, preferably legumes, that are regularly cut back to minimize tree-crop competition for light, water and nutrients (Tossah *el al*. 1999). The pruned materials are incorporated into soil at planting and/or during the cropping period so that pruned tree leaves release nutrients into the soil and improve the physico-chemical properties of soil; and ultimately improve the growth and development of the associated crops (Miah 1993). In addition, wood and fodder can be obtained from the hedges particularly during lean period (Kang *et al*. 1990). The overall purpose is to enhance or add income diversity (both short and long range), reduce wind and water erosion, improve crop production, improve utilization of nutrients, improve wild life habitat or aesthetics, and/or convert cropland to forest. The practice is especially attractive to landowners wishing to add economic stability to their farming system while protecting soil from erosion, water from contamination, and improve wild life habitat (USDA, 1999). Nutrient, particularly nitrogen can be added to the soil through leaf/root decomposition, nitrogen fixation through the roots of legume trees, so use of nitrogen fertilizer to the soil may be saved through this system. Subsistence farmers, who have little capacity to purchase high cost inorganic inputs, could be benefited by practicing alley cropping, because this system not only save nitrogen fertilizer but also conserve soil productivity. So, investigation of the benefits of this system in terms of nitrogen saving, crop productivity and soil fertility in the flat land agro-environment of Bangladesh would be of immense value to the farmers as well as researchers.

In alley cropping system, fast growing leguminous tree/shrubs species are grown because it usually recycle nutrients, contribute biologically fixed nitrogen, and provide fuel, fodder and timber which are presently harvested from dwindling forests (Kang *et al*. 1984). Many tree and shrub species have been evaluated for alley cropping in different part of the world. Of which *Gliricidia sepium, Indigofera tysmanii* and *Leucaena leucocephala* are the three most suitable species that can biologically fix N, can be established easily by direct seeding, tolerate frequent pruning, produce large amounts of biomass of high quality and under rapid decomposition release nutrients and are relatively long lived. *Cassia siamea* is also a widely adapted non-nitrogen fixing (but highly mycorrhizal) legume which is mostly known for relatively slow growing, good mulching properties, poor quality, slow decomposition and low nutrients yield (Okon *et al*. 1996 and Jama *et al*. 1995).

Since, alley cropping is usually practiced in upland condition, so, growing vegetables as alley cropping system may perform better as it requires much management practices.

In view of the above circumstances, a study was undertaken to examine the soil properties changes as well as growth performance of four MPTS in alley cropping system.

MATERIALS AND METHODS

The materials and methods followed in conducting this study are discussed in this chapter as follows:

Experimental Site: The experiment was carried out at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) research farm, Gazipur during the period from November 2002 to April 2003. It was the sixth season trial of a long-term alley cropping experiment. The experimental site was located at $24^{0}0^{/}$ N latitude and $90^{0}25^{/}$ E longitude with a mean elevation of 8.4 meter from the sea level.

Experimental Soil: The soil of the experimental site was originally Shallow Red Brown Terrace under Salna Series (Brammer 1978) in Madhupur tract (AEZ: 28), but the texture has been improved to a loam by depositing recent alluvial soil. Initially soil samples were analyzed to know the soil status of the experiment site in respect of organic carbon, total N, available P, exchangeable K, Ca and Mg, cation exchange capacity (CEC) and S. Initial status of the soil was compared with the soil status of the present study.

Tree Establishment: The seedlings of *G. sepium*, *L. leucocephala* and *C. siamea* were transplanted in June 1998 and I*ndigofera tysmanii* were transplanted in July 2001. Adequate management practices were done to establish the seedlings. Healthy seedlings replaced dead and poorly grown seedlings. Tree to tree distance was 50 cm for all the tree species in each line. Distance in between two alleys was 3 meter.

Pruning of Tree/Shrub Species: Tree species were pruned frequently as when needed and the pruned materials were added to the respective plots. For this study, all the MPTS were pruned above one-meter height from the ground during the first week of November 2002 and all the pruned materials were incorporated into the soil of respective alleys. Pruning materials were weighed for calculating the amount of total biomass added to the soil.

Management Practices

Soil parameters: Soils of experimental plots from different tree alleys were collected immediately after the harvest of the crops from N_0 + PM, N_{50} + PM, N_{100} + PM treatments and control plots as well, and compared with the initial soil status. In each case, soil samples were taken from 0-15 cm depth. Collected soil samples were mixed to make composite soil samples. The composite soil samples were then air-dried, pulverized, sieved and used for chemical analyses. Chemical analyses were done for pH, organic C, total N, available P, exchangeable K and Ca, cation exchange capacity (CEC) and S. The soil samples were analyzed by using the following methods:

a) Soil pH: Soil pH was measured using glass electrode pH meter as described by Jackson (1987). Soil-water mixture was made in the ratio of 1:2.5.
b) Organic carbon: Organic carbon was measured using wet combustion method as determined by Piper (1942).
c) Total N: Total N 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 (Yoshida *et al.* 1972). The absorbance was measured at 440 nm wave length by a double beam spectrophotometer (Model 200-20, Hitachi).
d) Available P: Available P was measured using double beam spectrophotometer at 710-nm wavelength.
e) CEC: CEC was measured using Schollen Bergen's method. Ammonium acetate solution was added to air-dried soil and allowed to stay over night. After centrifugation, the supernatant 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 for at least 3 times and was centrifuged.

Statistical Analysis: All the data relating to growth yield and yield contributing characters were analysed following the standard statistical procedure of IRRISTAT computer software. Duncan's Multiple Range Test (DMRT) was used to compare means of treatments.

RESULTS AND DISCUSSION

Amount of pruned materials produced and added to the soil: The pruned materials (leaf and branches) obtained from the tree/shrub species were incorporated into the soil. The pruned materials were recorded per tree basis and then the values were converted to ton/ha. Results showed that the highest amount of fresh leaves per tree (1058.00 g) and per hectare (7.03 ton) were obtained from *G. sepium* which was closely followed by *I. tysmanii* (1040 g tree^{-1} and 6.92 t ha^{-1}), while, the lowest was obtained from *L. leucocephala* (498.25 g tree^{-1} and 3.31 t ha^{-1}). *C. seamia* produced intermediate amount of fresh leaf (780.00 g tree^{-1} and 5.19 t ha^{-1}). In case of branch weight, the highest amount of fresh branches (540.52 g per tree) and (3.60 ton per ha) were found from *G. sepium* which, was close to *I. tysmanii* (532.26 g tree^{-1} and 3.56 t ha^{-1}). The lowest amount of fresh branches was found from *C. siamea* (382.58 g tree^{-1} and 2.54 t ha^{-1}), which was closely followed by *L. leucocephala* (386.20 g tree^{-1} and 2.57 ton ha^{-1}). The total amount of pruned materials (leaf + branch) produced by the tree species during the cropping season showed that *G. sepium* produced the highest amounts of fresh pruned materials (1598.52 g per tree) and per hectare (10.63 ton per ha) and the lowest amount was produced by *L. leucocephala* (884.45 g tree^{-1} and 5.88 t ha^{-1}). Total fresh pruned materials obtained from *I. tysmanii* and *C. seamia* species were 1572.36 g tree^{-1} and 10.48 ton ha^{-1} and 1162.58 g tree^{-1} and 7.73 ton ha^{-1}, respectively (Table 1).

Table 1. Fresh pruned materials obtained from different MPT species and added into the soil during experimentation

Tree species	Fresh Pruned materials produced and added to the soil					
	Per tree (g)			Per ha (ton)		
	Leaf	Branch	Total	Leaf	Branch	Total
G. sepium	1058	540.52	1598.52	7.03	3.60	10.63
I. tysmani	1040	532.26	1572	6.92	3.56	10.48
C. siamea	780	382.58	1162.58	5.19	2.54	7.73
L. leucocephala	489.25	386.20	884.45	3.31	2.57	5.88

Soil Chemical Properties Changes: The experiment was initiated about three years ago, i.e. 1998, therefore, soil properties values were compared with the initial values of the alley cropping plots as well as control plots where no pruned materials were added. However, the soil chemical property changes due to alley cropping are presented in Table 2 and discussed accordingly.

Soil pH: Soil pH was increased slightly in all the alley cropping plots due to incorporation of PM as compared to control (5.8) and initial level (5.8). Among the tree alleys, the highest mean soil pH (6.4) was recorded in *G. sepium* alley while the mean soil pH in other alleys was the similar (6.2). Among the treatments, the highest (6.6) and the lowest (6.0) soil pH were noted in *G. sepium* plus N_{50} and *C. seamia* plus N_0 treatments, respectively. The result indicated that soil pH was improved more favorably in GS alley compared to other alleys, though the variation was not remarkable. Its faster leaf decomposition (Miah *et al*. 1997) and higher foliar Ca level may explain the increase in soil pH under *G. sepium*. Increase in soil pH in alley cropping was also observed by Aihou *et al*. (1999), Jones *et al*. (1996), Agboola *et al*. (1982).

Organic Carbon: All the alley cropping treatments showed an increased trend of organic carbon status of soil compared to the control and initial level. The mean maximum organic carbon content (0.82) was noted in *I. tysmanii* plots, which was closely followed by other alley cropping plots. Among the treatments, the highest amount of organic carbon (0.84%) was observed in *I. tysmanii* plus N_{50} plot and the lowest (0.77%) in *C. seamia* plus N_0 plot. All the treatments exhibited superior result over control plot (0.62%) and initial level (0.65%). In a four-year research with *G. sepium*, Attah-Krah and Sumberg (1987) found 1.59% organic carbon with *G. sepium* compared with 1.13% without *G. sepium.* Miah *et al*. (1997) also found 0.0983% organic carbon with *G. sepium* compared with 0.847% without *G. sepium.* Increased organic carbon was also reported by Jones *et al*. (1996), Schroth *et al*. (1995a), Mazzarino *et al*. (1993) and Matta-Machado and Jordan (1995).

Total Nitrogen: Soil total N was considerably changed in all alley cropping plots compared to control plots and initial level. Among the tree species, *G. sepium, I. tysmanii* and *L. leucocephala* contributed more N to the soil than that of at *C. siamea* species. The mean (average of three N levels) result revealed that the highest (0.103%) and the lowest (0.095%) total N were recorded in *I. tysmanii* and *C. seamia* alleys, respectively, while the mean total N recorded in *L. leucocephala* (0.101%) and *G. sepium* (0.100%) were very close to *G. sepium* alley. Among different treatments, the highest N content was recorded at *I. tysmanii* plus N_{100} plot (0.106%) while the lowest value was recorded at *C. siamea* plus N_{50} plot (0.094%). All the treatments showed better performance over control (0.074) treatment and initial soil value (0.076%). Higher amounts of N in the plots of *G. sepium,* and *L. leucocephala* might be due to their higher content and faster leaf decomposition rate than that of *C. siamea* (Chowdhury 2000). Further, more, they might have greater ability of atmospheric N fixation. Mureithi *et al.* (1995) reported that at the end of the alley cropping experiment, soil N content could be increased up to 33%. Increased N status was also observed by Rhoades *et al.* (1998), Aihou *et al.* (1999), Jones *et al.* (1996), Matta-Machado and Jordan (1995) and Agboola *et al.* (1982).

Available Phosphorus (P): The available P content of soil in all alley cropping plots, where pruned materials of different tree species were applied, had changed remarkably compared to control and initial levels. Among the four tree species, *I. tysmani* (average of 3 N levels) contributed maximum P content (21.35 ppm), which was closely followed by *G. sepium* (21.24 ppm) and *L. leucocephala* (21.23 ppm), while the minimum P content was recorded in *C. siamea* (20.20 ppm). However, the highest available P content (21.69 ppm) was recorded in *I. tysmani* plus N_{100} treatment and the lowest (19.49 ppm) was recorded in *C. siamea* plus N_{50} treatment. Addition of higher available P from *G. sepium* was also observed by Agboola *et al.* (1982), Jones *et al.* (1996), Aihou *et al.* (1999), Matta-Machado and Jordan (1995) and Soriano (1991) from agroforestry system.

Exchangeable Potassium (K): The exchangeable K content of the soil in agroforestry treatments increased remarkably from the initial level. The mean maximum exchangeable K (0.73 meq/100 g) was recorded in *L. leucocephala* which was very closely followed by *G. sepium* plots (0.72 meq/100 g) and *I. tysmani* (0.70 meq/100) and the mean lowest K (0.69 meq/100 g) was recorded in *C. siamea* plots. Among the treatments, the highest content of exchangeable K (0.76 meq/100 g) was found in *L. leucocephala* plus N_{100} treated plot and the lowest (0.66 meq/100 g) was in *C. siamea* plus N_{100} treated plot. No addition of pruned materials, crop removal and losses through runoff may be attributed the lowest in exchangeable K in control plots, whereas, the increased in exchangeable K in plots with tree species was probably due to the return of K via tree leaf pruning and leaf litter fall to the soil surface (Miah *et al.* 1997). Higher content of exchangeable K under agroforestry system was also observed by Aihou *et al.* (1999), Jones *et al.* (1995), Wendit *et al.* (1995) and Matta–Machado and Jordan (1995).

Exchangeable Calcium (Ca): Exchangeable Ca content of the soil where pruned materials of different tree species were incorporated showed a positive change over control as well as the initial level. But variation was found among the tree alleys. Among the tree alleys, the mean (average of three N levels) highest exchangeable Ca content (12.49 meq/100 g) was recorded in *I. tysmanii* alley, which did not vary remarkably with *G. sepium* (12.34 meq/100 g) and *L. leucocephala* (12.24 meq/100 g), while the lowest value was noted in *C. seamia* alley as 11.53 meq/100 g. Among the treatments with different N levels, the highest and the lowest exchangeable Ca content were found in *I. tysmanii* plus N_{100} (13.33 meq/100 g) and *C. seamia* plus N_0 (10.75 meq/100 g), respectively. However, all the agroforestry treatments performed better over control (8.81 meq/100 g) plot and initial level (8.75 meq/100 g). Aihou *et al.* (1999), Miah *et al.* (1997), Jones *et al.* (1996); and Matta–Machado (1995) reported the similar results regarding in increasing of Ca content of soil in agroforestry system.

Cation Exchange Capacity (CEC): Cation exchange capacity in the alley cropping plots was higher than that of the control plot and initial level. The mean CEC in *G. sepium, I. tysmanii, L. leucocephala* and *C. seamia* were 23.02, 22.56, 22.47 and 22.20 meq/100 g, respectively while the values in control plot and initial soil were 19.63 and 19.56 meq/100 g, respectively. Among the treatments, the maximum and the minimum CEC content were 23.10 and 21.90 meq/100 g in *G. sepium* plus N_{100} and *C. seamia* plus N_0 treatments, respectively. Agboola *et al.* (1982) and Attah–Krah *et al.* (1986) also observed higher CEC with *G. sepium* treatment.

Sulfur (S): Incorporation of pruned materials of different tree species into the soil increased S content over control and initial levels. Initially the S content of the soil was 9.25 meq/100 g, which was raised to 11.55, 11.28, 10.31 meq/100 g in the *G. sepium, I. tysmanii, L. leucocephala* and *C. seamia* alleys, respectively, while the value in the control plot was 10.05 meq/100 g. Among the treatments, the highest and the lowest S content were recorded in GS plus N_{100} (12.40 meq/100 g) and CS plus N_{100} (10.51 meq/100 g) treatments, respectively. Jones *et al.* (1996) also observed the higher S content in agroforestry treatments.

Table 2. Trends of soil properties changes in alley cropping systems of different tree species along with variable nitrogen level after sixth season of experimentation

Treatments	pH	Organic C (%)	Total N (%)	Available P (ppm)	Exchangeable bases(meq/100g)		CEC (meq/ 100g)	S (meq/ 100g)
					K	Ca		
GS+N_0	6.3	0.80	0.100	21.39	0.70	11.67	22.96	10.48
GS+N_{50}	6.6	0.82	0.099	20.89	0.73	12.37	23.00	11.74
GS+N_{100}	6.2	0.83	0.101	21.45	0.75	13.00	23.10	12.40
Mean	**6.4**	**0.81**	**0.100**	**21.24**	**0.72**	**12.34**	**23.02**	**11.55**
LL+N_0	6.2	0.79	0.099	21.14	0.70	11.50	22.30	11.55
LL+N_{50}	6.1	0.81	0.104	20.94	0.74	12.37	22.65	11.21
LL+N_{100}	6.3	0.82	0.099	21.62	0.76	12.86	22.48	10.77
Mean	**6.2**	**0.81**	**0.101**	**21.23**	**0.73**	**12.24**	**22.47**	**11.17**
IT+N_0	6.3	0.79	0.100	21.10	0.70	12.30	22.35	10.21
IT+N_{50}	6.1	0.84	0.102	21.31	0.73	11.83	22.49	12.13
IT+N_{100}	6.3	0.83	0.106	21.69	0.67	13.33	22.86	10.86
Mean	**6.23**	**0.82**	**0.103**	**21.35**	**0.70**	**12.49**	**22.56**	**11.28**
CS+N_0	6.0	0.77	0.095	20.79	0.67	10.75	21.90	10.52
CS+N_{50}	6.1	0.80	0.094	19.49	0.67	12.17	22.06	10.69
CS+N_{100}	6.3	0.82	0.096	20.34	0.66	11.67	22.63	10.51
Mean	**6.13**	**0.80**	**0.095**	**20.20**	**0.67**	**11.53**	**22.20**	**10.31**
Control	5.8	0.62	0.074	17.56	0.55	8.81	19.63	10.05
Initial	5.8	0.65	0.076	18.00	0.46	8.75	19.56	9.25

GS=*Gliricidia sepium* (Gliricidia); LL=*Leucaena leucocephala* (Ipil-ipil)
CS=Cassia siamea (Minjiri); IT=Indigofera tysmanii (Indigofera)

SUMMARY

In alley cropping system, fast growing leguminous tree/shrubs species are grown because it usually recycles nutrients, contribute biologically fixed nitrogen, and provide fuel, fodder and timber. The overall purpose is to enhance or add income diversity (both short and long range), reduce wind and water erosion, improve crop production, improve utilization of nutrients, improve wild life habitat or aesthetics, and/or convert cropland to forest. The pruned materials are incorporated into soil at planting and/or during the cropping period so that pruned tree leaves release nutrients into the soil and improve the physico-chemical properties of soil; and ultimately improve the growth and development of the associated crops.

Tree performance: The height of the four tree species and the number of branches per tree were measured at 60, 90 and 120 days after pruning (DAP). Tree height of *G. sepium* maintained its superiority over other species and *C. siamea* was found as the shortest tree at all the measurement dates. Number of branches per tree was increased as the age of the tree increased. The highest number of branches per tree was produced by *G. sepium*, which was followed by *I. tysmanii*, *L. leucocephala* and *C. seamia* at all the measuring dates. Like tree height and branches per tree, *G. sepium* produced the highest amounts of fresh pruned materials both in terms of per tree (1598.52 g) and per hectare (10.63 ton) and the lowest amount was produced by *L. leucocephala* (884.45 g tree^{-1} and 5.88 t ha^{-1}). Fresh pruned materials obtained from *I. tysmani* and *C. siamia* were 1572.36 g tree^{-1} and 10.48-ton ha^{-1} and 1162.58 g tree^{-1} and 7.73 ton ha^{-1}, respectively.

Soil Properties: Incorporation of pruned material of four MPTS changed soil chemical properties in a positive direction. Soil properties like soil pH, organic C, total N, available P, exchangeable K and Ca, CEC and S were increased due to alley cropping practice. Soil pH increased slightly in all the alley cropping treatments and it varied from 6.0 to 6.4. Organic C, total N, available P, exchangeable K and Ca, CEC and S were increased 25, 31.25, 16.69, 53.26, 38.87, 15.35, and 19.75%, respectively, as compared to the initial status of the experimental soil. The results also revealed that, *G. sepium*, *I. tysmanii* and *L. leucocephala* performed better in building up of soil fertility than that of *C. siamea*. The better performance of *G. sepium, I. tysmanii* and *L. leucocephala* in building up of soil fertility could be attributed due to higher nutrient content and faster decomposition rate of the pruned materials.

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