CHAPTER 1

INTRODUCTION

Agroforestry is a land use management system in which trees or shrubs are grown around or among crops. It combines shrubs and trees in agricultural and forestry technologies to create more diverse, productive, profitable, healthy, ecologically sound, and sustainable land-use systems (https://en.wikipedia.org/wiki/Agroforestry). Alley cropping refers to planting agricultural crops between rows of trees. It has been promoted by Mike Hands (https://en.wikipedia.org/wiki/Inga_alley_cropping). According to (Wilson and kang, 1981) alley cropping implies the growing of arable crops in spaces provided by hedgerows of established leguminous shrubs. Periodic cutback of the shrubs provide organic materials which serve as mulch and nitrogen source. The use of legumes in farming systems is particularly important for two reasons: a) high prices of commercial inorganic fertilizers vis-a-vis the financial resource base of peasant farmers and b) reduction of fallow period in common land use systems as a result of increasing population pressure with a concomitant decline in soil productivity (NAS, 1978). A good soil should have at least 2.5% organic matter, but in Bangladesh about 60% of the cropped land has organic matter less than critical level of 1%, which indicates poor soil condition (Hossain and Kashem, 1997). It is believed that the declining productivity of the soils is the result of depletion of organic matter due to increasing cropping intensity, use of lower quantity of organic manure and little or no use of green manure (BARC, 2005). The need for legumes that could effectively restore soil fertility for sustained crop yield cannot be over-emphasized. According to Akobundu (1980), weed control alone constitutes over 40% of the total cost of production of most arable crops in the tropics. The need to identify shrubs that would effectively smother noxious weeds in traditional cropping systems cannot therefore, not be ignored. Indeed, inclusion of such shrubs in traditional cropping systems via the practice of alley cropping would greatly enhance the acceptability of the system. Sustainable agriculture is farming in sustainable ways based on an understanding of ecosystem services, the study of relationships between organisms and their environment. It has been defined as "an integrated system of plant and animal production practices having a site-specific application that will last over the long term", for example: a) Satisfy human food and fiber needs b) Enhance environmental quality and the natural resource base upon which the agricultural economy depends c) Make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls d) Sustain the economic viability of farm operations and e) Enhance the quality of life for farmers and society as a whole(https://en.wikipedia.org/wiki/Sustainable_agriculture). No-till alley cropping systems of leguminous trees must provide adequate levels of residue to provide good soil cover for the soil-crop system between the rows while maintaining or increasing root-zone nutrients for these crops. This tends to be easier in the humid tropics where trees grow quickly, increasing the yield of biomass and nutrient recycling (Moura et al., 2008). A big advantage of alley cropping systems is that smallholders can produce their crops and regenerate soil fertility in one place and at the same time; this is not possible with green manures, or in other systems such as slash-burnfallow agriculture (Atta-Krah, 1989). However, success depends upon several factors such as the ability of pruned materials to maintain soil cover through the crop growing season, the total nutrient release during decomposition and the synchronicity between nutrient release and the crop's needs (Mendonça and Stott, 2003). (Moura et al., 2009) have shown that application of plant residues in alley cropping systems in the Amazonian periphery altered soil conditions, increased rootable soil volume and water retention in the uppermost soil layer and significantly increased maize yield. Several authors have confirmed that using leguminous trees together with small inputs of phosphorus fertilizers makes nutrient recycling more efficient and allows farmers to use fewer inputs (Leite et al., 2008; Vanlauwe et al., 2005). Ensuring that nutrient demand and release are in synchrony means paying close attention to the application period, location, residue quality, and addition of inorganic nutrients (Myers et al., 1997). More information is needed with regard to nutrient use efficiency in alley cropping systems in tropical regions with well defined wet and dry seasons.

The potential nutrient contribution of alley shrubs is important in so far as the nutrients are made available to arable crops at the time the nutrients are most needed. Thus, a shrub with a large store of nutrients that are released after the food crop is harvested, will be of little value to that crop in terms of nutrient supply. This means that, for a given shrub, information pertaining not only to nutrient content but also the rate of decomposition and release of nutrients is important. The objectives of the study is

- To know the effect of alley cropping on crop production
- To know the change of soil properties in alley cropping systems

CHAPTER 2

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. So, no specific methods of studies are followed to prepare this paper. All data and information were collected and used from secondary sources. This seminar paper has been complied through reading of different books, journals, booklets, proceeding, newsletters, souvenir, consultancy report that are available in the libraries of BSMRAU.

Finally, this seminar paper was prepared with the consultation of my respective major professor and honorable seminar course instructors.

CHAPTER 3

REVIEW OF FINDINGS

As a soil management technology, the system retains the tree component of shifting cultivation while allowing continuous cropping with little or no external nutrient inputs. Moreover, the *Leucaena* (or *Gliiicidia*)-maize-cowpea system has been developed for cultivation on Alfisols and other high base-status soils in the humid tropical regions where rainfall distribution allows planting two crops within a year. The three types of alley cropping developed on high base-satus soils at IITA and elsewhere may be summarized in Table 1. The choice of tree species, alley spacing and pruning frequency will depend on the goal set by the farm household.

Table 1. Goal and practice of alley cropping on small-holder farms on Alfisols and other well-drained high based-status soils in humid and sub-humid tropics

Goal	Practice
Crop production	Green manure is supplied annually by 2 to 4 pruning's of trees with high N-fixing capacity, e.g. *Leucaena leucocephala.*
Crop production & fuelwood	Green manure is supplied by 2 to 4 pruning's of trees during cropping season; one-year cropping followed by 1 or 2 years of fallow for wood production.
Crop production & fodder	Two woody species may be established in alternate rows in the same field; e.g. *Leucaena* to provide green manure and mulch to the annual crop and *Gliricidia* to provide fodder to livestock.

Yield

Leguminous species such as *Leucaena* and *Gliricidia* grown in hedgerows in alley farming can yield large quantities of biomass and nutrient yield as compared to non legumes such as *Acioa* or *Alchornea cordifolia* (Table 2). Repeated additions of prunings can have a profound effect on soil properties.

Table 2. Biomass and nutrient yields of woody species from five prunings of hedgerows, Ibadan, southwestern Nigeria

Species	**Dry matter ($t\ ha^{-1} yr^{-1}$)**	**Nutrient yield ($kg\ ha^{-1} yr^{-1}$)**				
		N	P	K	Ca	Mg
Acioa baterii	3.0	41	4	20	15	5
Alchornea cordifolia	4.0	85	6	48	42	8
Gliricidia sepium	5.5	169	11	149	66	17
Leucaena leucocephala	7.4	247	19	185	98	16

(Source: Kang, 1987)

The grain yield of maize grown in alleys was influenced significantly ($P < 0.05$) by nitrogen levels (Table 3). Grain yield generally increased with the increase in applied N levels. The mean highest grain yield (4.15 t ha^{-1}) was obtained from 100% N plus PM treatment, which was followed by control (4.08 t ha-1) and 75% N plus PM (3.94 t ha^{-1}), while the lowest grain yield (1.64 t ha^{-1}) was found in no N but PM applied treatment. The effect of different woody species on grain yield was insignificant at their respective N levels, except 25% N plus PM treatment. At 25% N plus PM treatment, grain yield of maize produced in *S. siamea* alley was significantly lower compared to *G. sepium* but statistically identical to other species. The result indicates that by using 25% less N fertilizer, it is possible to get desired yield in alley cropping system. The result also suggests that the system would work more effectively if N fertilizer is used. Korwar and Radder (1997) reported N as limiting factor and observed higher sorghum yield when N was applied along with PM in alley cropping system.

Table 3. Grain yield (t ha^{-1}) of maize grown in alleys consisting of four different woody species as affected by different nitrogen levels along with pruned materials

Treatment Nitrogen dose (%) + PM*	**Woody species**				
	G. sepium	***L. leucocephala***	***C. cajan***	***S. siamea***	**Mean**
0 + PM	1.73 dA	1.67 dA	1.68 dA	1.94 dA	1.64 d
25 + PM	2.83 cA	2.71 cAB	2.69 cAB	2.50 cB	2.68 c
50 + PM	3.51 bA	3.42 bA	3.39 bA	3.31 bA	3.41 b
75 + PM	4.03 aA	3.95 aA	3.90 aA	3.76 abA	3.94 ab
100 + PM	4.28 aA	4.20 aA	4.11 aA	4.01 aA	4.15 a
100 (Control)**	4.08 a	4.08 a	4.08 a	4.08 a	4.08 ab

(Source: Rahman et al., 2009)

* Pruned materials (PM);

** Without tree and PM

Table 4 shows the spatial variation in maize grain yield across the alley as influenced by woody species and distances from the base. The highest mean grain yield (3.28 t ha^{-1}) was noted in *G. sepium* alley, which was closely followed by *L. leucocephala* (3.19 t ha^{-1}) and *C. cajan* (3.15 ton ha^{-1}) alley, while the lowest grain yield (3.10 t ha^{-1}) was produced in *S. siamea* alley and this yield was also identical to the grain yield produced in *C. cajan* and *L. leucocephala* alleys. It was noticed that maize yield was adversely affected when grown in the closest (50 cm) row position irrespective of woody species. The highest mean (average of four woody alleys) grain yield of maize (3.31 t ha^{-1}) was observed at 150 cm row position from the tree base, which was closely followed by 100 cm row position (3.13 t ha^{-1}). However, the grain yield (2.99 t ha^{-1}) was significantly lower at 50 cm row position. In *G. sepiu,*, *L. leucocephala* and *C. cajan* alleys, although the lowest yields of maize were observed at the 50 cm row position, but they did not vary significantly with that grown at the next row position (100 cm). Yield reduction at the closer row from the base of woody species might be due to competition for light, water and nutrients between woody species and crop. Similar results were obtained by others Friday and Fownes, 2002; Miller and Pallardy, 2001 in maize production with alley cropping.

Table 4. Spatial variation of grain yield (t ha^{-1}) of maize across the alley as influenced by different woody species

Tree species	**Distance from the tree base (cm)**			
	50	**100**	**150**	**Mean**
G. sepium	3.14 aB	3.29 aAB	3.34 aA	3.28 a
L. leucocephala	3.03 abB	3.22 aAB	3.32 aA	3.19 ab
C. cajan	2.94 abB	3.18 aAB	3.34 aA	3.15 ab
S. siamea	2.86 bB	3.10 aA	3.20 aA	3.10 b
Mean	2.99 B	3.19 A	3.31 A	

(Source: Rahman et al., 2009)

Despite the high nitrogen yield from *Leucaena* and *Gliricidia* prunings, it is inefficiently used by the associated crop. It is estimated that the N contribution from prunings of these two species is about 40 kg ha^{-1} (Table 5) to the associated maize crop.

Table 5. Nitrogen yield from hedgerow prunings during one maize crop. N uptake by the alley farmed maize and estimated N gain from hedgerows to the system

Woody hedgerow	**N yield from pruning[1] (kg ha^{-1})**	**N uptake by maize (kg ha^{-1})**	**Estimated N gain[2] (kg ha^{-1})**		**Maize grain yield (kg ha^{-1})**
Control	26.2				1632
Non-legumes:					
Acioa baterii	24.5	38.8	12.6	51.4	2588
Alchornea cordifolia	62.0	44.9	18.7	30.2	2557
Legumes:					
Gliricidia sepium	127.8	68.6	42.4	33.1	3349
Leucaena leucocephala	231.1	68.1	41.9	18.1	3210

(Source: Kang 1988)

[1]Not including N removed with wood harvested

[2]Figures in brackets give percentage N utilization from prunings

As shown in Table 6, alley-farmed plots with *Leucaena* and *Gliricidia* have higher soil organic matter and nutrient status than in tilled control plots. Alley farming also reduces runoff and soil erosion compared with control plots. Runoff and erosion is reduced by the physical barrier of the hedgerows, and also by the better physical condition of the soil under the hedgerows, resulting from higher faunal (earthworm) activity, which increases water infiltration.

Change in soil properties

Table 6. Effect of six years of alley farming on properties of surface soil, runoff, soil loss and maize yield on a Luvisol with 7% slope

Treatment	**pH (H_2O)**	**Organic carbon (%)**	**Exchangeable (cmol kg^{-1})**			**Runoff (mm(%))**		**Soil loss (t ha^{-1})**	**Maize yield (t ha^{-1})**
			K	**Ca**	**Mg**				
Control (without hedgerows)									
Tilled	5.3	0.5	0.2	2.2	0.4	66.0	9.4	6.18	2.3
No-till	5.4	0.9	0.3	2.2	0.6	5.6	0.8	0.43	2.4
Alley cropped and tilled									
2m-*Gliricidia*	5.2	0.8	0.4	2.3	0.5	4.8	0.7	0.57	3.2
4m-*Gliricidia*	5.1	0.8	0.4	2.4	0.5	23.1	3.3	1.44	2.8
2m-*Leucaena*	5.1	0.9	0.4	2.6	0.5	2.6	0.4	0.17	3.5
4m - *Leucaena*	5.1	1.1	0.5	2.8	0.6	10.7	1.5	0.82	3.1

(Source: Kang and Ghuman 1991)

Changes in chemical properties of the soil

The soil chemical properties before and after the harvest of maize are presented in Table 7. Soil pH did not vary significantly among the treatments, which varied from 5.8 to 6.1. Variation in organic C content among the alley treatments was insignificant, but this was significantly higher than initial and control soils. The highest (0.69%) and lowest (0.58%) organic C contents were noted in *G. sepium* alley and control soils, respectively. The highest total N content of soil (0.081%) was observed in *L. leucocephala* alley, which was followed by other alleys (0.079, 0.077 and 0.076% in *G. sepium*, *C. cajan* and *S. siamea* alleys, respectively), but this was significantly higher than those in initial (0.076%) and control (0.070%) soils. However, total N content in alleys, except *L. leucocephala*, did not change remarkably compared to initial soil. CEC content was the highest in *G. sepium* alley soil (50.57 meq 100g-1), which did not vary remarkably in *L. leucocephala* alley (20.32 meq $100g^{-1}$), but varied significantly over *C. cajan* (19.95 meq 100g-^{1}) and *S. siamea* (19.92 meq $100g^{-1}$) alleys. Although, the lowest value of CEC (19.21 meq $100g^{-1}$) was recorded in control soil, it did not vary much with initial soil (19.56 meq $100g^{-1}$). The increase in soil pH under *G. sepium* may be due to its faster leaf decomposition and higher foliar Ca levels. Miah et al. (1997) observed higher soil pH and organic C in alley cropping system with *G. sepium*. Higher N content in the L. leucocephala alley might be due to higher N-fixing ability (100-500 kg ha^{-1} $year^{-1}$) of the species (Nair, 1993) and higher leaf N content (Anthofer et al., 1998). CEC was also higher in the alley cropping treatments compared to control and initial soils. Increased top-soil CEC in alley cropping of the present study is supported by De Costa et al. (2005).

Table 7. Soil properties change in alley cropping system as influenced by incorporation of prune materials of four different woody species after harvesting maize

Treatment	pH	Organic C (%)	Total N (%)	CEC (meq 100g^{-1})
L. leucocephala	6.1 a	0.68 a	0.081 a	20.32 ab
C. cajan	6.1 a	0.67 a	0.079 ab	19.95 bc
S. siamea	6.0 a	0.67 a	0.079 ab	19.92 bc
Control	5.8 a	0.58 c	0.070 c	19.21 d
Initial	5.8 a	0.65 b	0.076 b	19.56 cd

(Source: Rahman et al., 2009)

Fresh pruned materials (PM) were separated into leaf and branch and all PM were incorporated to the soil (Fig. 1). The highest amount of leaves (8.9 t ha^{-1}) was pruned from *S. siamea* species, which was closely followed by *C. cajan* (7.5 t ha^{-1}) and *G. sepium* (6.8 t ha^{-1}). Remarkably lower leaf fresh weight was recorded in *L. leucocephala* (3.0 t ha^{-1}). In case of branch, the trend was different where *G. sepium* produced maximum (3.7 t ha^{-1}) followed by *L. leucocephala* (3.1 t ha^{-1}). However, branch fresh weight obtained from *C. cajan* and *S. siamea* was almost similar. The highest amount of total fresh PM of 11.7 t ha^{-1} was recorded in *S. siamea* species, which was almost similar to *G. sepium* (10.5 t ha^{-1}) and *C. cajan* (10.2 t ha^{-1}), whereas it was significantly lower in *L. leucocephala* (6.1 t ha^{-1}).

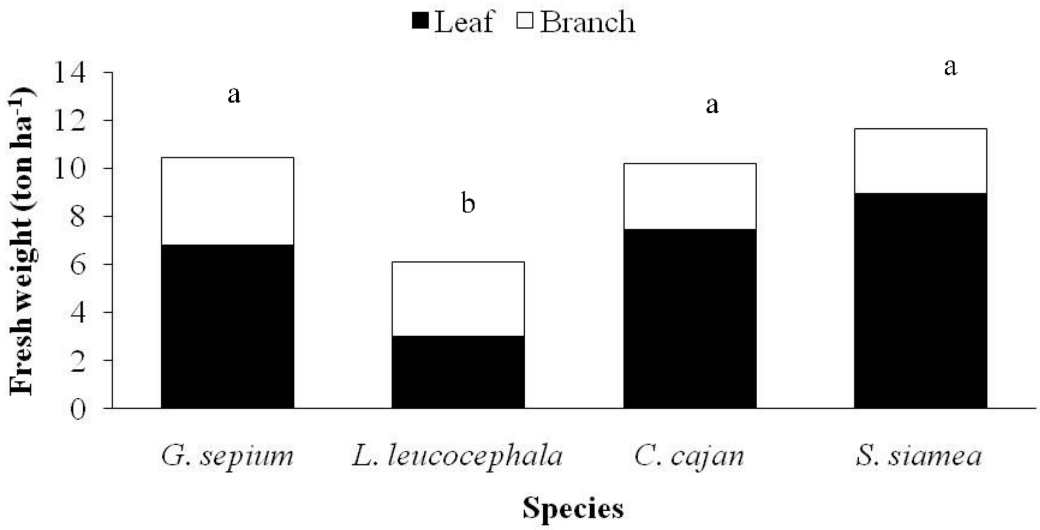

Fig 1. Fresh weight of pruned materials (leaves and branches) obtained from the woody species and added to the soil. Means followed by a common letter are not significantly different at the 5% level by DMRT. (Source: Rahman et al., 2009)

Microbial biomass and total PLFA

Means of MBC, MBN, and total PLFA contents as well as the contributions of MBC to SOC and MBN to total N were significantly lower in the organic than in the integrated farming system, whereas the SOC content was significantly higher (Table 8). The MB and C/N ratio remained unaffected. Tree species had little effect on MBC, MBN, total PLFA contents as well as the MB-C/N ratio and the contribution of MBN to total N (Table 8).

Table 8. Contents of soil organic carbon (SOC), microbial biomass, and total PLFA of all treatments associated with organic and integrated farming (21-year) and tree species (4-year)

Main effects	SOC (mg g^{-1} soil)	Microbial biomass					Total PLFA* (nmol g^{-1} soil)
		C (μgg^{-1} soil)	N (μgg^{-1} soil)	C/N	C (% SOC)	N (% SOC)	
Organic farming	13	168	19	9.8	1.3	1.3	70
Integrated	12.3	222	24	9.4	1.8	1.8	77
Poplar	11.3	193	21	9.6	1.7	1.6	71
Robinia	14	197	22	9.6	1.4	1.5	76
0 m	12.5	189	20	9.6	1.5	1.5	75
2 m	12.1	184	19	10.7	1.6	1.4	70
15 m	13.3	212	26	8.4	1.6	1.8	75

PLFA*-Phospholipid Fatty Acid

(Source: Sun et al., 2016)

The mean GalN content was significantly higher in the organic farming than that in the integrated farming system, whereas easily extractable glomalin of organic farming was lower (Table 9). The other microbial residue indices remained unaffected by farming practices, although organic farming tended to decrease MurN and GlcN. In contrast, tree species had little effect on the mean contents of individual amino sugar although the robinia system tended to decrease MurN and GlcN (Table 9).

Table 9. Contents of amino sugars, microbial residue C, and glomalin of all treatments associated with organic and integrated farming (21-year) and tree species (4-year)

Main effects	Fungal			Fungal C/ bacterial C	Microbial residue C	Glomalin	
	Mur μgg^{-1} soil)	Gal	GalcN			Total (mg g $^{-1}$)	EE
Organic farming	40.1	302	617	2.8	54	2.4	1
Integrated	42.7	275	658	2.8	59	2.4	1.2
Poplar	41.9	288	672	2.9	65	2.2	1
Robinia	41	289	604	2.7	48	2.6	1.2
0 m	42.6	280	625	2.7	56	2.3	1
2 m	39.6	298	634	2.9	58	2.4	1
15 m	42.2	287	654	2.8	56	2.5	1.3

(Source: Sun et al., 2016)

The climate is temperate with mild winter and hot, humid summer. The soil is characterized as a well-drained, Redbay sandy loam (a fine-loamy, siliceous, thermic Rhodic Paleudult) formed in thick beds of loamy marine deposits with an average water table depth of 1.8 m.The main chemical and physical properties of the soil are summarized in Table 1. This study included five landuse management practices as follows (hereafter referred to as treatments): 1) 47-year-old pecan/cotton alley cropping system (OA), 2) 3-year-old pecan/cotton alley cropping system (YA), 3) 47-year-old pecan orchard (OP), 4) 3-year-old pecan orchard (YP), and 5) cotton monoculture field (Mono). Understory vegetation in the OP and YP was composed of annual and perennial grasses such as ryegrass (*Lolium* spp.), crabgrass (*Digitaria* spp.), common

Bermuda grass (*Cynodon dactylon* (L.) Pers.), *purple nutsedge* (*Cyperus rotundus* L.), dogfennel (*Eupatorium capillifolium* (Lam.) Small), horseweed (*Conyza Canadensis* L.) common cocklebur (*Xanthium strumarium* Wallr.), curly dock (*Rumex crispus* L.), cudweed (*Gnaphalium purpureum* L.), *Virginia pepperweed* (*Lepidium virginicum* L.), wild mustard (*Sinapis arvensis*), cutleaf evening primrose (*Oenothera laciniata* Hill), Florida pusley (*Richardia scabra* L.), and yellow sorrel (*Oxalis stricta* L.).Annual litter fall in all treatments were obtained from a companion study based on pecan leaf fall, cotton leaf production, and understory biomass production, depending on the treatments (Table 10).

Table 10. Chemical and physical properties of the soils (top 10 cm) and leaf litter productions under five temperate land-use practices in Southern USA

Treatment	C (%)	N	P^H	CEC $cmolkg^{-1}$	Soil texture (%)			Bulk density $g\ cm^{-3}$	Leaf litter production $kgha^{-1}yr^{-1}$
					Sand	Silt	Clay		
OA	2.24	0.13	6	8	74	17	9	1.23	3556
YA	1.17	0.06	5.9	5.3	81	14	5	1.34	1128
OP	3.74	0.2	5.6	9.2	73	14	13	1.15	3139
YP	1.21	0.07	5	4.2	79	13	8	1.32	875
Mono	1.49	0.08	6.1	6.6	80	15	5	1.28	1147

OA: 47-year-old pecan/cotton alley cropping system, YA: 3-year-old pecan/cotton alley cropping system, OP: 47-year-old pecan orchard, YP: 3-year-old pecan orchard, and Mono: cotton monoculture. **(Source: Lee and Jose, 2003)**

Microbial biomass C, Organic matter, and Fine root biomass

Soil microbial biomass C was affected significantly by treatments ($P < 0.0001$). Soil microbial biomass C was highest in OP soil (398 mg C kg^{-1} dry soil) and lowest in YP soil (88 mg C kg^{-1}

dry soil) among treatments. OA and OP soils had higher soil microbial biomass C than YA, YP, and Mono soils (Figure 2B).

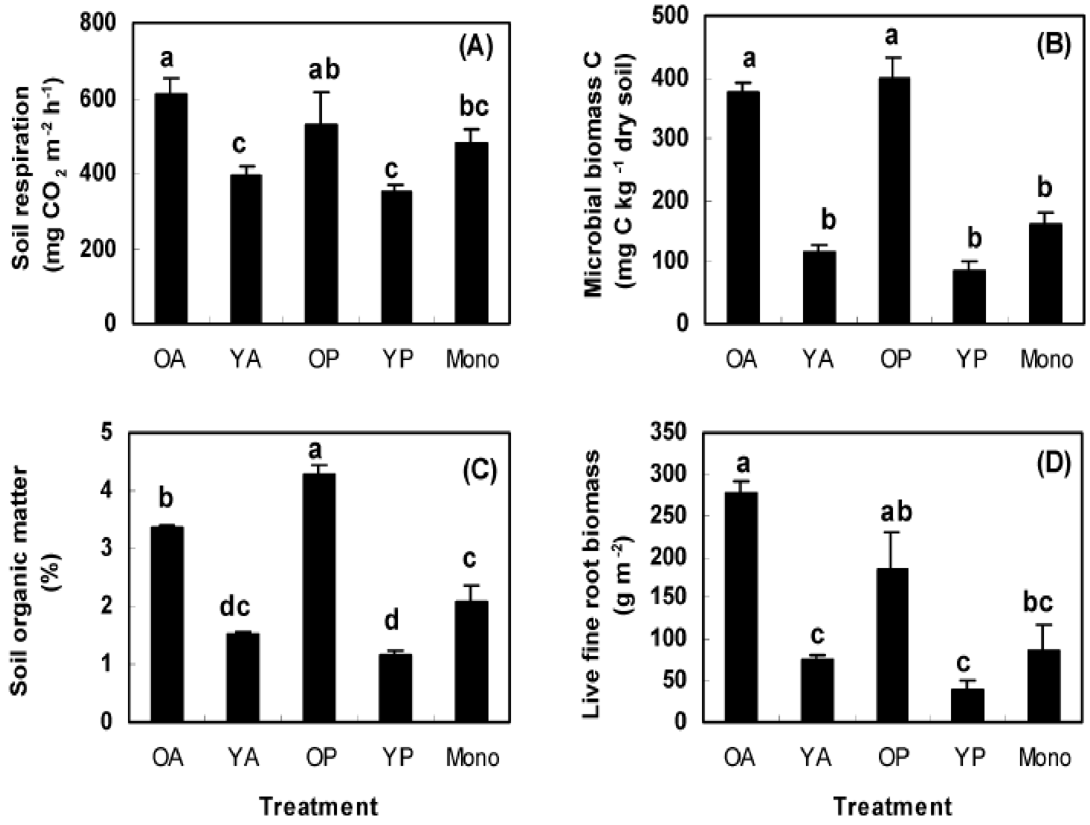

Figure 2. Effects of land-use practices on soil respiration (A), microbial biomass C (B), soil organic matter (C), and live fine root biomass (D). Measurements were taken in August, 2001.Vertical bars indicate standard error of the mean (n = 18). Different lower-case letters above bars denote significant differences among land-use practices ($P < 0.05$) (Source: Lee and Jose, 2003)

Soil organic matter was significantly different among treatments ($P < 0.0001$). The OP (4.3 %) and OA (3.4 %) treatments had significantly higher soil organic matter content than the YP (1.2 %), YA (1.5 %), and Mono (2.1 %) treatments (Figure 2C). It was found significant differences in live fine root (< 2 mm) biomass among treatments ($P < 0.001$) as well. The OA treatment had the highest live fine root biomass (277.2 g m^{-2}) while YP had the lowest (37.5 g m^{-2}) among treatments (Figure 2D).

CHAPTER 4

CONCLUSION

- Though in alley cropping system the individual production of crops is less than from sole crop production, because for the competition of water, sunlight, nutrient and other factors related to crop production. But the total production (woody perennial + annual crop) is higher than sole crop production.
- In alley cropping system maximum legume crops are cultivate. So, it increases soil nitrogen status, control P^H, soil organic carbon (SOC), microbial biomass C, Organic matter, and Fine root biomass etc.

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