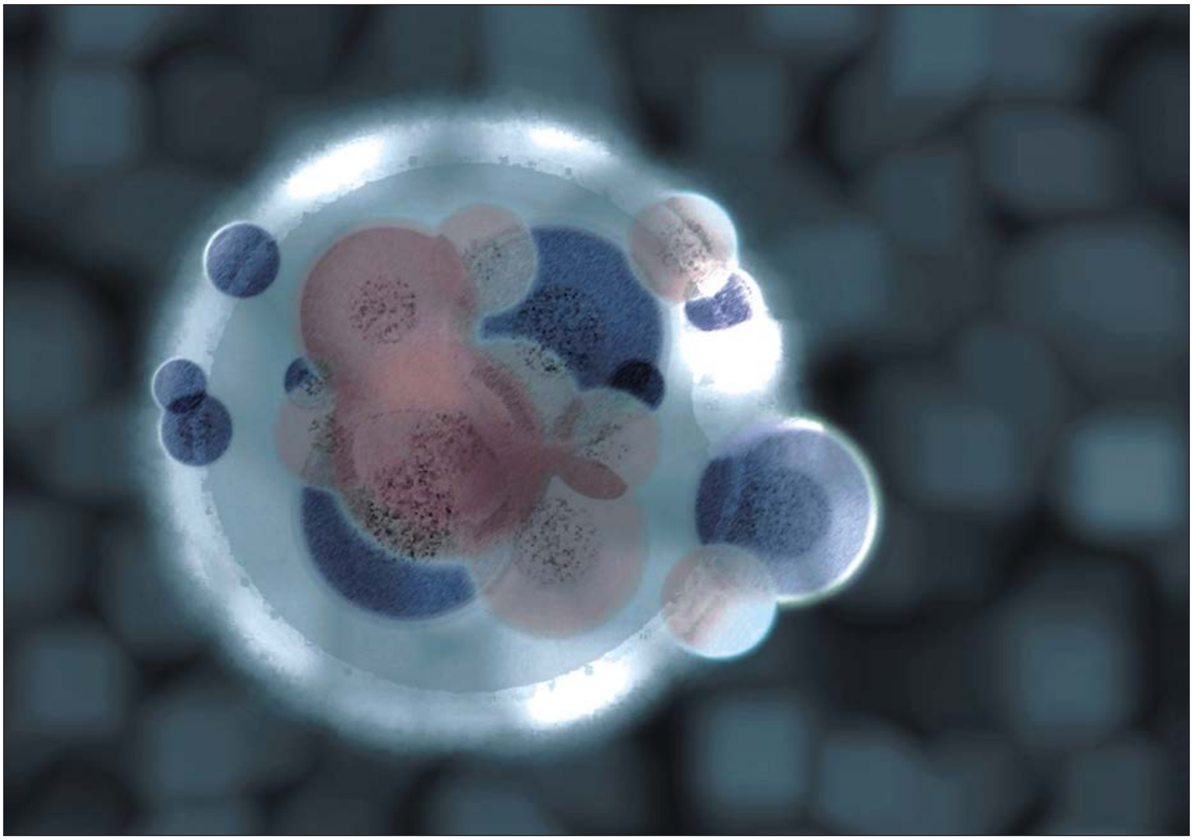

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Alley Cropping *Gliricidia sepium* with Maize: 1. The Effect of Hedgerow Spacing, Pruning Height and Phosphorus Application Rate on Maize Yield

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Abstract: During the 1996 farming season sprouted *Gliricidia sepium* seedlings were planted at three hedgerow spacing (alley width) to investigate the appropriate spacing, pruning height and phosphorus application rate that could improve and sustain soil fertility and increase crop production. The 3-hedgerow spacing (4, 6 and 8 m) was established as the main plot. Hedgerow spacing significantly influenced the quantity of *Gliricidia* biomass applied. In the farming seasons of 1997 and 1998 three pruning height (50, 100 and 150 cm) were imposed on the hedgerow spacing and three rates of phosphorus (0, 20 and 40 kg P ha^{-1}) were applied. Maize (*Zea mays*) was planted as a test crop in the first week of June each year. Pruned *Gliricidia* biomass yield was in a decreasing order of 150>100>50 cm pruning height. In a good rainfall year as in 1997 the 4 m hedgerow spacing significantly out yielded the 8 m hedgerow spacing, while in a relatively low rainfall year as in 1998 the 6 m hedgerow spacing gave the highest grain yield. In both years maize stover and grain yield followed closely the amount of pruned biomass applied per treatment. Application of 20 kg P ha^{-1} resulted in significant increase in maize dry matter yield.

Key words: Alley cropping, *Gliricidia*, grain, maize, phosphorus, stover

INTRODUCTION

Many soils of the tropics are inherently low in fertility and there is rapid decline in fertility when land is cleared and cultivated[1]. In these soils, the soil organic fraction plays an important role in nutrient retention and maintaining soil organic matter is an important factor in the long-term productivity[2,3].

Soils of the Guinea Savanna zone of Ghana are generally poor in nutrients especially, nitrogen, phosphorus and sulphur[4]. The poor vegetation cover, bad tillage practices and high soil temperature may be responsible for the low soil organic matter content. Generally, farmers in the zone rely on bush fallow and shifting cultivation systems to restore soil fertility. However, the length of the fallow period has been reduced considerably due to the population pressure on land. This has contributed immensely to poor soil fertility, land degradation and low food production.

Agroforestry technologies designed as an alternative to shifting cultivation and bush fallow systems include means of replenishing the soil organic matter content with biomass from the trees. The leguminous tree species, *Gliricidia sepium*, (Jacq) Walp is known to produce large amount of biomass, which provide nutrient on decomposition and improves soil organic matter. It is drought tolerant, has considerable tolerance to bush fires and can withstand repeated pruning[5]. *Gliricidia sepium* biomass yield of 20 t ha^{-1} is reported to have increased maize yield by 54% over that from an application of 120 kg N ha^{-1}. However, biomass yields less than 10 t ha^{-1} produced lower maize yield than that produced from 120 kg N ha^{-1}[6]. The low carbon-nitrogen ratio (C/N) of 12 and the low half-life value of 22 days of *Gliricidia* fresh biomass[7] make the tree ideal for alley cropping. Palm[8] observed that *Gliricidia* released 30-70% of its nitrogen, but nutrient recovery values of added biomass by companion crop was generally less than 20%. In alley cropping system, hedgerow trees are pruned periodically to prevent shading and to reduce competition with food crops[9]. The pruning is added to the soil to increase the organic matter content and recycle nutrients.

The width of the alley (hedgerow spacing) and the height at which the alley trees are pruned could influence the competition between the alley and the companion crop for sunlight, water and soil nutrients. Lawson and Kang[10] observed that though 2 m hedgerow spacing gave higher biomass, the yield of maize reduced on this hedgerow spacing compared to the 4 m hedgerow spacing.

Food crop yields under alley cropping could improve if the most limiting nutrients not adequately supplied or

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recycled by the leaves could be added as inorganic fertilizer supplement. According to Szott and Kass[11] in phosphorus deficient soils, adding pruned biomass alone cannot sustain productivity of continuous alley cropping since phosphorus may become limited. The influence of phosphorus on maize grain yield is well documented[12,13].

This trial was conducted to determine the appropriate hedgerow spacing, pruning height and the quantity of phosphorus required to improve and sustain soil productivity in *Gliricidia sepium* alley cropping systems.

MATERIALS AND METHODS

The experiment was conducted at Savannah Agricultural Research Institute's experiment farm at Nyankpala, in the northern region of Ghana (Latitude 09°25 'N, longitude 00° 58' W and altitude 183 m MSL). The soil at the experimental site is a typical upland soil, classified as Haplic Lixisols[14] and locally referred to as Tingoli series. The trial investigated three hedgerow spacing (alley width): 4, 6 and 8 m; three pruning heights: 50, 100 and 150 cm; three levels of phosphorus: 0, 20 and 40 kg P ha^{-1} applied as single super phosphate. The hedgerow spacing was the main plot (A) with the three pruning height (B) imposed on (A) and the three rates phosphorus © was applied. The experimental design used was randomised complete block (RCBD) with three replications.

The alley trees were established during the 1996-farming season from sprouted *Gliricidia sepium* (Jacq) Walp stem cuttings. The test crop used was maize (*Zea mays*, Var Okomasa, a full season maturity crop). The test crop was sown in June each year at a spacing of 80 cm between rows and 50 cm at a population of 50000 plants ha^{-1}.

The first pruning of the hedgerow trees was done two weeks before sowing the test crop in June and the second pruning six weeks after sowing. The pruned materials were spread on the plots and incorporated into the soil. Sub-samples of pruned materials were oven dried at 70°C for 48 h, milled and chemically analysed for the total N, P and K content as described in TSBF[15].

Soil samples were collected before establishing the alley and after harvesting the maize crop in 1998. The samples were air dried, ground and sieved with 2 mm mesh and stored for physical and chemical analysis in the laboratory. Soil pH was determined in 0.01 M $CaCl_2$ solution[16] in 1: 2.5 soil: solution ratio, soil organic carbon by Walkley and Black procedure as described in TSBF[15] total nitrogen by Kjeldhal method[17], extractable phosphorus by Bray 1[18] procedure and cation exchange capacity (CEC) by leaching with neutral ammonium acetate solution as described in TSBF[15].

Analysis of Variance (ANOVA) was generated and means of data taken were compared. Where significant differences at Probability of less than 0.05 were observed between the means, least significant difference (LSD) was calculated and used to separate the means.

RESULTS AND DISCUSSION

Addition of *Gliricidia* pruning and changes in some soil characteristics: Application of pruned *Gliricidia* biomass resulted in significant ($P<0.05$) increase in soil OC content, N and CEC over the control plot (Table 1). Percent increase in organic carbon (OC), total nitrogen (N) and cation exchange capacity (CEC) of soil amended with the pruned *Gliricidia* biomass over the control were 22, 32 and 34%, respectively. The initial soil analysis revealed that the soil is sandy loam with pH of 5.21, OC of 0.69%, N of 0.044%, available phosphorus (P) of 2.07 mg kg^{-1} and CEC of 3.84 Cmol (+) kg^{-1}. There was also a marked increase in these properties over the initial soil content by the end of the second farming season in 1998. The improvement in the soil parameters could be attributed to the incorporation of between 12 and 26 t ha^{-1} of pruned *Gliricidia* biomass into the soil. The soil pH increased from 5.21 (acidic) at the start of the trial in 1996 to a mean of 5.5 in 1998. This may be attributed to the release of cations from the added *Gliricidia* biomass.

Hedgerow biomass production and nutrient yield: The concentration of nitrogen (N), phosphorus (P) and potassium (K) in the pruned *Gliricida* biomass was 2.55, 0.32 and 1.8%, respectively (i.e. 25.5 kg N, 3.2 kg P and 18 kg K ton^{-1} of dry *Gliricidia* biomass). The pruned *Gliricidia* biomass has high nitrogen content but total phosphorus is considerably low[8]. In 1997, *Gliricidia* biomass yield ranged between 4 and 9 t ha^{-1} and it increased to between 7 and 17 t ha^{-1} in 1998 i.e. 24 months of growth. Araya-Sanchez[19] reported *Gliricidia* biomass production of 12 t ha^{-1} after 16 months of growth. In both years the 4 m hedgerow spacing received the highest biomass followed by the 6 m and lastly the 8 m hedgerow spacing (Fig. 2). Since tree population in each hedgerow is the same, the closer the spacing, the higher the quantity of biomass applied. Keerthisena[20] and Brook[21] observed that Gliricidia biomass yield decreased with increasing alley width. In both years, 150 cm pruned height gave significantly higher biomass than the 100 cm height, which was significantly higher than the 50 cm height

Table 1: Some chemical properties of soil under 2 year *Gliricidia* alley cropping system in the Guinea savanna zone of Ghana

	PH	Org. carbon	Total N	Bray P	CEC Cmol
		---------------%	-----------	mg kg^{-1}	(+) kg^{-1}
Hedgerow block 1*	5.47	0.76	0.03	8.83	4.16
Hedgerow block 2	5.55	0.80	0.05	8.99	4.79
Hedgerow block 3	5.40	0.80	0.05	8.64	4.55
Control block	5.32	0.64	0.03	8.71	3.36
LSD(P<0.05)	Ns	0.08	0.01	Ns	0.18
CV(%)	3.67	13.70	16.8	32.45	10.50

Table 2: Addition of pruned *Gliricidia* biomass to the soil and its effect on maize stover yield in an alley cropping system in the Guinea savanna zone of Ghana

	1997	1998
Hedgerow block 1*	2.09	1.71
Hedgerow block 2	2.07	1.82
Hedgerow block 3	2.21	1.84
Control block	1.87	1.31
LSD(P<0.05)	0.29	0.08
CV(%)	22.04	6.11

Table 3: Addition of pruned *Gliricidia* biomass to the soil and its effect on maize grain yield in an alley cropping system in the Guinea savanna zone of Ghana.

	1997	1998
Hedgerow block 1*	2.52	0.91
Hedgerow block 2	2.25	1.01
Hedgerow block 3	1.37	1.04
Control block	1.16	0.79
LSD(P<0.05)	0.21	0.07
CV(%)	30.02	9.02

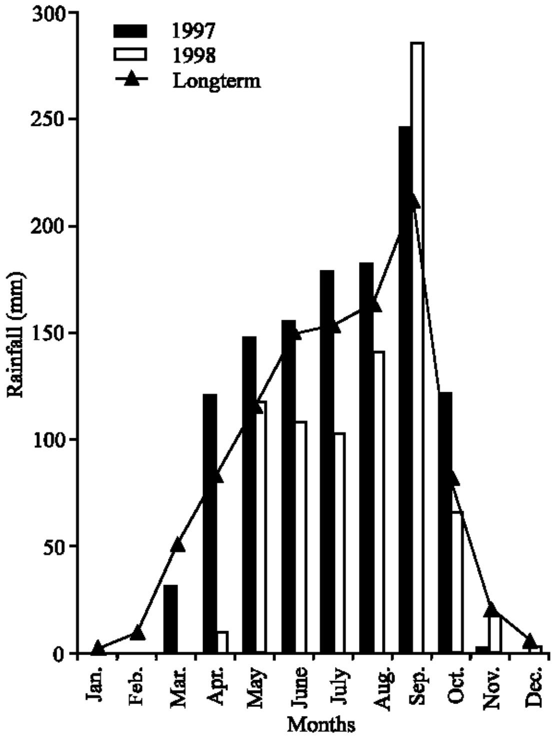

Fig. 1: Monthly rainfall for 1997, 1998 and long term average monthly rainfall at the trial site in the Guinea savanna zone of Ghana

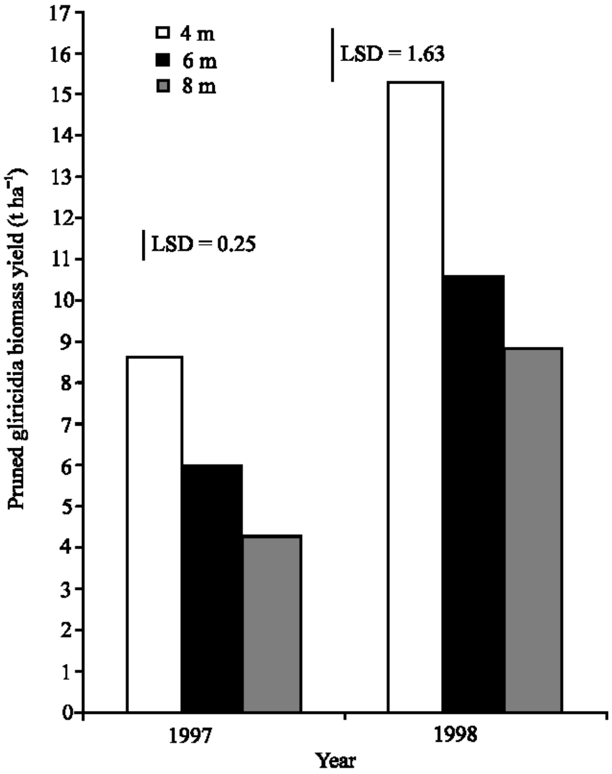

Fig. 2: Gliricidia biomass yield of different hedgerow spacing in 1997 and 1998

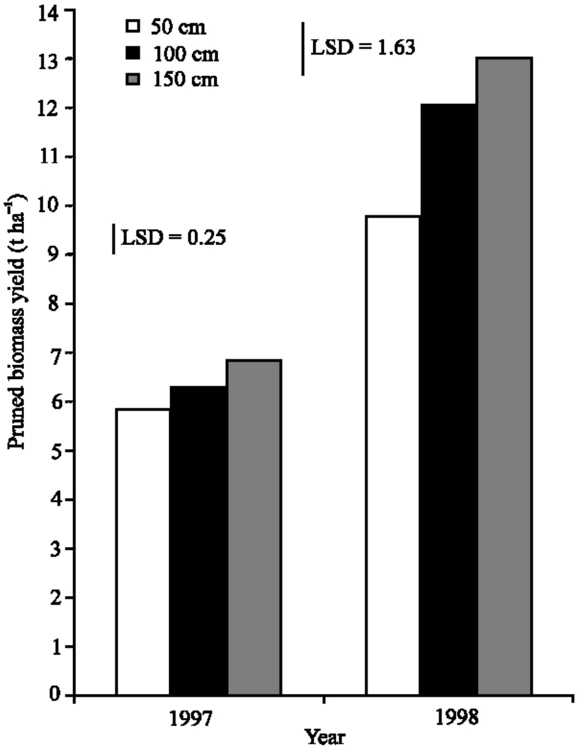

Fig. 3: Gliricidia hedgerow biomass yield as influenced by different pruning height

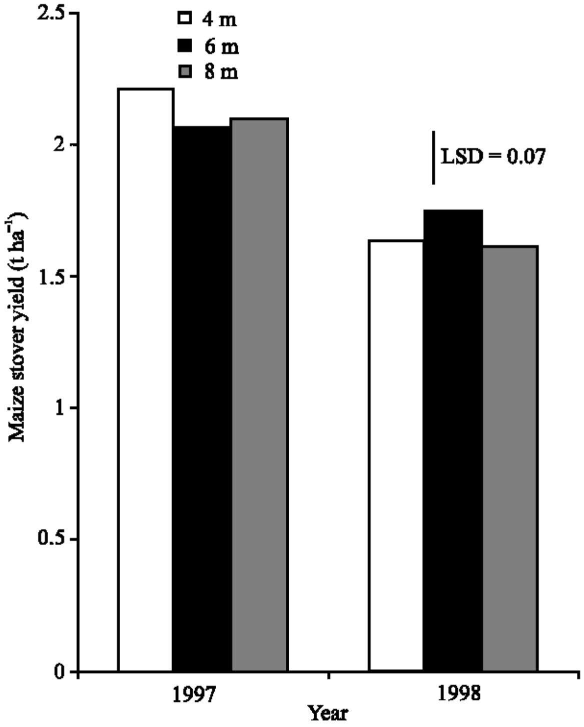

Fig. 4: Effect of Gliricidia hedgerow spacing of on maize stover yield in an alley cropping system in the Guinea savanna zone of Ghana

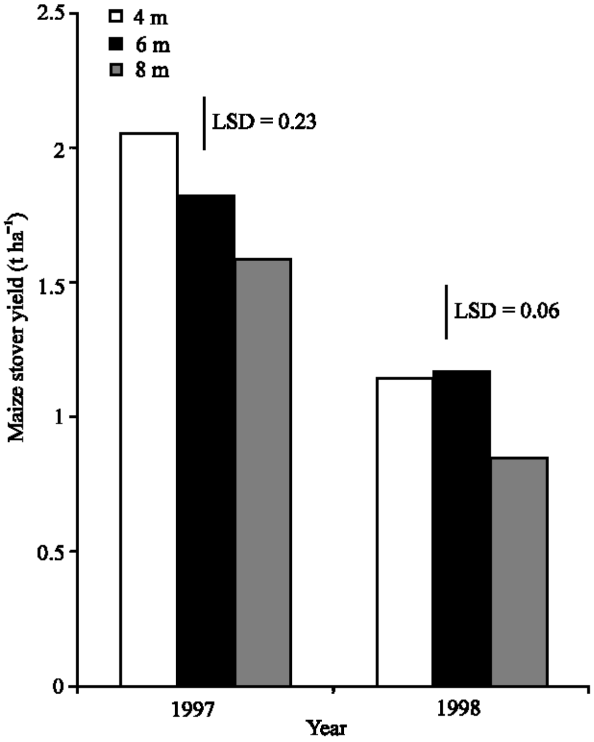

Fig. 5: Effect of Gliricidia hedgerow spacing on maize grain yield in an alley cropping in the Guinea savanna zone of Ghana

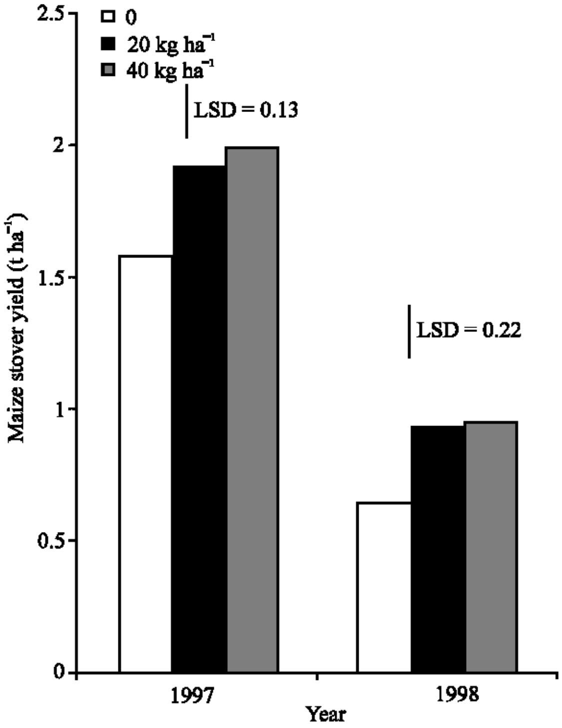

Fig. 6: Effect of phosphorus application rate on maize grain yield in an alley cropping system in the Guinea savanna zone of Ghana

(Fig. 3). Duguma *et al.*[22] made similar observation where higher pruning height gave higher biomass. Though the 50 cm pruned height reduced shading of the companion maize crop, the capacity to produce higher biomass was limited (Fig. 3) and hence limits nutrient recycling[23].

Phosphorus application did not influence *Gliricidia* biomass production significantly. Total P yield from the pruned *Gliricidia* biomass ranged between 12 and 29.5 kg P ha^{-1} in 1997 and in 1998 it ranged between 24 and 55 kg P ha^{-1}. Phosphorus content of the pruned *Gliricidia* biomass was not influenced significantly by the rate P application. This could be due to the fact that P was applied principally to the maize crop, which was planted on ridges with the closest ridge being at least 50 cm from the hedgerow. Total N yield ranged between 98 and 235 kg N ha^{-1} in 1997 and in 1998, it ranged between 184 and 431 kg N ha^{-1}. Considering 30 to 70% mineralization[8] and about 10% nutrient recovery from recently applied pruned biomass[24] it is expected that at between 10 and 24 kg N ha^{-1} and between 1 and 3 kg P ha^{-1} will be recovered from the applied biomass in 1997, while in 1998, between 18 and 43 kg N ha^{-1} and between 2 and 6 kg P ha^{-1} will be recovered by the maize crop. From above estimates, P recycled through the *Gliricidia* biomass would not adequate for good maize production, hence the need to supply P from external source.

Maize yield: In both years *Gliricidia* biomass application significantly ($P<0.05$) increased maize stover and grain yield compared to the control, where no pruned *Gliricidia* biomass was applied (Table 2 and 3). The percentage grain yield increase of the 3 blocks with *Gliricidia* hedgerow: 1, 2 and 3 (*Gliricidia* biomass applied) over the control (no *Gliricidia* biomass applied) in 1997 were 16, 33 and 50% and in 1998, were 14, 27 and 31%, respectively. The significant increase in maize dry matter yield on the blocks treated with pruned *Gliricidia* biomass compared to the control block could be attributed to the general improvement in soil physical, chemical and microbiological as a result of *Gliricidia* biomass application. The release of plant nutrient on decomposition and mineralisation of applied Gliricidia biomass contributed to the nutrient requirement of the crop[8]. The difference in maize yield between the 3 blocks treated with *Gliricidia* biomass is suspected to be due to difference in amount of biomass applied. Though biomass applied in 1998 was markedly higher than that of 1997, there was lower maize dry matter yield in 1998 compared to 1997. The relatively lower rainfall in 1998 (Fig. 1) as well as the dry spells within the growing season may account for the lower dry matter yield. In 1997 hedgerow spacing did not significantly influence maize stover yield. However in 1998, the stover yield at 6 m hedgerow spacing was significantly higher than that of 4 and 8 m (Fig. 4). The hedgerow spacing significantly ($P<0.05$) influenced maize grain yield in both years (Fig. 5). Maize grain yield decreased in order of 4>6>8 m in 1997 but in 1998, the grain yield was highest at 6 m hedgerow followed by the 4 m and lastly the 8 m hedgerow spacing. In an alley cropping system, below ground competition for moisture could be more pronounced especially in a low rainfall season. In 1998, the low rainfall and the short dry spells could have resulted in more severe competition for moisture at the 4 m hedgerow spacing compared to the 6 and 8 m spacing resulting in lower grain yield in spite of higher biomass application[25]. On the other hand, the observed significantly higher dry matter yield at 4 m hedgerow spacing in 1997 is attributed to the good rainfall condition comparing 1998 and long term average (Fig. 1). The consistent lower maize dry matter yield at the 8 m hedgerow spacing could be attributed primarily to the lower amount of pruned *Gliricidia* biomass applied, 4 and 9 t ha^{-1} in 1997 and 1998, respectively. Karim and Sail[6] reported that less than 10 t ha^{-1} of pruned *Gliricidia* biomass applied to the soil did not increase maize dry matter yield significantly. In both years maize dry matter yield followed a decreasing trend of 150>100>50 cm (Fig. 3). Though these differences were not significant, the higher maize dry matter at 150 cm pruning height could be attributed to the addition of higher pruned *Gliricidia* biomass. This result contradicted the observation of Duguma *et al.*[22], Lawson and Kang[10] who reported that higher pruning height reduced companion crop yield as a result of reduction in light transmission. In our opinion the West-East orientation of the hedgerow may have reduced the shading effect of the 150 cm hedgerow on maize crop and thus the competition for light transmission reduced.

Application of fertilizer phosphorus in the alley cropping system resulted in significant ($P< 0.05$) increased in maize grain yield of both years (Fig. 6). However, raising the level of P to 60 kg P_2O_5 did not bring corresponding yield increase. The soil has very low level of available P (P Bray) and the P in the applied biomass was very low. The fertilizer P therefore became the major source of P for the crop. At higher P application however, other factors including N may have limited the uptake and utilization of the higher P applied for increase maize dry matter yield[26]. There was generally an increase in soil P status at the end of 1998 farming season (Table 1) compared to the initial soil P status of 2.1 mg kg^{-1}. It is hope that subsequent crop will benefit from the improved soil P status.

With the high cost of inorganic fertilizer, this fast growing leguminous tree could be a source of organic manure for improved and sustainable crop production. The full benefit of the pruned *Gliricidia* biomass application on soil fertility status (physical, chemical and microbiological properties) and productivity may be felt in the future with the continuous application of pruned biomass. Beside improvement in maize grain yield observed, some other added benefit of the alley cropping system in the zone includes feeding the *Gliricidia* pruning to livestock and using the biomass for composting with other crop residues such as maize, sorghum, millet and rice straw. Hard wood from pruned hedgerow could serve as hard wood for staking yams and/or fuel wood for the household.

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