Influence of weeding regimes and NPK fertilizer on the establishment and symbiotic properties of selected hedgerow trees in alley cropping

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Abstract

Weed infestation is one of the problems of hedgerow tree establishment in farmers' fields in the humid and sub-humid tropics and to a large extent discourages farmers from adopting alley cropping, which necessitates planting of trees. The effect of weeding regimes and NPK fertilizer (40 kg ha^{-1}), on the establishment of Senna siamea and biological nitrogen fixation (BNF) of Gliricidia sepium cultivar ILG 50, and Leucaena leucocephala cultivar K28, were investigated on an Alfisol at the International Institute of Tropical Agriculture (IITA) Ibadan, southwestern Nigeria. At 3 months after planting (MAP), weeds reduced plant dry matter yield and height of the three tree species, but Senna was most affected, having a reduction of 78% dry matter yield in both fertilized and unfertilized plots. At 6 MAP, NPK fertilizer application significantly (P=0.05) enhanced the growth of Senna by 72%. There was no significant effect of fertilizer on the dry matter yield of Gliricidia and Leucaena. At 12 MAP Senna produced significantly(P=0.05) higher dry matter yield than Gliricidia or Leucaena. Nodulation in Gliricidia and Leucaena improved with the frequency of weeding. Fertilizer application reduced nodulation in Gliricidia as well as the nitrogenase activity in both Gliricidia and Leucaena. The study showed that adequate weed control in the first three months of tree planting is required for suitable establishment of Leucaena, Gliricidia, and Senna in an alley cropping system. However, application of NPK fertilizer reduced the frequency of weeding required for Leucaena, Gliricidia, and Senna growth, but affected the microbiological parameters of both Leucaena and Gliricidia. Only Senna responded significantly to fertilizer application in acquisition of dry matter yield. There was a change of weed flora from predominant grasses at the beginning of the study to about 80% broad-leaved weeds at 12 MAP

Key words: Alley cropping, establishment, *Gliricidia, Leucaena, Senna*, weed

Introduction

One of the reasons why farmers in the humid and sub-humid tropics abandon land following a short cropping cycle in the traditional bush fallow system is the increasing labour needed for weeding (Akobundu et al., 1995). With the consistent and steady increase in population growth in the tropics, intensification of land use is currently taking a centre stage in farming systems in sub-Saharan Africa. Alley cropping was one of the early technologies developed by the International Institute Tropical Agriculture (IITA) Ibadan, as one of the renewable natural resources in crop production. In alley cropping, weed infestation hampers the proper establishment of hedgerow trees in farmers' fields, and the problem of establishment to a large extent discouraged farmers in establishing alley cropping field (IITA, 1980; Okogun and Mulongoy, 1999). Weeds suppressed *Leucaena* soon after emergence and caused a yield reduction of as much as 99% during first growing season (Jones and Aliya, 1976). The rate of early establishment of tree species used in alley cropping is usually slow. Thus, competition with weeds or food crops for nutrients, water and light can militate against the proper establishment of hedgerow trees. Though weeds are notorious for their nuisance value in causing losses in yields, their total elimination from agricultural fields has disadvantages. These include a decrease in overall dry-matter production per unit area, a drastic reduction in total genetic resources in the ecosystem, and attack by insects, which had hitherto attacked weeds (Tripathi, 1977). Because of these, no ideal farming system totally eliminates weeds. However, a weed management system that will eliminate competition with the desired crop plant is necessary. Leguminous trees, extensively studied at the IITA and International Livestock Research Institute (ILRI), showed different growth rates. For instance, *Gliricidia* has faster seed germination and seedling growth rate than *Leucaena* (Atta-Krah and Sumberg, 1988). Weed pressure varies with land use intensity and management. Continuous cultivation without a bush fallow rest period leads to soil impoverishment and this increased weed infestation (Akobundu *et al.*, 1995). The present trial was carried out to investigate the effects of regulated weeding on the establishment of *Senna siamea*, *Gliricidia sepium* ILG 50, and *Leucaena leucocephala* K28, nodulation and nitrogen fixation in *Gliricidia* and *Leucaena* under low and high fertility management levels, and to determine the optimum weeding regime for hedgerow tree establishment.

Materials and methods

Site and Land preparation

The experiment was set up on a degraded Alfisol at the IITA Ibadan, Nigeria. IITA is in the transitional zone between rain forest to the south and savanna to the north, (3°54' E, 7°30' N). The field was under grass fallow and it was periodically mowed for two years before setting up the trial in May 1996. The field was sprayed with gramoxone (200 ml/20L). Five days after spraying the herbicide, the field was ploughed, disc harrowed and marked out for planting.

Experimental design

Treatments consisted of factorial combinations of three tree species: a local variety of *Senna*, *Gliricidia* and *Leucaena*; two rates of NPK (20:20:20) fertilizer (no fertilizer and 40 kg ha^{-1} fertilizer); and four weeding regimes (no weeding, weeding every 8 weeks, weeding every 4 weeks, and frequent weeding (removing weeds before they established). The treatments were laid out in a split-split-plot design with the trees as main plots, fertilizer application as subplots and weeding regime as sub-subplot. Each treatment was replicated three times.

The plot size was 4 m long and 7 m wide but the hedge trees were planted at 4 m long and 4 m wide to give an alley width of 4 m. Thus the space between each hedgerow and the boundary of each plot was 1.5 m. This was done to provide space for weeds to grow on either side of a hedgerow.

Seed preparation and planting

Senna and *Leucaena* seeds were scarified with concentrated sulphuric acid for 25 minutes before planting as described by Duguma, (1985). The seeds were planted at every 25 cm within rows. No rhizobial strain inoculation was done before planting.

Weeding

Weeding was done manually with hoe as at the frequency described earlier i.e. no weeding, weeding every 8 weeks, weeding every 4 weeks, and frequent weeding (removing weeds before they established).

Sampling for soils

Before land preparation, the plots were marked out and soil samples were collected at 0 – 15 cm. There were ten cores taken per plot and the samples were bulked together to have 4 composite samples per replication. The soil samples were air-dried, crushed to pass through 0.5 mm and 2 mm sieves and analysed for some physical and chemical characteristics, the results of which are shown in Table 1.

Sampling for plant dry matter yield

Three months after planting, (MAP) six trees were randomly harvested from each plot; and at 6 MAP, four trees were randomly harvested from each treatment for the determination of plant height and shoot dry matter yield, nodulation, and nitrogenase activity at the two different sampling periods. For nodule collection, roots were dug to 30 cm deep in a 1.5 by 1.5 m area round the trees. Nitrogenase activity was determined using the Hardy et al. (1973) method.

At 12 MAP, 4 trees were randomly selected and harvested from each plot for plant height and shoot dry matter yield.

The dominant weed species were also identified at 12 MAP using the method of Akobundu and Agyakwa (1987).

Statistical analysis

Data collected were subjected to ANOVA using GENSTAT (5.3 statistical package 1993). Duncan's multiple range test was used to separate the means.

Results

The dominant weed species at 12 MAP were broad leaves and included *Ageratum conyzoides*, *Celosia ulentus*, *Mariscus alternifolius*, *Physalis angulata*, *Synedrella nodiflora*, *Talinum* *triangulare* and *Tridax procumbens,* even though the field was predominantly covered with grasses before land preparation.

The result of the soil analysis showed that the soil was slightly acidic with high available P, the nitrogen level of the soil was low, and the soil was sandy loam (Table 1).

Table 1: Some characteristics of the soil of the field used

pH (H_2O)	6.4
Org. C (g kg^{-1})	1.2
Total N (g kg^{-1})	0.2
Avail. P (Bray 1) (mg kg^{-1})	25.1
Exchangeable (cmol (+) kg^{-1})	
Ca	2.4
Mg	1.1
Mn	0.02
K	0.4
Na	0.2
Sand (%)	76
Silt (%)	10
Clay (%)	14

Dry matter yield, and plant height

Senna had the least dry matter yield in the no weeding plot compared with *Gliricidia* and *Leucaena.* There were no significant differences between *Gliricidia* and *Leucaena* dry matter yield, and plant height (data not shown). Figures 1 to 4 show the effect of weeding and NPK fertilizer on the hedgerow dry matter yield, and plant height at 6 and 12 MAP. At 6 MAP, *Senna* shoot dry matter yield was 86% higher in the frequent weeding regime than in the no-weeding treatment. By keeping *Gliricidia* weed-free, the biomass yield was 64% higher than when it was weeded every 4 weeks. *Leucaena* dry matter yield was 73% higher when weeded every 8 weeks than in the no-weeding treatment. There were no significant interactions between weeding and fertilizer application on the dry matter yield of *Leucaena* and *Gliricidia.* At 12 MAP, there were no significant differences between *Gliricidia and Leucaena* dry matter yields when both species were weeded every 8 weeks, or once in 4 weeks, or kept weed-free (frequent weeding).

At 12 MAP, however, *Senna* biomass yield in no-weeding treatment was higher than the biomass yield of *Gliricidia* and *Leucaena* in all the treatments (Fig. 2) Only *Senna* dry matter yield responded significantly to fertilizer application. The response of *Senna* to fertilizer was observed even at 6 MAP and this persisted at harvesting at 12 MAP.

The effect of weeding regimes and fertilizer on the hedgerow tree heights, are shown in Fig 3 and 4. Even though the fertilizer applied did not have significant effect on the hedgerow tree heights, the trees were significantly higher when the plots were kept free of weed or weeded once every 8 weeks.

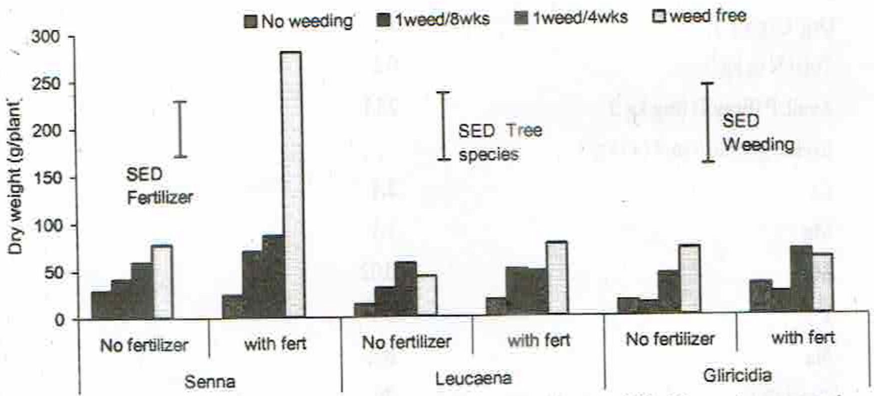

Fig. 1. Effect of NPK fertilizer and weeding regime on the biomass yield of Senna, Leucana and Gliricidia at 6 MAP

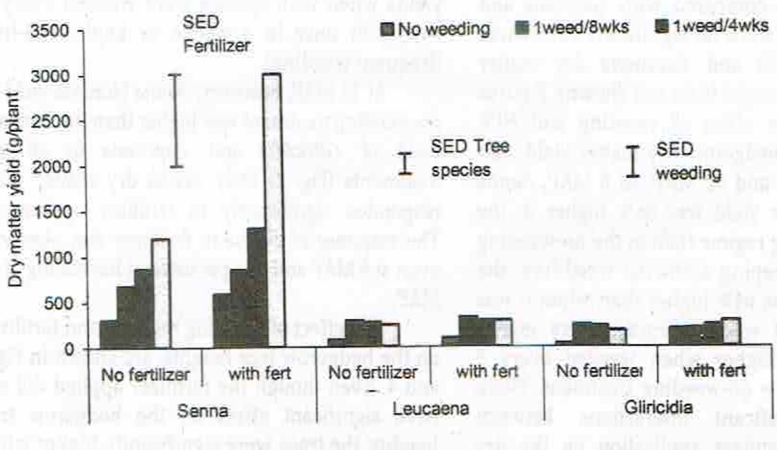

Fig. 2. Effect of NPK fertilizer and weeding regime on Senna, Leucaena and Gliricidia shoot biomass yield 12 MAP

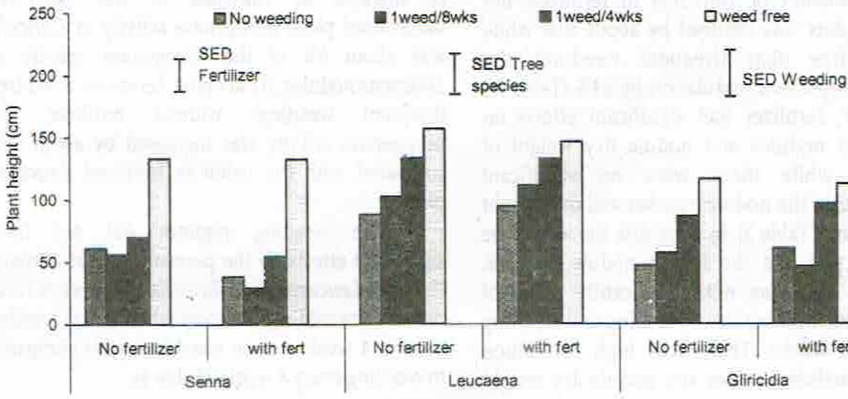

Fig. 3. Effect of NPK fertilizer and weeding regime on Senna, Leucaena and Gliricidia plant height 6 MAP

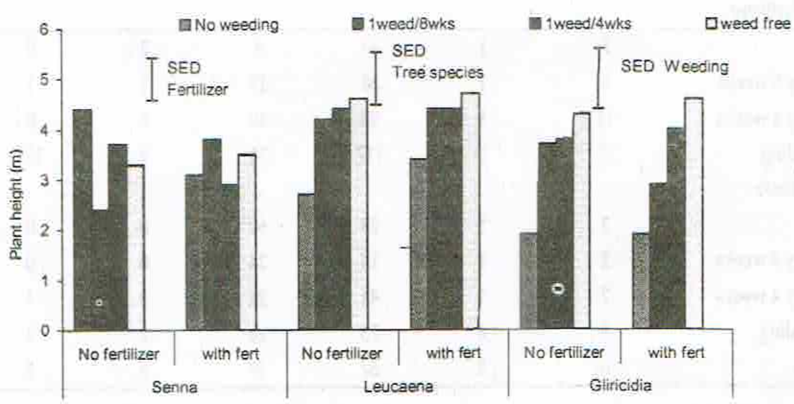

Fig. 4. Effect of NPK fertilizer and weeding regime on Senna, Leucaena and Gliricidia height 12 MAP

Nodulation

The effects of weeding regimes on nodulation in *Gliricidia* and *Leucaena* at 3 MAP are shown in Table 2. Nodule number in unweeded *Gliricidia* was 28% and in weeding every 8 weeks nodule number was 56% of the nodulation in weed-free unfertilized *Gliricidia*. Nodulation in *Leucaena* was significantly increased only at no-weeding treatment. *Gliricidia* produced more nodules than *Leucaena* in both fertilized and unfertilized plots.

Nodulation of *Gliricidia* in fertilized no-weeding plots was reduced by about 50% while in weed-free plots (frequent weeding), the fertilizer depressed nodulation by 64% (Table 2). At 6 MAP, fertilizer had significant effects on number of nodules and nodule dry weight of *Gliricidia* while there were no significant differences in the nodule number and dry weight in *Leucaena* (Table 3). In *Gliricidia*, the weed-free fertilized plot had the lowest nodule number. However, this was not significantly different from nodule number in no-weeding and weeding once in 8 weeks. There was high correlation between nodule number and nodule dry weight at 3 MAP and 6 MAP (P = 0.05. r=0.84 and 0.97) respectively. There was no significant correlation between nitrogenase activity and total N at 3 MAP.

Acetylene reduction assay (ARA) and percentage total N

Table 2 shows the effects of weeding and fertilizer application on nitrogenase activity of *Gliricidia* and *Leucaena*. Though the number of nodules in *Leucaena* was only 20% of the number of nodules in *Gliricidia* in the weed-free unfertilized plots, nitrogenase activity in *Gliricidia* was about 6% of the nitrogenase activity in *Leucaena* nodules. By keeping *Leucaena* weed-free (frequent weeding) without fertilizer, the nitrogenase activity was increased by about 99% compared with the value in fertilized *Leucaena* plots.

The weeding regimes did not have significant effects on the percentage total nitrogen (%TN) in *Leucaena* and *Gliricidia*. However, %TN in *Senna* increased significantly when it was weeded once in 4 weeks and in weed-free plots compared to weeding every 8 weeks (Table 4).

Table 2: Effect of weeding regime and fertilizer on nodulation and nitrogenase activity of *G. sepium* and *L. leucocephala* at 3 month after planting

Weeding regime	Nodule number plant^{-1}		Nodule dry weight (mg plant^{-1})		Nitrogenase activity (µmoles hour^{-1} plant^{-1})	
	Gliridicia	*Leucaena*	*Gliricidia*	*Leucaena*	*Gliricidia*	*Leucaena*
Without NPK fertilizer						
No weeding	7	1	46	4	2	0
Weeding every 8 weeks	6	1	38	17	1	1
Weeding every 4 weeks	14	1	95	10	8	0
Frequent weeding	25	5	117	34	9	133
With NPK fertilizer						
No weeding	3	1	23	60	0	0
Weeding every 8 weeks	2	1	13	24	0	0
Weeding every 4 weeks	7	1	41	24	0	1
Frequent weeding	9	6	73	24	2	2
LSD (5%)	16	2	57	19	8	5

Table 3: Effects of weeding regime on nodulation and nodule biomass of *G. sepium* and *L. leucocephala* 6 months after planting

Weeding regime	Number of nodule plant^{-1}		Nodule dry weight (mg plant^{-1})	
	Gliricidia	*Leucaena*	*Gliricidia*	*Leucaena*
Without NPK fertilizer				
No weeding	10	0	54	0
One weeding/8 weeks	9	1	51	10
One weeding/4 weeks	18	1	107	3
Frequent weeding	16	2	63	14
With NPK fertilizer				
No weeding	5	0	24	0
One weeding/8 weeks	5	1	19	10
One weeding/4 weeks	11	3	51	16
Frequent weeding	4	2	11	8
LSD (5%)	4	NS	15	NS

NS= Not significant

Table 4: Percentage Total Nitrogen of *S. siamea*, *G. sepium* and *L. leucocephala* 3 months after planting

	No weeding		Weeding every 8 weeks		Weeding every 4 weeks		Frequent weeding		
Tree species	-F	+F	-F	+F	-F	+F	-F	+F	LSD (5%)
S. siamea	2.5	2.5	2.0	2.2	3.1	3.1	3.3	3.2	0.5
G. sepium	3.3	3.2	3.5	3.7	3.5	3.8	3.3	3.5	NS
L. leucocephala	3.7	4.0	4.3	4.2	4.2	4.2	4.3	4.0	NS

NS – Not significant

Discussion

At the early growing stage, (3 MAP), growth in *Senna* was most affected by weeds. It had the highest biomass loss in unweeded plots compared to weed-free plots. This implies that at the early establishment stage *Senna* (3 MAP), is a poor competitor with weeds for growth factors compared with *Gliricidia* and *Leucaena*. Thus, *Senna* requires adequate weeding at the early stages of establishment. The results however, also show that *Senna* can establish well and the biomass production enhanced when weeded every 8 weeks when fertilized. It has been reported that application of NPK enhances legume growth (Sanginga, 1988; Hussain *et al.*, 1988). Thus, because the growth of *Senna* was enhanced in fertilized plots, it showed that the NPK fertilizer applied enhanced *Senna* establishment, because *Senna* though a tree legume does not nodulate. This implies that the application of NPK fertilizer could reduce labour required for *Senna* establishment. However, application of NPK fertilizer did not have significant effects on the dry matter yield of *Gliricidia* and *Leucaena* at 12 MAP. This showed that *Gliricidia* and *Leucaena* that did not receive NPK fertilizer were able to fix enough atmospheric nitrogen to meet up their demand for N, while both of the trees that received fertilizer depended on the fertilizer for N source. This is supported by the low nodulation and nitrogenase activity observed in both nodulating tree legumes when they receive NPK fertilizer (Table 2).

Senna had the shortest plants compared to *Leucaena* and *Gliricidia* but its dry matter production was significantly higher. Though *Leucaena* had the highest plants, it had the lowest dry matter yield. These differences may be genetic characteristics. It was observed that *Senna* produced lateral branches earlier and at lower levels to the soil level than *Leucaena* and *Gliricidia*. While the number of branches in *Senna* ranged between 16 in (no weeding plots) and 30 in (weed-free plots), *Gliricidia* had 2 branches in unweeded plots and 5 branches in weed-free plots at 12 MAP (Data not shown). This appeared to affect the weed infestation of the plots. The least weed biomass was recorded in *Senna* plots (Table 5). The branching habit of the tree species is a major factor influencing weed development because of competition between weed and tree for growth factors such as light and space. Late-branching trees such as *Gliricidia* and *Leucaena* allow a higher percentage of solar radiation to reach the ground and result in more weed development (Wilson, 1983).

Table 5: Weed biomass in *Senna, Gliricidia* and *Leucaena* plots at 12 months after planting

Weed regime	Fresh weed biomass (kg plot^{-1})		
	Senna	*Gliricidia*	*Leucaena*
Without NPK fertilizer			
No weeding	ND	ND	ND
Weeding every 8 weeks	68.7	69.3	65.3
Weeding every 4 weeks	93.1	100.8	87.8
Frequent weeding	67.3	115.4	83.1
With NPK fertilizer			
No weeding	ND	ND	ND
Weeding every 8weeks	83.0	63.7	73.0
Weeding every 4 weeks	85.5	90.3	77.3
Frequent weeding	68.4	102.3	95.4
Mean	77.7	90.3	80.2
LSD (5%) (treatments within tree)	NS	21.2	NS

ND = Not determined; NS = Not significant

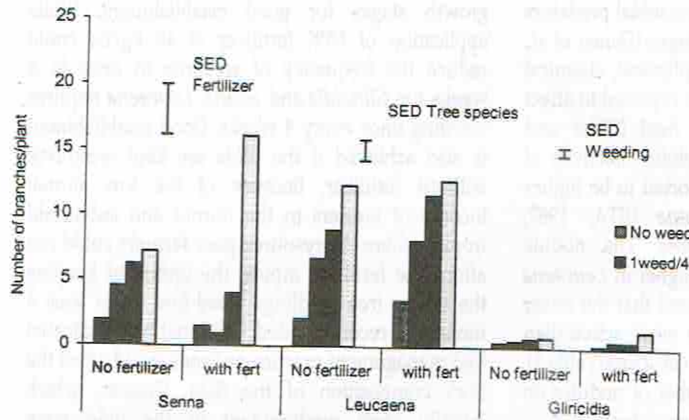

Fig. 5. Effect of NPK fertilizer and weeding regime on Senna, Gliricidia and Leucaena branching 6 MAP

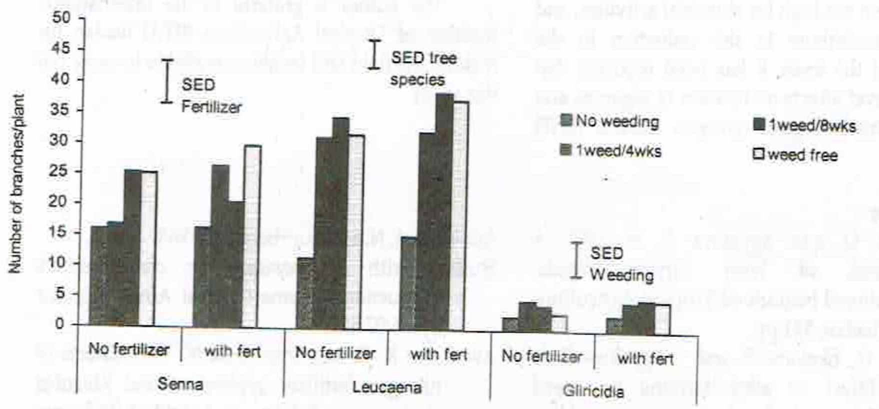

Fig. 6. Effect of NPK fertilizer and weeding regime on Senna, Leucaena and Gliricidia branching 12 MAP

Nodulation in *Leucaena* and *Gliricidia* increased as the weeding frequency increased most likely because of the removal of some of the stresses such as competition for nutrients, space and sunlight which weeds could pose on the tree development. The weeds might also produce rhizobial inhibitory root exudates that are toxic to rhizobia, while some may have rhizobial predators such as protozoa and bacteriophages (Danso *et al.*, 1975). Various stresses such as physical, chemical and biological stresses have been reported to affect nodulation of legumes in the field (Giller and Wilson, 1991). The relative symbiotic effectivity of *Gliricidia* and *Leucaena* was reported to be higher in *Gliricidia* than in *Leucaena* (IITA, 1987; Venkateswarlu and Singh, 1988). The nodule specific activity in this trial was higher in *Leucaena* than in *Gliricidia* and this indicated that the fewer nodules in *Leucaena* roots were more active than the higher nodules produced by *Gliricidia* (Table 2). This also indicates that the number of nodules on the roots of plants does not always have a close relationship with nitrogenase activity. The low nodulation in *Leucaena*, observed in this trial, confirms that *Leucaena* requires inoculation with *Rhizobium* for adequate nodulation (Sanginga, 1984). The observed reduction in the number of nodules in the roots of fertilized *Gliricidia*, suggests that the nitrogen level in the NPK fertilizer applied may have been too high for rhizobial activities, and this might contribute to the reduction in the nodulation of the trees. It has been reported that high soil N level affects nodulation of legumes and eventually the biological nitrogen fixation (BNF) (Awonaike and Oyemaobi 1982; Sanginga *et al* 1985). The use of an isotope of nitrogen in future studies would give more information on the roles of the native *Rhizobia* in the BNF potentials of the nodulating legume trees (*Leucaena* and *Gliricidia*).

This study shows that *Senna, Gliricidia* and *Leucaena* require adequate weeding in the early growth stages for good establishment. While application of NPK fertilizer at 40 kg/ha could reduce the frequency of weeding to once in 8 weeks for *Gliricidia* and *Senna, Leucaena* requires weeding once every 4 weeks. Good establishment is also achieved if the plots are kept weed-free without fertilizer. Because of the low annual income of farmers in the humid and subhumid tropics where the resource poor farmers could not afford the fertilizer inputs, the option of keeping the young tree seedlings weed-free for at least 4 months is recommended. This trial also indicated that management practice on lands could affect the flora composition of the field. Grasses, which initially were predominant in the field were overtaken by broad-leaf weeds. Akobundu *et al.* (1995) also reported that *Leucaena* caused a shift in weed flora away from fast growing annual weeds that are characteristic of frequently cultivated fields to shade-tolerant, less-competitive weeds.

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