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Cutting management of alley cropped leucaena/gliricidia-Guinea grass mixtures for forage production in southwestern Nigeria

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Abstract. A study was conducted at Fasola (7°45′ N and 3°5′ E) in southwest Nigeria to determine the best tree cutting scheme for forage production and the effects of hedge configurations on tree, grass and total forage productivity of 6–8-year-old leucaena (*Leucaena leucocephala* Lam. de Wit) and gliricidia (*Gliricidia sepium* Walp.) – Guinea grass (*Panicum maximum* Jacq. cv. Ntchisi) mixture. After a uniform cut at the end of January 1990 (mid-dry season), the trees were cut according to the following cutting regimes: one cut after a 12-month regrowth (12M); two cuts after three- and nine-month regrowth (3-9M); two cuts every six months (6-6M); two cuts after nine- and three-month regrowth (9-3M); three cuts, two cuts every three months and the third cut after a six-month regrowth (3-3-6M), and four cuts every three months (3-3-3-3M). Grass was cut every six weeks between April and October followed by a cut in January. The hedge configuration was either one or three hedgerows of mixed stands of leucaena and gliricidia. There were twice as many trees and one-third less grass in the triple than in the single hedgerow hedge configuration.

The 3-3-3-3M, 9-3M and 3-3-6M cutting regimes produced the highest total forage (tree foliage + grass) dry matter yields (DM) of 6.54, 5.80 and 5.77 t DM ha^{-1} $annum^{-1}$, respectively. The magnitude of the difference between the tree forage yields of the triple and single hedgerow plots (16%) did not reflect the theoretical difference in the number of trees (33%) in the two arrangements.

Introduction

A major constraint to livestock production in Nigeria, as well as other parts of the tropics, is the seasonal fluctuations in forage yield and quality. There is usually adequate forage of fair to good nutritive value in the wet season, but in the dry season available forage from natural pastures are usually inadequate both in terms of quality and quantity to meet even the maintenance requirements of livestock. Conservation of excess herbage in the wet season in the form of hay or silage for use in the dry season has not been successful due to unfavourable weather conditions during the period of excess, generally low quality herbage and lack of technical manpower and infrastructure

[Akinola, 1974]. The use of crop residues is not widely practiced in south-west Nigeria.

Perennial woody legumes have been shown to be capable of providing high quality fodder in the dry season [Adejumo, 1992; Costas et al., 1992]. This has aroused interest in their use in pastures leading to the development of tree-based forage production systems such as alley farming and intensive feed gardens in which gliricidia and leucaena feature prominently [Atta-Krah and Sumberg, 1988; Kang et al., 1990]. Tree management in alley farming has largely been directed at minimizing shading of associated arable crops. Information on the effects of pruning frequencies on biomass and nutrient yields of potential hedgerow species in alley farming are available [Duguma et al., 1988; Kang et al., 1990], but information on cutting management of tree-grass mixtures under fodder production systems, such as the intensive feed gardens, is scarce.

Management of tree-grass mixtures aims at striking a balance between the productivity of the components of the mixture. Tree spatial arrangement and harvesting regimes can be manipulated to achieve the balance [Huxley, 1986]. Tree management could be such that it would preserve foliage on-tree and assure high fodder yields at the onset of the dry season.

This paper reports the evaluation of different tree cutting management regimes and hedgerow arrangements on forage production of leucaena/gliricidia-Guinea grass mixtures grown in an alley cropping format.

Materials and methods

The trial was carried out at the International Livestock Centre for Africa (ILCA) sub-station at Fasola (7°45′ N 3°5′ E), Nigeria, located within the derived savanna zone. In general, the soil consists of gravelly sandy loam belonging to the Iwo Series, an alfisol, developed over basement complex [Fasehun, 1980]. The natural grassland is dominated by *Andropogon gayanus* Kunth. The mean daily maximum and minimum temperatures of the area are approximately 31 °C and 21 °C with only slight variations throughout the year. The relative humidity in the rainy (late March–October) and dry (November–early March) seasons are about 80% and 50%, respectively. Mean annual rainfall is about 1110 mm.

A plot of leucaena (*Leucaena leucocephala* Lam. de Wit) and gliricidia (*Gliricidia sepium*) which had been uncut for six to eight years was utilized for this trial. The trees were cut down at a height of 0.50 m above ground level in May/June, 1989. After clearing the cut trees, the land was manually cleared and four rows of Ntchisi variety of Guinea grass (*Panicum maximum* Jacq.) established in the 4-m wide alleys formed by the tree rows in July, 1989, without tillage. The grass was established at 0.50 × 0.80 m spacing, with 0.80 m between adjacent tree and grass rows. There were two different planting patterns of the tree in the hedges (hedge configurations) giving rise to single hedgerow and triple hedgerow hedges (Fig. 1). These arrangements resulted in 5714 tree/ha in the triple hedgerow hedge plots and 2857 trees/ha in the single hedgerow plots with 13,333 and 20,000 grass stands/ha, respectively. A unit plot measured 7.0 × 6.0 m (42 m^2) in the triple hedgerow plots and 7.0 × 4.0 m (28 m^2) in the single hedgerow plots.

The plots were kept weed-free during the establishment year by regular manual weeding. On 31 January, 1990 (mid-dry season), the trees and grass were cut back to 0.50 m and 0.15 m above ground level, respectively. Eighteen plots with uniform stands of trees and grass in the single and triple hedgerow areas, respectively, were selected. The tree cutting schemes thereafter commenced.

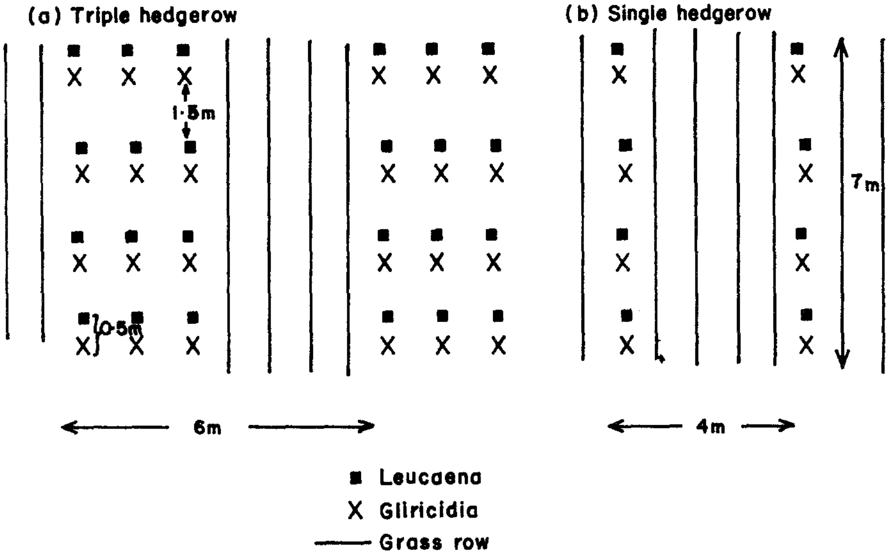

Fig. 1. Hedge configurations in the single and triple hedge plots and grass rows in the alleys.

Treatment factors

A. Hedge configuration (HC):

1. Single hedgerow.
2. Triple hedgerow.

B. Tree cutting schemes (TCS) (after a uniform cut in January, 1990):

1. Cut once in January, 1991 i.e. 12 month-regrowth (12M).
2. Cut twice: in April 1990 i.e. 3 month-regrowth and then 9 months later in January 1991 (3-9M).

3. Cut twice: in July 1990 i.e. 6 month-regrowth and then 6 months later in January 1991 (6-6M).
4. Cut twice: in October 1990 i.e. 9 month-regrowth and then 3 months later in January 1991 (9-3M).
5. Cut thrice: every 3 months in April 1990 and July 1990 and then 6 months later in January 1991 (3-3-6M).
6. Cut four times: every 3 months in April, July, October 1990 and January 1991 (3-3-3-3M).

C. Grass row position (RC):

1. Inner rows.
2. Outer rows (adjacent to the hedgerows).

Grass in all the plots were cut every six weeks between April and October followed by a cut in January, 1991.

At each harvest, the fresh cut herbage of the trees and grass in the inner (adjacent to the hedgerows) and outer rows in each plot were weighed separately. Sub-samples of about 1.0 kg of the tree cuttings were taken and separated into foliage and stem fractions and weighed separately. One bulk grass sample (combined across the rows) was also taken per plot. All the samples were dried in the oven at 70 °C to constant weight for determination of dry matter (DM) content. Dried samples were milled for the determination of nitrogen (N) content by the Kjeldahl method [AOAC, 1980]. Crude protein (CP) was estimated as N × 6.25%. All cut materials were removed from the plots.

Data was analysed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) [SAS, 1986] as a split-split plot with hedge configuration as the main plot, tree cutting scheme as the subplot and grass row position as the sub-subplot. There were three replications. Treatment means were separated by Least Significant Difference (LSD) or Duncan's multiple range test at 5% level of significance.

Results

Grass yields

The trends in grass DM yields under the different tree cutting schemes are presented in Fig. 2. The highest grass yields in all the plots were obtained in June. Grass yields in all the plots declined sharply thereafter and remained low through the dry season. However, the associated grass yields in the 3-3-6M and 3-3-3-3M tree cutting schemes were significantly higher than in the other schemes after the April harvest. There were no significant differences in the yields of grass under al the tree cutting schemes in April and in the dry season i.e. January, 1991 harvest.

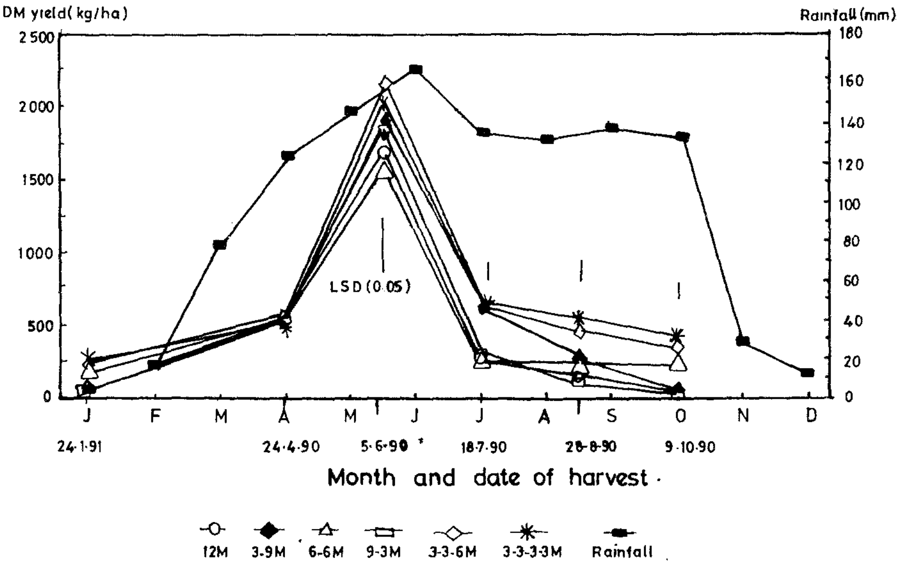

Fig. 2. Seasonal distributions of grass dry matter yields and rainfall.

The effects of the tree cutting schemes and grass row positions in the alleys on grass DM yields are presented in Table 1. During the rainy season, the relative differences in DM yields of the inner and outer rows varied among harvests and TCS. There were no significant differences between the total rainy season DM yields of grass in the inner and outer rows in the 3-3-3-3M, 3-3-6M and 3-9M treatments. However, in the other treatments *viz.* 12M, 6-6M, and 9-3M, total grass yields of the inner rows were significantly higher than those of the outer rows. In the dry season harvest, grass in the inner and outer rows under the 3-3-6M and 3-3-3-3M produced significantly higher DM yields than in the other treatments.

In the rainy season, significantly higher grass DM yield was produced under the single hedgerow arrangement than under the triple hedgerow one, but there was no significant difference between the the grass DM yields of the two arrangements in the dry season (Table 2). Total (rainy and dry season combined) grass DM yield under the single hedgerow arrangement was about twice that under the triple hedgerow arrangement. Total grass yields (inner and outer grass rows combined) of 3-3-3-3M and 3-6-6M treatments were also significantly higher than those of the other treatments at the respective rows (Table 2).

Tree foliage yields

The foliage DM yields of the trees under different cutting schemes are presented in Fig. 3. The foliage DM yields significantly increased as the

Table 1. Effects of tree cutting scheme and grass row position in the alleys on grass dry matter yields in the rainy and dry seasons.

Tree cutting scheme	Harvest date			
	Rainy season 1990		Dry season	
	Row position			
	Inner	Outer	Inner	Outer
	kg/ha			
12M	1432	1218	14	8
3-9M	1674	1772	60	2
6-6M	1665	1268	112	62
9-3M	1558	1375	31	23
3-3-6M	2061	2093	150	92
3-3-3-3M	1976	2154	150	130
LSD (0.05)	529	533	80	33

Table 2. Total forage (grass + tree foliage) dry matter yields and the contributions of grass and tree foliage in the rainy and dry seasons as affected by hedge configuration and tree cutting scheme.

Treatment	Season					
	Rainy grass	Forage	Dry grass	Forage	Total grass	Forage
	t/ha					
Hedge configuration (HC)						
Single	3.93	4.94 (20)[a]	0.13	0.67 (81)	4.06	5.61 (28)
Triple	2.82	3.86 (27)	0.14	0.79 (83)	2.96	4.65 (36)
LSD (0.05)	0.43	0.75	ns	ns	0.48	0.30
Tree cutting scheme (TCS)						
12M	2.65	2.65 (0)	0.02	0.47 (96)	2.67	3.12 (15)
3-9M	3.45	3.64 (5)	0.06	0.82 (92)	3.51	4.56 (20)
6-6M	2.93	3.86 (24)	0.17	0.96 (82)	3.10	4.82 (36)
9-3M	2.93	5.20 (44)	0.05	0.60 (91)	2.98	5.80 (48)
3-3-6M	4.15	5.01 (16)	0.24	0.76 (68)	4.39	5.77 (24)
3-3-3-3M	4.13	5.76 (28)	0.28	0.78 (64)	4.41	6.54 (33)
LSD (0.05)	0.74	0.93	0.10	ns	0.74	0.96

[a] Values in parenthesis are the proportions (%) of tree foliage in the forage yields.

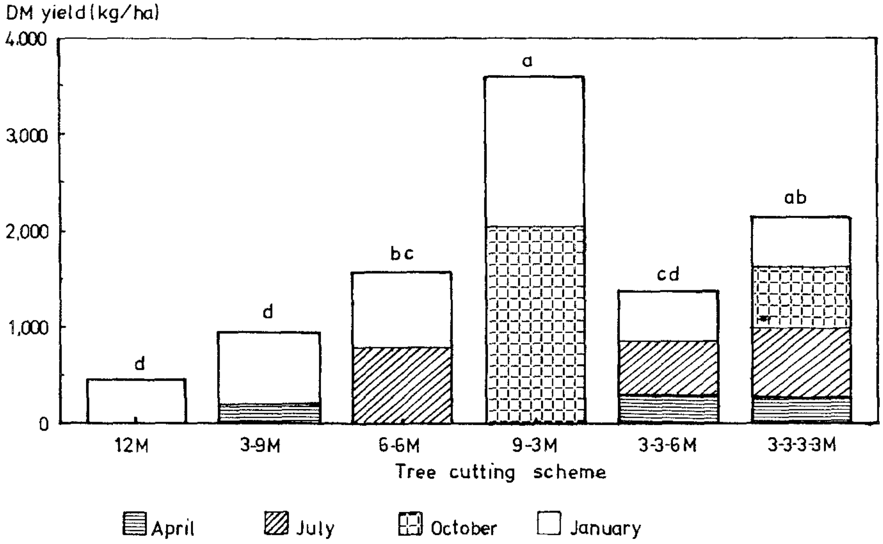

Fig. 3. Tree foliage dry matter yields under different tree cutting shcemes, bars with different letters are significantly different at 5% level of significance.

intervals between harvests increased from three to nine months as indicated by the foliage DM yields of 3-9M in April, 6-6M in July, and 9-3M in October. There was, however, a drastic decline in the foliage DM yield of the trees as the interval increased to 12 months (12M). The highest total foliage DM yield was obtained under the 9-3M, but this was not significantly higher than the yield under the 3-3-3-3M scheme. The total foliage DM yield of the trees under triple hedgerow arrangement (1.90 t DM ha^{-1} $year^{-1}$) was 16% higher than under the single hedgerow arrangement (1.64 t DM ha^{-1} $year^{-1}$), but the difference was not significant. The contributions of the tree foliage to forage DM yield were greatest in the dry season under all the tree cutting regimes (Table 2).

Tree stem yields

The stem DM yields of the trees are presented in Fig. 4. The stem DM yields of the trees increased as the intervals between harvests increased from three months in April (3-9M) to 12 months in January (12M). There were no significant differences between the total stem DM yields of trees under 12M and 9-3M schemes. The trees under 3-3-6M and 3-3-3-3M schemes produced the lowest stem DM yields. More frequent cutting or maintaining the same or not widely dissimilar cutting intervals resulted in less variable yields among harvests under the different cutting regimes.

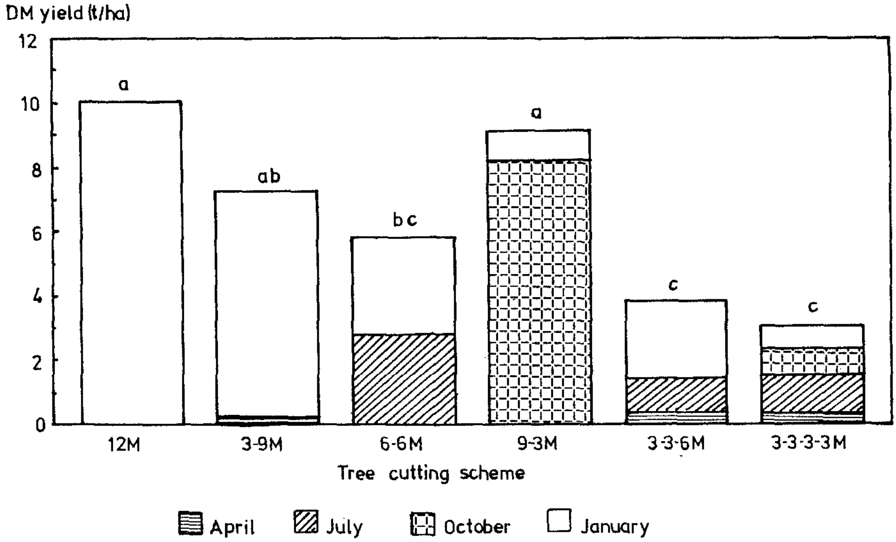

Fig. 4 Tree stem dry matter yields under different tree cutting schemes, bars with different letters are significantly different at 5% level of significance.

Tree biomass yields

The tree biomass (foliage + stem) at the different times of harvests under the different tree cutting schemes are shown in Fig. 5. The highest tree biomass in the dry season was produced by the trees under 12M and 3-9M schemes and the least under 3-3-6M and 3-3-3-3M. The total biomass yields of the trees under 6-6M and 3-3-6M schemes were intermediate. The same trends were obtained with total (rainy and dry seasons combined) yields.

Forage and crude protein production

The forage (grass + tree foliage) DM yields as affected by hedge configuration and tree cutting scheme are presented in Table 2. In the rainy season, forage production under the single hedgerow arrangement was 28% higher than under triple hedgerow arrangement. The highest forage yields were obtained in the 3-3-3-3M, 3-3-6M and 9-3M tree cutting regimes. The lowest forage production in the rainy season was produced by the 12M treatment. There were no significant effects of hedge configuration and tree cutting scheme on forage production in the dry season. The 3-3-3-3M tree cutting scheme produced the highest total forage yield followed by the yields under 9-3M and 3-6-6M regimes. The lowest total forage yield of 3.12 t DM ha^{-1} $year^{-1}$ was produced under the 12M tree cutting scheme.

There were negligible variations in the crude protein contents of the grass

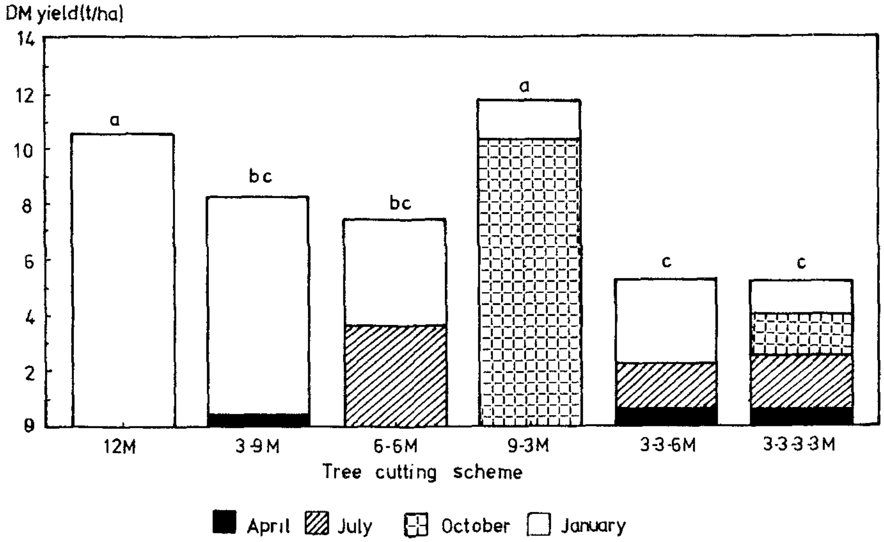

Fig. 5. Total biomass (foliage + stem) of trees under different tree cutting schemes, bars with different letters are significantly different at 5% level of significance.

and the tree foliage from harvest to harvest. The CP content of the tree foliage was, however, higher than that of the grass, i.e. 21.1%, 22.6% and 7.9% for gliricidia, leucaena and Guinea grass, respectively, when averaged over harvests. The crude protein yields and the contributions of tree foliage to total crude protein yields under the different hedge configuration and tree cutting schemes followed the same trends as the DM yields of the trees and grass.

Discussion

The seasonal trends in grass DM production under the different tree cutting regimes closely followed the rainfall pattern. Grass production invariably declines with the advancement of the dry season due to reduction in or lack of moisture and the accompanying reduction in uptake of nutrients from the soil. Thus, the highest grass yields in all the treatments were produced in June/July which coincided with the period of highest rainfall in the year. The sharp decline in the DM yields of grass after July may reflect decline in the reserve carbohydrate required for regrowth brought about by frequent harvests, and increased competition for moisture and soil nutrients from the associated trees which were cut less frequently.

The increases in the foliage and stem DM yields of the trees as the interval between harvests increased from three to nine months confirms the findings in other studies [Duguma et al., 1988; Guevarra et al., 1978; Krishnamurthy et al., 1986]. Under extended harvests, trees accumulate adequate carbohydrate reserves to support more foliage regrowth. Consequently, the adverse effects of the trees on the adjacent grass rows as a result of shading increased with the age of regrowth. Hence, the lowest grass yields in the dry season were produced under the tree cutting regimes which allowed up to nine months of tree regrowth during the year. The increased foliage biomass on the trees and consequently a larger area for transpiration might also have led to increased depletion in the soil moisture reserve as observed by Kennard and Walker [1973] in tree-grass associations.

The significant decline in foliage DM yields when a harvest was taken in the dry season after 12 month-regrowth was due to extensive leaf shedding of the trees. Unpruned gliricidia trees normally shed their leaves and commence flowering during the dry season [Adejumo, 1992; Atta-Krah and Sumberg, 1988]. The present results are similar to those reported by Atta-Krah [1990] and ILCA [1989] applying similar cutting regimes on hedgerows of leucaena and gliricidia in a followed alley farm. Extensive leaf shedding has also been reported in leucaena trees over extended cutting intervals [Cooksley and Goward, 1988; Guevarra et al., 1978]. The increased biomass of the trees with extended interval between harvests was largely due to the increase in the proportion of stem as has been observed by Guevarra et al. [1978]. Although growth is less affected by season among trees than in herbaceous species [National Academy of Sciences, 1980], more stem growth occurred in the rainy season.

More uniform distribution of grass yields was obtained under the 3-3-6M and 3-3-3-3M tree cutting schemes in which there was more frequent and regular cutting of the trees. Relatively frequent cutting of hedgerows permits better insolation in the alleys [Lawson and Kang, 1990], thereby facilitating photosynthetic activity and biomass accumulation. The lower grass yields of the 9-3M and 6-6M schemes as compared to the 3-9M scheme also indicate that early tree harvest during the rainy season facilitates high grass biomass production. The trees under 6-6M and 9-3M regimes had established larger shading canopies during the rainy season and by the time they were first cut. Therefore, cutting management which avoids shading of the grass during the rainy season or during the period of maximum growth may not adversely affect grass DM yield. Shading is in fact the most important pathway of interference of tree with associated herbaceous species where water is not limiting [Lawson and Kang, 1990]. The superior grass yields in the dry season of 3-3-6M over the 3-3-3-3M regimes suggest that the positive effect of frequent tree harvests in the rainy season is also reflected in higher grass yields in the dry season.

The higher grass yields obtained from the single hedgerow configuration is probably due to the greater number of associated grass stands than in the triple hedgerow configuration. However, the magnitude of the difference in the foliage yields of the trees under the two arrangements did not reflect the theoretical differences in the density of the trees in the respective arrangements which was supposed to be twice as much in the triple than in the single hedgerow arrangement. This was due to wide variations in the number of trees per plot in both hedgerow arrangements due to missing tree stands. The trees also differed widely in terms of the size and diameter of stumps. Therefore, the benefits of doubling the proportion of trees in the mixtures with the triple hedgerow arrangement in terms of total forage production failed to compensate for the 33% reduction in the proportion of associated grass compared with the single hedgerow arrangement.

The tree foliage made greater contributions to total forage and crude protein production in the dry season than in the rainy season, confirming the importance of trees for dry season forage production. The ability of leguminous trees to maintain their crude protein contents at higher levels than in grasses also make them particularly useful as supplements during the dry season.

The tree management regime that will be adopted will depend on several factors such as the needs of the farmer for fuelwood, evenly distributed high quality forage for supplementation throughout the year, maximizing forage yields in the dry season, and availability of labour for tree harvests. With its high yield of stem, the 9-3M tree cutting scheme will be more appropriate where firewood and accumulation of feed for use in the dry season are desired; leucaena and gliricidia have good fuelwood qualities [National Academy of Science, 1980]. Even though grass in the wet season may contain more crude protein than the 7% minimum, below which forage intake is depressed [Minson, 1983], crude protein requirements of ruminants for moderate levels of production are met at higher levels of 11-12% [Agricultural Research Council, 1980] due to inefficient utilization on N in grass [Van Eys et al., 1986]. Supplementation of grass diets with legume foliage may, therefore, be required even in the wet season. High animal productivity has indeed been reported with year-round supplementation [Van Eys et al., 1986].

It is concluded that the 3-3-3-3M and 3-3-6M tree cutting schemes strike the best balance between grass and tree foliage yields and produce high forage yields. The 9-3M scheme is equally productive in terms of forage yields. Any of these cutting schemes could therefore be adopted. However, the relatively frequent cutting with the 3-3-6M and 3-3-3-3M schemes would involve greater labour for cutting.

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