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Forage productivity of *Gliricidia* accessions on a tropical alfisol soil in Nigeria

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Abstract

The forage production of 28 accessions of *Gliricidia sepium* was assessed over four seasons: early and late dry season, and early and late rainy season on a tropical alfisol soil at Ibadan in Nigeria. The evaluation was over a period of 24 months after establishment. Five *Gliricidia* accessions of differing provenance produced the highest biomass. These consistently produced 4–5 t/ha/yr of leaf dry matter over the period of evaluation. During the early dry season, 8 *Gliricidia* accessions exhibited the greatest leaf growth rate (over 5 kg/ha/d). Three of the *Gliricidia* accessions have potential for greater forage production in both high and low rainfall environments.

Resumen

Se avaluó la producción forrajera de 28 accesiones de Gliricidia sepium *en un suelo tropical alfisol en Ibadan, Nigeria, durante cuatro períodos: al inicio y al final de la estación seca y de la estación lluviosa. La evaluación tuvo una duración de 24 meses después de la siembra. Cinco de las accesiones de orígenes diferentes produjeron las mayores biomasas. Estas accesiones produjeron consistentemente 4-5 t/ha/a de materia seca de hoja durante el período de evaluación. Ocho de las accesiones de tuvieron las mayores tasas de crecimiento de hoja durante el inicio de la estación seca (arriba a 5 kg/ha/d). Tres de las accesiones de* Gliricidia *tiene un gran potencial para la producción de forraje en medios ambientes ya sea con bajas o altas precipitaciones pluviales.*

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Introduction

The International Livestock Centre for Africa (ILCA), Humid Zone Programme in Nigeria, has worked since 1982 with the nitrogen-fixing, multipurpose trees *Leucaena leucocephala* and *Gliricidia sepium* for forage production. The two species are trees with deep root systems and can play an important role in alleviating the seasonal shortage of feed for ruminant livestock. Forage may be cut for stall-feeding or the trees, grown in association with grass, may be grazed.

Gliricidia sepium is a fast-growing, medium-sized tree with a high crude protein concentration (20%–25%) in the leaves. The foliage is palatable and has been shown to increase animal productivity when fed to ruminant livestock (Chadhokar and Kantharaju 1980; Chadhokar and Lecamwasam 1982). *Gliricidia* has no toxic factor to ruminants and can be fed *ad libitum* without any risk. Moreover, *Gliricidia* is not attacked by psyllid (*Heteropsylla cubana*), the insect pest that has caused great havoc to *Leucaena* in Latin America, the Pacific and Southeast Asia as reported by Brewbaker (1987). *Gliricidia*, unlike *Leucaena*, has not been the subject of any studies aimed at exploring the genetic variability with the view to developing cultivars for specific environment and management situations.

In 1983 ILCA organised a collection of *Gliricidia* germplasm seeds from Costa Rica, where the genus originated, in collaboration with Centro Agronomico Tropical de Investigation Y Ensenanza (CATIE). In all, a total of 49 accessions of differing provenance were collected and subsequently evaluated by Sumberg (1985). Four lines which had outperformed the local variety by 30% in that study were later crossed to produce a single composite line identified as HYB by Atta-Krah (1987). Subsequent germplasm collection expeditions were made by staff of the Oxford Forestry Institute (OFI) in 1984, 1985, and 1986 (Hughes 1987). Eleven accessions, released by OFI following the 1984 seed collection, were also evaluated in a separate trial which has been reported by Atta-Krah (1987). In that study, accessions 55, 58, and the composite HYB were the most productive in terms of forage yield.

The greatest potential of *Gliricidia* in a crop-livestock system will be as a supplementary legume fodder for ruminant livestock where the quantity and quality of grass is low. Because of its apparently deep root system when raised from seeds, *Gliricidia* can be expected to produce sufficient forage, even under drought conditions, when grass growth would be limited. Consequently, any study designed to screen germplasm material should assess as well their forage productivity during the dry season. Although previous studies by Sumberg (1985) and Atta-Krah (1987) assessed forage production under repeated cuttings, they did not measure the yield at the peak of the dry season. The study reported herein, therefore, evaluated the effect of frequent pruning management on leaf and wood dry matter production of the complete provenance collection over the four seasons typical of the humid tropics, viz., early dry season, late dry season, early rainy season and late rainy season.

Materials and methods

The study site was on the main campus of the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria (7° 30′N; 3° 54′E). The elevation is about 240 m. The soil at the experimental site was sandy loam and has been classified as anoxic paleustalf (Moormann *et al.* 1975). The chemical properties of the surface soil (0–15 cm) have been analysed and showed: pH (1:1, soil:water), 6.2; organic C, 0.91%; total N, 0.09%; Bray No. 1 extractable P, 7.5 mg/kg; exchangeable Ca, 151 mg/kg; Mg, 16 mg/kg; K, 51 mg/kg.

Rainfall and mean temperatures for 1987, 1988, and 1989 at the experimental site are presented in Figure 1. The patterns of rainfall distribution show some variation from the 16-year average and from year to year. The period August to October 1987 was very wet and resulted in rapid growth of the transplanted seedlings. In 1988 very much higher than expected rainfall was received in April and June while August was drier than normal. The temperature profile in 1987 and 1989 was similar to the 16-year average, but that of 1988 showed wide fluctuation.

The 28 *Gliricidia* accessions and two species controls, *Leucaena leucocephala* cv. Cunningham and *Guazuma ulmifolia* (presented in Table 1) were laid out in the field as randomised complete block design with 3 replicates. The unit plot was one row 5 m long. Container-grown seedlings, 8 weeks old, were transplanted at one plant per hill, spaced 0.5 m apart within rows, with rows 4.0 m apart, on May 9, 1987. In the establishment year, the tree seedlings were interplanted with maize during the main cropping season (May to August). No fertiliser was applied either to the maize or to the tree seedlings.

At 9 months after transplanting, the trees were cut back to 0.5 m above ground level and the primary dry matter (DM) yield was estimated from a sample. After the primary harvest, the coppice regrowth was also cut back to a height of 0.5 m every 3 months (see Figure 1) over a

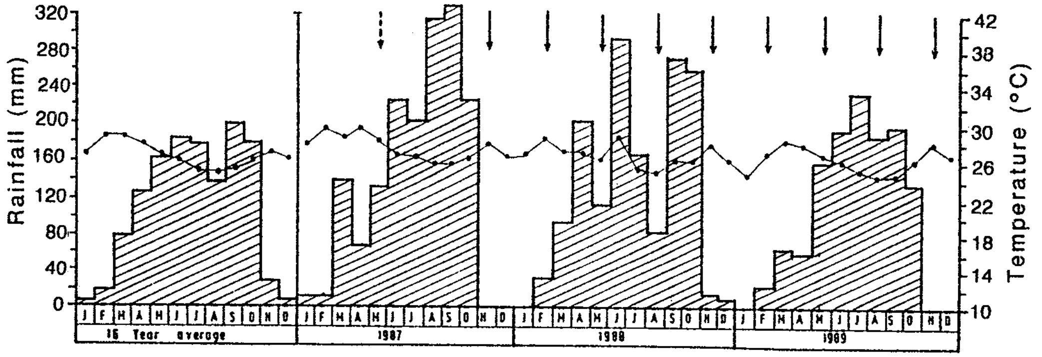

Figure 1. Climatic data for the experimental site from January 1987 to December 1989 with a 16-year average for comparison: rainfall (bars) and temperature (continuous lines). The arrows indicate pruning dates; dotted line arrow indicates date of planting.

Table 1. *Gliricidia* accessions used and some information about the collection site.[1]

Provenance	ILCA No.	OFI No.	Geographical origin		Climate
			Country	Altitude	Rainfall
				(m)	(mm)
Gliricidia sepium					
Oyo State	50	—	Nigeria	160	1500
Volcan Suchitan, Jutiapa	54	13/84	Guatemala	950	1060
Samala, Retalhuleu	55	14/84	Guatemala	330	3500
Gualan Zacapa	56	15/84	Guatemala	150	700
Vada Hondo, Chiquimula	57	16/84	Guatemala	450	830
Monterrica, Santa Rosa	58	17/84	Guatemala	5	1650
Guayabillas, Choluteca	59	24/84	Honduras	480	1400
Masaguara, Intibuca	60	25/84	Honduras	825	1100
Oju de Aqua, Boaco	61	29/84	Nicaragua	220	1200
Piedra Larga, Esteli	62	30/84	Nicaragua	605	800
Mateare, Managua	63	31/84	Nicaragua	60	1100
Los Amates, Puebla	64	33/85	Mexico	1100	650
Palmasola, Veracruz	65	34/85	Mexico	10–50	1130
San Mateo, Oaxaca	66	35/85	Mexico	10–30	950
Barosa, Veracruz	67	36/85	Mexico	100–150	1500
Tzimol, Chiapas	68	37/85	Mexico	600–700	1030
Playa Azul, Michoacan	69	38/85	Mexico	0–30	900
San Jose, Guerrero	70	39/85	Mexico	30	1400
Arriaga, Chiapas	71	40/85	Mexico	30	1796
Chamela, Jalisco	72	41/85	Mexico	60–100	905
Mariara, Carabobo	73	1/86	Venezuela	520	800
La Garita, Choluteca	74	10/86	Honduras	450	1200
El Roblar, Guanacaste	75	11/86	Costa Rica	20–100	1000
Playa Tamarindo, Guanacaste	76	12/86	Costa Rica	20–100	1000
Pedasi, Los Santos	77	13/86	Panama	5–10	850
Belen, Rivas	78	14/86	Nicaragua	75	1650
Pontezuelo, Bolivar	79	24/86	Colombia	20–50	950
Gliricidia sepium	HYB[2]	—	Costa Rica	160	—
Leucaena leucocephala	LUC	—	—	—	—
Guazuma ulmifolia	GUZ	—	—	—	—

[1] Source: Table was adapted from Hughes (1987).
[2] This is a composite of four Costa Rican accessions evaluated earlier by Sumberg (1985).

period of 24 months. A total of 8 coppice regrowth harvests were done. At each harvest time, subsamples of coppice regrowth were separated into leaf (including tips of stems) and wood, and weighed after being dried at 70 °C for 72 h. Dried subsamples were ground and analysed for nutrient concentrations by procedures described by Juo (1979).

Results

Primary growth

At 9 months after transplanting, the mean height was 225 cm (Table 2). The tallest *Gliricidia* accession (No. 55) was about 20% taller than the local variety (No. 50), and 60% taller than *Leucaena*.

The total DM produced at 9 months after transplanting varied among the different accessions. The accession (No. 55) which produced the highest total DM was three times more productive than the local variety (No. 50) and also six times more productive than *Leucaena*. In fact, the least DM was produced by *Leucaena* which was slow to establish. Generally, the leaf DM on *Gliricidia* accessions at 9 months after planting was relatively smaller than the 3 months coppice regrowth. On average, the leaf DM constituted only 12% of total DM at this early stage of growth, an indication that substantial leaf shedding had already taken place by the time of harvest.

Coppice leaf and wood dry matter

The total leaf and wood DM for 4 prunings taken in each of 2 years are presented in Table 3. As will be shown later, the individual harvests were variable, being mainly a reflection of the effects of the seasons of the year. In the first year following establishment, leaf DM yield for the *Gliricidia*

Table 2. Growth parameters of *Gliricidia* accessions, Leucaena (LUC) and Guazuma (GUZ) at 9 months after transplanting.

ILCA No.	DM yield		Stem height	Stem girth
	Total	Leaf		
	(t/ha)		(cm)	
55[1]	3.23	0.55	281.0	2.76
78	2.24	0.19	250.6	3.46
HYB	2.19	0.28	266.6	3.70
54	2.09	0.20	263.6	3.50
59	1.82	0.17	250.3	3.23
79	1.68	0.15	253.6	3.36
74	1.67	0.15	260.3	3.26
57	1.65	0.14	251.0	3.23
71	1.53	0.07	233.6	3.60
73	1.47	0.27	226.3	3.13
58	1.44	0.22	198.0	3.10
69	1.41	0.05	253.0	3.00
60	1.38	0.21	242.0	3.06
62	1.37	0.18	226.6	2.96
75	1.35	0.32	231.6	2.96
70	1.33	0.10	216.6	2.90
67	1.27	0.23	206.3	2.96
76	1.23	0.20	196.3	3.03
68	1.20	0.17	204.3	2.90
61	1.14	0.12	210.6	2.86
50	1.12	0.13	223.0	3.13
56	1.10	0.11	225.0	3.00
64	0.98	0.08	195.3	2.83
66	0.97	0.12	208.0	2.83
65	0.90	0.04	183.3	2.90
63	0.82	0.11	219.3	2.83
GUZ	0.82	0.11	178.3	2.43
77	0.77	0.05	211.6	3.13
72	0.77	0.04	226.6	2.63
LUC	0.54	0.25	166.6	2.00
LSD (0.05)	0.44	0.12	34.2	0.38
CV (%)	19.60	44.91	9.3	7.78

[1] Accessions were ranked in order of total DM yield.

Table 3. Total leaf and stem dry matter of the coppice regrowth *Gliricidia* accessions, Leucaena (LUC) and Guazuma (GUZ).

ILCA No.	Leaf		Stem	
	1988	1989	1988	1989
	(t/ha)			
55[1]	6.62	5.47	6.07	4.89
58	5.92	4.50	4.26	3.07
HYB	5.70	4.00	6.06	3.72
LUC	5.62	5.69	7.18	8.03
57	5.56	4.09	4.49	3.26
67	5.43	3.85	4.30	2.89
59	5.36	4.40	4.72	3.55
60	5.34	3.77	3.76	2.71
78	5.18	3.76	4.92	3.06
75	5.13	3.40	3.39	2.40
50	4.98	3.86	5.24	3.74
54	4.88	3.72	4.72	3.60
79	4.87	4.14	5.00	3.59
56	4.86	3.80	3.55	3.27
69	4.85	3.76	4.33	3.50
76	4.83	3.56	3.81	2.43
70	4.69	3.95	3.72	3.48
64	4.67	3.54	4.70	3.20
66	4.67	3.21	3.65	2.24
74	4.58	2.52	3.33	2.28
61	4.53	3.56	3.62	2.80
62	4.39	3.69	3.53	2.65
71	4.32	3.00	3.62	2.46
63	4.30	3.44	3.99	2.83
68	4.25	3.48	3.43	2.53
73	4.17	3.29	4.62	3.69
65	3.83	3.08	3.16	2.47
77	3.77	2.83	3.27	1.85
GUZ	3.76	4.13	4.24	4.38
72	2.90	2.68	2.60	2.22
LSD (0.05)	0.66	0.75	0.52	0.84
CV (%)	8.41	12.38	7.45	15.96

[1] Accessions were ranked in order of 1988 leaf dry matter.

accessions ranged from 2.9 to 6.6 t/ha. In contrast, in the second year after establishment year, the leaf DM yields of *Gliricidia* accessions dropped by 17–45% (average 24%) to a range of 2.5 to 5.5 t/ha. *Leucaena* maintained a constant leaf DM yield whilst *Guazuma* showed about 10% increase in leaf DM yield over the 2-year period. The top 5 *Gliricidia* accessions were 55, 57, 58, 59, and HYB. These maintained high leaf DM yields of 4–5 t/ha during the 2 years after establishment. The highest leaf DM yield of 6.6 t/ha in the first year, and 5.5 t/ha in the second year after establishment was produced by the *Gliricidia* accession No. 55. This accession yielded 40% more than the local variety, No. 50.

Wood DM for the *Gliricidia* accessions ranged from 2.6 to 6.0 t/ha in the year following the year of establishment and dropped, on average by 28%, to a range of 2.2 to 4.9 t/ha in the second year. In general, wood DM yield of the *Gliricidia* accessions was lower than the leaf DM; the average leaf to wood ratio was 1:1.2. *Leucaena* produced the greatest amount of wood in the 2 years of assessment. The leaf to wood ratio of *Leucaena*, unlike that of *Gliricidia*, was low being on the average about 1:0.7.

Coppice shoot growth

The coppice shoot heights of the different accessions varied according to the season of the year (data not presented). During the periods February–May, May–August, and August–November of the first year following the year of establishment, the coppice shoots were 150 cm or more in height. In contrast, during November–

February only the accession HYB, 50, 55, 57, 62, 67, 73, 78, and 79 reached a height of 100 cm or more. This result underlines the adverse effects that the drier period, covering November-February at the experimental site, has on the growth of the *Gliricidia* accessions.

A correlation analysis (not shown graphically) revealed a significant ($P < 0.01$) positive correlation ($R^2 = 0.59$) between height and leaf DM of the *Gliricidia* accessions. This result indicates that, within the physiological maturity age bracket, as *Gliricidia* grew taller their leaf DM yields increased. However, the *Gliricidia* accession No. 58 deviated from this generality. No. 58 has a small stature and yet it is highly productive in leaf DM. The high leaf productivity is due possibly to the profuse branching characteristics (data not presented) starting near the soil surface level. In fact, *Gliricidia* accession No. 58 has the growth form of a true shrub.

Effect of season on leaf growth rate

The leaf growth rates of all the accessions calculated from the leaf DM over the early (Nov–Feb) and late (Feb–May) dry season, and early (May–Aug), and late (Aug–Nov) rainy season for the year after establishment are shown in Table 4. On average, leaf growth rate was lowest (4.5 kg/ha/d) during early dry season, increased to 16.3 kg/ha/d in late dry season, and declined to 14.2 kg/ha/d in early rainy season, and still downward to 12.2 kg/ha/d in late rainy season. It was only *Leucaena* that showed a consistent increase in leaf growth rate from a low rate of 9.5 kg/ha/d during the early dry season to a high rate of 22.0 kg/ha/d during late rainy season. Those *Gliricidia* accessions which showed the greatest leaf growth rate (5 kg/ha/d or more) during early dry season were 50, 55, 58, 63, 67, 78, 79, and HYB. *Gliricidia* accessions which performed exceptionally well during early dry season originated from regions with annual rainfall greater than 1000 mm (Table 1). The accession No. 55 had a growth rate comparable to that of *Leucaena* (8.4 *vs*. 9.5 kg/ha/d) during early dry season. The *Gliricidia* accession 55, 58, and HYB were among the top five in leaf production reported in an earlier paragraph.

During the late dry season, all *Gliricidia* accessions grew three to four times faster than in early dry season. In fact, for most *Gliricidia* accessions,

Table 4. Coppice leaf growth rate of *Gliricidia* accessions, Leucaena (LUC) and Guazuma (GUZ) in 4 different seasons of the year.

ILCA No.	Early dry season (Nov–Feb)	Late dry season (Feb–May)	Early rainy season (May–Aug)	Late rainy season (Aug–Nov)
	(kg/ha/d)			
54	4.2	16.5	15.0	11.8
55	8.4	26.8	16.4	15.9
56	4.4	19.3	13.5	11.1
57	4.3	21.2	14.9	13.5
58	5.5	21.1	17.7	13.8
59	4.6	18.4	16.7	14.3
60	4.1	21.1	13.6	12.2
61	4.5	15.6	12.8	11.5
62	4.6	17.3	12.5	10.5
63	5.1	14.4	12.4	11.0
64	4.3	15.1	15.1	10.8
65	3.0	13.5	11.9	10.8
66	4.4	13.9	15.1	10.3
67	5.6	16.4	15.0	12.6
68	4.2	15.8	12.8	11.0
69	3.5	17.7	14.0	12.2
70	3.8	15.9	16.2	11.7
71	3.0	14.8	13.3	9.7
72	1.8	10.7	11.4	7.8
73	3.7	17.1	10.5	10.1
74	3.8	11.1	12.8	11.6
75	4.2	15.1	15.5	12.4
76	3.3	15.7	15.6	11.8
77	2.1	10.7	11.8	10.0
78	4.9	18.4	14.6	11.9
79	4.9	15.8	15.8	13.1
50	5.3	16.5	14.4	13.1
GUZ	4.6	12.8	12.9	13.1
HYB	5.5	17.4	15.8	14.8
LUC	9.5	13.4	17.1	22.0
Mean	4.5	16.3	14.2	12.2
LSD (0.05)	for comparison of provenance means			1.8
	season means for same provenance			1.5
	provenance means in same or different season			3.5

the late dry season leaf growth rate was higher than that for early or late rainy season. It is not clear from the experimental data what factor could have contributed to the great surge of biomass production just at the tail-end of the dry season. It is most likely, however, that carbohydrate, accumulated in the root and stump during the dry season when relatively little leaf growth occurred, was mobilised immediately when there was rain that enhanced the growth of leaf.

Nutrient concentration in leaves

The N and K concentrations in the leaves of the *Gliricidia* accessions (3.9% N; 1.8% K) are comparable to that of *Leucaena* (4.1% N; 1.7% K). However, the concentrations of P, Ca, and Mg in *Leucaena* (0.18% P; 0.9% Ca; 0.28% Mg) are lower than the average concentration in the *Gliricidia* accessions (0.20% P; 1.5% Ca; 0.35% Mg). Those *Gliricidia* accessions which emerged as the top five in leaf DM yields also had relatively high concentrations of the nutrients N, P, K, Ca, and Mg (data not presented).

Discussion

The rapid growth rate exhibited by *Gliricidia* accession No. 55 in the establishment year was sustained in the following years with high leaf DM production, thus confirming the outstanding performance of accession No. 55 as a fodder crop, as had been reported by Atta-Krah (1987). The results of the study by Atta-Krah (1987) corroborate earlier evidence in the current study that, despite its relatively slow initial growth rate, *Leucaena* has the potential for rapid growth.

The high leaf DM production by the *Gliricidia* accessions 55, 58, 63, 67, 78, 79, and HYB during early dry season (Nov–Feb) suggests that these accessions could produce a reasonably high yield even in drier environments. Although rainfall data from the collection sites indicate high annual precipitation, the much disturbed and freely drained stony soils (Hughes 1987) will cause rapid loss of soil moisture in the rooting zone particularly during the dry season. It is likely that the accessions developed, over the years, some adaptive mechanism such as an extensive root system which enables them to remain highly productive, even during periods of extremely low soil moisture.

The total leaf DM yield of 5.5–6.6 t/ha produced by *Gliricidia* accession No. 55 is high. Nevertheless, it agrees with values reported for *Gliricidia sepium* in an alley farming production system (Atta-Krah and Sumberg 1988) which was the same as the system used in this evaluation. The *Gliricidia* accessions 55, 58, and HYB which were among the top five in leaf DM production, were those reported by Atta-Krah (1987) to be highly productive. This confirms their consistent performance as fodder trees on the non-acid alfisol of southwestern Nigeria. Although there are no data available for comparison in this study, it is likely that stake-propagated *Gliricidia* plants would have yielded higher than those established as transplanted seedlings. In the study by Atta-Krah and Sumberg (1988), stake-established *Gliricidia* yielded higher than those established by direct seeding, especially for the initial harvest. In West Africa, farmers are encouraged to use seeds to establish *Gliricidia* hedgerows in alley farming practices because seeds are less bulky (Atta-Krah and Sumberg 1988).

Although there was a significant positive correlation between coppice shoot height and leaf DM, the correlation coefficient ($R^2 = 0.59$) was not very high. In this study, the coppice shoot height was taken as the vertical distance between the ground and the highest living part of the coppice shoot. Since the basal 0.5 m height was the stump, it is likely that the measured height underestimated the leaf DM yields. It is suggested that the actual length of the coppice shoot, measured as the distance from the cut end to the tip of the growing point, should be used in a situation where it is intended to predict leaf DM yield from coppice shoot height.

The Ca concentrations in the leaves of all the *Gliricidia* accessions are comparable to that of an unspecified variety in a study by Carew (1983). However, the Mg and K concentrations are very low and could be the result of low soil availability. The concentrations of P in some accessions are high relative to that reported by Carew (1983). The extractable P content of 7.5 mg/kg is low according to Olsen and Sommers (1984), and it may be expected that uptake will be correspondingly low. The high concentrations in some accessions may be related to a more efficient mechanism of uptake. The greater uptake of P from a source of low availability may be linked with the possible association of the genus with VA-mycorrhizae. It is reported by Kang and Mulongoy (1987) that *Gliricidia* roots can be heavily infected by VA-mycorrhiza fungi whose hyphae can extend the root absorption zone for P further into the soil body.

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