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Effect of tree canopy cover on grass species in Nigerian Guinea savanna

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The effect of tree canopy cover on the yield, crude protein (CP), and fibre content of grass species in the Nigerian Guinea savanna was studied. The following grass species, *Andropogon gayanus*, *Hyparrhenia involucrata*, *Hyparrhenia smithiana*, *Pennisetum polystachion*, *Rottboellia cochinchinensis*, and *Setaria barbata* occur more under tree canopies than in the open. The overall yield under tree canopy and in the open was influenced by the proportionate contribution of these species to the total yield. Grass yields were significantly higher under canopies provided by trees taller than 7 m than under shorter canopies. The difference between percentage CP, fibre, and lignin in plants growing under tree canopies and those in the open were not significant.

Keywords: Nigeria; Savanna; Grass yield; Tree canopy

Several researchers (Walker *et al.*, 1972; Afolayan and Fafunsho, 1978) have advocated the retention of trees and shrubs while managing savanna habitats for livestock and wildlife because of their beneficial effect. Other researchers (Edroma, 1979; Brinckman and de Leeuw, 1979) have suggested the removal of trees to improve rangeland utilization and increase fodder supplies. However, Barnes (1979) has noted that not all the changes in species composition with tree clearing are favourable. He therefore suggested that the most important consideration in relation to clearing of the woody components of savanna is clearly the possible changes in composition of the herbaceous layer. Similarly, Dye and Spear (1982) have stated that in assessing the desirability of clearing bush in semiarid savanna, it is important to have information on the likely long-term effects on grass yield and species composition.

Du Toit (1972) and Teague (1973) have reported that grass productivity was extremely low at high tree densities but recovered markedly when all trees were removed. The proportion of shade (De Leeuw, 1978) and woody cover (Rose Innes and Mansfield, 1976) have also been reported to be inversely related to grass yield in Nigerian savanna. However, Billé (1985), in a summary of comparative values for tree and grass production in Senegal, Upper Volta, and Ivory Coast (Cote D'Ivoire) rangelands, reported that grass production increased with an increase in the number of trees up to a given limit seemed to be independent of the climate. He explained the phenomenon on the beneficial influence of trees on the organic matter content and water budget in the soils carrying moderate tree densities. Sanford *et al.* (1982) reported that a light high tree canopy in Nigerian savanna produced greater dry matter yield of grasses than either full exposure or dense canopy and that some shading provided a microclimate where favoured species, e.g., *Andropogon,* replaced some others such as *Schizachyrium* and *Hyparrhenia*.

Several workers have evaluated the effect of tree canopies on grass production, but there is a dearth of information on the effect of tree canopies on the nutritive quality of grasses.

In West Africa, the Guinea zone offers the greatest possibilities for rangeland development. The Sudan zone is overpopulated and overgrazed, and the Sahel has low rainfall as its major constraint. The length of the rainy season in the Sahel does not exceed two to three months. The Guinea savanna is currently relatively underutilized; is sparsely populated; and could be developed as rangeland after the tsetsefly, the major constraint to livestock development in the zone, has been eliminated.

Trees are abundant in the Guinea savanna and therefore this study was undertaken to determine the effect of tree canopies on the yield and nutrient content of grass species in the Nigerian Guinea savanna zone.

Materials and Methods

Study area

The study was done in the Kainji Basin area of north-western Nigeria (between latitudes 10° and 13° N; longitudes 3°50′ and 5°50′ E). Three 1-ha sample plots designated 1, 2,

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and 3 located in minimally disturbed areas of northern Guinea savanna (Keay, 1959) were used for the study.

The climate, geology, and soil of the study area have been described by Usman (1981), Nnadi and Balasubramanian (1982), and Isichei and Muoghalu (1992).

Each 1-ha block was divided into four equal quadrants. In each quadrant, five permanent 25 m × 5 m belt transects were randomly laid out as sample plots. Tree density was estimated by complete enumeration within the belt transect of every tree greater than 1 m high. The girths of woody plants greater than 3 m high were measured at breast height (GBH) and at midpoint, if less than 3 m. The girth measurements were used to calculate the basal area (m^2 $tree^{-1}$) of each tree using the formula:

$$\text{Basal area} = \frac{C^2}{4\pi}$$

where C = girth size (circumference).

The basal area of each tree was summed for the trees in a belt transect sampled and expressed on a per hectare basis.

The height of each tree within the belt transects was measured with a Haga altimeter. Crown area was obtained from an average of two diameter (D) measurements of these, since these did not form perfect circles, using the formula:

$$\frac{\pi D^2}{4}$$

The data from belt transects (considered as sampling units) were used to estimate means and variances for each quadrant. Plot means and variances were estimated as for stratified sampling (Cochran, 1963).

Tree canopies were classified into three types based on height: canopy 1, trees under 3 m high; canopy 2, between 3 m and 7 m high; and canopy 3, trees above 7 m high. Tree measurements were carried out in July of each year of the study. The experiment was arranged as a randomised complete block design with three replicates.

Sampling grass species for yield estimation and chemical analysis

These parameters were estimated in July (early herbaceous growth period) and October (peak herbaceous growth period) in 1985 and 1986.

Grass species yield was estimated by clipping all grass species at ground level within a 50 cm × 50 cm quadrat placed systematically at every fifth metre point along a 25-m central line transect within the belt transects used in estimating the tree parameters in each quadrant. The presence or absence and type of canopy above the point of clipping was noted. The clipped material was sorted into species and oven-dried at 80°C to a constant weight, and weighed. The oven-dried weights were used to estimate yield in the plots. Oven-dried samples were ground in a laboratory mill through a 1-mm mesh screen and preserved for chemical analysis.

Grass cover was estimated both as aerial and basal cover. Aerial cover was taken in July and basal cover in October of each year of the study period. Percentage basal cover was estimated by dropping a pointed metal rod perpendicularly to the base of the grass and consistently on the same side at every metre point along the central line transect of the belt transects. Percentage cover was computed as the number of hits (i.e. the number of times the rod hits the base of the grass) divided by the number of sampling points times 100. The same procedure was followed for aerial cover but in this case the number of times the leaves of the grass touched the rod was recorded. Percentage aerial cover was estimated in a similar manner as basal cover. Cochran's (1963) method for semi-systematic stratified sampling was used to calculate plot means.

Chemical analyses

Crude protein was estimated by determining total nitrogen in the ground sample by the Kjeldahl method times 6.25. Fibre [acid-detergent fibre (ADF) and neutral-detergent fibre (NDF)] and acid-detergent lignin (ADL) contents of the samples were determined by the method of Goering and Van Soest (1970).

One-way analysis of variance was used to test for significant difference between data from the open and those under tree canopy.

Results

Vegetation characteristics of the plots

Table 1 shows the results of the vegetation characteristics of the plots. Aerial cover was more than 100%, which was mainly due to vertical packing of the leaves in layers.

Table 1 Some vegetation characteristics of the study plots in Guinea savanna zone of Nigeria

Vegetation characteristics	Mean ±95% confidence interval
Woody plant density (ha^{-1})	561±13
Woody plant basal area (m^2 ha^{-1})	10.8±0.2
Woody plant Crown area (m^2 ha^{-1})	5442.7±150.2
Woody plant height class (plants ha^{-1})	
<3 m	261±18
3–7 m	229±16
>7 m	70±9
Grass aerial cover (%)	176.4±14.8
Grass basal cover (%)	11.0±2.5

Percentage grass cover under tree canopy and in the open

Grass aerial cover under tree canopy in July was significantly lower ($P < 0.001$) than that in the open (Table 2). Basal cover under tree canopy cover was also significantly lower ($P < 0.05$) than that in the open. The basal cover under tree canopy in October was dominated by *Andropogon gayanus* [Botanical nomeclature is according to Hutchinson and Dalziel (1954–1972)], and *Rottboellia cochinchinensis*.

Tree canopy and grass yield

No significant difference was found between yield of individual grass species under tree canopy and in the open. However, the following grass species, *A. gayanus*, *Hyparrhenia involucrata*, *H. smithiana*, *Pennisetum polystachion*, *R. cochinchinensis*, and *Setaria barbata* occurred more often and generally produced higher DM under tree canopy than in the open (Table 3). Some species (Table 3) occurred and tended to perform better in the open than under tree canopy cover while others performed better under tree canopy cover than in the open at different stages of their growth (Table 3).

There was no significant difference between composite yield of all the species under tree canopy cover and in the open (Table 3). However, when composite grass yields under tree canopy cover and in the open in the three 1-ha plots were considered, the yields under the canopy were not consistently greater than in the open for the tree plots. The higher yields under canopy in some of the plots were associated with the dominance of grass species (Table 4).

Grass yield in relation to the three canopy classes

There was a significantly higher grass yield ($P < 0.001$) under tree canopy >7 m than that under the other two lower canopies in October (Table 5). The yields under the different canopy classes in July were not significantly different from one another.

Effect of tree canopy on CP, fibre, and lignin content

There was no significant difference between CP, NDF, ADF, and ADL content of grass species

Table 2 Mean percentage aerial and basal grass cover under tree canopy cover and in the open in Guinea savanna zone of Nigeria

Period	Canopy	Open
Aerial cover (July)	53.5±15.1	122.9±23.2
Basal cover (October)	4.1±3.3	6.8±3.6

The means are pooled data from three study plots ±SE (P = 0.05)

Table 3 Mean grass species yield as oven-dried weight (g m^{-2}) under tree canopy and in the open in Guinea savanna zone of Nigeria

	July		October	
Species	Canopy	Open	Canopy	Open
Andropogon gayanus	5.4±2.8	2.9±2.1	29.4±11.2	18.0±9.9
Andropogon schirensis	—	—	20.1±7.60	29.1±10.5
Brachiaria lata	0.7±0.5	—	—	3.3±1.1
Brachiaria jubata	3.0±1.5	4.3±1.9	—	1.3±0.1
Brachiaria stigmatisata	—	0.3±0.4	—	0.8±0.3
Brachiaria villosa	0.3±0.4	0.3±0.1	—	—
Cymbopogon giganteus	—	—	—	1.2±0.5
Digitaria argillacea	2.2±0.8	1.8±1.0	4.6±1.3	5.4±3.1
Hackèlochloa granularis	—	—	—	0.5±0.4
Hyparrhenia involucrata	—	—	20.1±6.8	12.2±5.9
Hyparrhenia rufa	—	—	4.8±3.0	0.7±0.6
Hyparrhenia smithiana	—	—	9.0±2.9	—
Hyperthelia dissoluta	—	—	4.9±4.0	11.2±6.0
Loudetia arundinacea	—	—	—	3.6±2.9
Pennisetum polystachion	—	—	0.5±0.5	0.3±0.1
Rottboellia cochinchinensis	1.5±0.6	0.7±0.4	15.9±5.2	7.8±3.5
Schizachyrium brevifolium	0.1±0.2	—	—	0.6±0.2
Schizachyrium sanguineum	—	—	5.2±3.3	5.4±3.2
Setaria barbata	0.4±0.4	—	3.4±2.5	2.4±1.0
Setaria pumila	7.3±1.9	7.1±1.6	9.8±3.4	13.6±3.0
Sorghastrum bipennatum	2.3±0.9	4.1±1.1	11.0±4.2	19.1±6.7
Sporobolus festivus	0.3±0.4	0.7±0.4	—	1.7±0.4
Unidentified spp.	19.3±5.9	33.2±5.3	22.7±6.8	47.6±6.3
Grand mean	42.8±5.7	55.4±55	161.4±19.1	185.8±20.5

The means are pooled data from three study plots ±SE (P = 0.05)

Table 4 Mean grass species yield (g m^{-2}) under tree canopy and in the open in three study plots in Guinea savanna zone of Nigeria

	July		October	
Plot	Canopy	Open	Canopy	Open
1	16.3±2.5	16.9±2.5	89.9±15.7	79.2±2
2	29.9±4.7	24.2±5.3	124.2±19.6	104.9±22.4
3	35.8±9.7	61.0±8.8	125.2±21.8	173.7±22.3

Data represent mean ±SE (P = 0.05)

Table 5 Mean grass yield (g m^{-2}) under three different canopy classes in Guinea savanna zone of Nigeria

Period	Canopy 1	Canopy 2	Canopy 3
July	5.1±1.4	9.3±2.1	13.0±2.3
October	10.2±2.2	40.8±5.2	62.1±7.6

Canopy 1, <3 m high; Canopy 2, 3–7 m high; Canopy 3, >7 m high
The means are pooled data from three study plots ±SE (P = 0.05)

growing under tree canopy cover and those in the open. However, some species had a higher content of these constituents under tree canopy than in the open during the two stages of growth (Table 6).

There were variations in these constituents in the species (Table 6). The mean CP in all the species declined with maturity while the structural components (NDF, ADF, and ADL) increased with maturity and were higher in October (peak growth) than in July (early growth) (Table 6).

Discussion

Grass yield under tree canopy cover

The yields of the following grass species, *A. gayanus*, *H. involucrata*, *H. smithiana*, *P. polystachion*, *R. cochinchinensis*, and *S. barbata* were generally higher under tree canopies than in the open though the differences were not significant. The overall yield under tree canopy and in the open was influenced by the contribution of these species to the total yield. Observations in the savanna also show that taller and denser stands of these grass species especially *A. gayanus*, *R. cochinchinensis*, and *S. barbata* can be seen under tree canopies which gradually diminish with distance from the tree. Higher yields under tree canopy than in the open by other species have been reported for *Panicum maximum* (Kennard and Walker, 1973) and *Cenchrus ciliaris* (Christie, 1975). The higher grass production under tree canopies than under full sunlight reported by some workers (Le Houérou, 1980; Sanford *et al.*, 1982) could have been the result of a high contribution to overall plot yield by shade-favoured species in their study sites.

A comparison of yield under tree canopy classes showed that grass yield was highest under canopy provided by trees above 7 m and lowest under canopy provided by trees under 3 m high. This agrees with the assertion of Sanford *et al.* (1982) that a light, high, tree canopy leads to greater production of grasses in the Nigerian Guinea savanna than either full exposure or dense canopy. The lower yield obtained under the lowest canopy was possibly due to deeper shading of this canopy class and direct competition for space and nutrients by woody plants providing such canopy.

CP, fibre, and lignin

The effect of tree canopy on CP, fibre, and lignin content of grasses studied varies from

Table 6 Mean values of some chemical attributes of grass (per cent dry matter of whole plant) under tree canopy and in the open in July and October 1985–1986 in Guinea savanna zone of Nigeria

Species	Canopy	July				October			
		% CP	% NDF	% ADF	% ADL	% CP	% NDF	% ADF	%ADL
Andropogon gayanus	Canopy	7.44±0.70	70.16±1.52	50.44±1.00	6.70±0.18	2.78±0.12	78.00±0.78	52.88±0.73	7.55±0.16
	Open	7.97±0.58	71.43±0.80	49.98±0.80	6.27±0.13	2.36±0.11	78.83±1.02	53.85±1.09	7.61±0.11
Andropogon schirensis	Canopy	—	—	—	—	2.47±0.16	76.65±0.71	51.31±0.93	7.81±0.10
	Open	—	—	—	—	2.37±0.14	75.88±1.07	52.72±1.08	7.06±0.20
Hyparrhenia involucrata	Canopy	—	—	—	—	2.20±0.12	80.24±0.77	56.41±1.38	7.89±0.06
	Open	—	—	—	—	2.43±0.20	79.33±1.11	54.80±1.39	7.78±0.17
Hyperthelia dissoluta	Canopy	—	—	—	—	2.12±0.23	77.73±3.12	57.76±1.06	8.09±0.22
	Open	—	—	—	—	2.23±0.27	77.10±1.43	57.59±1.11	7.66±0.17
Rottbellia cochinchinensis	Canopy	7.56±0.38	68.44±1.60	46.37±1.45	5.68±0.09	3.79±0.30	76.80±0.80	54.18±0.65	7.29±0.15
	Open	8.34±0.49	65.17±1.71	45.72±1.09	5.64±0.14	3.29±0.21	77.15±0.84	53.35±0.82	7.01±0.08
Schizachyrium sanguineum	Canopy	—	—	—	—	3.23±0.31	74.62±1.47	52.93±2.39	7.18±0.37
	Open	—	—	—	—	2.60±0.27	75.35±0.89	53.95±1.67	7.42±0.24
Setaria pumila	Canopy	8.17±0.27	65.58±0.84	43.25±0.61	5.10±0.11	2.92±0.16	75.95±0.72	55.44±0.37	7.35±0.18
	Open	8.04±0.22	63.31±1.12	44.05±0.76	5.47±0.10	2.54±0.16	77.45±1.01	54.72±0.46	7.23±0.07
Sorghastrum bipennatum	Canopy	8.20±0.42	70.51±1.16	48.38±1.38	5.80±0.24	3.72±0.14	75.12±0.97	55.82±1.30	7.22±0.19
	Open	8.28±0.27	70.30±0.95	47.84±1.56	5.57±0.21	2.90±0.15	74.82±0.93	56.13±0.89	7.48±0.21

CP, crude protein, NDF, neutral-detergent fibre; ADF, acid-detergent fibre; ADL, acid detergent lignin
The means are pooled data from three study plots ±SE (P = 0.05)

species to species. Generally a higher CP, fibre, and lignin content in some species under tree canopy than in the open was observed. However, none of these was statistically significant. Thus it could be concluded that in the area of study, tree canopies do not have a significant effect on these parameters in grass species growing under them.

The chemical composition of these species showed that they accumulated fibrous material at an early stage of growth. As the plants aged, their fibre and lignin content increased and CP content decreased.

Conclusion

The results of this study show that trees in savanna do not have a significant effect on the overall mean yield of the grass species. However, yield under a tree canopy may be higher than in the open depending on the proportionate contribution of shade-favoured species to the total yield. Canopies provided by trees above 7 m lead to significantly higher grass yield than lower canopies. Observation in the savanna shows that grasses beneath tree canopies remain green for longer in the dry season than they do in exposed sites. The results also indicate that tree canopy may improve the CP content and decrease the fibre content in some species thereby improving the nutritive quality of these species under them.

In managing savanna as rangeland, consideration should therefore be given to trees because of the beneficial effect they may have on the yield and nutritive quality of some grass species.

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