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EFFECT OF LEVEL AND SOURCE OF SHADE ON THE BIOMASS OF SPEARGRASS IN NIGERIA

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ABSTRACT

Field studies were conducted in Oyo, Nigeria, to determine the effect of level and source of shade (polyethylene plastic fabric and velvetbean canopy) on the dry matter of speargrass (*Imperata cylindrica* (L.) Raeuschel). Shade levels provided by the plastic fabric were 0 (full solar radiation), 50, 75, and 88% of the incident solar radiation. Velvetbean shade levels of 40.5 to 97% were provided by densities of 4, 8, and 16 plants m^{-1}. In 1999, the velvetbean canopy intercepted 40.5% of solar radiation at 3 weeks after treatment (WAT) and 82% between 5 and 11 WAT. At 11 WAT, velvetbean shading reduced the speargrass biomass by 48% and shade from plastic fabric by 41%. In 2000, radiation interception by the velvetbean canopy was 86.7 - 97.2% between 3 and 11 WAT. Shade from the velvetbean canopy reduced speargrass biomass by 90% and shade from plastic fabric by 44% at 11 WAT. Velvetbean biomas and LAI were negatively correlated with speargrass biomass ($r = -0.85$ to -0.91, $P < 0.05$) and incident solar radiation ($r = -0.88$ to -0.89, $P < 0.05$). Solar radiation was positively correlated with speargrass biomass ($r = 0.46$ to 0.79, $P = 0.05$). The similarity of the effects on speargrass biomass of shading by plastic fabric and velvetbean indicated that shading was the principal mechanism by which velvetbean suppresses speargrass.

Key Words: LAI, phothosynthetically active radiation, velvetbean

RÉSUMÉ

Les études de terrain étaient conduites en Oyo au Nigeria, pour déterminer les effets du niveau et source d'ombrage (fabrique de polyéthylène plastique et baldaquin de velours d'haricot) sur la matière sèche d'herbe poussée (*Imperata cylindrica* (L.) Raeushel). Les niveaux d'ombrage fournit par les fabriques de plastique étaient 0 (complète radiation solaire), 50, 75, et 88% de la radiation solaire incidente. Les niveaux de velours d'haricot de 40,5 à 97% étaient fournit par la densité des 4, 8, et 16 plantes m-2. En 1999, le baldaquin de velours d'haricot a intercepté 40,5% de radiation solaire trois semaines après traitement (WAT) et 82% entre 5 et 11 WAT. Onze WAT après, l'ombrage de velours d'haricot a réduit la biomasse de poussée d'herbe de 48% et l'ombrage de fabrique de plastique de 41%. En 2000, l'interception de la radiation par le baldaquin de velours d'haricot était de 86,7 – 97,2% entre 3 et 11 WAT. L'ombrage de baldaquin de velours d'haricot a réduit la biomasse de poussée d'herbe de 90% et l'ombrage de fabrique de plastique de 44% à 11 WAT. La biomasse de velours d'haricot et LAI étaient négativement corrélées avec la biomasse d'herbe poussée (r=-0,85 à -0,91, P<0,05) et la radiation solaire incidente (r=-0,88 à -0,89 ; P<0,05). La radiation solaire était positivement corrélée avec la biomasse d'herbe poussée (r=0,46 à 0,79 ; P=0,05). La similarité des effets sur la biomasse d'herbe et l'ombrage par de fabrique plastique et de velours d'haricot a indiqué que l'ombrage était le principal mécanisme par lequel le velours d'haricot contient la poussée d'herbe.

Mots Clés: LAI, radiation photo synthétiquement active, velours d'haricot

INTRODUCTION

Speargrass (*Imperata cylindrica (*L.) Raueschel) is a rhizomatous, perennial grass weed, which is widely distributed throughout the humid and subhumid tropics, and some parts of the warm temperate regions of the world (Holm *et al.*, 1977) In West Africa, it is found in the forest/savanna transition zone where recurrent fires and farming activities prevent the natural vegetation to growth to levels that can shade out weeds (Garrity *et al.*, 1997). Speargrass is a serious weed, a potential fire hazard in plantation crops (Tominaga *et al.*, 1990), and a major problem in arable crops because most of the control methods employed by farmers are not effective (Akobundu and Fagade, 1978). Estimated crop yield losses attributed to speargrass competition are ≥ 80% in maize (*Zea mays* L.), 78% in yam *(Dioscorea rotundata* Poir*)* and cassava (*Manihot esculenta* Crantz) (Koch *et al.*, 1990; Udensi *et al.*, 1999) and up to 41% in soybean (*Glycine max.* (L.) Merr.) (Avav, 2000).

Strategies for speargrass management include hoe-weeding, slashing, deep tillage, chemical control, burning, abandoning the land to fallow, and the use of short-term planted fallow (e.g., cover crops and alley cropping). Small-scale farmers in West Africa use hoe-weeding and slashing as the most common control methods.. These options are not effective on rhizomes and are labour intensive, consuming up to 70% of the total farm labour budget (Avav, 2000; Akobundu *et al.*, 2000; Chikoye *et al.*, 2002). Deep tillage is not commonly used because of the cost. Herbicides are unavailable when needed and when available are expensive (Ivens, 1975; Akobundu *et al.*, 2000). Burning is not a sustainable option as it damages only the foliage of speargrass and stimulates the regrowth of new shoots.

Traditionally, small-scale farmers abandoned severely infested fields to fallow for 5 to 15 years. This allowed bush regrowth to levels that could shade and smother weeds including speargrass (Nye and Greenland, 1960). Long fallow periods are no longer possible as increasing human population puts pressure on land. Many studies have shown that planted fallow, e.g., a cover crop, is a potential option for reclaiming infested land (Akobundu *et al.*, 2000; Chikoye *et al.*, 2001) as it retains most of the benefits of bush fallow. Cover crops are not used widely for speargrass control because their effect is inconsistent, even within the same ecology. They may compete with the primary crop, and have no food or cash benefit (Carsky *et al.*, 1998; Akobundu, *et al.*, 2000; Chikoye *et al.*, 2001).

In controlled environments, studies have shown that cover crops suppressed speargrass by shading and allelopathic mechanisms (Fujii *et al.*, 1991). Under field conditions, the mechanism by which cover crops suppress weeds is unknown. We tested the hypothesis that shading is also the suppressive mechanism under field conditions. The objective of this study was to determine the response of speargrass to different levels of shading provided by plastic fabric and velvetbean canopies.

MATERIALS AND METHODS

Experimental site. This study was conducted in 1999 and 2000 at Oyo (7 °54'N, 3 °46'E), Nigeria, in the forest/savanna transition zone. The zone receives an average annual precipitation of 1200 to 1500 mm in a bimodal distribution pattern with peaks in July and September. The average temperature is 26 °C. The soil type at the site is sandy loam. Soil tests indicated a pH of 6.1, organic matter < 2%. The experimental site had been in fallow for more than 5 years and the dominant vegetation was speargrass.

Experimental procedures. Cubicle frames each measuring 1.2 m (height) x 1.0 m x 1.0 m were constructed from metal square pipes (Moosavinia and Dore, 1979). Each frame was covered with a translucent plastic fabric (high density polyethylene) (Clovis Lande Associates Ltd, Brandbridges Road, East Peckham, Tonbridge, Kent, TN12 5HH, UK.). Specifications were 32 mesh (32 x 32 threads/square inch, thread thickness = 0.16 mm, approximate hole size = 0.62 mm x 0.68 mm and estimated permeability approximates 70%). Shade provided by the fabric was 50% (single), 75% (double), and 88% (triple). The plastic fabric did not alter the quality of the solar radiation received by the plants.

Control plots consisted of frames without any plastic fabric, which received full solar radiation. Velvetbean shade was provided by planting at densities of 4, 8, and 16 plants m^{-1} in 6 conical pots

(= 2, 4, and 8 plants per pot, pot diameter = 50 cm, volume=35 litres). These were buried in the ground around each of the cubicle frames (1 m away from the frame) (Fig. 1). These velvetbean densities per pot gave populations of 12,739, 25,478, and 50, 955 plants ha^{-1}. Populations were calculated, based on the surface area of the pot ($2\pi r^2$) and the number of plants per pot. Velvetbean was grown in pots to prevent any root interaction which might have resulted in competition for belowground resources. Strings were used to support velvetbean vines on the metal frames. All treatments were replicated three times. Plot size was 4 m x 4 m. In each plot, the area that was covered by each frame (1 m x 1 m) was used for data collection. The experimental design was a randomised complete block design.

In the second year, 2000 the frames were moved to a different part of the field and the whole process was repeated. Plastic fabric shade was imposed 5 weeks after planting velvetbean. This coincided with the time when velvetbean fully covered the microplots without any frames in an adjacent field. Speargrass under each frame was slashed before shading treatments were imposed.

At 3 weeks after the above treatments were imposed, photosythetically active radiation (PAR) intercepted by each treatment was recorded at solar noon ± 2 hr and subsequently at 2-weekly intervals, above and below the plastic fabric shade and velvetbean canopies. PAR was measured using a ceptometer (Decagon Devices Inc., Pullman, WA, USA). Leaf area index (LAI) of velvetbean was measured using a plant canopy analyzer at solar noon (Model LAI-2000, SR PCA 0488, with optical sensor Lai-2050 PC + P-482; LI- COR, Inc. Lincoln, NE 68504-0425 USA). The experiment was terminated at the end of the rainy season [11 weeks after treatment (WAT])] when the velvetbean canopy began to senesce. Speargrass shoot and rhizome biomass were sampled from an area of 0.5 m^2, within each microplot for biomass determination after being oven-dried at 80 °C for 48 hr.

Transmitted PAR was calculated as (100-x)%, where x = percentage PAR intercepted by each treatment. Velvetbean biomass was measured from an area of 0.5 m^2 in each plot. Dry leaves of velvetbean were picked every day from the microplots in each plot to prevent litter fall.

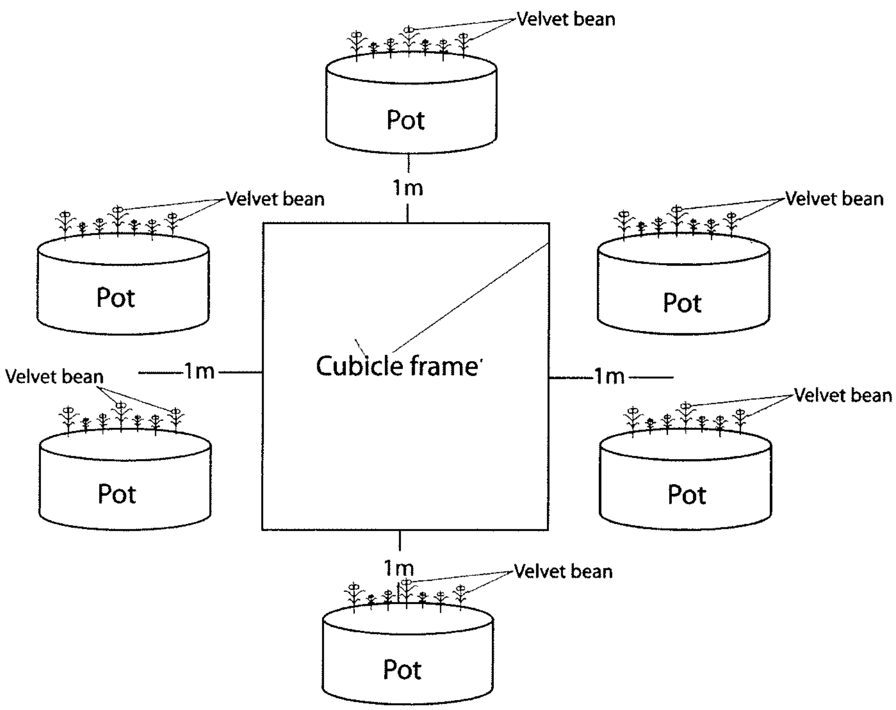

Figure 1. Diagramatic representation of buried pot positions relative to the cubicle frame position on the field.

Statistical analysis. PAR, shoot, and rhizome biomass of speargrass, LAI, and biomass of velvetbean were analysed using Mixed Model Procedures (SAS, 1995). In the model, the type of shade (plastic fabric or velvetbean) and the level of shading were considered fixed effects. Replicates were random effects. Single degree of freedom orthogonal contrasts were used to compare specific treatment effects (e.g., plastic fabric vs velvetbean canopies). Means were separated using the standard error of the mean, and were considered different at $P \leq 0.05$. Pearson's correlation analysis was performed to determine the relationship between speargrass biomass, PAR, and biomass and LAI of velvetbean. Regression analysis was used to determine the relationship between shading and speargass biomass.

RESULTS

Speargrass shoot biomass. Speargrass shoot biomass measured before imposing the shading treatments was 119.6±28.2 g m^{-2} in 1999 and 58.7 ± 12.3 g m^{-2} in 2000. In 1999, at 11 WAT, shoot biomass was significantly affected by shading from both sources except for 50% shade from plastic fabric and 4 plants m^{-1} velvetbean (Table 1). The effect of shade of 75 and 88% from plastic fabric was similar (P>0.05) and reduced shoot biomass by 46 and 49%, respectively, compared to the unshaded control (P< 0.001) (Table 1). The effect of 50% shading by plastic fabric on speargass biomass was not significantly different from the unshaded control. Velvetbean at densities of 8 and 16 plants m^{-1} reduced shoot biomass by 56 and 70%, compared to the unshaded control (P < 0.001). Shoot biomass in velvetbean at densities of 8 and 16 plants m^{-1} was similar. Velvetbean at a density of 4 plants m^{-1} had shoot biomass similar to the unshaded control (P > 0.05), which was higher than 8 and 16 plants m^{-1}. Shade of 75 and 88% from plastic fabric had effects on the shoot biomass similar to that of the velvetbean canopy of 8 and 16 plants m^{-1} (P > 0.05) (Fig. 2 and Table 1). Velvetbean at 8 and 16 plants m^{-1} was more effective in reducing speargrass shoot biomass than shade of 50% from plastic fabric (P < 0.001). Averaged over shade levels, shading with plastic

TABLE 1. Effect of shade on the growth of speargrass shoots and rhizomes 11WAT at Oyo in Nigeria†

Treatment	Shoot biomass (g m^{-2})		Rhizome biomass (g m^{-2})	
	1999	2000	1999	2000
50 % Plastic fabric shade	292.8 a	180.2 a	283.9 ba	152.8 a
75 % Plastic fabric shade	162.2 bc	81.3 b	208.5 b	108.2 b
88% Plastic fabric shade	152.2 bc	52.3 b	207.5 b	66.6 c
Velvetbean 4 plts m^{-1}	229.5 ba	2.5 c	305.6 ba	43.9 c
Velvetbean 8 plts m^{-1}	131.0 c	2.0 c	241.5 b	34.9 c
Velvetbean 16plts m^{-1}	90.1 c	0.5 c	159.0 b	29.3 c
Full sunlight (unshaded))	299.4 a	199.2 a	433.9 a	179.4 a
Mean plastic fabric shade	202.4	104.6	233.3	109.2
Mean velvetbean shade	150.2	1.7	235.4	36.0
SED‡	34.5	21.9	75.21	18.15
Contrast	**Probability**			
Full sunlight vs all shade treatments	0.0005	<.0001	0.0046	<.0001
Plastic fabric shade vs velvetbean shade	0.0224	<.0001	0.9629	<.0001
50% vs 75 and 88% plastic fabric shade	0.0007	<.0001	0.2663	0.0013
75% vs 88% plastic fabric shade	0.7765	0.2106	0.9893	0.0408
4 plants m^{-1} vs 8 and 16 plants m^{-1} velvetbean shade	0.0018	0.9509	0.1316	0.4699
8 plants m^{-1} vs 16 plants m^{-1} velvetbean shade	0.2587	0.9468	0.2946	0.7575

†Means followed by the same letter are not significantly different at *P*=0.05 based on PDIFF option (Proc MIXED in SAS). ‡SED, denotes standard error of the difference between means

fabric reduced shoot biomass by 32.3%, shading by the velvetbean canopy reduced shoot biomass by 49.9% (P=0.0224).

Shoot biomass was 69.9% lower in 2000 than in 1999. Shoot biomass at 11 WAT was 176.3 g m^{-2} in 1999 and 53.0 g m^{-2} in 2000. In 2000, velvetbean at all densities reduced shoot biomass better than the unshaded control and plots shaded with plastic fabric (Fig. 2 and Table 1). Shoot biomass did not vary among the densities of velvetbean (P > 0.10). At all levels of shade from plastic fabric (except 50%), shoot biomass was less than in the unshaded plots ($P \leq 0.001$) (Table 1). Averaged over shade levels, shade from fabric reduced shoot biomass by 47.5% and shade from the velvetbean canopy reduced it by 99.2% (P<0.0001) (Table 1). Averaged over the two years, velvetbean biomass (r =–0.86, P = 0.05) and LAI (r = –0.85, P<0.05) were negatively correlated with the shoot biomass of speargrass (Table 2).

Rhizome biomass. Rhizome biomass was 74.3% higher in 1999 (mean biomass = 273.3 ± 44.0 g m^{-2}) than in 2000 (mean rhizome biomass = 70.02 g m^{-2} ± 20.7) before shading treatments were imposed. At 11 WAT in 1999, irrespective of source shading significantly reduced rhizome biomass compared to full solar radiation (P<0.001). Shade from plastic fabric reduced rhizome biomass in the following order 88% and 75% shade by 52%; and 50% shade by 35% compared to the unshaded control (P > 0.01). The effect of all levels of fabric shade on rhizome

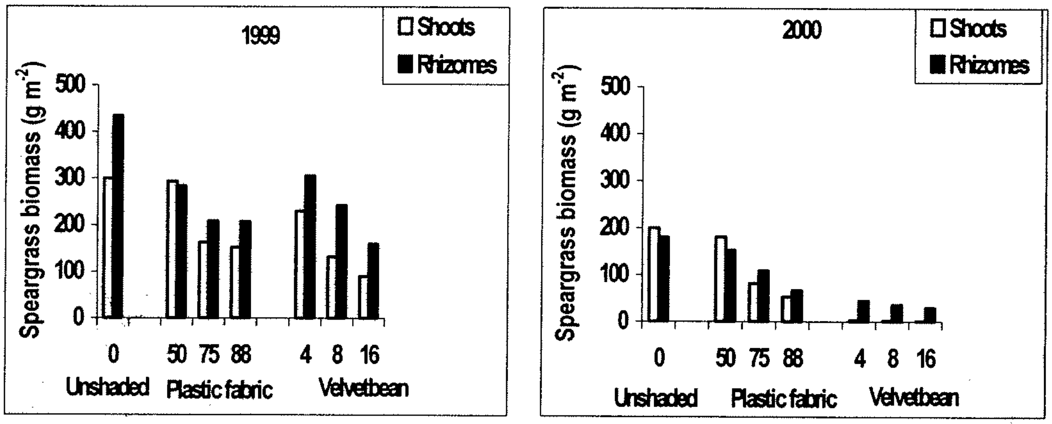

Figure 2. Response of speargrass to shading by plastic fabric and velvetbean canopy at 11 WAT. Plastic fabric shade expressed as percentages and velvetbean as densities (plants m^{-1}).

TABLE 2. Pearson's correlation coefficient(r) between speargrass biomass (shoot and rhizome) and velvetbean biomass, velvetbean LAI, and PAR transmittance (PAR) (means of 1999 and 2000 combined)

	Rhizome biomass	Velvetbean biomass	Velvetbean LAI	PAR
Shoot biomass	0.80***	-0.86*	-0.85*	0.79***
Rhizome biomass	1.00	-0.90*	-0.91*	0.46
Velvetbean biomass		1.00	0.97***	-0.89*
Velvetbean LAI			1.00	-0.88*
PAR				1.00

*, **, *** Significant at 0.05, 0.01, 0.001 level of probability

biomass was similar (Fig. 2 and Table 1). Velvetbean shade reduced rhizome biomass as follows: 16 plants m^{-1} by 63%, 8 plants m^{-1} by 44%, and 4 plants m^{-1} by 30% compared to the unshaded control. All velvetbean densities had a similar effect on rhizome biomass ($P>0.05$) (Table 1). The effect of velvetbean densities on rhizome biomass was comparable to any level of shade from plastic fabric ($P>0.05$) (Table 1). Averaged over shade levels, plastic fabric shade reduced rhizome biomass by 44% and velvetbean densities by 46% compared to unshaded control.

In 2000, shading significantly affected rhizome biomass, with the velvetbean canopy having the greatest effect (Table 1). Reducing solar radiation by 88% significantly reduced rhizome biomass compared to shading levels of 75 or 50%. Plastic fabric shade of 75% had a better effect on rhizome biomass than shade of 50%. Shade of 88% reduced rhizome biomass by 63%, while shade of 75% by 40% compared to the unshaded control ($P\leq0.01$). Velvetbean at all densities reduced rhizome biomass better than the unshaded control, 50%, and 75% of plastic fabric shade ($P\leq0.001$). The effect of 88% plastic fabric shade was not significantly different from shade from all densities of velvetbean (Table 1 and Fig. 2). Overall, plastic fabric shade reduced rhizome biomass by 39% and velvetbean densities by 80% compared to the unshaded control ($P<0.001$) (Table 1). Averaged over the years, rhizome biomass was negatively correlated with velvetbean biomass ($r = -0.90$, $P<0.05$) and LAI ($r = -0.91$, $P<0.05$). The correlation between rhizome biomass and the amount of PAR was not significant. More biomass was partitioned into rhizomes than in shoots (Fig. 2).

Photosynthetically Active Radiation (PAR). In both years, plastic fabric provided uniform shading throughout the duration of this study (Fig. 3). In 1999, at all sampling dates, all densities of velvetbean significantly reduced PAR under its canopy compared with the unshaded control ($P\leq0.001$) (Fig. 3). Velvetbean densities of 16 and 8 plants m^{-1} had less PAR transmitted below their canopies than at a density of 4 plants m^{-1} at 3 and 5 WAT ($P\leq0.05$). These differences disappeared at 7 WAT, when velvetbean at all densities had fully covered the ground. Averaged over the sampling period and densities in 1999, velvetbean intercepted 76% of PAR.

In 2000, at all sampling dates, the velvetbean canopy significantly reduced light transmitted under its canopy compared to the unshaded control ($P<0.001$). Velvetbean at all densities intercepted more PAR than all treatments with plastic fabric except at 3 WAT where 88% shade from plastic fabric was better than velvetbean at densities of 4 and 8 plants m^{-1} ($P<0.001$). The velvetbean density of 16 plants m^{-1} reduced PAR better than velvetbean densities of 4 and 8 plants m^{-1}. There

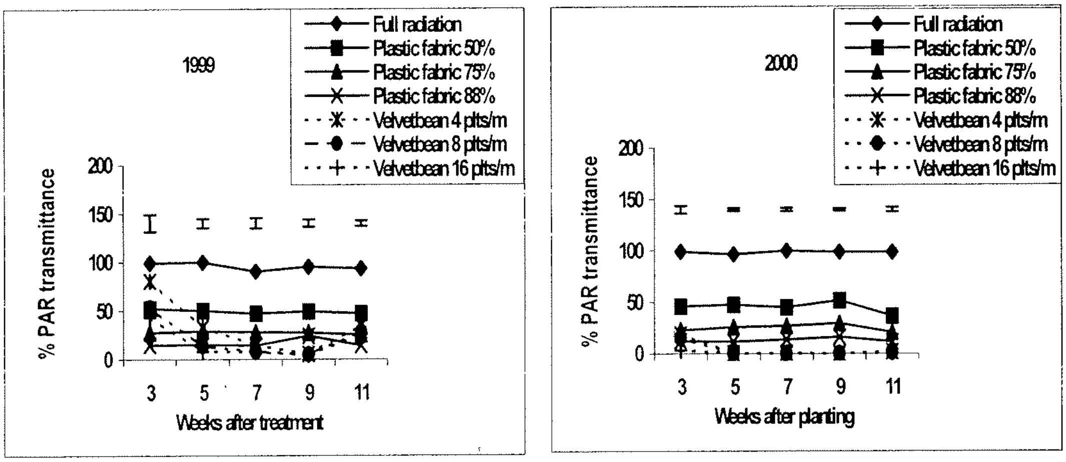

Figure 3. Percentage of incident photosynthetically active radiation (PAR) transmitted by plastic fabric and velvetbean canopy densities at different sampling times in 1999 and 2000.

was no significant difference between densities of 4 and 8 plants m^{-1} in the amount of intercepted PAR. Averaged over time, plastic fabric transmitted 27.7% and velvetbean canopy 2.7% of the PAR.

PAR interception by the velvetbean canopies was 22% better in 2000 than in 1999. The overall effect of treatments on PAR from this study indicates that velvetbean at full canopy intercepted more PAR than plastic fabric. Averaged over years, the velvetbean canopy intercepted 86% and plastic fabric intercepted 70% of PAR. There was a positive correlation between PAR and shoot biomass of speargrass (r=0.79, P≤0.001). Shading had more effect on shoots (slope = -34) than on the rhizomes (slope = -19.7) and substantial shading effect on biomass started at 60 to 80% shading (Fig. 4).

Velvetbean LAI and biomass. There were no significant LAI differences between the velvetbean densities at all sampling time in both years (Fig. 5). LAI peaked at 9 WAT in 1999 for all densities and dropped by about 40% at 11 WAT. In 2000,

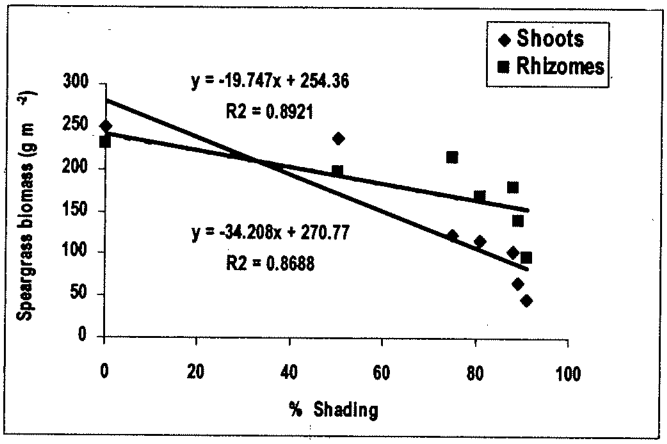

Figure 4. Shoot and rhizome biomass of speargrass 11 WAT under different shading level. Biomass values are an average of 1999 and 2000.

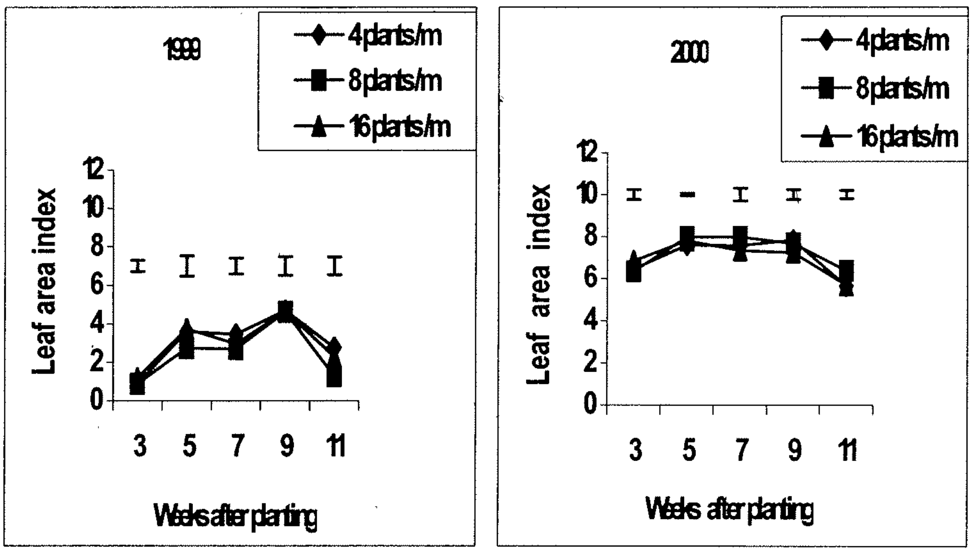

Figure 5. Leaf area index of velvetbean in 1999 and 2000.

LAI peaked between 5 and 7 WAT and dropped by 20% at 11 WAT. LAI was lower in 1999 than in 2000. The maximum LAI in 1999 was 4.67 ± 0.497 at 9 WAT. In 2000, the maximum LAI value was 7.98 ± 0.299. There were no significant differences in velvetbean biomass across all treatments in both years (Fig. 6). However, biomass was higher in 2000 than in 1999, with a mean of 994 ± 447 g m^{-2} in 1999 and 3495 ± 447 g m^{-2} in 2000. From the correlation analysis, velvetbean biomass accounted for 74% and 81% variation in shoot and rhizome biomass of speargrass, respectively. LAI accounted for 72% and 83% variation in speargrass shoot and rhizome biomass, respectively.

DISCUSSION

The effect of shade on speargrass biomass was more in 2000 than in 1999. The speargrass biomass at the onset of the experiment was lower in 2000 than in 1999 because in 2000, the frame was moved to a different part of the same field, that had relatively lower speargrass infestation than the portion used for the 1999 trial. This might partly explain why shading appeared to have had more effect on biomass in 2000 than in 1999. However, with the velvetbean densities, the effect of shading in 2000 can further be attributed to better rainfall distribution during the growing period in 2000 than in 1999 (Fig. 7). This may

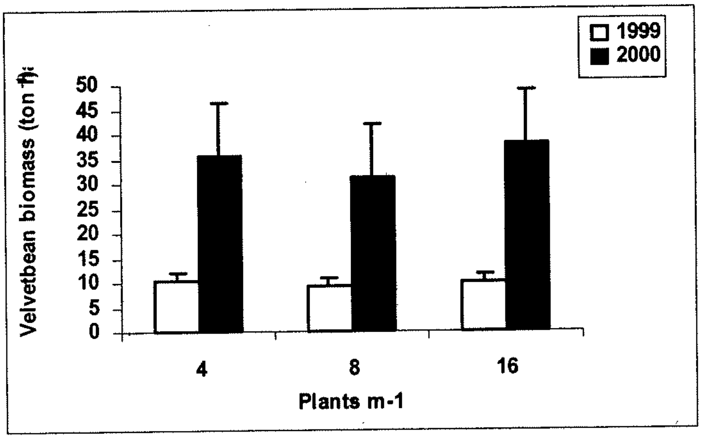

Figure 6. Velvetbean biomass at 4, 8, and 16 plants m^{-1} 11 WAT, in 1999 and 2000.

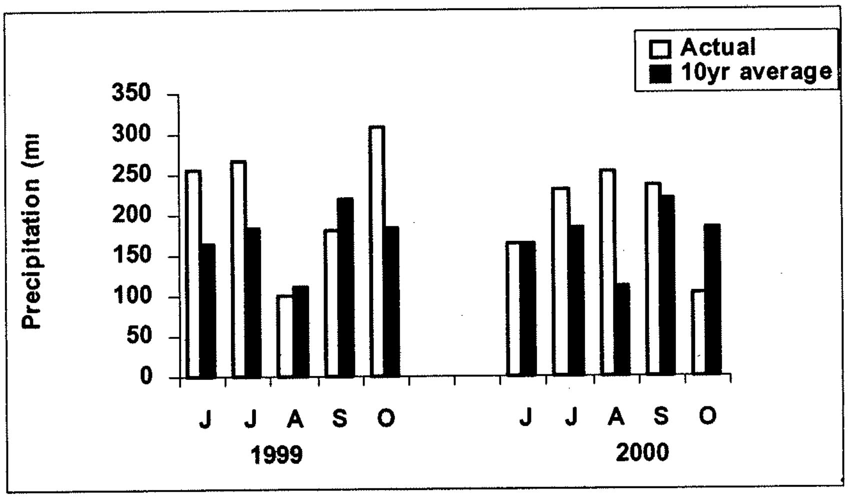

Figure 7. Total monthly precipitation during the growing season (July to October) in 1999 and 2000.

have encouraged good growth of the velvetbean canopy and biomass. Thus, the higher velvetbean canopy LAI in 2000 than in 1999 may have induced greater shading on speargrass. Also because of higher LAI in 2000, velvetbean intercepted more PAR and shaded speargrass more than in 1999. Chikoye and Ekeleme (2001) also reported a negative correlation between velvetbean LAI and speargrass biomass. Shoot and rhizome biomass decreased as the level of shading increased, irrespective of the source of shade, and had more effect on shoots than rhizomes. These results are in agreement with previous studies on speargrass and other perennial weeds (Moosavi-nia and Dore, 1979; Patterson, 1980; Santos *et al.*, 1997).

Velvetbean at full canopy (approximately 5 WAP), provided shade levels that were similar to or more than shade from plastic fabric, especially in 2000. Shading levels of ≥75%, which were provided by velvetbean at densities of 8 and 16 plants m^{-1}, reduced shoot and rhizome biomass significantly. Shading levels of ≤50%, which were provided by 4 plants m^{-1}, were not very effective in suppressing the growth of speargrass. The slight effect of 50% shade on speargrass shoot biomass observed in this study has been reported in previous studies (Moosavi-nia and Dore, 1979). Contrary to our finding and that of Patterson (1980), Moosavi-nia and Dore (1979) reported that 50–75% shade significantly affected speargrass rhizome biomass.

When grown under conditions of full solar radiation, speargrass stores more of its biomass in the shoots (Chikoye and Ekeleme, 2001). As the shading levels increased, more biomass was apportioned into the rhizomes than into shoots. This is contrary to previous studies which showed that speargrass invested more biomass in shoots than in rhizomes when growing under shaded conditions (Moosavi-nia and Dore, 1979; Patterson, 1980; Macdicken *et al.*, 1997). Higher partitioning into rhizomes might be necessary to support the growth of vegetative buds on the rhizomes which later grow into shoots (Santos *et al.*, 1997).

The reduction in speargrass in velvetbean treatments could be largely attributed to shading since growing velvetbean in pots eliminated competition for other growth resources (i.e. nutrients). This finding is supported by the negative correlation of LAI of velvetbean and speargrass biomass. The similarity observed in the shading effects of plastic fabric and velvetbean on speargrass indicates that shading was the principal mechanism by which velvetbean suppresses speargrass. Velvetbean populations between 8 and 16 plants m^{-1} (approximately 3 and 5 plants m^{-2}) are recommended for the better suppression of speargrass under field conditions. The importance of this shade study is that management of speargrass could be achieved by reducing light through planting a rapidly growing dense crop canopy, especially in the moist savanna area where solar radiation is intense.

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