PLANTAIN PRODUCTION IN AN ALLEY CROPPING SYSTEM ON AN ULTISOL IN SOUTHEASTERN NIGERIA

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Abstract: *Plantain requires mulching for high yields and sustained productivity. Mulching is, however, labor-intensive and requires extra land for production. An experiment was conducted to determine the potential of alley cropping to supply in situ mulch for plantain production. Foliage from hedgerows of Dactyladenia barteri, Alchornea cordifolia, Senna siamea and Gmelina arborea were compared with mulch from elephant (napier) grass (Pennisetum purpureum) carried into plots that served as the no-tree control. Plantain performed best with P. purpureum mulch because this mulch shortened its fruiting cycle and gave the highest yield (17.8 t ha^{-1}). Among the hegderow species, D. barteri mulch produced the best results because the plantain produced 85% as much bunch yield as P. purpureum mulch. However, relative yields of plantain were 77, 72 and 66% for A. cordifolia, S. siamea and G. arborea, respectively. Due to differences in cycle length, cumulative yield after two years was highest in P. purpureum (35.4 t ha^{-1}). After two years, cumulative relative yields were 51% or less for A. cordifolia, S. siamea and G. arborea in contrast with 66% for D. barteri. D. barteri mulch reduced diurnal soil temperature fluctuations and moisture depletion as well as P. purpureum mulch. High diurnal soil temperature fluctuations, high weed infestation and superficial rooting of the hedgerow species were observed with A. cordifolia, S. siamea and G. arborea treatments which resulted in poor performance of plantain. Although P. purpureum mulch gave the best results, its use is subject to serious constraints such as the high labor requirement for cutting, transportation, application and management in addition to the extra land required for its production which cannot be justified by the higher yield. D. barteri is therefore recommended as an in-situ mulch for plantain production in this acid Ultisol.*

1. Introduction

Plantains (*Musa* spp. AAB group) are a well-characterized group among the starchy bananas [Tezenas du Montcel et al. 1983]. Fruits are angular and produce a yellow orange pulp. At maturity, fruit starch amylose content is about 11% [Eggleston et al. 1992]. They are among the most important carbohydrate sources in the diet of people in the lowland humid forest zones of Africa [Wilson 1987]. Africa alone produces more than 50% of all plantains in the world [FAO 1990].

In the humid tropics, plantains are cultivated in compound gardens and in fields mixed with other food crops. In the compound, plantains benefit from household refuse which increases soil fertility [Wilson et al. 1987]. Yields are high and continuous and estimated at 30-50 t ha^{-1} yr^{-1}. In contrast, yields in mixed cropping systems as practiced in shifting cultivation are seasonal and low (4-8 t ha^{-1} yr^{-1}) [Nweke et al. 1988]. The beneficial effects of household refuse and mulch on plantain have been attributed to many factors [Braide and Wilson 1980, Swennen et al. 1988].

Household refuse and mulch are sources of nutrients and organic matter and thus act as fertilizers. In addition, since they cover the soil surface, ramification of the plantain roots is stimulated. This results in increased nutrient uptake by the plantains and increase in bunch weights. The plantains are also able to resist strong winds and are less affected by drought.

However, since increased root development results in faster sucker growth and thus shorter production cycles per unit time, mulching increases the longevity of a field. Mulching thus reduces the rapid decline in plantain yield which would otherwise become obvious through low yields from the second cycle onward, even with high fertilizer applications [IITA 1982, Wilson et al. 1987]. Other beneficial effects of mulch include reduced soil erosion, temperature fluctuations, moisture loss and improved weed control [Obiefuna 1991, Salau et al. 1992].

Although the benefits of mulching plantain as well as other food crops have been amply demonstrated, the logistics of producing, transporting and application of mulch limits its use [Akobundu 1987]. Mulching is a labor-intensive activity. The production of mulch between the plantain plants therefore is attractive [IITA 1982, Wilson and Swennen 1989]. Alley cropping, which has been successful with cereals, legumes and root crops [Kang et al. 1990] is such an in situ mulch production system. Shrubs and trees grown in hedgerows alongside the food crops are pruned regularly during the cropping period. Prunings serve as mulch and a source of nutrients.

The aim of the present study was to assess the performance of plantains alley cropped with selected hedgerow species to provide mulch, in such a way that the plantains always occupy the upper canopy during the cropping period [Wilson and Swennen 1989].

2. Materials and Methods

The trial was carried out at the International Institute of Tropical Agriculture (IITA) Onne Station near Port Harcourt, in southeastern Nigeria. The mean annual rainfall of 2400 mm is monomodal. The rainy season starts in March and ends in November. The relative humidity remains high throughout the year with mean values between 62 and 87%. Temperatures range from 23.1°C to 30.2°C. Sunshine averages 4.2 hours per day, ranging from 2.0 hours in September to 6.1 hours in February.

The soil at the experimental site is an Ultisol derived from coastal sediments and is classified as loamy, siliceous, isohyperthemic, Typic Paleudult [Hulugalle et al.

1990]. It is deep, well-drained with good physical properties, but low in nutrients (table 1).

The treatments consisted of five types of mulch and two cropping systems. The mulches were prunings of *Dactyladenia barteri* (Hook f.ex Oliv.) Engel., *Alchornea cordifolia* (Schum & Thonn.) Muell. Arg., *Senna siamea* (Lam.), *Gmelina arborea* (Roxb.) and *Pennisetum purpureum* Schum. (elephant grass) as the no-tree control. The experimental design was a split plot with four replications; sources of mulch were the main plots and cropping systems the subplots. The hedgerow trees and shrubs were planted in April-May 1985 at a spacing of 4 m x 1 m giving a population of 2500 stands ha^{-1}. The trees and shrubs were cut back to a height of 30 cm in March-April, 1989. The foliage obtained from cutting back and from subsequent prunings was applied in the alleys. Fresh *P. purpureum* mulch was applied twice to give a total of 80 tons fresh weight ha^{-1} annually. *In vitro*-plantlets of the French plantain (*Musa* spp., AAB group) cultivar locally known as 'Obino L'Evai' were planted in May, 1989 in the alleys at a staggered spacing of 3 m x 1.70 m to give a population of 1,582 plants ha^{-1}. After flowering, the male buds of the plants were cut off. Maize was sown between the plantain stands and next to the hedgerows at 1 m x 0.8 m spacing. Nitrogen and K fertilizers were applied at the recommended rates.

Furadan, a nematicide-insecticide was used for banana weevil and nematode control. Bayfidan and Tilt, fungicides, were applied during the rainy and dry seasons respectively, to control black sigatoka. Weed control was either manual or chemical using Gramoxone weed killer.

At cutting back and during the regular pruning of the hedgerows, the foliage biomass was determined. The field capacity moisture was determined 24 hours after a heavy rain by means of hand auger at 0-5 cm and 5-15 cm. Soil core samples were also collected at the same depths starting at the onset of the dry season (December, 1989) for gravimetric water determination. Soil temperature was measured at 6, 8, 10, 12, 14, 16 and 18 hours using stem mercury-in-glass thermometers installed at 0-5 cm depth. Observations were made on 18 plantain plants in each subplot to assess the effect of the mulch types on plantain productivity. There were no differences between the cropping systems in pruning biomass, soil properties or plantain yield. The results presented are, therefore, the average of the two cropping systems.

3. Results

3.1 Hedgerow species pruning yield

The pruning biomass (leaves + twigs) productivity of the hedgerow species (figure 1) show that at initial pruning, *D. barteri* had the highest pruning yield followed by *A. cordifolia* whereas *S. siamea* and *G. arborea* had the lowest. During the first year, *D. barteri* regrowth was slow, giving the lowest pruning dry matter which was obtained in one pruning. Other hedgerow species were pruned several times; *G.arborea* required five prunings whereas *A. cordifolia* and *S. siamea* were pruned

Table 1. Selected physical and chemical properties of the soil at the experimental site [Ruhigwa et al., 1992]

Soil depth	Texture	Bulk density	pH (H_2O)	Organic C	Total N	Bray-1 P	Exchangeable K	Exchangeable Ca	Exchangeable Mg	Total acidity	ECEC
(cm)		(gcm^{-3})		(%)	(%)	($mg\ kg^{-1}$)	($cmol\ kg^{-1}$)				
0-10	LS[a]	1.36	4.05	1.67	0.14	50.7	0.13	1.95	0.34	1.47	4.02
10-20	LS	1.48	4.05	1.37	0.12	49.9	0.13	1.36	0.24	1.86	3.72
20-30	SL[b]	1.44	4.05	1.22	0.10	46.5	0.08	1.02	0.20	2.01	3.38
30-40	SCL[c]	1.41	4.05	1.01	0.10	47.4	0.07	0.97	0.16	2.14	3.52
40-50	SCL	1.44	4.15	0.84	0.08	39.5	0.06	0.93	0.15	2.28	3.52
50-80	SCL	1.45	4.18	0.60	0.07	27.4	0.06	0.76	0.14	2.33	3.40
80-120	SCL	1.46	4.35	0.35	0.07	23.1	0.05	0.72	0.14	2.00	3.03

Note: [a] Loamy sand
[b] Sandy loam
[c] Sandy clay loam

three times. However, during the second year, *D. barteri* and *G. arborea* produced higher amounts of prunings than *A. cordifolia* and *S. siamea*. The pruning frequency of *G. arborea, A. cordifolia* and *S. siamea* was maintained as in the first year whereas *D. barteri* was only pruned twice.

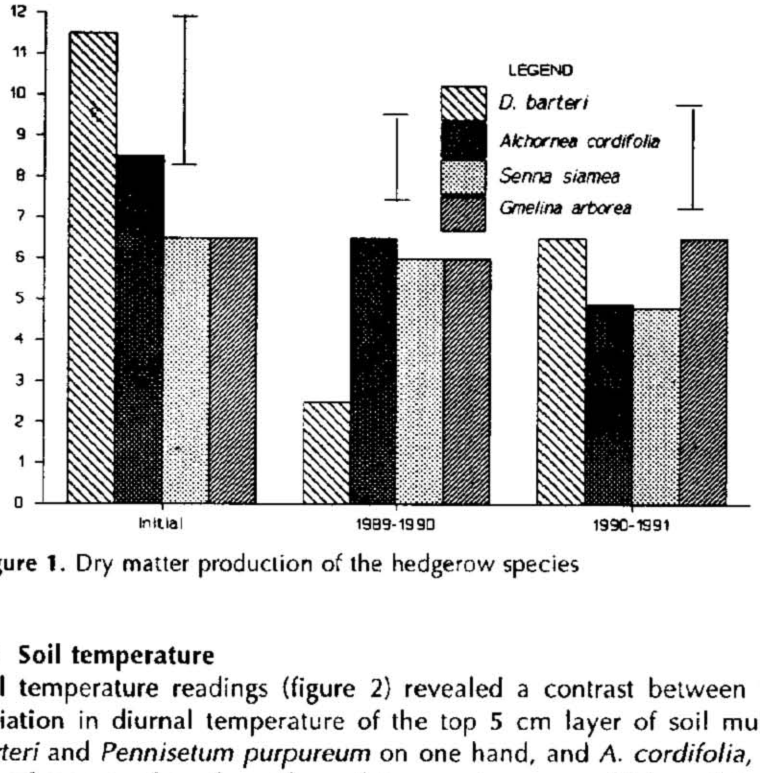

Figure 1. Dry matter production of the hedgerow species

3.2 Soil temperature

Soil temperature readings (figure 2) revealed a contrast between the pattern of variation in diurnal temperature of the top 5 cm layer of soil mulched with *D. barteri* and *Pennisetum purpureum* on one hand, and *A. cordifolia, S. siamea* and *G. arborea* on the other. The soil temperatures were higher at 6 a.m. under *A. cordifolia, S. siamea* and *G. arborea* mulched plots and remained much higher throughout the day. Under *D. barteri* and *P. purpureum* mulched plots, the temperatures remained low with a maximum of about 27-28°C. In addition, the amplitude of temperature variation was smaller during the day.

3.3 Soil moisture

Soil gravimetric water content during the dry season in plots mulched with *D. barteri, G. arborea* and *P. purpureum* is presented in table 2. At field capacity and 9 days later, no significant differences were observed in soil gravimetric water content between the treatments in the 15 cm soil depth. But at 19 days, after a period of rainless days, the water content of the top 5 cm soil layer of the alley cropped plots was lower than that of the *P. purpureum* plot, while in the 5-15 cm soil layer, *G. arborea* plots had the lowest amount of water. At the end of the dry season in 1990, the amount of water in the *G. arborea* plots in the soil profile examined was still the lowest.

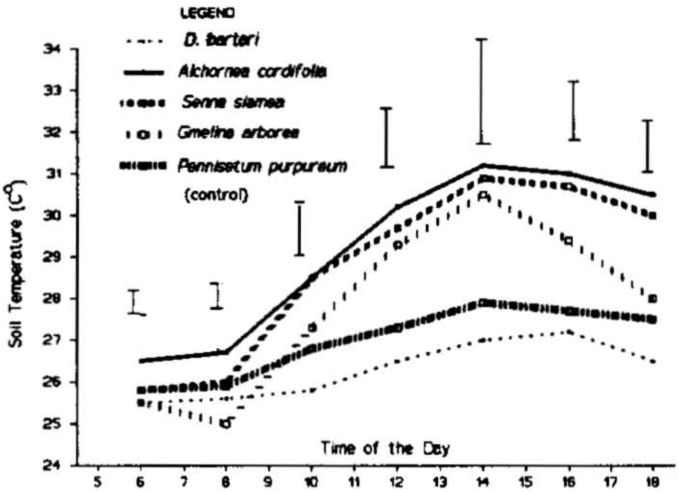

Figure 2. Diurnal variations of soil temperature at 0-5 cm depth under different mulches (between 15 January - 28 February 1990)

3.4 Plantain crop

The length of cycle and plantain yield are shown in table 3. The results indicate significant differences in plantain response to mulch treatments. The plants growing in plots mulched with *P. purpureum* (control) completed the first cycle 25, 62, 78, and 84 days earlier than those in *D. barteri, S. siamea, A. cordifolia* and *G. arborea* plots, respectively. A shorter cycle indicates better growth in plantain and is positively correlated with yield [Swennen and de Langhe 1985]. In the first cycle (plant crop), higher yields were obtained in *P. purpureum* plots than in the alley cropped treatments. The relative yields were 85, 77, 72 and 66% for *D. barteri, A. cordifolia, S. siamea* and *G. arborea*, respectively. The cumulative yield 2 years after planting (May, 1989-May, 1991) showed the same trend with highest total yield obtained in *P. purpureum* mulched plots followed by *D. barteri, S. siamea, A. cordifolia* and *G. arborea*. Among the four hedgerow species, *D. barteri* produced the highest plantain crop plots because of a shorter cycle.

Table 2. Effect of different mulches on gravimetric soil water content (%)

Mulch	Date			
	29/11/89*	8/12/89	18/12/89	27/1/90
	0-5 cm depth			
Dactyladenia barteri	16.3	10.8	6.4	10.4
Gmelina arborea	16.1	10.1	6.5	6.8
Pennisetum purpureum (control)	18.5	11.2	8.8	9.1
LSD (0.05)	NS	NS	0.8	1.6
CV (%)	19.5	16.4	27.6	17.1
	5-15 cm depth			
Dactyladenia barteri	14.6	11.2	10.0	11.3
Gmelina arborea	14.6	11.3	8.8	8.7
Pennisetum purpureum (control)	15.3	11.9	10.3	10.1
LSD (0.05)	NS	NS	0.9	0.3
CV (%)	9.6	13.5	14.7	11.4

Note: * = Field capacity

Table 3. Effect of different mulches on plantain production during the first 2 years after planting

Mulch	Cycle length	Yield plant crop	Cumulative yield 2 YAP*
	(days)	(t ha^{-1})	
Dactyladenia barteri	449	15.1	23.2
Alchornea cordifolia	502	13.7	17.5
Senna siamea	486	12.8	18.1
Gmelina arborea	508	11.8	15.8
Pennisetum purpureum (control)	424	17.8	35.4
LSD (0.05)	38.4	2.5	5.1
CV (%)	7.2	16.7	26.9

Note: * YAP = Years after planting

4. Discussion

Of the four hedgerow species, *D. barteri* produced the highest amount of prunings after four years of fallow (figure 1). The advantage of this shrub during the first two years of the experiment was that it produced relativey high amounts of foliage from much fewer prunings than the three other hedgerow species. This shrub appears, therefore, to be a promising species for *in-situ* mulch production on Ultisols.

Considering the pruning frequency of the hedgerow species during the first two years, the results showed that *C. arborea* had to be pruned more frequently (5 times annually) than *A. cordifolia* (3 times), *S. siamea* (3 times) and *D. barteri* (once in the first year, twice in the second year) due to the rapid growth of shoots after coppicing. The use of *G. arborea* in agroforestry systems such as alley cropping would, therefore, result in higher labor requirements than the other three hedgerow species. The rapid growth of *G. arborea* and to some extent *A. cordifolia* and *S. siamea* coupled with the tendency of the coppice shoots to grow vertically rather than laterally required more frequent pruning to reduce light competition. In addition, rapid growth implies more exploitation of soil resources by these hedgerow species leading to more competition for nutrients with the associated food crop(s). The potentially high competition for soil resources under *A. cordifolia, S. siamea* and *G. arborea* hedgerows as a consequence of their rapid growth may in part have affected the growth of the intercropped plantain.

The results indicate that plantains in *P. purpureum* plots fruited earlier than those in the alley cropped plots. This confirms previous observations that *P. purpureum* is a suitable mulch in terms of early maturity, bunch weight and yield of plantain [Swennen 1984]. The implication of a shorter fructification duration as observed in *P. purpureum* mulched plots is that the first ratoon crop will start fruiting earlier; thus the following ratoon crop(s) will be produced sooner and land use will be more efficient.

Reduced soil temperature and high water content of surface soil under a 3 m x 2 m spaced plantain field mulched with *P. purpureum* were reported in a recent study carried out at Onne [Salau et al. 1992]. Among the hedgerow species, *D. barteri* was most similar to *P. purpureum* (table 2 and figure 2). However, *P. purpureum* required extra land for its production as well as high labor for cutting, transportation, application and the prevention of cuttings from sprouting. The higher yield obtained from *D. barteri* plots in comparison with the other hedgerow species is partly attributed to the slow decomposition of *D. barteri* [van der Kruijs et al. 1989], resulting in longer protection of the superficial plantain roots.

Poor plantain performance in *A. cordifolia, S. siamea* and *G. arborea* plots compared to *D. barteri* and *P. purpureum* mulched plots could also be due to the below ground competition. Ruhigwa et al. (1992) observed that the three hedgerow species had most of their fine roots in the top 20 cm layer. Therefore, these species can compete for soil resources with the shallow-rooted intercropped food crop(s) such as plantain [Swennen 1984, Swennen et al. 1988]. Our results have shown that the soil water depletion in the top 15 cm depth during the dry season was more pronounced in *G. arborea* plots than in *P. purpureum* and *D. barteri* plots. The soil water depletion in *A. cordifolia* and *S. siamea* plots is expected to be similar to that in *G. arborea* plots based on their fine root distribution pattern, growth habit, the amount of mulching materials produced and in their decomposition patterns.

5. Conclusions

The evaluation of the growth of four hedgerow species indicated that *D. barteri* appears to be most promising for in-situ mulch production for plantain cultivation. This species produced the highest pruning yield at cutting back after the fallow period than *A. cordifolia, S. siamea* and *G. arborea*. In addition, its growth did not seem to be affected by the reduced light resulting from the shade cast by the plantain trees. It also showed the merit of producing more mulching material from fewer prunings. Although *P. purpureum* was the best mulch treatment, its high labor requirement is not compensated for by increased yield. *D. barteri* is therefore considered as a potential source for low input mulch for plantain production. The final conclusion depends on the results of plantain productivity over several cycles.

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