Yield and Economics of Plantain Production under Six Weed Management Systems in a Derived Savanna Agro-Ecosystem

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Summary

The cost of weed management could account for up to 45% of the total cost of plantain plantation management in Nigeria. Thus, the importance of studies on integrated approaches to weed management that will enhance sustainability and profitability of False Horn plantain production. Field studies were conducted to evaluate the growth, bunch yield and economics of plantain production (cv "Agbagba") under six weed management techniques. The studies were carried out during the two cropping seasons 2005 and 2006 at Nsukka, Nigeria. Experimental layout was a randomized complete block design (RCBD) with six treatments; each replicated four times. The six weed management systems evaluated were weed-free (control), slashing at 8-weekly interval, mulching with sawdust, slashing + glyphosate application, mulching with saw dust + glyphosate application and glyphosate application alone. Plots that received mulching with saw dust + glyphosate treatment performed better than other plots in terms of reducing flowering period (334 days), increasing number of hands per bunch (4.7), number of marketable fingers per bunch (18.6), length of longest finger (24.2 cm), largest finger girth (15.7 cm), bunch yield (4.6 t/ha), return on investment ($11,126.2), benefit cost ratio (3.9) and gross margin (74.2%). There was an additive mulching + glyphosate effect on bunch yield and other economic indices assessed relative to where either mulching or glyphosate alone was applied resulting in about 65% fruit yield increase over weed-free by hoeing. Mulching plantain with sawdust + glyphosate at 2.16 kg/ha therefore was recommended based on better fruit yield and higher economic returns.

Résumé

Rendement et économie de la production de la banane plantain avec six techniques de gestion des mauvaises herbes dans un agro-système de la savane dérivée

Le coût de la gestion des mauvaises herbes pourrait représenter jusqu'à 45% du coût total de gestion des plantations de banane plantain au Nigeria. Ainsi, l'importance des études sur l'approche intégrée de la gestion des mauvaises herbes qui permettront d'améliorer la durabilité et la rentabilité de la production du faux corne plantain. Les études de terrain ont été menées pour évaluer la croissance, le rendement des grappes et l'économie de la production de la banane plantain avec six techniques de gestion des mauvaises herbes. Les études ont été menées au cours de deux saisons culturales en 2005 et 2006 à Nsukka, au Nigeria. Le dispositif expérimental était un dispositif en blocs aléatoires complets (blocs de Fisher) avec six traitements, chacun reproduit quatre fois. Les six systèmes de gestion des mauvaises herbes évalués ont été exempts de mauvaise herbe (témoin), coup de bâton à 8 semaines d'intervalle, paillage avec de la sciure, coup de bâton + application de glyphosate, paillage + application de glyphosate et de l'application du glyphosate seul. Les parcelles qui ont reçu le paillage + traitement au glyphosate avaient de meilleurs résultats que d'autres parcelles en termes de réduction de la période de floraison (334 jours), augmentation du nombre de mains par régime (4,7), le nombre de doigts commercialisables par grappe (18,6); la longueur du doigt le plus long (24,2 cm), la plus grande circonférence de doigts (15,7 cm), le rendement (4,6 t/ha), le retour sur investissement (11.126,2 $), le ratio coût-bénéfice (3,87) et la marge brute (74,2%). Il y avait un paillage additif + effet glyphosate sur le rendement du peloton et d'autres indices économiques évalués par rapport à ou soit le paillage ou le glyphosate seul a été appliqué. Le paillage de la banane plantain avec la sciure + glyphosate à 2,16 kg/ha a été recommandé et repose sur une amélioration du rendement en fruits et une augmentation du rendement économique.

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Introduction

Plantains, *Musa* sp. are major food staples in developing countries and in Western and Central Africa. About 70 million people are estimated to depend on *Musa* fruits for a large proportion of their daily carbohydrate intake (20). Plantains and bananas represent the world's second largest fruit crop with an annual production of 129,906,098 metric tons (8). They rank as the fourth most important global food commodity after rice, wheat and maize in terms of gross value of production (11).

Over the years a myriad of problems tend to militate against the production of this crop especially in the tropics. Some of these problems are weeds. Robinson (19) stressed that weeds are a major constraint in the production of this crop for subsistence farmers. In West Africa, weed growth is very prolific and lack of effective weed control is a key factor in the overall cotton yield decline (24). Currently, most researchers are particularly concerned with identifying management techniques that could suppress weed without paying attention to the economics of such identified technique. Anderson (1) reported that weeds in plantain can be controlled through mulching, use of herbicides and manually. According to Obiefuna (18), it is also feasible to control weeds in plantain biologically using Egusi melon (*Colocynthis citrullus*). Obiefuna observed that intercropping plantain with 5000 melon seeds per hectare suppressed weed growth and significantly increased plantain yield. At 2500 melon seeds per hectare, weed control was inadequate and at 10,000 melon seeds per hectare, plantain yield declined due to direct competition with the melon vines. Swennen (21) found mulching most efficient in weed control because a mulch layer impedes or prevent weed growth. Anderson (1) while recommending mulching as an efficient weed control technique enumerated several other mulched materials that could be used as hay, manure, grass clippings, straw sawdust, wood chips, rice hulls, paper and plastic films. Whereas, chemical weed control was judged to be expensive and noxious, manual weeding was reported as damaging maize root systems (22). Avarez De La Pena (2) reported good control of different weed species with the use of Roundup (glyphosate) applied at 3-5 litres/ha for *Cyperus* or at 5-7 litres/ha for *Cynodon dactylon* in bananas without injury.

Plantain production as a business like every other enterprise is aimed at profit maximization by the farmer. There is therefore the need to have a comparative understanding of the economic return on production investment of this crop. The aim of this study therefore was to evaluate the economics of producing plantain under six weed management systems considering the bunch yield and other yield parameters of the crop.

Table 1
Physico-chemical properties of the experiment site before commencement of the study

Soil property	Value
Mechanical analysis	
Clay (%)	29.6
Silt (%)	7.6
Fine Sand (%)	25.8
Coarse Sand (%)	37.2
Textural class	Sandy clay loam
pH (H_2O)	5.1
pH (KCl)	4.2
Carbon (%)	0.99
Organic Matter (%)	1.72
Exchangeable bases (meq/100g soil)	
Na	0.120
K	0.196
Ca	1.2
Mg	6.8
CEC	9.2
Available phosphorus	21.09

Materials and methods

Study location

The studies were conducted at the Teaching and Research Farm of the Department of Crop Science, University of Nigeria, Nsukka during the two cropping seasons of 2005 and 2006. Nsukka is located on latitude 06^{0}52'N, longitude 07^{0}24'E and at an altitude of 447.2 m above sea level. Rainfalls over the years have been bi-modal with peaks around July and September and spans from April to November (15). The field had been fallowed for three years before the commencement of the study. The vegetation is mainly derived savanna with some relics of rainforest distributed in patches (12). Predominant weed species in the area include *Panicum maximum* Jacq., *Aspilia africana* (Pers.), *Cyperus* sp. (Sedges), *Anthephora ampullacea* (Stapf & C.E. Hubbard), *Brachiaria lata* (Schumach) C.E. Hubbard, *Chromolaena odorata* (L.) and *Digitaria horizontalis* (Willd). The soil is a reddish sandy loam Oxisol of Nkpologu series (12).

Soil analysis

Soil samples were randomly collected from 10 sites (0-20 cm depth) over the entire experimental field using an auger before the commencement of the experiment. The samples were later mixed thoroughly and bulked for chemical analyses. The result of the physical and chemical analysis of the soil is shown in table 1.

Experimental materials

Plantain early sword suckers (cv. "Agbagba" a False Horn variety) were obtained from a healthy vigorously growing 4-year old plantain plantation at Ajassor in Cross River State of Nigeria. Suckers were cut back to 30 cm and the corms parred with a matchet. Fully composted poultry manure was obtained from

a commercial poultry farm. The sawdust used was collected from Nsukka timber shade. Glyphosate as Roundup (R) was supplied by "Candel Agrochemical" Company Ltd, Nigeria, an associate company of Monsanto Company, Belgium.

Field layout

A total land area of 50 m x 45 m (0.225 ha) was used for this study. The area was ploughed, harrowed and marked out into six plots; each replicated four times. The experimental layout was a randomized complete block design (RCBD) with four replications. Each plot representing a experimental unit had a dimension of 10 m x 7.5 m. The distance between two plots was 0.6 m and between two blocks was 1 m.

Suckers were planted at a spacing of 2.0 m x 2.5 m giving a total plant population of 15 suckers per plot, 360 suckers for the 24 plots and an extrapolated plant population of 2,000 suckers per hectare. Fully composted poultry manure mixed with Isozophos (nematicide) at the rate of 2.5 g per plant was applied to each stand 4 weeks after planting (WAP). Compound fertilizer NPK (20:10:10) was later applied 4 weeks after treatment application as a side dressing (13).

Application of treatments

Treatment comprised a weed-free (control) by hoeing, slashing at eight-weekly intervals using matchet, mulching with sawdust alone, mulching with sawdust + glyphosate, glyphosate + slashing and glyphosate application alone. Sawdust was applied at 75 cm radius and 5 cm thickness round each stand at the rate of 15 kg per stand. Glyphosate, as Roundup(R) N-(phosphoneomethyl) glycine, a broad-spectrum, systemic foliar herbicide was applied at the rate of 2.16 $kg.ha^{-1}$, using a CP-15 manual knapsack sprayer fitted with a shield to avoid contact. The first application started with 3 months old young plant foliage.

Data collection

Data were collected on days and months to first flowering, number of hands per plantain bunch, number of marketable fingers per bunch representing fingers that were fully formed at the time of harvesting, number of unfilled fingers, bunch fresh weight in kg/plant and t/ha. Data were also collected on the estimated cost of acquiring the piece of land for the project. Other variable costs recorded included cost of soil analysis, cost of land preparation (ploughing and harrowing), cost of digging planting holes, purchase of seeds at $ 0.69 each, purchase of manure and fertilizer, transportation of suckers, manure, fertilizer, hoeing, slashing and sawdust. Records were also taken on cost of applying sawdust and glyphosate. Considering the minimal cost of spraying equipment, hoes, machetes and other equipment used in this study and their relatively long life span, their depreciation costs were omitted in the cost item listed in this study.

Revenue accruing from the bunch yield sales was recorded using the prevailing bunch price of $ 0.92 per bunch in the open market. Both the benefit-cost ratio and the gross margin (%) were also calculated and recorded. The benefit-cost ratio was computed as: Revenue realized/Total cost, while the gross margin was calculated as

$$\frac{\text{Total Revenue} - \text{Total Cost}}{\text{Total Revenue}}$$ expressed in per cent.

Statistical analyses

The data on yield and yield components were subjected to analyses of variance (ANOVA) according to the procedure outlined for randomized complete block design (RCBD) using GENSTAT 7.3 edition (2003). Detection of differences among treatment means for significance were done using Fisher's Least Significant difference (F-LSD) at 5% probability level as described by Obi (14).

Results

The different weed management techniques significantly ($P< 0.05$) affected the yield and yield components of plantain in the field (Table 2). Plots where mulching + glyphosate was applied significantly ($P< 0.05$) flowered earlier (334 days) than plots where slashing at 8-weekly interval was applied (457 days). Slashing at 8-weekly interval significantly ($P< 0.05$) prolonged flowering more than other treatments.

The number of plantain hands per bunch (4.7), number of marketable fingers per bunch (18.6), length of longest finger (24.2 cm), circumference of largest fingers (15.5 cm), number of unfilled fingers (20.4) and bunch weight (6.1 kg/plant) were significantly ($P< 0.05$) higher in plots that received glyphosate + mulching treatment than those that were slashed at 8-weekly intervals, which produced the least number of hands per bunch (2.2), number of marketable fingers per bunch (6.8), length of longest fingers (12.1 cm), circumference of largest fingers (8.1cm), number of unfilled fingers (10.2), bunch weight per plant (1.7 kg) and yield per hectare per year (1.6 t). This resulted in 27.4%, 31.3%, 25.6%, 18.9%, 31.7%, 0.39%, and 116% increase in these bunch traits over those of slashing at 8-weekly interval. Other weed management techniques produced yields and yield components that was significantly higher ($P< 0.05$) than slashing at 8-weekly intervals but significantly ($P< 0.05$) lower than mulching + glyphosate treatment.

Both the fixed and variable cost items involved in the production process are shown in table 3.

The result shows that the cost of items like land acquisition, soil analysis, land preparation, digging of planting holes, purchase of seeds, transportations

Table 2
The effects of six weed management techniques on period to flowering, yield and yield components of plantain

Weed management technique	NDTF	NHPB	NMFPB	LOLF (cm)	COLF (cm)	NOUF	Bunch weight (kg/ plant)	Yield (t/ha/year)
Weed-free (by hoeing)	401.5	3.4	12.8	18.0	12.6	13.9	3.7	5.5
Slashing 8-weekly	457.4	2.2	6.8	12.1	8.1	10.2	1.7	1.6
Mulching with sawdust	439.0	3.9	15.3	19.4	13.6	15.0	3.6	5.3
Glyphosate + slashing	416.7	3.4	11.4	19.4	12.4	13.1	3.8	5.6
Mulching + Glyphosate	334.1	4.7	18.6	24.2	15.5	20.4	6.1	9.2
Glyphosate alone	374.8	3.0	10.4	18.1	11.5	12.5	2.3	3.5
F-LSD$_{(0.05)}$	50.0	0.7	2.5	2.4	1.0	1.7	1.1	1.6

NDTF: Number of days to flowering, NHPB: Number of hands per bunch, NMFPB: Number of marketable fingers per bunch, LOLF: Length of longest finger, COLF: Circumference of largest finger, and NOUF: Number of unfilled fingers.

Table 3
Fixed and variable cost items ($) in plantain production as affected by six weed management techniques

Item/(ha)	Weed management technique					
	Weed-free (By Hoeing)	Slashing 8-weekly	Mulching with sawdust alone	Glyphosate + slashing	Mulching with sawdust + glyphosate	Glyphosate alone
Hoeing	919.5	-	-	-	-	-
Slashing	-	3678.0	-	735.6	-	-
Sawdust (30,000 kg/ha)	-	-	206.9	-	206.9	-
Transportation of sawdust	-	-	69.0	-	69.0	-
Application of sawdust	-	-	46.0	-	46.0	-
Glyphosate (2.16 kg/ha)	-	-	-	41.4	41.4	41.4
Application of glyphosate	-	-	-	20.7	20.7	20.7
Total cost ($)	919.5	3678.0	321.9	797.7	384.0	62.1

of suckers, manure and fertilizer, purchase and application of poultry manure were uniform in all the six management techniques.

Other cost items like hoeing, slashing, cost of sawdust and glyphosate, their placement and transportation, varied with the treatment. On the whole, the total cost incurred using glyphosate treatment alone was the least ($ 62.1), followed by mulching with sawdust alone ($ 321.8), mulching + glyphosate ($ 383.9), glyphosate + slashing ($ 797.7), weed free ($ 919.5) and then slashing at 8-weekly interval ($ 3678.0) incurring the highest total cost. This result further shows that mulching with sawdust alone, mulching + glyphosate, glyphosate + slashing, weed-free and slashing at 8-weekly interval increased total input cost by 80.7%, 83.8 %, 92.2%, 93.2% and 98.3% respectively over treatment with glyphosate alone.

Results of this study further show that the fruit yield (6.1 kg/plant or 9.2 t/ha/year) produced in plots treated with mulching + glyphosate was appreciably higher than those produced in the other treatments (Table 2). Plots that received slashing at 8-weekly intervals produced the poorest fruit yield (1.7 kg per plant or 1.6 t/ha/year) compared to other treatments. The corresponding yield reduction of these treatments over mulching + glyphosate treated plots in terms of bunch yield was 38.0% for glyphosate + slashing, 39.3% for weed free, 41.3% for mulching with sawdust, 61.8% for glyphosate alone, and 82.3% for slashing at 8-weekly interval. At a prevailing market price of $ 0.92 per kg bunch, the total economic revenue realized by the production processes shows that plants that received mulching with sawdust + glyphosate produced the highest economic revenue of $ 1112.2. This revenue was over 456% higher than the total revenue accruing from slashing at 8-weekly interval, 160% by glyphosate alone, 70% by mulching with sawdust alone, 60% by weed-free and 60% by glyphosate + slashing. Similarly, treatment with mulching + glyphosate produced the highest benefit-cost ratio of 3.9. This ratio was followed by mulching with sawdust (2.3), glyphosate + slashing (2.1), weed-free (2.0), glyphosate alone (1.6) and slashing (0.03) in that order. Also, the gross marginal return on crops that received mulching + glyphosate of 74.2% was higher than other crops of other treatments. Plots where weeds were slashed at 8-weekly intervals produced the least gross marginal returns (-213.5%), which was lower than those produced from glyphosate alone (38.6%), weed-free (49.5%), glyphosate + slashing (52.3%), mulching with sawdust (56.9%) and mulching + glyphosate (74.2%) (Table 4).

Table 4
Gross revenue, benefit/cost and gross margin in plantain production as affected by six weed management techniques

Weed Management Technique	Gross Revenue ($)	Benefit Cost Ratio [1]	Gross Margin [2] (%)
Weed-free (by hoeing)	6749.3	2.0	49.5
Slashing 8-weekly	1967.8	0.03	-213.5
Mulching with sawdust	6528.6	2.3	56.9
Glyphosate + slashing	6896.4	2.1	52.3
Mulching with sawdust + glyphosate	11126.2	3.9	74.2
Glyphosate alone	4234.4	1.6	38.6

(1) Benefit/Cost Ratio = $\frac{\text{Revenue Realized}}{\text{Total Cost}}$

(2) Gross Margin (%) = $\frac{\text{Total Revenue – Total Cost}}{\text{Total Revenue}}$

(3) Cost of a 6 kg plantain bunch= $ 5.52

(4) Unit Cost of plantain per kg= $ 0.92

Discussion

Weed suppression in plantain plots using mulching with sawdust + glyphosate considerably reduced crop maturity period and enhanced bunch yield and other yield components assessed. This treatment increased bunch yield by about 100% over glyphosate + slashing or mulching with sawdust alone and by about 200% over glyphosate treatment alone. Combination of mulching + glyphosate therefore conclusively produced an additive bunch yield effect than when either mulching or glyphosate was applied alone. This effect was also found to be greater than where hoeing was done. Studies by Obiefuna (16) and Swennen and Wilson (20) showed that mulching gave higher and more sustained yield in field-grown plantain than did unmulched controls. According to Bhattachrayya and Madhava Rao (4) soil covers are beneficial to the plantation crops such as plantain because of their capacity to conserve moisture and make the moisture available over a longer period. IITA (10) reported a yield increase of about 400% of a mulched plantain plot over that of unmulched fertilized plot (22.8 t/ha vs 4.8 t/ha) at the end of the fourth year. In most instances, the yield responses of crops of glyphosate appeared to be inconsistent. While Thomas *et al.* (22) observed no influence of glyphosate on glyphosate-resistant maize, many other workers like Endfield *et al.* (7), Gilreath *et al.* (9), Yamashita and Guimaraes (24, 25), and Zablotowicz *et al.* (26) reported a yield reduction with glyphosate treatment. On the other hand, Clayton *et al.* (5) reported a yield increase of Canola (*Brassica napus*) with glyphosate application. They however explained that a yield response of the crop to glyphosate application was a function of the crop growth stage in relation to the stage of weed emergence. They were able to achieve the highest Canola yield in one location when glyphosate was applied early to the crop, but in another location (Lacombe and Edmonton), the yield benefit was achieved at late crop growth stages. They however concluded that the yield benefit likely resulted from the control of late-emerging weeds that exerted competitive pressure on Canola. The yield benefit recorded in this study by glyphosate application alone or over weed-free (control) may therefore likely be due to the suppression of the weeds that could have exerted competitive pressure to the crop at the early stages of the crop growth. This competitive advantage to the crop through weed suppression by glyphosate and the favorable beneficial effect created by mulching probably resulted in the additive mulching + glyphosate effect obtained in this study. The best performances recorded in the mulching with sawdust alone and mulching + glyphosate plots agree with an earlier report of Baiyeri *et al.* (3) which showed that the use of Siam weed (*Chromolaena odorata*) mulch enhanced more vigorous plant growth and induced more sucker production. The significantly better fruit yield of plantain in the mulching + glyphosate treated plots could be attributed to the effective weed control, increased moisture holding capacity of the soil and enhanced water use efficiency of the plantain created by the weed management system. This result is in agreement with De *et al.* (6) who reported decreased soil moisture depletion and thus increased yield of grain sorghum. This result also agrees with Obiefuna (17) and Wilson (23) who reported heaviest bunches with the highest number of hands and marketable fingers with sawdust mulch.

From the result of this experiment, it is evident that plots subjected to slashing at 8-weekly interval weed management option performed poorest in terms of both plant growth and bunch yield when compared to the other weed management practices. This poor performance might probably be attributed to the increased root density of the slashed weeds which subsequently reduced water infiltration thereby affecting the circulation of air and mineral nutrients in the soil. Besides, it could probably be due to competition for water and nutrients before the weeds were slashed. Management practices also revealed that the highest benefit-cost ratio of 3.9 was recorded for yields from the mulching + glyphosate treated plots. This implies that for every one dollar used in the production of plantain using mulching + glyphosate

weed management option, there is a profit of $ 3.9 on it. This treatment option also recorded the highest gross margin of 74% when compared to other weed management techniques with slashing at 8-weekly interval still recording the least and negative gross marginal returns of -213.5%.

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