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EFFECT OF WEED CONTROL METHODS ON PROFITABLE KENAF (*HIBISCUS CANNABINUS*) PRODUCTION IN RAINFOREST-SAVANNA TRANSITION AGRO-ECOLOGY OF NIGERIA

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ABSTRACT: *A study was conducted at Institute of Agriculture Research and Training, Ibadan in 2015 and 2016 to investigate the effect and profitability of selected weed management methods on weeds, kenaf growth and yield. Ibadan is a rainforest-savanna transition agro-ecology. Seven treatments were applied, viz. weed-free control, weedy control, pre-emergence herbicide (metolachlor 1.44kg active ingredient/ hectare (a.i/ha) + hoe weeding at 4 weeks after planting (WAP), Citrullus lanatus (melon) cover + hoe weeding (4 WAP), sweet potato cover + hoe weeding (4 WAP), mulch cover (Panicum maximum) + hoe weeding (4 WAP) and two hoe weeding regimes at 4 and 8 WAP. Results showed that weed-free treatment had the tallest kenaf plant height, widest butt girth and greatest number of leaves in both years of trail. Dissimilarity to other treatments in plant height, butt girth, number of leaves, canopy cover, and core yield was found in weedy control which had the least value for these parameters throughout the study. However, butt girth was comparable across treatments applied except the weedy control. With the exception of weedy control and weed-free, other treatments had kenaf plants with similar canopy width which were significantly greater than that of weedy control and significantly less than that of weed-free treatment. Relative to weedy control, other weed management treatments had a significantly reduced weed dry weight and weediness. Kenaf plant height had significant positive correlation with butt girth, bast fibre, core fibre, canopy cover and weed control rate. However, weed biomass and weediness had significant negative correlation with kenaf traits measured. Partial budgeting analysis showed that Net income (NI) in bast fibre was highest in weed free (₦3,608, 324.00/ha = US$12, 027.75/ha) and lowest net income (NI) was recorded in weedy control (₦437, 098.25/ha = US$1, 456.99/ha).*

KEYWORDS: Weed management, Cover Crop, Kenaf Production, Profitability

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is a warm season annual fiber crop closely related to cotton and okra. As the commercial use of kenaf continues to diversify from its historical role as a cordage crop (rope, twine, and sackcloth) to its various new applications including paper products, building materials, absorbents, and livestock feed, choices within the decision matrix will continue to increase and involve issues ranging from basic agricultural production methods to marketing of kenaf products. These management decisions will require an understanding of the many different facets of kenaf production as a fiber, feed, industrial and seed crop. In order to achieve an economic and large scale production of kenaf, weed management is of importance in kenaf cultivation.

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Kenaf grows quickly and competes well with weeds. However, the initial growth is slow and weed competition at this stage can be critical on the overall performance of the crop. Ajibola and Modupeola (2014) reported a significant reduction in kenaf growth and yield when weeded once or kept weedy. Consequently, weed control is often required for optimum kenaf performance. Different weed control methods are used in crop production with varying degree of success, shortcomings and profitability. Manual weeding is an effective means of controlling weeds (Fischer and Hill, 2004) and has been reported by Chikoye *et al*., (2002) as the predominant method of weeding used by smallholder farmers in Africa. It has been discovered that 25 – 40 people are needed to weed one hectare of maize farm and this may account for 50 – 80 % of total labour budget (Darkwa *et al*., 2001; Chikoye *et al*., 2002). The mass migration from rural farm areas to urban centre increases cost of labour and encouraged dependence on herbicides usage (Fischer *et al*., 2004). However, this does not impact on the value and price of the crops (Saqib *et al*., 2012). Delayed weeding causes significant crop losses (Chikoye *et al*., 2004) especially when economic threshold of weed infestation is exceeded. Hoe weeding is uncongenial and laborious. However, resource poor farmers have depended on this manual weeding method for a long time.

Chemical control is better alternative because it is cheaper, faster and gives better control (Chikoye *et al*., 2004). Adigun *et al*., (1993) reported that herbicides use is more profitable than hoe-weeding for cropping activities in Nigeria. A similar report was given by Nezeer *et al*., (2004), that chemical weed control gave better results and attractive return than hoe weeding in wheat field infested with broadleaf weeds. This was also in line with Koricocha *et al*., (2011), who noted that a mixture of atrazine + metolachlor gave higher marginal return per naira in sweet potato (*Ipomea batatas*) production over hand weeding. However, negative environmental impact and human health hazard are major downsides to herbicides application (Johnson and Mortimer, 2005; Khaliq *et al*., 2012).

Mulching crop field for weed management has been reported to give excellent result in terms of weed control and benefit cost ratio in maize (Omovbude and Udensi, 2012). James (1999) reported that mulching eliminates the establishment of vegetation germinant and weeds did not readily reestablish following the deterioration of the mulch. Mulch reduced the weed seed-bank by creating environmental sieve and the fibrous cover improves water infiltration and soil structure. The soil is more resilient to high temperature and erosion. Grass mulch was identified among other suitable materials as good mulching material for weed control (Anderson, 1996).

Cover cropping suppresses weeds and limit weeding regimes. Chikoye *et al*., (2000) reported that simultaneous cropping of cover crops with arable crops has a good potential for reducing cost of weed control and production. Relay intercropping involving maize - velvetbean combination at planting interval of 40 – 45 days was reported to have relatively increased the yield of maize compared to yield from pure stands of maize (Buckles *et al.*, 1998). However, where soil fertility is limiting, the yield of the food crop may be compromised due competition with cover crops for soil nutrients.

Some efficacious pre-emergence herbicides have been used with positive result for weed control in kenaf (Webber, 1992). To produce enough biomass of high quality, there is need to identify various treatments and the best economically viable management practices for the control of weeds (Agbaje *et al*, 2008). However, scanty information is available on weed management in kenaf and the profitability of these weed control methods in rain forest – savannah agro-ecology of Nigeria. Further study on the use of chemical and non-chemical

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methods of weed control in concurrence with kenaf economic production is of importance. These will facilitate the cultivation of kenaf amongst farmers as well as integration of kenaf into farmers'cultural practices. Hence, this study investigated the profitability of some selected weed control methods for weed control in kenaf in rainforest-savanna transition agro-ecology of southwestern Nigeria.

MATERIALS AND METHODS

Field experiments were carried out at the Institute of Agricultural Research and Training (IAR&T) Ibadan ($7^o38'$ N 3^o 84' E) between June and September, 2015 and 2016. Prior to planting, the experimental plot was a year fallow with major weeds such as *Tectonia diversifolia*, *Panicum maximum*, and minor weeds such as *Maricus* spp, *Tridax procumbens*, and *Talinum fruticusum*.

The land was ploughed and harrowed before planting. Kenaf variety – Ifeken 400 was planted with four seeds per hole with a spacing of 50 x 10 cm. This was later thinned to two plants /stand at two weeks after planting (2 WAP). Fertilizer was applied at the rate of 150 kg/ha of NPK 15:15:15 at 4 and 7 WAP in two equal halves. Treatments were randomly assigned to the plots (3m x 3m) in a Randomized Complete Block Design (RCBD) with three replicates. The treatments were different weed control methods viz. weed-free control, weedy control, pre-emergence herbicide application of metolachlor at the rate of 1.44 kg (a.i)/ha, sweet potato cover (*Ipomoe batatas*) + hoe weeding (4 WAP), Egusi- melon cover (*Citrullus lanatus*), manual hoe weeding (4 and 8 WAP) and mulching (*Panicum maximum*) + hoe weeding (4 WAP)

Data collection

Data were collected from ten tagged kenaf plants in each plot. Kenaf plant height and stem butt diameter were measured using a graduated meter rule and Venier calipers respectively. Kenaf leaf number at harvest was counted and the average recorded per plot. The weeds were identified with Hand book of West African weeds by Akobundu and Agyakwa, (1998). Kenaf canopy cover, weediness and weed control rates (WCR) were visually rated using a range of 0 – 10, where 0 represents no score and 10 is the maximum score. Fibre yield (bast and core) was determined after retting and oven drying at 80^0C for 48 hours in Carbolite Oven and later weighed with sensitive scale (And 2000). Data collected were analyzed statistically, with means separated using the Duncans' Multiple Range Test (DMRT). The relationship between the parameters was also determined.

Partial budgeting Analysis

In determining the most economically acceptable treatment practiced, partial budgeting analysis was carried out to estimate the gross value of the bast fibre yield from the different treatments on weed control using the prevailing market price of kenaf fibre and inputs used. The prevailing wage rates paid for labour were used to estimate the labour costs. Economic data from cost of inputs and farm operations used for each treatment were used to estimate the total cost of production (TCP). The gross income (GI) was a product of the total yield and price of prevailing price of fibre which is N850 per kg. The GI minus TCP is the net income.

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RESULTS

Kenaf plant height

The result showed that weed-free plots had the highest plant height throughout the study, whereas weed control had lowest plant height consistently (Table 1 & 2) and it was comparable with kenaf plant height in Egusi melon cover + hoe weeding and hoe weeding regimes (4 + 8WAP) in 2015 (Table1). Herbicide + hoe weeding and mulching + hoe weeding also had similar kenaf plant height which is not significantly different from the maximum recorded in weed-free plot (Table 1 & 2). In 2016, kenaf plant height was comparable among treatments applied except in weedy control plot.

Widest kenaf stem butt was found in weed-free plots throughout the study (Table 1& 2). This was comparable with two hoe weeding of regimes (4 + 8WAP), herbicide + hoe weeding and mulching + hoe weeding in 2015 (Table 1) and all other treatments except weedy control in 2016 (Table 2). However, thinnest kenaf stem butt found in the weedy control (Table 1& 2).

Leaf Number

Weed- free and hoe weeding (4 + 8 WAP) treatments had the highest number of kenaf leaf per plant in 2015 and 2016 respectively. These were comparable with each other and with mulching + hoe weeding. Weedy control had the lowest number of leaves and it is significantly different from other treatments. Meanwhile, other treatments had comparable number of kenaf leaves (Table 1 & 2).

Weed Dry Weight

Maximum weed dry weight was recorded in weedy control. This was distinctly higher than the weed dry weight produced from other treatments. Minimum weed dry weight was found in weed-free plot (Table 1 & 2). Other treatments applied gave comparable weed dry weight at 12WAP except sweet potato cover in 2015 trail (Table 1). However, sweet potato cover was comparable with herbicide + HW (4WAP) which had the lowest number of leaves amongst the weed management treatments in 2016 (Table 2).

Weediness

Weedy control had the highest weediness rate ($^{8.67}/_{10}$) and ($^{8.00}/_{10}$). The lowest weediness was found in weed-free plot. Other treatment applied had comparable weediness score in both years of the study (Table 1 & 2)

Weed Control Rate (WCR)

The highest weed control rate was recorded in the weed-free plot. Weedy control had the lowest score ($^{0}/_{10}$) and it is significantly less than other treatments (Table 1 & 2). Other treatments had comparable weed control rate in the range of $^{6}/_{10} - ^{7.33}/_{10}$ in 2015 (Table 1) and $^{6.5}/_{10} - ^{7.77}/_{10}$ in 2016 (Table 2).

Canopy Cover

The lowest canopy cover rate of ($^{2.33}/_{10}$) and ($^{3}/_{10}$) were recorded in weedy control plots. Weed-free plots gave the highest canopy cover rate of ($^{8.33}/_{10}$) and ($^{9}/_{10}$) (Table 1 & 2) which was comparable to Sweet potato cover + hoes weeding, Herbicides + hoe weeding and mulching +

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hoes weeding in 2015 (Table 1). Except for weed-free plots, weed management treatments applied had comparable canopy cover rate in the range of $^{6.67}/_{10}$ – $^{7.00}/_{10}$, in 2015 and $^{7.00}/_{10}$ – $^{7.50}/_{10}$ in 2016 (Tables 1& 2).

Bast Fibre Yield

Highest bast fibre yield was recorded in weed-free plot and the lowest was found in weedy control. Other treatments applied had comparable bast fibre yield (Table 1 & 2). In 2016, bast fibre yield from weed-free plot was comparable with those harvested from hoe weeding (4 + 8WAP), herbicide + hoe weeding and mulching + hoe weeding (Table 2).

Core Fibre Yield

Weed-free had the highest core fibre yield throughout trial. This was distinctly higher than core fibre yield from other treatments. Comparable core fibre yield was recorded in other treated plots. Weedy control had the lowest core fibre yield in 2015 and 2016 (Tables 1 & 2).

Correlation of kenaf traits and weed growth

Kenaf traits had varying relationships with weed growth. Kenaf plant height had significant positive correlation with butt girth, weed control rate, canopy cover, bast fibre, and core fibre in both years of the trial. However, weed biomass and weediness had significant negative correlation with plant height, butt girth, weed control rate, canopy cover, bast fibre and core fibre in both years of the study (Table 3).

Weed flora composition

Table 4 shows the weed flora composition as influenced by the treatments applied at the end of the study. Weedy control had twelve weed species these cut across different plant families. Egusi melon cover + hoe weeding and Sweet potato cover + hoe weeding had seven and eight weed species respectively. Hoe weeding and Mulching + hoe weeding had four weed species each.

Associated Cost of Production and Returns

The cost of production (CP) for each treatment was estimated in Table 5. The results showed that highest Net income (NI) was recorded in weed-free (₦3, 286,480/ha) and lowest in weedy control, (₦442, 585 / ha). The low NI value recorded in the weedy plots might not be unconnected to marked reduction in bast fibre yield from critical weed infestation. The treatments applied had NI in this descending order; Herbicide + HW (4WAP) > Mulching + HW (4WAP) > HW (4 + 8WAP) > SP + HW (4WAP) > EM + HW (4WAP). .

DISCUSSION

Results showed that tallest kenaf plant height was recorded in weed-free plot in both years of the trial. Dissimilarity in plant height was found between treated plots and weedy control that had the shortest plants in both years of the study. Crop – weed competition in weedy control plot was critical. Thus, reduction in kenaf plant height and other parameters measured was evident in the weedy control plots. This is in line with the report of Ajibola and Modupeola

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(2014) that a weedy kenaf plot and once weeded plot suffered comparable reduction in plant height and seed yield.

Hoe weeding (4 + 8 WAP) may be too late to control weeds and give optimum kenaf productivity. This justifies the findings of Ajibola and Modupeola (2014) that suggested early weeding at 3 and 6 WAP for optimum seed yield in kenaf. Weed interference in crop fields are critical during the early crop plant establishment and growth. Delayed or untimely weeding may reduce crop performance significantly (Chikoye *et al*., 2004). This might be responsible for fairly to low fibre yield recorded in Hoe weeded plots (4 + 8 WAP).

The simultaneous planting of cover crop for weed suppression and reduce cost of weed control and production in food crops was reported by Chikoye *et al*., (2000). However, reduction in kenaf component yield from weed invasion may be aggravated under limited soil nutrients (Aluko and Olasoji, 2017). Hence, the introduction of cover crops to smother weeds may be responsible for the reduction in kenaf plant height compared to the maximum from the weed-free plots. The competition for soil nutrients involving cover crops and kenaf plants cannot be under estimated. This might be responsible for reduction in kenaf performance in Egusi melon cover + hoe weeding and sweet potato + hoe weeding treated plots. The time lag in the establishment and canopy formation in Egusi melon and sweet potato is prolonged to combat eminent weed interference at early growth of kenaf plant. This invariably influenced the success of this method of weed control.

Comparable high bast yield in weed-free control plot, herbicide + hoe weeding (4WAP) and mulching + hoe weeding (4WAP) in 2016 might have resulted from early and better weed control methods applied. Chemical weed control has been reported to be effective (Adigun *et al*., 1993; Chikoye *et al*., 2004; Nazeer *et al*., 2004; Korieocha *et al*., 2011) likewise, hoe weeding (Fischer and Hill, 2004). The combination of these weed control significantly reduced early weed competition, prolonged season-long weed suppression and improved kenaf fibre yield. Mulching + hoe weeding (4WAP) reduced weed flushes as a result of mulch barrier, environmental sieve was imposed that prevented weed seeds germination. Hoe weeding in mulched plot further enhanced the effectiveness of weed control. According to James (1999), mulching eliminates the establishment of vegetation germinant and reestablishment of vegetation is retarded following the deterioration of mulch materials. The mechanism of weed suppression in plant based mulches may be partly allelopathic. Mulching + HW (4WAP) suppressed weeds and gave significantly high NI. This was similar to the findings of Omovbude and Udensi (2014) that reported the profitability of sawdust mulch for weed suppression in maize cultivation.

CONCLUSION

Weeds interference in kenaf field significantly reduced fibre yield. Delayed weeding may critically reduce kenaf fibre yield. Early anticipation and control of weeds in kenaf plots significant improved kenaf components yield as recorded in weedfree plot and Herbicide + HW (4WAP). Reduction in weed pressure through the use herbicide for pre-emergence weed control + hoe weeding (4WAP) and application of mulch + hoe weeding (4WAP) will improve kenaf fibre yield for higher net return. Invariably, cultural practices that can guarantee early weed suppression should be adopted. Integrated weed management will enhance season-long weed suppression and guarantee profitable kenaf productivity.

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Table 1: Effects of weed management strategies on kenaf traits and weed growth at 12 WAP in 2015

Treatments	Plant height (cm)	Stem butt (cm)	Leaf number	Weed dry weight ($g.m^{-2}$)	Weediness (0 – 10)	WCR (0 -10)	Canopy cover (0 - 10)	Bast fibre yield (kg/ha)	Core Yield (kg/ha)
Weedy control	105.05^{c}	0.87^{c}	54.00c	174.99^{a}	8.67^{a}	0.00^{c}	2.33^{c}	687.19^{c}	1012.12^{d}
Weed-free	191.54^{a}	1.86^{a}	79.00^{a}	5.53^{d}	0.00^{c}	10.00^{a}	8.33^{a}	4856.08^{a}	6670.07^{a}
E/M Cover + HW (4 WAP)	127.80^{bc}	1.22^{b}	65.00^{bc}	53.14^{b}	2.33^{b}	7.33^{b}	6.67^{b}	2517.45^{b}	4251.76^{b}
Hoe weeding (4 + 8WAP)	131.27^{bc}	1.48^{ab}	75.00^{ab}	40.53^{b}	2.00^{b}	7.00^{b}	6.67^{b}	2135.89^{b}	4513.49^{b}
S/P Cover + HW (4 WAP)	145.93^{b}	1.28^{b}	57.00^{bc}	34.89^{c}	2.33^{b}	6.67^{b}	7.00^{ab}	2206.67^{b}	4452.48^{b}
Herbicide + hoe weeding	167.86^{a}	1.44^{ab}	67.00^{b}	53.56^{b}	2.60^{b}	7.33^{b}	7.00^{ab}	2685.57^{b}	4773.20^{b}
Mulching + HW 4WAP	163.87^{a}	1.39^{ab}	71.00^{ab}	45.56^{b}	3.00^{b}	6.00^{b}	7.00^{ab}	2459.85b	4829.65^{b}

Table 2: Effects of weed management strategies on kenaf traits and weed growth at 12 WAP in 2016

Treatments	Plant height (cm)	Stem butt (cm)	Leaf number	Weed dry weight (kg/ha)	Weediness (0 – 10)	WCR (0 - 10)	Canopy Cover (0 - 10)	Bast fibreYield (kg/ha)	Core Yield (kg/ha)
Weedy control	173.13b	0.89c	51.00c	113.64a	8.00a	0.00c	3.00c	700.10c	1092.00d
Weed-free	248.33a	1.99a	74.00a	1.36f	0.00c	10.00a	9.00a	4098.80a	7816.83a
E/M Cover + HW (4 WAP)	217.73a	1.77a	61.00b	93.64b	0.00c	7.00b	7.00b	3096.00b	5037.86c
HW (4 + 8 WAP)	240.27a	1.90a	77.00a	27.95e	3.00b	6.50b	7.50b	3294.80b	5581.54bc
S/P Cover + HW (4 WAP)	214.27a	1.09b	64.00b	66.78c	3.50b	7.00b	7.00b	3137.40b	5448.32bc
Herbicide + HW (4 WAP) weeding	203.60a	1.87a	60.00b	56.08c	3.00b	7.50b	7.50b	3583.10ab	6095.91b
Mulching + HW (4 WAP)	238.87a	1.83a	74.00a	41.16d	3.00b	7.77b	7.00b	3453.00ab	6017.85b

Legend: WCR- weed control rate, E/M- Egusi melon, S/P- sweet potato, HW- hoe-weeding

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Table 3: The relationship between kenaf traits and weed growth in 2015 and 2016

Treatments	Plant height	Butt girth	Weed biomass	Weediness	WCR	Canopy cover	Bast yield	Core yield
Plant height.	-	0.87**	-0.52**	-0.53*	0.71**	0.48*	0.61**	0.68**
Butt girth	0.90**	-	-0.56**	-0.51*	0.72**	0.64**	0.65**	0.87**
Weed biomass	-0.59*	-0.63**	-	0.71**	-0.93**	-0.71**	-0.54**	-0.51*
Weediness	-0.62*	-0.42**	0.69**	-	-0.87**	-0.65**	-0.58*	-0.56*
W C R	0.68**	0.68**	-0.91**	-0.79**	-	0.61*	0.62*	0.59*
Canopy cover	0.56*	0.69**	-0.63**	-0.62**	-0.51*	-	0.58*	0.66*
Bast yield	0.68**	0.67**	-0.59*	-0.54**	0.59*	0.66*	-	0.57*
Core yield	0.71**	0.81**	-0.52**	-0.48*	0.61*	0.73**	0.65*	-

** Correlation is significance at P≤ 0.01 (2 tailed), * correlation is significance at P ≤ 0.05 (2 tailed).

Yellow coloration and ordinary print show 2015 and 2016 correlation values respectively.

Table 4: Weed flora composition as influence by the treatments applied in 2015 and 2016

Weed Species	Family	Morphology	Life-cycle	Herbicide + HW	S/P cove + HW	Weed-free	Manual weeding	E/M cover + HW	Weedy control	Mulching + HW
Penicum maximum	Poaceae	Grass	P	-	b	-	-	b	b	b
Pennisetum purpureum	Poaceae	Grass	P	b	b	-	-	a	a	b
Cynodon spp	Poaceae	Grass	A	a	-	-	-	-	a	-
Tithonia diversifolia	Asterceae	Broad leaf	A	b	a	-	a	-	b	a
Ageratum conizoides	Asterceae	Broad leaf	A	a	a	-	a	a	a	a
Tridax procumbens	Asterceae	Broad leaf	A	-	b	-	-	b	b	-
Commelina communis	Herbaceous	Spider worth	P	b	b	b	-	-	a	-
Talinum frutricuson	Herbaceous	Broad leaf	A/P	-	b	b	-	-	a	-
Centrosema pubisens	Fabaceae	Broad leaf	A	-	-	-	b	b	b	-
Mimosa pudica	Fabaceae	Broad leaf	A	-	-	-	b	b	a	-
Chromolea na odorata	Asterceae	Broad leaf	A/P	-	b	-	-	b	b	-

Legends: P- perennial, A- annual, A/P- Annual/Perennial, a- major weed, b – minor weed, HW – hoe weeding, E/M – Egusi melon, S/P – Sweet potato

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Table 5. Partial Budgeting Analysis for the Treatments

Variables	Weedy control	Weed-free	E/M Cover + HW (4 WAP)	HW (4 + 8 WAP)	S/P Cover + HW (4 WAP)	Herbicide + HW (4 WAP)	Mulching + HW (4 WAP)
Cost of seed	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Cost of labour	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Land preparation	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Herbicides	0.00	0.00	0.00	0.00	0.00	12,500	0.00
Cost of weeding	0.00	45,000	15,000	30,000	15,000	15,000	15,000
Cost of harvesting and retting	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Total Cost	152,500	197,500	167,500	182,500	167,500	180,000	167,500
Bast Fibre yield (Kg/ha) (Annual average)	693.65	4477.44	2806.73	2715.34	2672.04	3134.34	2956.43
Price/Kg/ha (₦)	850	850	850	850	850	850	850
Gross Income (₦)/ha	589,598.25	3,805, 824.00	2,385,716.25	2,308, 043.25	2,271,229.75	2, 664, 184.75	2,512,961.25
Net Income (₦)/ha	437,098.25	3,608,324.00	2,218,216.25	2,125,543.25	2,103,729.75	2,484,184.75	2,345,461.25

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