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Full Length Research Paper

Influence of agronomic practices on yield and profitability in kenaf (*Hibiscus cannabinus* L.) fibre cultivation

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Field trials were conducted in 2003 and 2004 at the Institute of Agricultural Research and Training, Ibadan (7° 38' N 3° 84' E), Nigeria to determine the influence of some agronomic practices on yield and profitability in kenaf bast fibre production. Three kenaf varieties, Cuba 108, Ifeken 400 and Ibadan local, were subjected to three agronomic practices in a split-plot experiment. The agronomic practices include the farmers' practice where no input was used and two levels of improved management practices (IMP) where the influence of pests and soil nutrition were ameliorated. The results showed that total dry matter, fibre and core yields increased by 150 – 170%, incidence of nematode reduced by 50% and severity scores of insects attack on foliage reduced by 83% in the improved management practice (IMP). The three kenaf varieties differ significantly in their leaf biomass, reaction to nematode and foliage pests attack. In the control treatment, Ibadan local had more leaf biomass and was tolerant to pests attack while other varieties were susceptible. Economic analysis showed that net return was higher in the local cultivar than in the improved varieties under the farmers' practice. However, economic returns and marginal rate of returns were higher under IMP's than the control in Cuba 108 and Ifeken 100 varieties than the local cultivar.

Key words: Management practices, economic viability, soil nutrition, pest.

INTRODUCTION

All the component parts of a kenaf plant, that is, leaves, bast fibre and core are of industrial importance. The leaves are rich in protein (15 - 30%) and are used as animal feed (Banhgoo et al., 1986; Francois et al., 1992; Webber, 1992). The bast fibre can be converted to pulp for newsprint, hydro-carbon free bags, ropes and textiles (Theisen et al., 1978; Robinson, 1988; Webber et al., 2000; Kuchinda and Ogunwole, 2000). The core can be used as animal beddings, soil amendments, oil absorbents in chemical industries and in ethanol production. Ethanol bio-fuel is a biodegradable energy source that can replace or partially substitute petroleum. Ethanol produced from kenaf ("kenafanol"), is currently being marketed in the United States of America (Castleman, 2000).

To produce enough biomass of high quality which can be converted to fibre, animal feed, ethyl alcohol and other chemicals, there is need to identify kenaf varieties with potential for high biomass yield and specific quality traits. The best economically viable management practices for growing such kenaf variety must also be developed. This is necessary for farmers and industrialists to benefit from the recent innovative use of kenaf as a bio-renewable energy resource

Kenaf production is rain-fed in Nigeria and the crop is attacked by high population of flea beetles and other insects that attack both the leaves and pods. The effects of the pest attack are extensive because farmers lack the insecticides and technologies to control them (Taylor, 1974; Fadare, 1981; Fadare and Amusa, 2005). Protection of leaf biomass in kenaf from pest attack will not only enhance crop growth due to longer leaf area duration and higher photosynthetic capacity, it will also preserve the

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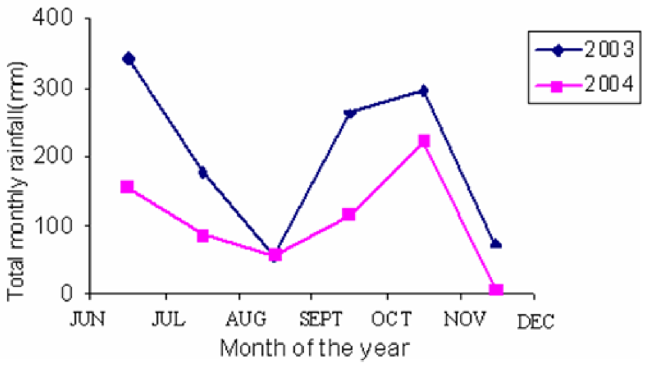

Figure 1. Rainfall pattern during the period of trial.

leaf biomass which are utilized as animal feed component. The control of flea beetles (*Podagrica* spp.) and other insect pests at vegetative stage had been reported to enhance yield and productivity in okra (Agbaje and Daramola, 2000).

Plant parasitic nematodes, particularly *Meloidogyne* spp., has been identified to be a major problem affecting kenaf production. It causes stunted growth and death of plant seedlings. Plants that survived high nematode infestation often have lower dry matter yield than the uninfected plants (Summer and Seale, 1958). The integration of suitable crop rotation system, fallow period, chemical control and development of tolerant varieties are the suggested strategies for nematode control in kenaf (Shoyinka, 1990).

Kenaf has high fertilizer requirement and responds to 112 kg of N ha^{-1} (Wood and Stuart, 2001; Banghoo et al., 1986; Adamson et al., 1979; Stricker, et al., 2001; Webber, 1996; FAO, 2002). Most tropical soils are poor in nutrient status hence the supplementary addition of fertilizers in kenaf production is necessary. The low soil fertility is caused by intensive cultivation of the soils and short fallow periods which are common practices in the region. These practices are encouraged by the high population pressure on agricultural lands and rapid infrastructural developments in the rural agrarian communities (Pieri, 1992; Agbaje et al., 2005)

This project aims at comparing farmers' practice with two improved production practices which ensured that the effects of pests attack and inadequate soil nutrition were ameliorated during kenaf production. It has been established that the sustenance of such innovations depend, to a large extent, on its effectiveness in increasing productivity and generating commensurate returns to farmers. Farmers' constantly weigh the resulting cost and benefit associated with an innovation before deciding whether to adopt or continue with an innovation or not (Sevilleja, 2000; Clayton, 2005). The economic analysis will assess the economic viability and sustainability of the different management options in kenaf fibre production before the technologies are transferred to the farmers.

MATERIALS AND METHODS

Location and soil characteristics

Field trials were conducted in 2003 and 2004 at the Institute of Agricultural Research and Training (IAR&T), Ibadan, to determine the effect of improved management practices on kenaf productivity. Ibadan (7^{o} 38'N 3^{o} 84' E) is located in the dry rain forest area of South-western Nigeria. The soil of the experimental site is Rhodic haplustalf and the physical and chemical characteristic of the soil were taken before planting from within 15 cm depth in both years of the trial. The average soil characteristics are pH 6.80, sand 88%, silt 10%, clay 2%, exchangeable bases (Me/100 g): Ca 0.88, Mg 2.0, K 0.37, Na 0.47, H^{+} 0.07, CEC 3.79, %base 98%, %OC 0.68, %N 0.07, average P (ppm) 13.54, average Zn (ppm) 9.85. The total monthly rainfall during the period of experiment is in Figure 1.

Experimental treatments

Three kenaf varieties, Cuba 108, Ifeken 400 and Ibadan Local obtained from the Institute of Agricultural Research and Training, Ibadan and three production practices including two improved management practices and a control constituted the experimental treatments. The control practice mimics the resource poor farmers by not applying fertilizer or pesticides. Improved management practice 1(IMP 1) involves the following cultural practices: application of (a) compound fertilizer N_{60} P_{30} K_{30} ha^{-1} (b) 100 kg ha^{-1} of Furadan 3G (30 g kg^{-1} Carbofuran (carbamates) nematicide granules) and (c) two pre-flowering spray of Nuvacron (Monocrotophos) insecticide at a concentration of 0.68 kg ha^{-1} active monocrotophos in 225 L water. These treatments were applied with the fertilizer and nematicide granules in two equal splits at 4 and 6 WAP while the insecticide was applied at 4 and 5 WAP.

Improved management practice 2(IMP 2): The IMP 1 nitrogen rate and weight of Furadan ha^{-1} were doubled and the insecticide spray regimes extended by two additional sprays to arrive at the IMP 2. The nematicide and fertilizer were applied in two equal splits at 4 and 6 WAP while the insecticide was applied weekly from 4 to 7 WAP.

Experimental design and farm practices

The experiment was laid in a split plot design with the management practices as main plot and the varieties as sub-plot. The treatments were replicated six times within a plot area of six rows of 5 m length and an inter-row spacing of 50 cm. Plots were ploughed and harrowed and a pre-emergence herbicide, Pendimethalin (500 EC) at the rate of 1.7 kg ai ha^{-1} was applied, using a knap sack sprayer. Seeds were planted within an intra-row spacing of 10 cm and thinned to two plants per stand at three weeks after planting. Planting was done on 10^{th} June, 2003 and 8th June, 2004 and crops were harvested on 16^{th} and 20^{th} September, 2003 and 2004, respectively.

Agronomic traits

Plants were uprooted from four inner rows in each plot at 25% flowering and the roots cut off for nematode assessment. The above ground biomass was weighed immediately to determine the fresh weight per plot. Ten plants were randomly selected from the harvest and the fresh weight in gram was measured using a sensitive measuring scale. The ten plants were then stripped into their different parts: leaves, bark, core. These parts were weighed fresh and then oven-dried at $70^{o}C$ until a constant dry weight was attained. The values of the fresh and dry weights of the various

Table 1. Pre-cropping population of plant parasitic nematodes extracted from 200 g soils.

Nematode Genera	Pre-cropping population	
	2003	2004
Meloidogyne spp.	12542 ± 250	20565 ± 156
Scutellonema spp.	8154 ± 125	1765 ± 148
Pratylenchus spp.	6834 ± 150	16543 ± 130
Aphelenchoides spp.	4325 ± 105	8958 ± 66
Trichodorus spp.	3254 ± 85	7335 ± 50
Radopholus spp.	3795 ± 66	7056 ± 45
Helicotylenchus spp.	3561 ± 54	6592 ± 40
Rotylenchus spp.	1975 ± 50	5996 ± 40
Longidorus spp.	1453 ± 75	1234 ± 65
Xiphinema spp.	1054 ± 40	1234 ± 65

plant parts were used for the following estimations: (i) Total dry matter yield (TDY, t ha^{-1}): this is the dry weight of the whole plant above ground level. This is calculated as dry biomass from selected 10 plants /fresh weight of its above ground biomass x total fresh biomass weight from four internal rows per plot. This is expressed in tonnes per hectare (t ha^{-1}) on dry weight basis. (ii) Fibre yield (FY, t ha^{-1}): this is the dry weight of bark from 10 plants/total dry weight of 10 plants x total dry matter yield (t/ha). (iii) Leaf biomass (LB, t ha^{-1}): this is the dry weight of leaves from 10 plants/total dry weight of 10 plants x total dry matter yield (t ha^{-1}). (iv) Core yield (CY, t ha^{-1}): this is the dry weight of core in 10 plants/total dry weight of 10 plants x total dry matter yield (t/ha). (v) Plant height (HE, m): This is the length of the plant from the above ground level to the tip of stem.

Insect damage assessment on leaves

The extent of insect damage on leaves was assessed at 20% flowering stage. The severity of insect damage on leaves (INS) was visually rated as 1, indicating no infestation (0% foliage perforation), 2, as mild attack (<20 % foliage perforation), 3, as moderate(< 40% foliage perforation), 4, as severe(> 50 % perforation) and 5 as very severe (> 80% foliage perforation).

Nematode severity (NEMS) and incidence (NI) assessment

The level of nematode inoculums in the soil and severity of nematode infection on roots were obtained from the pre-cropping soil samples (Table 1) and plant roots assessment at harvest, respectively. The nematodes in the soil samples were extracted using the method of Whitehead and Hemming (1965) and identified according to Sasser and Taylor (1978).

Nematodes severity on roots was assessed at harvesting using the visual ratings where 1 indicate no injury symptom, 2 - mild infection, 3 – moderate infection, 4 - severe infection and 5 - very severe infection.

The total number of roots infested by nematodes per plot was also counted and expressed as percentage over the total number of plants harvested per plot to obtain the percent (%) nematode incidence.

Statistical analysis

The agronomic data collected were statistically analyzed using the SAS mixed procedure (Schabenberger and Pierce, 2002). A combined analysis was done for the two years using the fixed effects based model. The management practices, variety and their interactions as fixed while replication, year, year x replication, year x variety and year x management practices as random effects. Differences in fixed effects and interaction was determined using least square means comparison at $P < 0.05$.

Economic analysis

In determining the most economically acceptable (treatment) practice, partial budget analysis was carried out to estimate the gross value of the fibre yield from the different kenaf varieties under the different practices using the adjusted fibre yield at the prevailing market price for Kenaf fibre and inputs. The prevailing wage rates paid to farm labourers at the location were used to estimate the labour cost that varies. The accruing net benefit and the costs that vary were then compared across the treatments in dominance analysis based on the criterion that any treatment that had net benefit equal to or lower than that of another treatment with lower cost is dominated and as such would not be considered for investment by the farmer (CIMMYT, 1988).

Marginal analysis was also carried out on the non-dominated treatments in a stepwise manner, starting from one treatment with the lowest costs that vary to the next. This is to show how the net benefit from a decision to change from one kenaf variety/production practice to another increases with cost. A minimum Marginal rate of return (MRR) of 50% (CIMMYT, 1988; Dillon and Hardaker, 1993; Asumadu et al., 2004) was set as the criterion for acceptability of any practice for investment as the technologies under examination do not require acquisition of new skills or complex equipment by farmers. Hence, any treatment that returns MRR above 50% is considered worthy of investment by farmers.

RESULTS

Agronomic traits

Agronomic yield components were significantly influenced by management practices (Table 2). The fibre, core, leaf and whole plant dry weight increased with improved management practice (IMP). Application of IMP 2 gave a significantly higher yield across the traits except for plant height where IMP 1 and 2 had similar values.

The dry weight of the whole plant and its components like fibre and core yields were similar between varieties. However, leaf biomass was significantly higher in Ibadan local than Cuba 108 and Ifeken 400. The latter varieties were taller in height than the local cultivar. Interaction between the management practices and variety was significant on all the agronomic traits except plant height. Figure 2 shows that Ibadan local had the highest total dry matter yield under the control. Cuba 108 and Ibadan local had the highest yields in IMP 1 while Cuba 108 and Ifeken had the highest yields in IMP 2.

Fibre yield (FY) increased with improved management practices from IMP 1 to IMP 2 as in TDY. However, FY was similar in the three varieties at IMP 2 (Figure 3). Ibadan local had the highest core yield in the control, but under IMP 2, Cuba 108 and Ifeken 400 had the highest core yields (Figure 4). Leaf biomass in Ibadan local was more than others under the control, but at IMP 2, Ifeken

Table 2. Influence of management practices and variety on agronomic traits of kenaf in 2002 and 2003 (combined).

Treatment	Agronomic trait				
	TDY (t/ha)	**FY (t/ha)**	**CY (t/ha)**	**LB (t/ha)**	**HE (m)**
Control	6.66c	1.29c	2.74c	2.20b	1.24b
IMP 1	11.19b	2.28b	4.84b	3.24b	1.57a
IMP 2	17.03a	3.37a	7.44a	5.02a	1.71a
SE	0.61	0.16	0.39	0.51	0.14
Variety					
Cuba 108	11.36a	2.27a	5.17a	2.97b	1.69a
Ifeken 400	11.35a	2.18a	5.06a	3.02b	1.69a
Ibadan local	12.18a	2.49a	4.95a	4.48a	1.14b
SE	0.61	0.16	0.44	0.19	0.06

* IMP- Improved management practices, TDY- Total dry matter yield, FY- Fibre yield, CY- Core yield, LB- Leaf biomass, HE- Plant height.
** Means in the column followed by the same letters are not significantly different at P < 0.05.

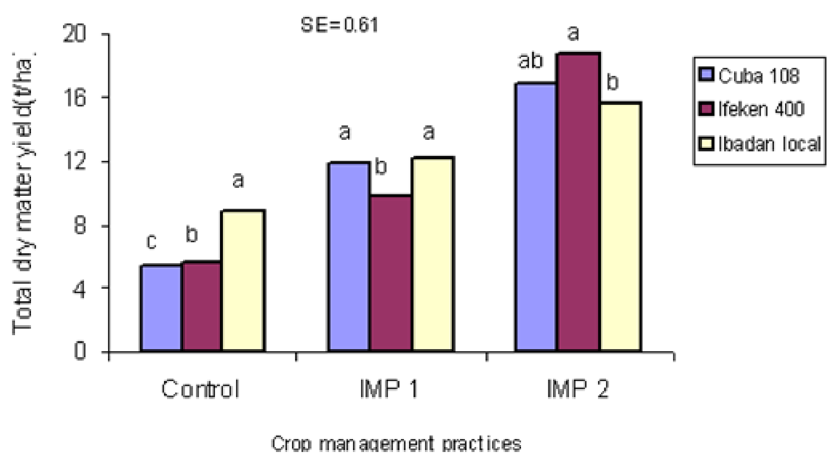

Figure 2. Crop management by variety interaction on TDM yield (t/ha).

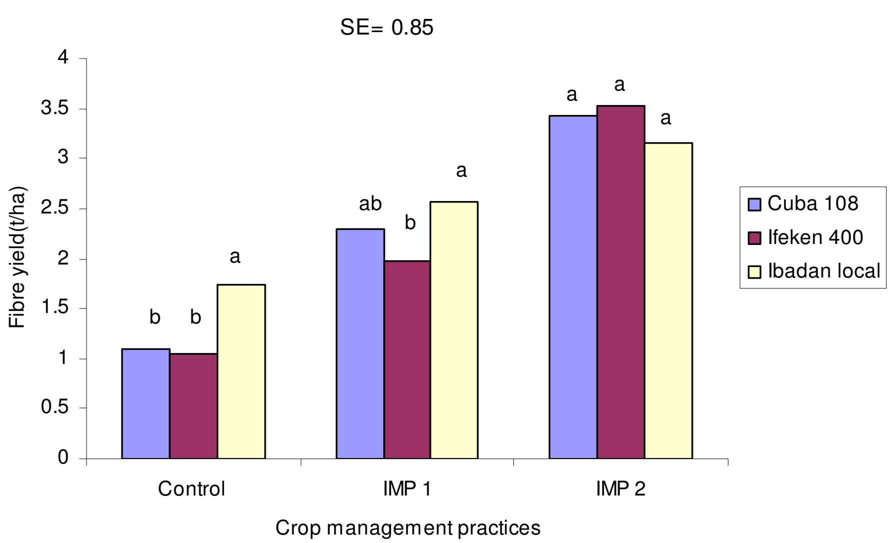

Figure 3. Crop management by variety interaction on fibre yield (t/ha).

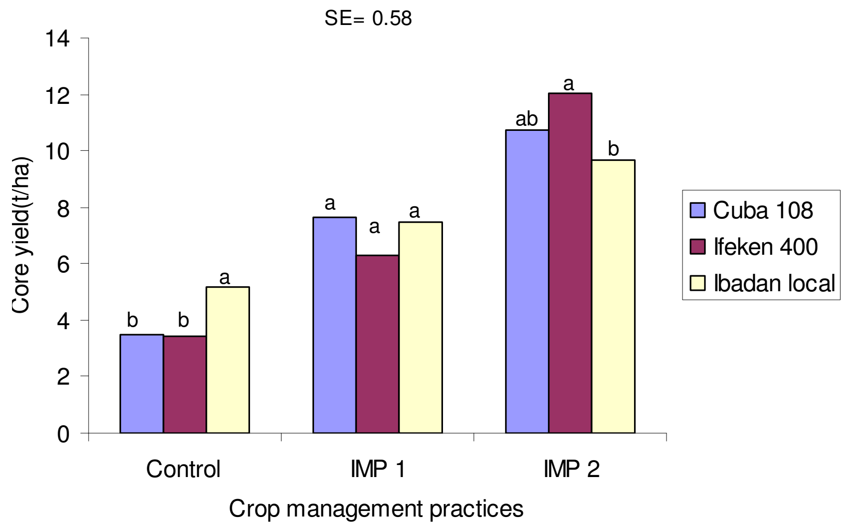

Figure 4. Crop management by variety interaction core yield (t/ha).

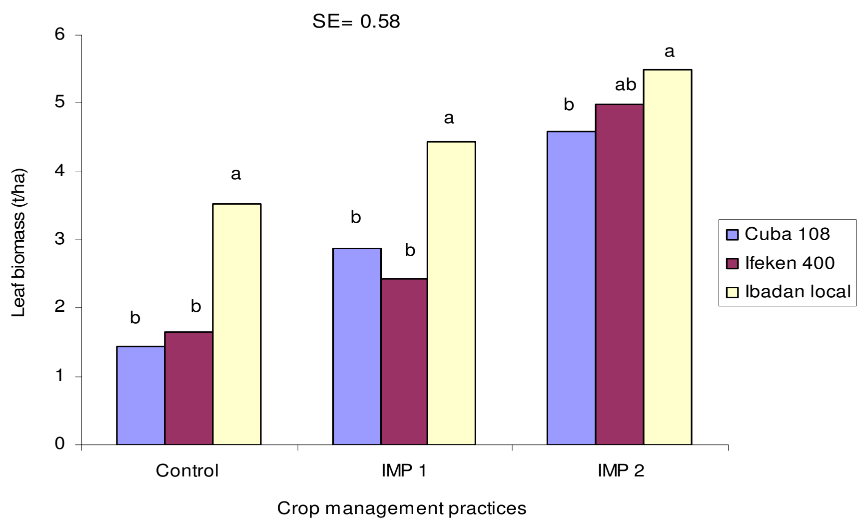

Figure 5. Crop management and variety interaction on leaf biomass yield (t/ha).

400 had similar yield with Ibadan local (Figure 5).

Pests' reaction

Severity of insects attack on leaves, incidence and severity of nematode attack on roots were significantly influenced by the management practices at P <0.05 (Table 3). Severity of insect holing and nematode infestation in IMP were rated as mild. The incidence of nematode attack reduced by 13-20% with improved management practices.

There were significant differences (P < 0.05) between varieties in severity of foliage holing by insects and nematode infestation. The Ibadan local was tolerant to both pests while Cuba 108 and Ifeken 400 were severely attacked (Figure 6). The incidence of nematode attack was lowest in Ibadan local across the management practices (Figure 7). However, nematode incidence reduced from 50% in control to 30 and 26% as intensity of management practices increased from IMP 1 to IMP 2, respectively. Also the severity of nematode on roots (Figure 8) was lowest in Ibadan local when compared to other varieties under control and in IMP 1. However, all the varieties had low insect severity scores below 2.0 in IMP 2.

Economic analysis

The results of the economic analysis are presented in Tables 4 and 5. The partial budget analysis indicated that

Table 3. Influence of management practices and variety on root nematode and flea beetles attack.

Treatment	Reaction to pests		
	Incidence of Nematode attack (%)	Nematode severity (n) (1-5)	Severity of insect attack (n) (1-5)
Control	34.60c	3.21b	3.33b
IMP 1	21.03b	2.41a	1.61a
IMP 2	15.42a	2.00a	1.72a
SE	1.08	0.38	0.50
Variety			
Cuba 108	34.34b	2.98b	2.51b
Ifeken 400	34.87b	2.99b	2.47b
Ibadan local	1.81a	1.60a	1.66a
SE	1.08	0.16	0.16

*IMP- Improved management practices.
**Means in the column followed by the same letters are not significantly different at P < 0.05.

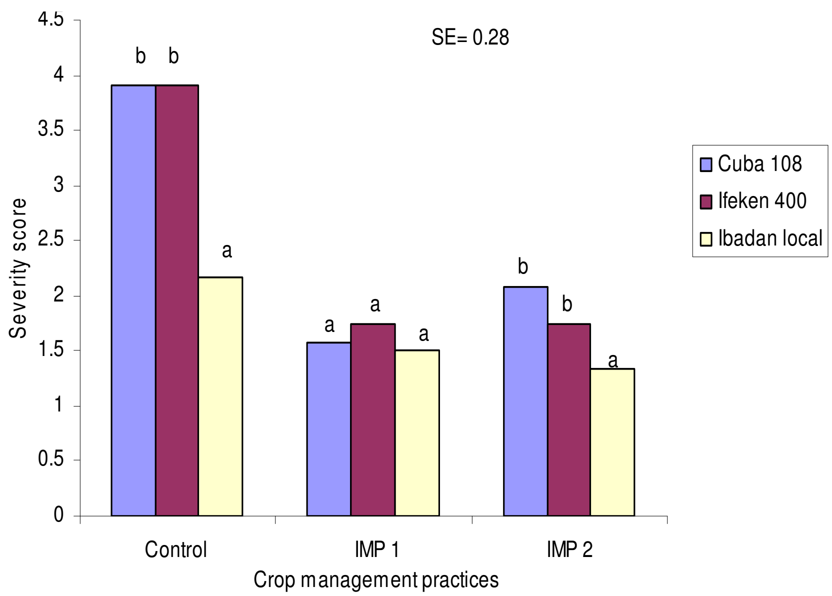

Figure 6. Crop management and variety interaction on severity of insect pest attack.

net benefit from kenaf fibre varied with increase in use of the external inputs across all varieties. While the control (non use of external inputs) returned the lowest net benefit of ₦98,100, ₦93,600 and ₦155,700 for Cuba 108, Ifeken 400 and local respectively, IMP 2 returned the highest net benefit of ₦210,008, ₦218,208 and ₦184,808 for the three varieties in the same order, respectively. Also, net benefit under IMP 1 were ₦153,754, ₦124,954 and ₦178,954 for Cuba 108, Ifeken 400 and local, respectively.

The analysis shows that while the net benefit returned by the farmer's (local) variety was higher than that of the other two varieties under the control and IMP 1, but its net benefit was lower than of Cuba 108 and Ifeken 400 under IMP 2. In addition, the result of the dominance and marginal rate of return analysis shows that farmers stand the chance of making more earnings from kenaf fibre production when they change from non usage of the external inputs to either IMP 1 or 2 which gave the highest rate of return for both Cuba 108 and Ifeken 400.

In the local variety, the marginal rate of return for moving from non-use of the external inputs to IMP 1 fell below the 50% MRR criterion. A shift from IMP 1 to IMP 2 further reduces the marginal rate of return. With a MRR value of 106.3 and 59.9 respectively for Cuba 108 and Ifeken 400, farmers stand to gain ₦106 and ₦60 respectively in return for every ₦100 spent in changing from non-usage of the external inputs to IMP 1. While changing from IMP 1 to IMP 2 gave about ₦121 returns for every ₦100 spent in Cuba 108 and N201 for Ifeken

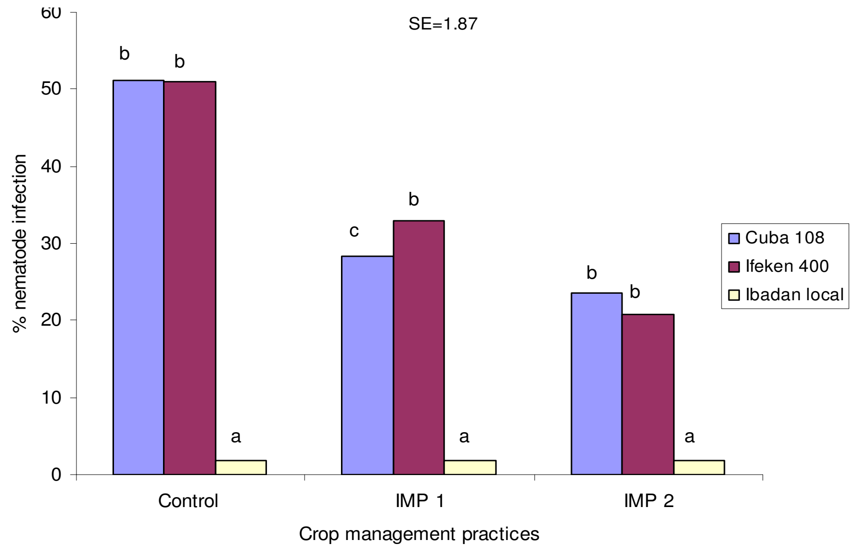

Figure 7. Crop management and variety interaction on % nematode infected plants.

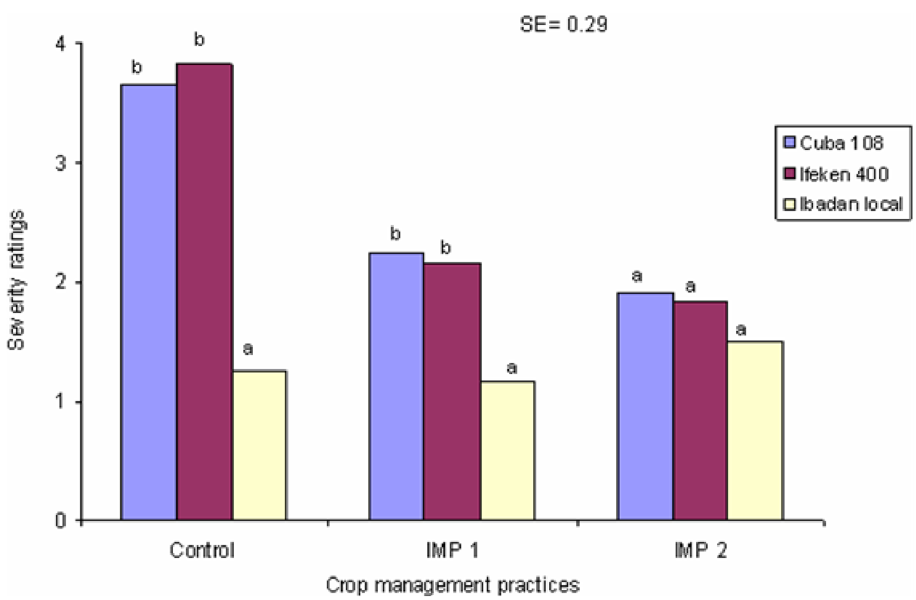

Figure 8. Crop management and variety interaction on nematode severity.

400 (i.e. MRR values of 121.3 and 200.9, respectively). However, similar change from non-use of input to IMP 1, and IMP 1 to IMP 2 in the local variety gave a return of about ₦44 and ₦13, respectively.

DISCUSSION

The pre-cropping soil analysis for major nutrients and nematode population showed that the soil used was low in N (0.07%). It also had a predominant and high population of *Meleidogyne incognita*, nematode species (Table 1). Rainfall was high in 2003 but moderate in 2004 with a short break in August in both years (Figure 1). This indicated that soil moisture was not a limiting factor to kenaf productivity in both years of trial.

Management practices rather than variety influenced total dry matter yield, fibre yield and core yield. These yield traits increased by 150 to 170% under IMP 2 when compared to the control. Other traits like leaf biomass and plant height increased by 128% and 38%, respectively in IMP 2. Agronomic yields was higher in IMP 2 than IMP 1 by 48 to 55%, so also was the incidence of nematode lower. The effects could be due to higher N

Table 4. Partial budget analysis for chemical application in kenaf fibre production (2004 and 2005 average).

Benefits	CUBA 108			IFEKEN 400			LOCAL		
	Contr.	**IMP-1**	**IMP-2**	**Contr.**	**IMP-1**	**IMP-2**	**Contr.**	**IMP-1**	**IMP-2**
Fibre Yield (2-year Average)	1.09	2.29	3.43	1.04	1.97	3.52	1.73	2.57	3.15
Adjusted Yield	0.981	2.061	3.087	0.936	1.773	3.168	1.557	2.313	2.835
Fibre Value at ₦100'000/ton	98100	206100	308700	93600	177300	316800	155700	231300	283500
Cost that vary									
Material Cost									
Cost of Fertilizer at ₦50/kg	0	15000	30000	0	15000	30000	0	15000	30000
Cost of Furadan at ₦585	0	29250	58500	0	29250	58500	0	29250	58500
Cost of Nuvacron ₦1600/Lit	0	96	192	0	96	192	0	96	192
Total Material Cost	**0**	**44346**	**88692**	**0**	**44346**	**88692**	**0**	**44346**	**88692**
Labour Cost									
Fertilizer Application 4 manday @ ₦500/manday		2000	2000		2000	2000		2000	2000
Furadan Application N500/Manday		2000	2000		2000	2000		2000	2000
Nuvacron Application ₦500/manday/application		4000	6000		4000	6000		4000	6000
Total Labour Cost	0	8000	10000	0	8000	10000	0	8000	10000
Total Cost	**0**	**52346**	**98692**	**0**	**52346**	**98692**	**0**	**52346**	**98692**
Net Benefit	**98100**	**153754**	**210008**	**93600**	**124954**	**218108**	**155700**	**178954**	**184808**

Contr. = Control; IMP-1 = Improved Management Practice 1; IMP-2 = Improved Management Practice 2.
$US1 = ₦136.

Table 5. Marginal rate of return analysis for chemical inputs application in Kenaf fibre production.

Variety	Treatment	Cost	Net Ben	Dominance	Incr. Ben	Incr. Cost	MRR (%)
Cuba 108	contr	0	98100	Un	-	-	-
	IMP-1	52346	153754	Un	55654	52346	106.3195
	IMP-2	98692	210008	Un	56254	46346	121.3783
Ifeken 400	contr	0	93600	Un	-	-	-
	IMP-1	52346	124954	Un	31354	52346	59.8976
	IMP-2	98692	218108	Un	93154	46346	200.9968
Local Variety	contr	0	155700	Un	-	-	-
	IMP-1	52346	178954	Un	23254	52346	44.42364
	IMP-2	98692	184808	Un	5854	46346	12.63108

Incr. Ben = Incremental Benefit; Incr. Cost = Incremental cost; Net Ben = Net Benefit.

rates and decreased nematode population (Adamson et al., 1979; Webber, 1996; Summer and Seale, 1958). This work has shown that kenaf productivity will be enhanced by the adoption of improved production practices by farmers. Breeding for varieties with low N requirement and resistance to nematode attack is suggested as a panacea to chemical inputs in the nearest future.

Rating for insect holing was severe in the control treatment (>4.0) but low (<2.0) indicating mild attack under IMP1. The significant interaction between management practices and variety on insect severity ratings (Figure 6) showed that Ibadan local was tolerant and other varieties were highly susceptible under the control. The tolerance of Ibadan local was due to its hairy or pubescent leaves. The other varieties have smooth or glaborous leaves which were severely perforated under the control treatment.

In the study, as the severity of leaf damage reduced with improved management, the agronomic yields increased. This corroborated earlier observation that yield in okra increased as insects damage to leaves were controlled at the vegetative stage (Agbaje and Daramola, 2000). The development of pubescent leaves in kenaf will be also be an advantage in the control of leaf damage by insects as observed by the low insect damage in Ibadan local cultivar. This will not only reduce the use of chemicals in insect control but will also reduce the cost of production in kenaf.

Pre-cropping soil analysis (Table 1) shows that *M. incognita* is preponderant in the soil hence the response of susceptible varieties to increased nematicde application. The incidence of nematode in kenaf roots was lowest in IMP 2, and between varieties, Ibadan local was the least affected. The use of Ibadan local in the development of nematode tolerant varieties could be exploited due to its tolerance to nematode attack.

The adoption of either IMP 1 or IMP 2 will depend on the economic profitability of the practice. The empirical evidence from this study has revealed the degree of economic responsiveness of the two improved kenaf varieties to improved production practices with Ifeken 400 yielding more profit than Cuba 108. The local variety is much less responsive to IMP rendering it less attractive and uneconomic for adoption by farmers. The study shows that farmers stand to gain better when they plant Cuba 108 or Ifeken 400 kenaf varieties under IMP 2 while similar treatment on the local variety is uneconomical.

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