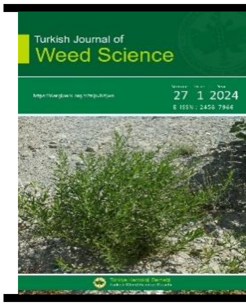

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Aratırma Makale / Research Article

Understanding the Interplay between Weeding Frequency, Weeding Cost, and Kenaf (*Hibiscus cannabinus*) Yield in Southwest Nigeria.

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ABSTRACT

Kenaf *(Hibiscus cannabinus* L.) cultivation holds significant promise in Nigeria. However, there exists a gap in understanding the optimal weeding frequency for maximizing kenaf yields in this region. This study aimed to address this gap by investigating the impact of different weeding frequencies on kenaf crop productivity. A field experiment was conducted at two locations in Southwest Nigeria during the 2022 and 2023 rainy seasons. Three different hoe weeding frequencies were implemented as experimental treatments: weeding at 2 weeks after sowing (WAS), weeding at both 2 and 4 WAS, and weeding at 2, 3, and 6 WAS. The experiment also featured weed-free and weedy checks which were the control treatments. The experimental treatments were laid out in a Randomized Complete Block Design, and replicated three times. Data on weed density, weed weight, kenaf growth parameters, biomass production, fibre yield, and economic variables were collected and analyzed. The results revealed a clear correlation between higher weeding frequency and reduced weed density and biomass, highlighting the effectiveness of frequent weeding in controlling weed proliferation and enhancing kenaf cultivation. Significant differences in kenaf growth metrics were observed in three or more hoe-weeding regimes compared to weedy check, emphasizing the adverse impact of weed competition on kenaf development. Moreover, biomass parameters of kenaf increased in response to increased weeding frequency, particularly thrice-weeded plots. Weeding at least twice a season is recommended for optimal kenaf growth and yield. Net income varied between locations, underscoring the importance of location-specific weeding strategies.

***Keywords*:** Hoe-weeding, Income, kenaf yield, weeding frequency, weeding cost

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.), belonging to the Malvaceae family, holds recognition as a valuable vegetable and fibre crop (Udemba *et al.*, 2023). Global production of kenaf fibre currently stands at 0.30 million tons, with India, China, Bangladesh, Brazil, and Cuba contributing 47%, 26%, 13%, 6%, and 2% respectively (Rahman *et al.,* 2022). Despite historical insignificance as a primary crop in Nigeria (Akubueze *et al.*, 2014), kenaf plays a crucial role as a raw material for manufacturing bags, high-quality paper, and newsprint. Furthermore, its bark serves in cordage, particularly for rope-making. Nigeria stands out as a significant producer of kenaf in Africa, yielding approximately 1,460 tonnes of kenaf fibre in 2020, with the southwestern region dominating production and contributing nearly 60% of the total national output (LINKS, 2022).

The southwest ecology of Nigeria is characterized by a tropical climate with distinct wet and dry seasons (Adedoyin *et al.,* 2019). During the wet season, the region experiences excess rainfall, which creates favourable conditions for weed growth, as moisture and warmth promote rapid proliferation (Anwar *et al.,* 2021). Weeds thrive in moist soils, competing with crops for nutrients, water, and sunlight, thus posing challenges for crop production in the region. Additionally, the combination of high humidity and warmth in the southwest provides an ideal environment for weed propagation throughout the year, further exacerbating the issue for farmers. Effective weed management strategies, including manual weeding, timely cultivation practices and the use of herbicides, are essential to mitigate weed infestation and ensure optimal kenaf yields in this ecological context (Aluko *et al.,* 2017).

Manual weeding remains a predominant weed management approach due to concerns surrounding the cost, environmental impact, and health implications associated with herbicide use (Ologbon *et al.,* 2023). Despite requiring more labour and time compared to herbicide application, manual weeding provides additional benefits such as employment opportunities for rural communities, contributing to local livelihoods and economic growth. The rationale for determining the appropriate frequency of weeding lies in the cost of repeating this agronomic practice in relation to the marginal yield. The frequency of weeding directly affects the overall farm economics by impacting labour costs and influencing crop yields (Gbaraneh & Briggs, 2018). In the framework of Pest Management Concept, weed management strives to pinpoint the most advantageous frequency of weeding. This entails determining the frequency that justifies the cost of weeding by mitigating economic losses incurred from weed competition (Cortés *et al.*, 2010).

Additionally, the factors influencing weeding costs depend on a number of variables, including labour availability, the type of weeds, and their density. Labour availability and wages play a significant role in determining weeding costs. Regions with plentiful and inexpensive labour resources may incur lower weeding costs compared to areas where labour is scarce or costly due to factors such as competition from other industries or government regulations (Ansong *et al.,* 2021). Moreover, the type and abundance of weeds in kenaf fields influence the cost of weed control measures, with fields infested with aggressive weed species attracting higher labour costs (Agbaje *et al.,* 2008; Nur *et al.*, 2021).

Research on weeding frequency has been extensively conducted across various crops, driven by the distinct production values of each crop, necessitating tailored decisions. Increasing the frequency of weeding has shown the potential to effectively reduce yield losses in many agricultural contexts. However, there remains a notable gap in knowledge regarding weeding frequency specifically in kenaf production within southwest Nigeria. As such, this study aims to address this gap by investigating the impact of varying weeding frequencies on kenaf crop yields and overall productivity. By filling this research gap, the study seeks to provide valuable insights and guidance for optimizing weed management practices in kenaf cultivation in the region.

MATERIALS AND METHODS

Collection of materials

The Ifeken DI 400 kenaf variety seeds were procured from the Institute of Agricultural Research and Training (IAR&T) Ibadan, Nigeria. Afterward, Italian grape hoes featuring 18cm blades were bought from an agricultural equipment store.

Experimental sites

Field experiment was conducted at the Research Station of the Faculty of Agriculture, Adekunle Ajasin University, Akungba Akoko, Nigeria (7° 37' N, 5° 44' E), during the 2022 rainy season. Similar experiment was carried out in the same rainforest-savannah transitional agroecology, at the research farm of the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria (7° 38' N, 3° 84' E), during the 2023 rainy season. The physicochemical properties of the soil at each experimental site are detailed in Table 1, while weather data for the respective locations are provided in Table 2. Weed survey before land preparation showed that the sites were predominately dominated by broad-leaf weeds including *Talinum triangulare* and *Euphorbia heterophylla* at Akungba, and *Tithonia diversifolia* in Ibadan. Standard land preparation practices such as clearing, ploughing, and harrowing were done at each site. The experimental sites were divided into plots measuring 2 m × 2 m, with a 0.5 m alley between plots and a 1 m gap between blocks.

Sowing of kenaf

Kenaf seeds (Ifeken DI 400) were sown at a spacing of 25 cm × 50 cm on level ground, with four seeds per hole at a depth of 1 cm. Two weeks after sowing (WAS), seedlings were subsequently thinned to two plants per stand.

Experimental treatment and design

The study comprised five experimental treatments, namely: weed-free, weedy check, and varying weeding frequencies of hoe weeding at 2 WAS, 2 and 4 WAS, and 2, 4, and 6 WAS. These were laid out in a Randomized Complete Block Design with three replicates. The weed-free plots attained a weed-free status through eight sessions of hoe-weeding conducted over a span of ten weeks. Consequently, this frequency of weeding was utilized to calculate the cost of weeding in the weed-free plots. The rate of weed biomass accumulation for each weeding regime was calculated by dividing the fresh and dry weights of the removed weeds by the fourteen-day interval.

Data collection and analysis

At 8 weeks after sowing (WAS), weed density and weights were evaluated using 0.25 m² quadrats randomly positioned at two locations along the diagonals of the plots. Weeds collected from each plot were counted to measure the weed density, gathered and weighed fresh to determine the fresh weight, oven-dried at 80°C for 48 hours, and reweighed to evaluate the dry weight. The growth parameters of kenaf, including plant height, stem girth, and leaf count, were assessed at 8 WAS using four tagged plants within each plot. Plant heights and stem diameters were measured using a meter rule and vernier caliper, respectively. At 10 WAS, kenaf plants were harvested, biomass was assessed, and fibre yield was quantified after the retting process. Information regarding the market price of kenaf fibre and the cost of weeding on a per-hectare basis was obtained from the Kenaf & Jute Improvement Programme, Institute of Agricultural Research and Training, Ibadan.

Partial Budgetary Analysis

A partial budgetary analysis was carried out for Kenaf production at Akungba and Ibadan. The analysis focused on variables such as Weeding Cost (₦), Bast Fibre Yield (t ha⁻¹), Bast Fibre Price (₦ t⁻¹), Gross Income (₦), and Net Income (₦). Major variables were derived as follow:

Gross Income (₦) = *Bast fibre yield (t ha⁻¹) X Bast fibre price (₦ t⁻¹)*

Net Income (₦) = *Gross Income (₦)* **-** *Weeding Cost (₦)* **-** *Other production cost*

Marginal yield = *Change in production output due to change in variable input*

Marginal Return on Investment =

$$\frac{\text{Change in net income due to change in weeding regime}}{\text{change in weeding cost}}$$

RESULTS

The cumulative weed density and weed weight removed increased with higher weeding frequencies in both Akungba and Ibadan (Table 3). Based on the weeding frequencies, Akungba recorded a fresh weed weight growth ranging from 9.96 to 13.58 g day^{-1}, with a corresponding dry weed weight growth of 1.3 to 2.79 g day^{-1}. Ibadan recorded a fresh weed weight growth ranging from 0.46 to 6 g day^{-1}, with a dry weed weight growth of 0.09 to 0.78 g day^{-1} (Table 4).

At 8 weeks after sowing, the weed density and both fresh and dry weed weights were found to be highest in the weedy check plots at both the Akungba and Ibadan sites (Table 5). Conversely, the weed-free plots exhibited no weed presence, showing a significant difference from the weedy check plots in terms of weed density, as well as both fresh and dry weed weights in these sites. In Akungba, weeding at 2 weeks after sowing (WAS) resulted in comparable weed density and weight with weedy check plots. Conversely, in Ibadan, weeding at 2 WAS led to significant differences in weed density and weight compared to the weedy check plots. Weeding twice, at 2 and 4 weeks after sowing (WAS), and weeding thrice, at 2, 4, and 6 WAS, led to significantly lower weed density, as well as both fresh and dry weed weights, compared to the weedy check plots at both the Akungba and Ibadan sites. Notably, in both locations, these weeding frequencies resulted in weed density, as well as both fresh and dry weed weights, that were statistically comparable. In contrast to the situation in Ibadan, where all weeding frequencies resulted in weed density and growth comparable to weed-free, in Akungba, only weeding twice and thrice resulted in weed density statistically comparable to weed-free conditions. Additionally, weeding thrice in Akungba yielded fresh weed weight statistically comparable to the weed-free.

The growth of kenaf, at 8 WAS, indicated that weedy check plots had the lowest plant height, number of leaves, and stem girth, while the weed-free plots exhibited the highest growth in both Akungba and Ibadan, except for the number of leaves per plant in Ibadan (Table 6). In both Akungba and Ibadan, the various weeding frequencies did not yield significantly different kenaf plant heights. However, in Ibadan, comparable plant heights were observed between the weeding frequencies and the weed-free plots, whereas in Akungba, plant heights were comparable to those of the weedy check plots. The number of leaves per plant resulting from plots weeded once and twice did not show significant differences in both Akungba and Ibadan. Notably, the leaf count per plant from plots weeded once was significantly lower than those from plots weeded thrice in both locations. The stem girth of kenaf across the weeding frequencies did not show significant differences in Akungba and Ibadan. Nonetheless, a slight increase in stem girth was observed with increasing weeding frequency.

At 10 WAS, biomass parameters of kenaf, including total fresh weight, total dry weight, dry core weight, and dry bast fibre weight, were lowest in the weedy check plots and highest in the weed-free plots in both Akungba and Ibadan, with the exception of dry core weight and dry bast fibre weight in Ibadan, where hoe-weeding regime of 2, 4 and 6 WAS had the highest values (Table 7). Notably, in Ibadan, hoe-weeding at 2 WAS resulted in kenaf with total fresh weight, total dry weight, dry core weight, and dry bast fibre weight statistically comparable to those of the weed-free plots, unlike in Akungba. Additionally, hoe-weeding regimes of 2 and 4 WAS involving weeding twice and 2, 4 and 6 WAS involving weeding thrice resulted in comparable yield components (total fresh weight, total dry weight, dry core weight, and dry bast fibre weight) in both locations.

The yield components, core and bast fibre, were found to be lowest in weedy check plots and highest in weed-free plots in both Akungba and Ibadan, (Table 8). The yield from plots weeded once, twice, and thrice did not show significant differences in both locations, except for bast fibre, which was significantly higher in plots weeded thrice compared to those weeded once in Akungba. Additionally, higher weeding frequency resulted in a slightly increased yield in both locations.

The partial budgetary analysis indicated that with an increase in the frequency of weeding, the associated costs of weed management also escalated (Table 9). In the study, the expenditure for conducting a single weeding operation per hectare amounted to ₦50000, resulting in a total range of ₦50000 to ₦150000 for weeding conducted once to thrice. Moreover, the gross income from kenaf was highest in the weed-free plots and lowest in the weedy-check plots in both Akungba and Ibadan. Furthermore, the gross income from kenaf exhibited an upward trend as the frequency of weeding increased. However, the net income from kenaf, subject to varying weeding frequencies, displayed distinct return patterns at these locations. Of particular note is the observation that net income increased proportionally with the weeding frequency in Akungba. Conversely, in Ibadan, net income decreased when weeding was conducted twice compared to once, but subsequently rebounded and increased when conducted thrice. Overall, the net income from kenaf was higher in Ibadan than in Akungba under the same weeding frequency.

In Akungba, the bast fibre yield of kenaf increased by 0.17 t ha^{-1} when weeding was performed twice instead of once, and by 0.34 t ha^{-1} when weeding was carried out thrice instead of twice. This led to marginal revenues of ₦94,500 and ₦239,000, respectively (Table 10). In Ibadan, the bast fibre yield of kenaf rose by 0.01 t ha^{-1} when weeding was done twice instead of once, and by 0.35 t ha^{-1} when weeding was conducted thrice instead of twice. This resulted in marginal revenues of -₦41,500 and ₦247,500, respectively.

DISCUSSION

`This study demonstrates a clear correlation between higher frequency of weeding and decreased weed density and biomass. These results underscore the effectiveness of frequent weeding in curbing weed emergence and growth, thus enhancing the cultivation of kenaf. Notably, these findings support the earlier observation by Adenawoola *et al.* (2005) that intensifying weeding frequency leads to significantly reduced weed growth.

Table 1: Physicochemical properties of soil in the experimental sites

	pH	OC	OM	N	P	K	Na	Ca	Mg	Sand	Clay	Silt
		%			ppm	cmol/kg				%		
Akungba	4.76	1.26	2.18	0.21	4.8	0.58	0.8	1.4	0.6	56.8	27.2	16
Ibadan	6.7	2.76	4.75	0.28	4.2	0.76	0.29	3.3	2.21	69.4	10.2	20.5

Table 2: Weather Information of the experimental site

Weather Parameters	Akungba	Ibadan
Maximum Temperature (°C)	31	32
Minimum Temperature (°C)	19	21
Total Precipitation (mm)	664	593
Maximum Daily Precipitation (mm)	110	33
Raining Days	71	71

***** Akungba: 5th August - 19th October 2022, Ibadan: 13th July – 21st September 2023

Source: Visual Crossing Corporation (*https://www.visualcrossing.com)*

Table 3: Quantifying cumulative weeds removed across various weeding frequencies

Treatment	Akungba			Ibadan		
	Density (m^{-2})	Fresh weight ($g\ m^{-2}$)	Dry weight ($g\ m^{-2}$)	Density (m^{-2})	Fresh weight ($g\ m^{-2}$)	Dry weight ($g\ m^{-2}$)
Weedy check	0	0	0	0	0	0
Weeding 2 WAS	573.08	190.21	39.08	184.02	84.00	10.88
Weeding 2 & 4 WAS	935.35	329.61	57.31	296.33	129.60	18.40
Weeding 2, 4 & 6 WAS	1301.00	486.62	85.31	320.49	136.00	19.72

Table 4: Quantifying weed biomass accumulation rate across weeding regimes

Treatment	Akungba		Ibadan	
	Fresh weight (g day^{-1}.)	Dry weight (g day^{-1})	Fresh weight (g day^{-1})	Dry weight (g day^{-1}.)
Weedy check	0	0	0	0
First weeding (2 WAS)	13.58	2.79	6	0.78
Second weeding (4 WAS)	9.96	1.3	3.26	0.54
Third weeding (6 WAS)	11.22	2	0.46	0.09

Table 5: Effect of weeding frequency on weed emergence and growth at 8 weeks after sowing (WAS)

Treatment	Akungba			Ibadan		
	Density (Plant m^{-2})	Fresh weight (g m^{-2})	Dry weight (g m^{-2})	Density (m^{-2})	Fresh weight (g m^{-2})	Dry weight (g m^{-2})
Weedy Check	1227.26^{a}	1654.91^{a}	346.19^{a}	418.67^{a}	828.27^{a}	167.84^{a}
Weeding 2 WAS	1160.57^{ab}	1315.27^{ab}	271.24^{a}	82.67^{b}	229.87^{b}	56.08^{b}
Weeding 2 & 4 WAS	496.63^{bc}	784.04^{bc}	160.35^{b}	50.27^{b}	156.80^{b}	40.48^{b}
Weeding 2, 4 & 6 WAS	328.33^{c}	476.43^{cd}	100.64^{b}	24.00^{b}	29.60^{b}	13.44^{b}
Weed-free	0^{c}	0^{d}	0^{c}	0^{b}	0^{b}	0^{b}

Means with the same letters within a column are not significantly different based on DMRT (P= 0.05).

Table 6: Effect of weeding frequency on kenaf growth at 8 weeks after sowing (WAS)

Treatments	Plant height (cm)		Number of leaves (plant^{-1})		Stem Girth (mm)	
	Akungba	Ibadan	Akungba	Ibadan	Akungba	Ibadan
Weedy Check	79.30^{b}	68.75^{b}	18.59^{c}	19.83^{c}	5.63^{c}	6.13^{b}
Weeding 2 WAS	100.53^{b}	108.83^{a}	27.00^{c}	71.58^{b}	7.65^{bc}	11.06^{a}
Weeding 2 & 4 WAS	100.43^{b}	108.00^{a}	43.38^{bc}	95.50^{ab}	9.96^{b}	11.14^{a}
Weeding 2, 4 & 6 WAS	99.70^{b}	107.75^{a}	60.04^{b}	108.08^{a}	10.61^{b}	11.79^{a}
Weed-free	141.30^{a}	115.42^{a}	90.96^{a}	99.00^{ab}	15.44^{a}	12.23^{a}

Means with the same letters within a column are not significantly different according to DMRT (P= 0.05).

Table 7: Effect of weeding frequency on biomass accumulation of kenaf at 10 weeks after sowing (WAS)

Treatments	Total fresh weight (g plant $^{-1}$)		Total dry weight (g plant $^{-1}$)		Dry core weight (g plant $^{-1}$)		Dry bast fibre (g plant $^{-1}$)	
	Akungba	Ibadan	Akungba	Ibadan	Akungba	Ibadan	Akungba	Ibadan
Weedy Check	17.95^{d}	36.58b	4.42^{c}	8.51b	1.48^{d}	2.48b	0.78d	1.37b
Weeding 2 WAS	54.07^{cd}	118.17ab	13.12^{bc}	28.82ab	4.45^{cd}	9.77a	2.34cd	5.65a
Weeding 2 & 4 WAS	89.54^{bc}	169.08a	25.28^{b}	48.31a	7.73^{bc}	11.57a	3.38bc	5.69a
Weeding 2, 4 & 6 WAS	127.59^{b}	202.83a	26.79^{b}	39.00a	10.51^{b}	16.16a	5.53b	7.89a
Weed-free	250.44^{a}	209.67a	67.23^{a}	55.18a	20.63^{a}	13.55a	10.86a	6.40a

Means with the same letters within a column are not significantly different based on DMRT (P= 0.05).

Table 8: Effects of weeding frequency on kenaf yield per hectare

Treatments	Core weight (t ha^{-1})		Bast fibre yield (t ha^{-1})	
	Akungba	Ibadan	Akungba	Ibadan
Weedy check	0.24d	0.40b	0.12d	0.22b
Weeding 2 WAS	0.71cd	1.56a	0.37cd	0.90a
Weeding 2 & 4 WAS	1.24bc	1.85a	0.54bc	0.91a
Weeding 2, 4 & 6 WAS	1.68bc	2.59a	0.88b	1.26a
Weed-free	3.300a	2.17a	1.74a	1.02a

Means with the same letters within a column are not significantly different based on DMRT (P= 0.05).

Table 9: Partial budget analysis of weeding frequency in kenaf production at Akungba and Ibadan

Variables	Weed-free	Weeding frequency			Weedy check
		1	2	3	
Akungba					
Weeding cost (₦)	400,000	50,000	100,000	150,000	0
Bast fibre yield (t ha^{-1})	1.74	0.37	0.54	0.88	0.12
Bast fibre Price (₦ t^{-1})	850,000	850,000	850,000	850,000	850,000
Gross Income (₦)	1,479,000	314,500	459,000	748,000	102,000
Net Income (₦)	1,079,000- þ	264,500- þ	359,000- þ	598,000- þ	102,000 - þ
Marginal ROI (%)	-	3.25	1.89	4.78	-
Ibadan					
Weeding cost (₦)	400,000	50,000	100,000	150,000	0
Bast fibre yield (t ha^{-1})	1.02	0.9	0.91	1.26	0.22
Bast fibre Price (₦ t^{-1})	850,000	850,000	850,000	850,000	850,000
Gross Income (₦)	867,000	765,000	773,500	1,071,000	187,000
Net Income (₦)	467,000 – þ	715,000- þ	673,500- þ	921,000- þ	187,000 - þ
Marginal ROI (%)	-	10.56	-0.83	4.95	-

ROI- Return on Investment; Þ – other production costs (₦); ***1₦=USD1,000

Table 10: Marginal kenaf yield and revenue (₦) from weeding frequencies at Akungba and Ibadan

Marginal Yield (t ha^{-1}) in Akungba

Weeding frequency	weed-free	3	2	1	weedy check
weed-free	0				
3	0.86	0			
2	1.2	0.34	0		
1	1.37	0.51	0.17	0	
weedy check	1.62	0.76	0.42	0.25	0

Marginal Revenue (₦ ha^{-1}) in Akungba

Weeding frequency	weed-free	3	2	1	weedy check
weed-free	0				
3	481,000	0			
2	720,000	239,000	0		
1	814,500	333,500	94,500	0	
weedy check	977,000	496,000	257,000	162,500	0

**1₦ =USD 1,000

Marginal Yield (t ha^{-1}) in Ibadan

Weeding frequency	3	weed-free	2	1	weedy check
3	0				
weed-free	0.24	0			
2	0.35	0.11	0		
1	0.36	0.12	0.01	0	
weedy check	1.04	0.8	0.69	0.68	0

Marginal Revenue ((₦ ha^{-1}) in Ibadan

Weeding frequency	3	1	2	weed-free	weedy check
3	0				
1	206,000	0			
2	247,500	41,500	0		
weed-free	454,000	248,000	206,500	0	
weedy check	734,000	528,000	486,500	280,000	0

**1₦ =USD 1,000

Discernible disparities in key kenaf growth metrics, such as leaf count and stem diameter, were evident between regular weeding of three or more regimes (weed-free) and the weedy check, indicating the presence of a growth-enhancing threshold associated with weeding. Consistently, kenaf plants in weed-free plots exhibited notably superior growth attributes compared to the weedy check plots, underscoring the adverse impact of weed competition on crops. Additionally, the current observations align closely with the conclusions drawn by Aluko *et al.* (2017), whose research demonstrated a decline in kenaf growth parameters with escalating weed biomass and population. Thus, the findings not only corroborate the results but also accentuate the critical role of effective weed management in optimizing kenaf growth and development. The stark disparities observed between the weed-free plots and 3-weeding regime plots, and the weedy check underscore the significance of minimizing weed competition to maximize kenaf productivity.

Furthermore, the measured agronomic parameters of kenaf, encompassing total fresh weight, total dry weight, dry core weight, and dry bast fibre weight, exhibited significant increases in response to weeding conducted twice and thrice. This phenomenon is plausibly attributable to the augmented number of leaves, potentially fostering heightened photosynthetic capacity and the accumulation of increased photosynthates (Hossain *et al.,* 2010). The findings of this study suggest that a single weeding event may suffice to maintain kenaf plant height, but increased weeding frequency, particularly 3-weeding regime, enhanced leaf development and fibre production. Weeding contributes to increased plant biomass production by mitigating resource competition, particularly in environments with high weed pressure. Among the different weeding frequencies, 3-weeding regime had the highest plant biomass values due to more reduced competition, facilitating availability of water and soil nutrients for crop utilization and superior fibre yield.

The cultivation of kenaf in weed-free plots undoubtedly fosters optimal growth compared to the specified weeding regimes. Nonetheless, it is imperative to recognize that maintaining complete weed eradication is not environmentally sustainable. Weeds fulfil crucial ecological roles, including soil erosion prevention, wildlife sustenance, and pollinator attraction (Blaix *et al.,* 2018). Thus, while prioritizing kenaf growth, a balanced approach between weed control and preservation of weed-derived ecological benefits is essential for sustainable agricultural practices.

During the study period, Akungba experienced higher rainfall than Ibadan, which likely led to increased weed growth in Akungba compared to Ibadan (Gandía *et al.,* 2021) and reduced kenaf yield where weeds were present in Akungba compared to Ibadan (Aluko *et al.,* 2017). Conversely, kenaf plants in weed-free plots in Akungba capitalized on the ample soil moisture, resulting in improved yield compared to Ibadan. The notable variations between Akungba and Ibadan, particularly in weed growth rates, emphasize the importance of tailoring weed management strategies to local conditions. Differences in fresh and dry weed weight growth rates suggest varying rates of weed proliferation and environmental influences. Specifically, the effectiveness of weeding conducted once at 2 weeks after sowing (WAS) differed between the two locations. In Akungba, this intervention yielded results similar to the weedy check plots, while in Ibadan, significant improvements were observed. These disparities underscore the necessity for customized weed management strategies based on local conditions for optimal efficacy.

In terms of the effect of weeding regimes on yield and income, a positive correlation was observed between weeding frequency and gross income from kenaf. This suggested that more frequent weeding contributed to enhanced yields and higher revenue generation. However, the relationship between weeding frequency and net income was more nuanced. In Akungba, net income rose proportionally with weeding frequency, indicating a favourable return on investment. Conversely, in Ibadan, while net income initially decreased with weeding conducted twice, it rebounded and increased with weeding done thrice, highlighting the dynamic nature of profitability in different locations.

The Marginal Return on Investment (ROI) analysis provides valuable insights into the economic viability of different weeding frequencies in kenaf cultivation. In Akungba, the marginal ROI for weeding twice was 189%, indicating that for every ₦1 invested in this additional weeding frequency, a return of ₦1.89 was achieved. Similarly, weeding thrice resulted in a substantially higher marginal ROI of 478%, indicating a return of ₦4.78 for every ₦1 invested on additional weeding. These positive marginal ROIs highlight the profitability of increasing weeding frequency, with weeding thrice showing a more significant return compared to weeding twice. Conversely, in Ibadan, weeding twice resulted in a negative marginal ROI of -83%, indicating a loss of ₦0.83 for every ₦1 invested on additional weeding. However, weeding thrice demonstrated a positive marginal ROI of 495%, indicating a return of ₦4.95 for every ₦1 invested on additional weeding. These findings underscore the importance of considering location-specific factors and economic implications when determining the optimal weeding frequency for kenaf cultivation. Farmers and policymakers can use this information to make informed decisions, balancing the economic benefits with factors such as labour availability and environmental sustainability.

The disparity in gross income between weed-free and weedy-check plots underscored the detrimental impact of weeds on kenaf yield and income. Moreover, the response of kenaf yield and income to weeding frequency varied across locations, suggesting the influence of environmental factors. Despite variations in weeding frequency and its impact on income, Ibadan consistently exhibited higher net income compared to Akungba. This disparity underscored the influence of location-specific factors, such as soil fertility, climate conditions, on overall profitability.

CONCLUSION

In summary, frequent weeding proves effective in reducing weed density and biomass, thereby improving kenaf yield and profitability. A weeding frequency of at least twice a season is recommended for optimal kenaf growth and yield, particularly in areas with significant weed pressure due to high rainfall. This recommendation is supported by observed correlations between higher weeding frequency and reduced weed proliferation. Disparities in kenaf growth metrics between regular weeding of three or more regimes (weed-free) and the weedy check highlight the detrimental impact of weed competition. Increases in kenaf biomass parameters emphasize the importance of effective weed management in mitigating resource competition. While weed-free conditions are ideal, a balanced approach to weed control is necessary for sustainability, considering the ecological benefits of weeds and profitability. Location-specific factors such as soil fertility and climate conditions should inform tailored weed management strategies to optimize profitability and inform sustainable agricultural practices.

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