RESPONSES OF OKRA (ABELMOSCHUS ESCULENTA) TO VARIOUS PERIODS OF WEED INTERFERENCE IN A HUMID TROPICAL ENVIRONMENT.

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ABSTRACT
Studies were made to estimate the effect of critical period of weed removal on the yield and profitability of okra production in the humid ultistol location. Plant height, stem girth, number of leaves, leaf area index, total dry weight, days to 50% flowering, pod yield and economic analysis were evaluated under five treatments (zero weeding, T0; weed-free for the first two weeks, T1; weed-free for the first four weeks, T2; weed-free for the first six weeks, T3 and weed-free-till-harvest, T4)) using randomized complete block design and replicated three times. Weeding significantly increased all the tested parameters. The best weed management for successful production of okra with 9.82 t ha-1 produced from weed free till harvest plots which also had the highest revenue (N 982, 000), gross margin (N 782,728.97), net return (N 763, 291.34), benefit cost ratio (4.49) and return per naira (5.93).

Keywords: Benefit: cost ratio, competition, growth resources, critical period, yield loss.

INTRODUCTION
Okra (Abelmochus esculentus Moench) known as lady's finger is valued for its edible green seed pods. Originating in Africa, the plant is cultivated in tropical, subtropical and warm temperate regions around the world (NRC, 2006). Okra contains carbohydrate, proteins and vitamin C in considerable quantities (Adeboye and Oputa, 1996). The essential and non essential amino acids that okra contains are comparable to that of soybean. Hence it plays a vital role in human diet. For consumption, young immature fruits are important fresh fruit – vegetable that can be consumed in different forms. They could be boiled, fried or cooked. In Nigeria, okra is usually boiled in water resulting in slimy soups and sauces, which are relished. The fruits also serve as soup thickeners (Schippers, 2000). The leaves buds and flowers are also edible. Okra seed could be dried. The dried seed is a nutritious material that can be used to prepare vegetable curds, or roasted and ground to be used as coffee additive or substitute. Okra leaves are considered good cattle feed, but this is seldom compatible with the primary use of the plant. Okra mucilage is suitable for medicinal and industrial applications. It has medically found application as a plasma replacement or blood volume expander (Kumar et al. 2010). Industrially, okra mucilage is usually used in glaring certain papers; and useful in confectionery (Markose and Peter, 1990).

Okra production is estimated at 6 million tonnes per year in the world. The total area of okra has increased over the years. India is the world largest producer followed by Nigeria and Sudan (Varmudy, 2011). One of the major constraints to Okra production is weeds, which must be controlled up to 9 weeks after sowing (Adejonwo et al., 1989). Yield loss as a result of uncontrolled weeds in okra fields was reported to be up to 91% in the northern Guinea savanna (Adejonwo et al., 1989). Comparing fruit yield on uncontrolled weed plot to plastic mulch plot. Olabode et al (2006) reported 85% loss in the southern Guinea savanna. The bulk of labour requirement in crop production goes into weed control (Olabode et al., 1999). Weed control accounted for 30 - 45 % of the total cost of production in Nigeria (Usoroh, 1995). The frequency and cost of weeding depends on weed type, crop grown, cultivation practices and farming system and season of the year. Okra has a slow juvenile development against weeds characterized by aggressive growth and successful competitor on most crop field. This was responsible for 93% and 99% loss in seed viability in an uncontrolled weed/okra competition (Olabode 2004). The objective of this study was to determine the critical period of weed removal in order to obtain optimum economic yield of okra.

MATERIAL AND METHODS

Site description

This study was conducted at the Teaching and Research Farm of Benson Idahosa University, Benin City, Nigeria. The study area lies at latitude 5^0 45′ N and longitudes 5^o 41′ N and is within the humid rainforest agro-ecological zone of Nigeria. The area has a bimodal rain-fall with mean annual total of 1762 mm and mean temperature of 26.5 ^{0}C (EADP, 1995). Prior to the time field trials were established, the site was under maize (Zea mays) cultivation for two years.

Treatment and experimental design

There were five treatments: weedy check (T_0), weed-free for the first two weeks after sowing (T_1), weed-free for the first four weeks after sowing (T_2), weed-free for the first six weeks after sowing (T_3) and weed-free till harvest (T_4). These were laid out in a randomized complete block design with three replications.

Cultural practices

Three seed of early maturing okra cultivar (NHAe 47-4) were sown per stand at a spacing of 50 cm x 30 cm to obtain plant population of 66, 666 plants per hectare. Missing stands were replanted at one week after sowing (WAS). Seedlings were thinned to give the required plant per stand at two WAS. Insect pests on the okra plants were controlled with Cypermethrin 10 days after sowing and 5 days interval thereafter. Weeding regimes were carried out on all treatment plots except the weedy check (T0). NPK 15: 15: 15 was applied at 200 kg per hectare by ring method.

Data collection

Three plants from the middle row were randomly tagged in each plot for measurement. Plant parameters measured include plant height, stem girth, number of leaves, leaf area index (LAI) and total dry matter (TDM)) at 2 WAS, 4 WAS and 50 % flowering. Plant height was measure using metre rule calibrated in centimetres from the base of the stem to the tip of the stem. Stem girth was measure by use of a Venier Caliper about 5 cm above the soil line. Leaf discs were punched out with a cork borer and the relationship between area and dry weight of the disc
was used to estimate leaf area. From the leaf area, leaf area index (LAI) was computed as:

$$LAI = \frac{Leaf\ area}{Land\ area}$$ (Remison, 1997).

For TDM determination, two okra plants were uprooted from each plot, chopped and packed into sample bags and oven dried at 60 ^{0}C to a constant weight. Weed biomass was taken as cumulative of 2 WAS, 4 WAS, 50 flowering and harvesting. Harvesting was done thrice as pods reach marketable size. At harvest, yield was assessed and estimated as number of pods per plant, pod weight per plant and pod yield per hectare.

Data analysis

Analysis of variance was carried out on each of the observation recorded using GENSTAT programme, version 8.1 (GENSTAT, 2005). The least significant differences (LSD) test was used to detect significant differences between treatment means at 5 % level of probability.

Economic analysis

Economic analysis was carried out to determine the net farm income for okra production. The net farm income or return (NR) is the difference between total revenue (TR) and total cost of production (TC) (Olukosi and Erhabor, 1988).

NR = TR - TC

The model used for estimating net farm income can be expressed by the equation:

$$NR = \sum_{i=1}^{n} Pyi \;\; Yyi - \sum_{j=1}^{m} Pxj\ Xj \; - \; \sum_{k=1}^{k} Fk$$

Where NR = Net return

Yi= Enterprise's product (s) (where 1, 2, 3….. n products)

P_{yi} = Unit price of the product

Xj = Quantity of the variable inputs (where j = 1, 2, 3… n variable inputs)

F_k = cost of fixed inputs.

$\sum$ = summation.

Return per naira invested = $\frac{TR}{TVC}$

Where TVC = Total variable cost.

Benefit: cost Ratio (BCF) = $\frac{TR}{TC}$

RESULTS

Growth and vegetative characters

Effects of weed removal on the growth of okra at 2 WAS are presented in Table 1. Generally, the treatments did not have significant effect on growth and vegetative characters except LAI and TDM. For leaf area index (LAI), weeded plots were significantly different from weedy check (control). Although T_2 and T_4 had the highest LAI (0.300), they were statistically similar to T_1. Total dry matter (TDM) showed a range from 0.037 to 0.200 t ha^{-1} and there was a significant difference among treatments. T_3 plots had the highest TDM but at par with other treatments and statistically different from weedy check plots.

Table 1: Effects of weeding regime on the growth of okra at two weeks after sowing (WAS)

Treatment	Plant height (cm)	Stem girth (cm)	Number of Leaves	LAI	TDM (t ha^{-1})
T_0	7.00	1.27	4.33	0.0100	0.037
T_1	7.00	1.17	4.33	0.0267	0.183
T_2	8.33	1.23	5.00	0.0300	0.200
T_3	7.00	1.27	4.67	0.0267	0.167
T_4	7.67	1.27	4.67	0.0300	0.183
Mean	7.40	1.24	4.60	0.0247	0.154
SE	0.810	0.060	0.247	0.00316	0.0153
$LSD_{(0.05)}$	ns	ns	Ns	0.00447	0.0216

ns - not significant; T_0 - weedy till harvest, T_1 – Weed-free for the first two WAS

T_2 – Weed-free for the first four WAS; T3 – weed-free for the first six WAS; T4 – Weed-free throughout

TDW - Total dry matter; LAI - Leaf area index

There were significant difference among treatments at 4 WAS for plant height, stem girth, number of leaves, LAI and TDM (Table 2). At four WAS, T_4 plots had plants with the highest height (35.67cm) which were comparable with plant heights (35.00 cm) observed on T_2 and T_4 plots (Table 2). The weedy check plots had plants with the least plant height (14.43cm). T_2 plots had plants with the thickest stem girth (3.13cm) while plants with the thinnest stem girth (1.23cm) were observed in the weedy check plots. T_2, T_3 and T_4 plots were comparable but were significantly differently from T1 (1.93cm) and weedy check (1.23cm) plots in plant stem girth. Number of leaves ranged from 5.33 (weedy check) to 14.33 (T_2 and T_3) per plant (Table 3). T_3 plots had the highest LAI (0.243) while weedy check plots had the least (0.093). Weeded plots had LAI which were significantly different from control. However, T_2, T_3 and T_4 were comparable in LAI. The greatest TDM value of 0.50 t ha^{-1} was produced from T_3 plots. TDM followed the same trend as LAI.

Table 2: Effects of weeding regime on the growth of okra at four WAS

Treatment	Plant height (cm)	Stem girth (cm)	Number of Leaves per plant	LAI	TDM (t ha^{-1})
T_0	14.43	1.23	5.33	0.0093	0.12
T_1	23.33	1.93	10.67	0.1530	0.30

T_2	35.00	2.93	14.33	0.2300	0.47
T_3	35.00	3.13	14.33	0.2340	0.50
T_4	35.67	3.07	14.00	0.2370	0.47
Mean	28..69	2.46	11.73	0.1910	0.37
S E	1.596	0.154	0.596	0.01010	0.016
LSD $_{(0.05)}$	5.204	0.502	1.945	0.02320	0.052

At 50 % flowering, there was a marked variation among treatments (Table 3). Days to 50% flowering varied from 31.67 to 38.67 days. Lowest number of days to 50% flowering was observed in plots treated with T_3 while highest number of days to 50% flowering was observed in weedy check plots (38.67 days). T_3 and T_4 plots were comparable and superior to T_1 and T_2 plots. The shortest and the thinnest plants were observed for the weedy check plots. Number of leaves ranged from 6.33 to 15.67 leaves per plant. Results generally show that T_3 and T_4 plots had plants with the highest LAI (1.28 and 1.27, respectively) and were significantly different from all other treatments. TDM ranged from 0.27 t ha^{-1} for weedy check to 1.28 t ha^{-1} for T_4 plots. TDW at 50% flowering was in the following decreasing order: T_4 and $T_3 > T_2 > T_1 >$ weedy check.

Table 3: Effects of weeding regime on the growth of okra at 50 % flowering

Treatment	Days to 50 % flowering	Plant height (cm)	Stem girth (cm)	Number of Leaves per plant	LAI	TDW (t ha^{-1})
T_0	38.67	16.47	1.40	6.33	.0.22	0.27
T_1	35.00	27.30	2.73	10.67	0.78	0.78
T_2	33.00	38.13	3.37	13.67	1.07	0.97
T_3	31.67	42.43	4.43	15.67	1.28	1.27
T_4	32.00	42.73	5.67	15.67	1.27	1.28
Mean	34.07	33.41	3.32	12.40	0.92	0.91
S E	0.428	0.949	0.212	0.582	0.030	0.056
LSD $_{(0.05)}$	1.396	3.094	0.693	1.898	0.098	0.182

Yield and yield components

Yield and yield components were significantly affected by the weed regime treatments (Table 4). Plants on T4 plots had the highest (30.77) pods per plant which was significantly different from other treatment plots that had number of pods per plant ranging from 4.1 for T_0 to 21.5 for T_3. Pod weight per plant ranged from 17.33 g for T_0 to 196.30 g for T_4. Pod yield ranged from 0.87 t ha^{-1} for T_0 to 9.82 t ha^{-1} for T_4.

Table 4: Effects of weeding regime on pod yield of okra

Treatment	Pod yield		
	Number of pod per plant	Pod weight (g plant^{-1})	Pod yield (t ha^{-1})
T_0	4.10	17.33	0.87
T_1	8.90	47.50	2.38
T_2	11.83	75.10	3.77
T_3	21.50	117.67	5.88
T_4	30.77	196.30	9.82
Mean	15.42	90.78	4.54
S E	0.45	2.139	0.109
LSD $_{(0.05)}$	1.468	6.976	0.356

Weed species and weed biomass.

Eleusine Indica, Cypersus rotundus, Cynodon dactylon, Amaranthus viridus, Echinochloa crusgalli and Cyperus rotundus were identified in the various treatments. Data on weed biomass are presented in Table 5. Weed biomass was significantly influenced by different treatments. Highest weed biomass (0.29 t ha^{-1}) was observed in T_0 plots while the lowest weed biomass (0.06 t ha^{-1}) was recorded for T_4 plots. However, weed biomass for T_4 plots was not significantly different from those observed in T_2 and T_3 plots.

Table 5: Effects of weeding regime on weed biomass

Treatment	Weed biomass (t ha^{-1})
T_0	0.29
T_1	0.09
T_2	0.08
T_3	0.07
T_4	0.06
Mean	0.12
S E	0.008
$LSD_{(0.05)}$	0.025

Economic Analysis

Economic analysis of okra production under the different weeding regimes is shown in Table 7. The highest total cost of ₦ 218, 708.66 was recorded on T_4 plots, followed by T_3 plots (₦ 202, 708.66) and then T_0 plots (₦154, 708.66). The highest revenue (₦ 982,000.00) and gross margin (₦=782,728.97) were obtained from T_4 plots and the least (-₦ 42, 271.03) from T_0 plots. The weeded plots produced higher net return values (ranging from ₦ 67,708.66 for T_1 plots to ₦ 763,291.34 for T_4 plots) than the weedy check (- ₦ 67,708.66).

Table 6: Economic analysis of the effect of weeding regime on the performance of okra

Item (₦)	Treatment				
	T_0	T_1	T2	T_3	T_4
Fixed cost					
Land (rent)	10,293.23	10,293.23	10,293.23	10,293.23	10,293.23
basket	758.83	758.83	758.83	758.83	758.83
Weeding hoe	2,496.48	2,496.48	2,496.48	2,496.48	2,496.48
Hand glove	1,372.18	1,372.18	1,372.18	1,372.18	1,372.18
Land mat	1,259.40	1,259.40	1259.40	1259.40	1259.40
Matchet	1,293.00	1,293.00	1293.00	1293.00	1293.00
Basin	1,964.28	1,964.28	1,964.28	1,964.28	1,964.28
Total fixed cost (TFC)	19,437.63	19,437.63	19,437.63	19,437.63	19,437.63
Variable cost					
Seeds	7,531.03	7,531.03	7531.03	7531.03	7531.03
Fertilizer (NPK)	24,000.00	24,000.00	24000.00	24000.00	24000.00
Pesticides (Cypermetrin)	3,500.00	3,500.00	3,500.00	3,500.00	3,500.00
Transportation	11,200.00	11,200.00	11,200.00	11,200.00	11,200.00
Land clearing	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00

Ploughing and harrowing	23,600.00	23,600.00	23,600.00	23,600.00	23,600.00
Sowing	17,120.00	17,120.00	17,120.00	17,120.00	17,120.00
Thinning	4,800.00	4,800.00	4,800.00	4,800.00	4,800.00
Weeding	0.00	16,000.00	32,000.00	48,000.00	64,000.00
Fertilizer application	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00
Pesticide application	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00
Harvesting	16,800.00	16,800.00	16,800.00	16,800.00	16,800.00
Total variable cost (TVC)	135,271.03	151,271.03	167,271.03	183,271.03	199,271.03
Total cost of production (TC)	154,708.66	170,708.66	186,708.66	202,708.66	218,708.66
Total revenue (TR)	87,000.00	238,000.00	377,000.00	588,000.00	982,000.00
Gross margin (GM)	-42,271.03	86,728.97	209,228.97	404,728.97	782,728.97
Net Return (NR)	-67,708.66	67,291.34	190,291.34	385,291.34	763,291.34
Return per naira invested	0.64	1.57	2.75	4.21	5.93
Benefit: Cost ratio	0.56	1.39	2.02	2.90	4.49

DISCUSSION

Our study showed that the different weeding regimes significantly affected the growth and yield of okra. The weedy check yield of 0.97 t ha^{-1} was below the previously reported yield of 2.1 t ha^{-1} under Nigerian cropping situation (FAOSTAT, 2012). This is an indication of okra sensitivity to weed competition at early stage of growth. The marked variation among the various treatments supports earlier report that yield is dependent on time of weed removal (Adeosun, 2005). Earlier, Iremirem (1988) reported that 2-4 weeks after sowing would be the critical period for weed removal in okra production. However, Akobundu (1987) suggested that okra field should be kept weed-free throughout growth and production period to obtain maximum pod yield. Interference of weed with okra plant resulted in 91.1, 75.8, 61.6 and 40.1% pod yield reduction when planted on T_0, T_1, T_2 and T_3 plots respectively. To avoid pod yield loss due to weed interference, the field must be kept free of weeds through out the entire growing season.

The thinner and shorter plants on the weedy check plots may be due to competition with weeds for growth resources (Nolarubu et al, 2003). The highest number of leaves, LAI and TDM obtained when plots were kept weed-free till harvest suggest that most of assimilates were partitioned into pod yield principally because weed interference at this critical period of weed removal did not confer any adverse effect on the source and sink metabolic process of the crop. This could be attributed to adequate LAI which make it easy for the crop to intercept solar radiation better than the weedy check plots, hence making the weed interference less effective on the pod yield of the crop (O'Donovan, et al, 1997).

The non significant effect of weed removal on plant height, stem girth and number of leaves per plant at two WAS may be due to the fact that at the beginning of the growth, the requirement for growth resources was small enough that both the crop and weeds could co-exist without affecting each other. But with the advancement of growth, weeds began to out-compete the crop for growth resources and the yield potential was negatively impacted. This may imply that adequate provision should be made for a consistent weed control on okra fields. Controlling weeds at early stage of growth may boost plant growth. This may give the crop a good start with minimal weed interference.

Changes in the number of leaves as a result of treatment effect may affect the performance of the plant as the leaves serves as an organ for photosynthesis. Increase in number of leaves led to greater LAI and there was a positive correlation between number of leaves and LAI (r = 0.62). It is known that the LAI of any plant is a measure of the capacity of the photosynthetic system. The LAI generally was most outstanding with the weeded plots throughout the sampling periods due to increased foliage. As a consequence, a high amount of radiation was intercepted contributing to an increase in TDM and pod yields. Weedy check plots had the highest weed biomass. Weed biomass increased with increasing periods of weed infestation. T_3 reduced weed biomass by 79.3% compared to weedy check. T_2 and T_1 reduced by 75.9% and 72.4%, respectively compared to weedy check. This was not unexpected since weeds continued growth throughout the production period. This however, gave the weeds competitive advantage over the crop.

Economic analysis showed that there was positive relationship between pod yield improvement and viability in okra production. The revenue realized from the weedy check plots were the least while the weed free till harvest had the highest revenue. The benefit cost ratio was highest from weed free till harvest. Optimum yield was produced from weed free till harvest based on the fact that it had the greatest gross margin and net return. In terms of viability, weed free till harvest was the most viable as indicated through return per naira invested value of 5.93 and resulted in the highest benefit cost ratio in opera production (4.49)

CONCLUSION

Based on the research findings, it can be deducted that weed-free till harvest is appropriate for optimum production of okra in rain forest agro-ecological zone for good profitability. This would boost okra productivity in the humid tropical environment of Nigeria.

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