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SOCIETY FOR SCIENCE AND EDUCATION

Effect of Integrated Weed Control Options on Growth and Yield of Cassava at Kilosa District, Tanzania

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ABSTRACT

Weeds are among of the major pest that hinders cassava growth and production. Also, weeds can host insect and disease pathogens, thus brings up difficulty in the growth of cassava. The effect of different weed control treatment combinations was studied at Ilonga village, Kilosa district during 2019/2020 planting season. Till only and till + Ridge, pre-emergence herbicides (Primagram Gold a.i 290 g/L S-metolachlor + 370 g/L atrazine and Oxfen a.i Oxyfluorfen 24% EC), post emergence herbicides (Force up a.i 480 g/L of Glyphosate-Isopropylamine salt and back pack weeder with modified tines were tested on Cassava variety Kiroba in a factorial experiment arranged in a randomized complete block design (RCBD) replicated three times. Combination of tillage practices and pre-emergence herbicides application increased number of days weeds took to re-emerge. The correlation analysis showed a highly significant strong positive relationship, r = 0.925, $p < 0.001$ and r = 0.781, $p < 0.05$ between cassava stem height and cassava fresh root weight, and cassava stem girth and cassava fresh root weight, respectively. Weed control combinations did not significantly affect the cassava fresh root weight, p = 0.514 and cassava biomass p = 0.732. Also weed control combinations did not significantly affect soil quality. The combination of till + ridges, application of S-metolachlor + atrazine herbicides and glyphosate provided favorable environment for cassava growth and root formation as compared to other treatment combinations. Therefore, it is recommended as a best option for controlling weeds in cassava production system.

Keywords: Cassava, Weed control combination(s), Days after planting, Fresh root weight, Cassava biomass

INTRODUCTION

Weeds has been the major challenge in production of many fields crops due to its competition towards fundamental requirements for plants to grow [1]. Weeds grow faster and in a large number in one area which this latter on reduces crop yield [2]. Cassava as the one of crops produced for commercial purpose or as food crop, it also faces difficulties caused by weeds during growing. In order to avoid yield loss in cassava production weed control within the first four weeks after planting is crucial. Islami et al. [2] and Ekeleme et al. [3] reported that, poor weeding might cause yield loss of up to 90%.

In order to reduce cassava yield losses, various methods of weed control have been suggested; Schwartz-Lazaro and Copes [4] suggested the proper soil tillage as the fore most important weed control technique as it kills the emerged weeds and exposes weed seeds to conditions unfavorable for their gemination thus reducing the seed bank. Kraehmer et al. [5] and Ekeleme et al. [6] suggested the use of herbicides as they are effective in controlling weeds if applied at appropriate rate and time. There are different types of herbicides depending on the requirement of the user, crop growth stage and weed type and their growth stage, some of herbicides are pre-emergence ones which are applied in the soil to kill the weed seeds and early emerged weeds [6] others are post emergence herbicides which are applied after weed emergence and they either control weeds emerged at the time of application or already emerged weeds and provide residual activity against late emerging weeds [5]. But intensive care should be taken when using these herbicides as some studies revealed the excessive use or improper use of herbicide can cause detrimental effects to human health and environment in general [7].

At the time of weed control, the most important thing to note is the growth stage of cassava and the time taken for the weeding to be done as some of the weeding methods consume a lot of time and need huge labor force. This is the major factor contributing to cassava yield reduction as the more you delay in weeding, the more you will loss the cassava yield. Reshma et al. [8] reported that cassava requires good weed management during the first three to four months after planting, as it has a tendency of exhibiting slow initial growth and incomplete canopy cover, thus the effectiveness of any weed control measures depends largely on timeliness of application. Therefore, this study was conducted to determine the best package from different integrated weed control techniques which will keep cassava farm free from weeds for a longer period of time and resulting to optimum cassava root yield production.

MATERIALS AND METHODS

Description of the Study Site

The study was conducted in Ilonga village, Kilosa district, Morogoro region at a geographical location of latitude 6°46’ 27” S and longitude 37°2’14” E, and elevation of 479.95 m asl. The district experiences an average of eight months of rainfall (October to May), with the highest levels between February and March. The rainfall distribution is weakly bimodal in good years, with short rains (October to January), followed by long rains (mid-February to May). Mean annual rainfall ranges between 1 000 and 1 400 mm in the southern flood plain, while further north (Gairo Division) the annual rainfall ranges from 800 to 1 100 mm. The mean annual temperature in Kilosa district is about 25°C [9, 10].

Treatments and Experimental Design

Experimental design used was factorial experiment (2 × 2 × 2) arranged in randomized complete block design, whereby eight plots were established to make one replication. Plot size was 20 m^2 (4 m × 5 m) and plots were separated by 1 m and replication was separated by 2 m. Treatments were replicated three times in each site.

Treatments were two tillage practices (Till only and till + Ridge), two pre-emergence weed control options (herbicide) (Primagram Gold a.i 290 g/L S-metolachlor and 370 g/L atrazine and Oxfen a.i Oxyfluorfen 24% EC) and two post emergence weed control options (herbicide; Force up a.i 480 g/L of Glyphosate-Isopropylamine salt and mechanized weeder tool; back pack weeder with modified tines). Pre emergence weed control treatments were applied at planting. Post emergence weed control treatments were applied when weed population reached 30% (three to four leaves stage) within a plot. Cassava (Kiroba variety) planted at a population of 10 000 plants/ha was used.

Data Collection

Crop Data Collected:

Growth Characteristics:

After treatments application five months after planting (5 MAP), data on cassava stem height and girth were collected.

Harvest Data:

On the 10^{th} MAP, the above ground plant parts (leaves with petioles, stem and planting stalk) and roots were weighed to determine harvest index (plant biomass).

For the roots; data on number of marketable/storage cassava roots, cassava root yield (fresh root weight per plant, fresh root weight per Ha, dry storage root weight per 500 g sample of cassava root according to [11] were recorded. Dry matter content was estimated after oven dry at 105°C for 24 hours according to [12]. These data were collected from two middle rows in the plot leaving two lines on each side of the plot as borders.

Weed Data Collected:

Weed species and number of days (time) at which weed population reaches 30% (three to four leaves stage) were recorded in order to determine the duration at which pre-emergence and post emergence weed control treatments suppressed weed growth as per [13] procedure.

Soil Data Collected:

Soil samples were collected in each field at the depth of 0 – 20 cm and 21 – 50 cm before land preparation for assessment of the initial soil fertility status. A total of five samples were collected in a zigzag pattern at each depth to make a compost sample and then this sample was used to make a single sample [14].

Data Analysis

The data collected were subjected to analysis of variance (ANOVA) at ($P \leq 0.05$) using R statistical package version 3.5.2. The treatment means were compared using Tukey's honestly significance test at alpha 5%. Correlation analysis (Pearson's correlation coefficients) was performed among variables. Also, both physical and chemical characteristics of the soil sample collected were determined.

RESULTS

Physical and Chemical Characteristics of the Soils at the Studied Site

Soil chemical characteristics and particle size class of the surface and subsurface soils (0 to 20 cm and 21 to 50 cm deep) in 2019/2020 planting season are shown in Table 1. The method used for analysis of each nutrient was pH meter, Walkley – Black, Bray 1, Kjeldahl, Ammonium Acetate Extraction pH 7.0, DTPA Extraction pH 7.3 and Hydrometer for soil pH, Organic carbon, Phosphorus, Nitrogen, Exchangeable bases (Ca, Mg, K and Na), Micro nutrients (Cu, Zn, Mn and Fe) and Textural class, respectively.

Table 1: Soil characteristics of the studied area

Parameter	Soil depth		Range suitable for cassava production	Rated according to:
	0-20 cm	21-50 cm		
pH (in H_2O)	5.88	5.61	4.5 - 7.0	[15]
OC (%)	1.48	1.26	4.0 - 10.0	[16]
P ($mgkg^{-1}$)	5.07	2.86	< 4.2	[17]
N (%)	0.25	0.2	0.20 - 0.50	[16]
Ca ($cmol_ckg^{-1}$)	10.8	10.82	1.0 - 5.0	[15]
Mg ($cmol_ckg^{-1}$)	2.57	2.66	0.40 - 1.00	[15]
K ($cmol_ckg^{-1}$)	0.67	0.38	0.15 - 0.25	[15]
Na ($cmol_ckg^{-1}$)	0.08	0.12	< 2	[17]
Cu ($mgkg^{-1}$)	2.04	2.24	0.3 - 0.8	[18]
Zn ($mgkg^{-1}$)	0.59	0.39	1.0 - 3.0	[18]
Mn ($mgkg^{-1}$)	21.5	21.31	1.2 - 3.5	[18]
Fe ($mgkg^{-1}$)	55.35	50.56	4.0 - 6.0	[18]
Textural class	SCL	SCL		

SCL = silty clay loam soil

Influence of Tillage Practice, Pre-Emergence Weed Control and Post Emergence Weed Control Treatments on Weed Growth

Days to First Post Emergence Weed Control:

The results on effect of tillage practice, pre-emergence weed control treatments and post emergence weed control treatments on days to first post emergence weed control treatment application for Ilonga site are shown in Table 2. There was a highly significant ($p<0.001$) effect of tillage practice on a number of days to the first post emergence weed control treatments application. Whereby, the application of tillage and ridging resulted into the highest number of days to first post emergence weed control treatments application.

Additionally, there was a highly significant ($p<0.001$) effect of pre-emergence weed control treatments on a number of days to weeds emergence. The application of Primagram gold as pre-emergence herbicide resulted the highest number of days to weed emergence. Also, there was non-significant ($p>0.05$) effect of post emergence treatment application on the days to weeds reemerge. The application of Force up herbicide as a post-emergence treatment led to many numbers of days weeds took to reach three leaves stage.

Days to Second Post Emergence Weed Control:

Table 2 shows the results on effect of tillage practice, pre-emergence weed control and post emergence weed control treatments on weed growth after the first post-emergence weed control treatment application. The results showed that, there was a highly significant (p<0.001) effect of tillage practice on days to second post-emergence weed control treatments application, whereby till and ridge showed highest number of days to second post-emergence weed control treatment application.

There was no significant (p>0.05) effect of pre-emergence weed control treatments on days to second post emergence weed control treatment application. The application of Primagram gold as pre-emergence herbicide showed the highest number of days to second post-emergence weed control treatment application in both sites.

Furthermore, there was a highly significant (p<0.001) effect of post emergence treatment application on days to second post emergence weed control treatment application. The application of Force up herbicide significantly increased the number of days to the next post-emergence weed control treatment application.

Table 2: Influence of Tillage practice, Pre-emergence and Post-emergence weed control treatments on weed growth at the studied site

Treatment factors		**Days to 1st PEWC**	**Days to 2nd PEWC**
Factor A	Till	32.17b	70b
(Tillage practice)	Till and Ridge	44.08a	78.58a
	Mean	*38.13*	*74.29*
	p value	*<.0001*	*<.0001*
Factor B	Oxfen	35.58b	74.08a
(Pre emergence treatment)	Primagram	40.67a	74.5a
	Mean	*38.13*	*74.29*
	p value	*<.0001*	*0.6186*
Factor C	Force up	38.08a	77.08a
(Post emergence treatment)	Mechanical weeding	38.17a	71.5b
	Mean	*38.1*	*74.29*
	p value	*0.8619*	*<.0001*

Values in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly significance test, PEWC = post-emergence weed control.

Interaction's Effect of Weed Control Treatments on Weeds Growth

Days To First Post Emergence Weed Control:

The results on the weed control treatment interaction on a number of days to the first post emergence weed control treatment application are shown in Table 3.

The combination of tillage practices and pre-emergence weed control significantly ($p<0.05$) increased the number of days of weeds reemergence. Till and ridge × Primagram herbicide treatment combinations, controlled weeds for many days, while on plots where till × Oxfen treatment combination were applied showed the lowest number of days to the next treatment application.

The combination of tillage practices and post-emergence weed control were significantly ($p<0.05$) increased the number of days to weed emergence. Till and ridge × Force up herbicide treatment combinations, controlled weeds for more days, while on plots where till × Force up herbicide treatment combinations were applied had the lowest number of days.

The combination of pre-emergence weed control and post-emergence weed control treatments did not significantly ($p>0.05$) increase the number of days to weed emergence. Primagram herbicide × Force up herbicide treatment combinations, controlled weeds for more days, while on plots where Oxfen × mechanical weeding treatment combinations were applied had the smaller number of days.

The application of tillage practice, pre-emergence herbicides and post-emergence weed control treatment combinations did not significantly ($p>0.05$) increase the number of days to weed emergence. Till and ridge × Primagram × Force up treatment combinations showed the highest number of days while till × Oxfen × Force up showed the lowest number of days to the next treatment application.

Days To Second Post-Emergence Weed Control:

The results on effect of tillage practice, pre-emergence and post-emergence weed control treatment interactions on days to second post-emergence weed control treatment application are shown in Table 3. The combinations of tillage practices and pre-emergence weed control significantly ($p<0.05$) increased the number of days to second post emergence weed control treatment application. Till and ridge × Primagram herbicide treatment combinations-controlled weeds for more days. The plots where till × Primagram treatment combinations were applied showed the lowest number of days.

The combinations of tillage practices and post-emergence weed control treatments significantly ($p<0.05$) increased the number of days to second post-emergence weed control treatment application. Till and ridge × Force up herbicide treatment combinations-controlled weeds for more days. The plots where till × Force up herbicide treatment combinations were applied had the lowest number of days.

The combinations of pre-emergence weed control and post-emergence weed control treatments did not significantly ($p>0.05$) increase the number of days to second post-emergence weed control treatment application. Primagram herbicide × Force up herbicide treatment combination-controlled weeds for more days. The plots where Primagram × mechanical weeding treatment combinations were applied had the lowest number of days. The application of tillage practice, pre-emergence herbicides and post-emergence weed control treatment combinations significantly ($p\leq0.05$) increased the number of days to the next post-emergence weed control treatment application. Till and ridge × Primagram × Force up treatment combinations showed the highest number of days and till × Primagram × Force up showed the lowest number of days. During this stage of post-emergence treatment application, perennial weeds; *Cyperus rotundus* and *Cynodon species* were predominant.

Table 3: Interaction effect of weed control treatments on weed growth at Ilonga site

Treatments factors		**Days to 1st PEWC**	**Days to 2nd PEWC**
A × B	Till × Oxfen	29d	71b
	Till × Primagram	35.33c	69b
	Till and Ridge × Oxfen	42.17b	77.17a
	Till and Ridge × Primagram	46a	80a
	p value	*0.0174*	*0.0095*
A × C	Till × Force up	31.5b	69b
	Till × Mechanical weding	32.83b	71b
	Till and Ridge × Force up	44.67a	85.17a
	Till and Ridge × Mechanical weeding	43.5a	72b
	p value	*0.0174*	*<.0001*
B × C	Oxfen × Force up	36.17b	76.17a
	Oxfen × Mechanical weeding	36b	72b
	Primagram × Force up	41a	78a
	Primagram × Mechanical weeding	40.33a	71b
	p value	*0.1312*	*0.1036*
A × B × C	Till × Oxfen × Force up	28d	71cd
	Till × Oxfen × Mechanical weeding	30d	71cd
	Till × Primagram × Force up	35c	67d
	Till × Primagram × Mechanical weeding	35.67c	71cd
	Till and Ridge × Oxfen × Force up	42.33b	81.33b
	Till and Ridge × Oxfen × Mechanical weeding	42b	73c
	Till and Ridge × Primagram × Force up	47a	89a
	Till and Ridge × Primagram × Mechanical weeding	45ab	71cd
	Mean	38.12	74.29
	CV%	3.2	2.7
	p value	*0.8619*	*0.0007*

Values in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly significance test, CV = coefficient of variation, PEWC = post-emergence weed control, A = Tillage practice, B = Pre-emergence weed control treatment, C = post-emergence weed control treatment.

Influence of Tillage Practice, Pre-Emergence and Post-Emergence Weed Control Treatments on Cassava Plant Height and Stem Girth At 5 Months After Planting

The results in Table 4 shows that there was significant ($p>0.005$) influence of tillage practices on cassava plant height and stem girth at five months after planting between treatments. Till and ridge treatment showed the highest stem height and stem girth.

There was no significant (p>0.05) effect of pre-emergence weed control treatments on cassava plant height and stem girth at 5 months after planting. Oxfen treatment applied as pre-emergence weed control showed the highest stem height and stem girth.

There was no significant (p>0.05) effect of post-emergence weed control treatments on cassava plant height and stem girth at 5 months after planting. Force up herbicide applied as post-emergence weed control recorded the highest stem height and stem girth.

Table 4: Influence of Tillage practice, Pre-emergence and Post-emergence weed control treatments on cassava plant height and stem girth at 5 months after planting

Treatment factors		**Stem Height (cm)**	**Stem Girth (cm)**
Factor A	Till	62.0667b	6.56b
(Tillage practice)	Till and Ridge	81.6833a	7.53a
	Mean	*71.88*	*7.05*
	p value	*0.0119*	*0.0184*
Factor B	Oxfen	72.25a	7.13a
(Pre emergence treatment)	Primagram	71.5a	6.96a
	Mean	*71.88*	*7.05*
	p value	*0.915*	*0.6569*
Factor C	Force up	74.15a	7.26a
(Post emergence treatment)	Mechanical weeding	69.6a	6.83a
	Mean	*71.88*	*7.05*
	p value	*0.5201*	*0.2565*

Values in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly significance test

The Influence of Weed Control Treatment Interactions on Cassava Plant Height and Stem Girth at 5 Months After Planting

The Influence of Weed Control Treatment Interactions on Cassava Plant Height At 5 Months After Planting:

Table 5 shows the influence of weed control treatment interactions on cassava plant height. The combinations of tillage practices and pre-emergence weed control treatments did not significantly (p>0.05) affect the stem height. Till and ridge × Oxfen treatment combinations, had the highest stem height at the studied site. Plots where till × Primagram herbicide treatment combinations were applied had the lowest stem height.

The combinations of tillage practices and post-emergence weed control treatments did not significantly (p>0.05) affect the stem height. Till and ridge × Force up herbicide treatment combinations showed the highest stem height. The plots where till × mechanical weeding treatment combinations applied showed the lowest stem height at the studied site. The combinations of pre-emergence weed control and post-emergence weed control treatments did not significantly (p>0.05) affect the stem height. At the studied site, Oxfen × Force up herbicide treatment combination showed the highest stem height while Oxfen × mechanical weeding treatment combination showed the lowest stem height.

Also, the application of tillage practice, pre-emergence herbicides and post-emergence weed control treatment combinations did not significantly (p>0.05) increase the stem height. Till and Rigde × Oxfen × Force up and Till and Ridge × Oxfen × Mechanical weeding resulted to the highest cassava stem height while till × Oxfen × Mechanical weeding led to the lowest stem height.

The Influence of Weed Control Treatment Interactions on Cassava Plant Stem Girth At 5 Months After Planting:

Table 5 shows the influence of weed control treatment interactions on cassava stem girth. The combinations of tillage practices and pre-emergence weed control did not significantly (p>0.05) affect the stem girth. Till and Ridge × Oxfen treatment combinations, showed the highest stem girth at the studied site. Plots where till × Primagram herbicide treatment combinations were applied showed the lowest stem girth. The treatment combinations of tillage practices and post-emergence weed control did not significantly (p>0.05) affect the stem girth at Ilonga sites. Till and Ridge × Mechanical weeding treatment combinations showed the highest stem girth. The plots where till × Mechanical weeding treatment combinations were applied, showed the lowest stem girth. The treatment combinations of pre-emergence and post-emergence weed control did not significantly (p>0.05) affect the stem girth. At Ilonga site, Oxfen × Force up herbicide treatment combinations showed the highest stem girth while Oxfen × Mechanical weeding treatment combinations showed the lowest stem girth.

The application of tillage practice, pre-emergence herbicides and post-emergence weed control treatment combinations did not significantly (p>0.05) increase the cassava stem girth in the studied sites. Till and Ridge × Oxfen × Force up and Till and Ridge × Oxfen × Mechanical weeding treatment combinations had the highest stem girth while cassava plants in till × Oxfen × Mechanical weeding treatment combinations had the lowest stem girth.

Table 5: The influence of weed control treatment interactions on cassava plant height and stem girth at 5 months after planting

Treatment interactions		Ilonga village	
		Stem Height (cm)	Stem Girth (cm)
A × B	Till × Oxfen	59.93a	6.58a
	Till × Primagram	64.2a	6.53a
	Till and Ridge × Oxfen	84.57a	7.67a
	Till and Ridge × Primagram	78.8a	7.38a
	p value	*0.4789*	*0.7555*
A × C	Till × Force up	66.07a	7.05ab
	Till × Mechanical weeding	59.07a	6.07b
	Till and Ridge × Force up	82.23a	7.47ab
	Till and Ridge × Mechanical weeding	81.12a	7.58a
	p value	*0.6248*	*0.1548*
B × C	Oxfen × Force up	75.87a	7.5a
	Oxfen × Mechanical weeding	68.63a	6.75a
	Primagram × Force up	72.43a	7.02a

	Primagram × Mechanical weeding	70.57a	6.9a
	p value	*0.7033*	*0.4026*
A×B×C	Till × Oxfen × Force up	65.93a	7.33a
	Till × Oxfen × Mechanical weeding	53.93a	5.83a
	Till × Primagram × Force up	66.2a	6.77a
	Till × Primagram × Mechanical weeding	62.2a	6.3a
	Till and Ridge × Oxfen × Force up	85.8a	7.67a
	Till and Ridge × Oxfen × Mechanical weeding	83.33a	7.67a
	Till and Ridge × Primagram × Force up	78.67a	7.27a
	Till and Ridge × Primagram × Mechanical weeding	78.93a	7.5a
	Mean	71.9	7.04
	CV%	15.9	7
	p value	*0.8515*	*0.5946*

Values in the same column, followed by the same letter(s) do not differ significantly ($P \le 0.05$) according to Tukey's honestly significance test, CV = coefficient of variation, A = Tillage practice, B = Pre-emergence weed control treatment, C = post-emergence weed control treatment.

The Influence of Tillage Practice, Pre-Emergence and Post-Emergence Weed Control Treatments on Cassava Yield, Biomass and Dry Matter Content:

Results on the influence of tillage practices on cassava fresh root weight (t ha^{-1}), cassava biomass (t ha^{-1}) and cassava dry weight are shown in Table 6 below. Tillage practice significantly ($p \le 0.05$) influenced the cassava fresh root weight, cassava biomass and cassava dry weight respectively. Till and ridge treatment showed the highest cassava fresh root weight, biomass and dry weight. The pre-emergence and post-emergence treatments did not significantly ($p > 0.05$) affect the cassava fresh root weight, biomass and dry weight. Oxfen treatment showed the highest cassava fresh root weight, biomass and lowest dry weight for pre-emergence treatment while mechanical weeding led to lowest cassava fresh root weight, highest biomass and highest dry weight for post-emergence treatment.

Table 6: The influence of tillage practice, pre-emergence weeds control and post-emergence weed control treatments on cassava yield, biomass and dry matter content at the studied site

Treatment factors		**Fresh root weight (t ha^{-1})**	**Cassava biomass (t ha^{-1})**	**Cassava dry weight (g)/ 500 g sample**
Factor A	Till	8.2b	18.12b	144.58a
(Tillage practice)	Till and Ridge	21.14a	36.57a	194.58a
	Mean	*14.67*	*27.35*	*169.58*
	p value	*0.0109*	*0.0211*	*0.0502*
Factor B	Oxfen	14.8a	27.7a	167.92a
(Pre-emergence treatment)	Primagram	14.55a	26.98a	171.25a
	Mean	*14.68*	*27.34*	*169.59*
	p value	*0.9561*	*0.9214*	*0.8895*

Factor C	Force up	14.85a	26.57a	164.58a
(Post-emergence treatment)	Mechanical weeding	14.5a	28.11a	174.58a
	Mean	*14.68*	*27.4*	*169.58*
	p value	*0.9391*	*0.8337*	*0.6775*

Values in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly significance test

The Influence of Weed Control Treatment Interactions on Cassava Fresh Root Weight, Biomass and Dry Matter Content

The results presented on Table 7 shows the influence of weed control treatment interactions on cassava fresh root weight, biomass and dry matter content at Ilonga sites. The combinations of tillage practices and pre-emergence weed control treatments did not significantly (p>0.05) affect the cassava fresh weight, biomass and dry weight. At Ilonga site, Till and Ridge × Oxfen treatment combinations showed the highest cassava fresh weight, biomass and dry weight while till × Oxfen herbicide treatment combinations showed the lowest cassava fresh weight, biomass and dry weight.

The treatment combination of tillage practices and post-emergence weed control did not significantly (p>0.05) affect the cassava fresh weight, cassava biomass and cassava dry weight. Till and Ridge × Force up herbicide treatment combinations showed the highest cassava fresh weight, while Till and Ridge × Mechanical weeding treatment combination showed the highest cassava biomass and dry weight. Similarly, till × Force up herbicide treatment combinations showed the lowest cassava fresh weight, biomass and dry weight.

The treatment combinations of pre-emergence and post-emergence weed control treatments did not significantly (p>0.05) affect the cassava fresh weight, biomass and dry weight. The application of tillage practice, pre-emergence herbicides and post-emergence weed control treatment combinations did not significantly (p>0.05) affected both cassava fresh root weight and cassava biomass.

Till and Ridge × Oxfen × Force up treatment combinations produced the highest fresh root weight and biomass while till × Oxfen × Mechanical weeding treatment combinations had the lowest fresh root weight and biomass.

Also, weed control treatment combinations did not significantly (p>0.05) affect the cassava dry matter content. Till × Primagram × Mechanical weeding, Till and Ridge × Oxfen × Mechanical weeding and Till and Ridge × Oxfen × Force up treatment combinations showed the highest cassava dry matter content. Till and Ridge × Oxfen × Force up and till × Oxfen × Force up treatment combinations gave the lowest dry matter content.

Table 7: The influence of weed control treatment combinations (interaction) on cassava fresh root weight, biomass and dry weight at Ilonga

Treatment interactions		Fresh root weight (t ha^{-1})	Cassava biomass (t ha^{-1})	Cassava dry weight (g)/ 500 g sample
A × B	Till × Oxfen	5.91a	16.24a	132.5a
	Till × Primagram	10.49a	19.99a	156.67a
	Till and Ridge × Oxfen	23.68a	39.16a	203.33a
	Till and Ridge × Primagram	18.6a	33.97a	185.83a
	p value	*0.2983*	*0.5448*	*0.3906*
A × C	Till × Force up	7.86a	16.75a	142.5a
	Till × Mechanical weeding	8.54a	19.48a	146.67a
	Till and Ridge × Force up	21.83a	36.39a	186.67a
	Till and Ridge × Mechanical weeding	20.45a	36.74a	202.5a
	p value	*0.8209*	*0.8717*	*0.808*
B × C	Oxfen × Force up	17.37a	31.63a	163.33a
	Oxfen × Mechanical weeding	12.22a	23.78a	172.5a
	Primagram × Force up	12.32a	21.51a	165.83a
	Primagram × Mechanical weeding	16.77a	32.44a	176.67a
	p value	*0.3013*	*0.2116*	*0.9723*
A×B×C	Till × Oxfen × Force up	9.17a	20.63a	123.33a
	Till × Oxfen × Mechanical weeding	2.66a	11.86a	141.67a
	Till × Primagram × Force up	6.55a	12.87a	161.67a
	Till × Primagram × Mechanical weeding	14.43a	27.1a	151.67a
	Till and Ridge × Oxfen × Force up	25.58a	42.62a	203.33a
	Till and Ridge × Oxfen × Mechanical weeding	21.79a	35.7a	203.33a
	Till and Ridge × Primagram × Force up	18.09a	30.15a	170.00a
	Till and Ridge × Primagram × Mechanical weeding	19.11a	37.79a	201.67a
	Mean	14.67	27.34	170
	CV%	59.8	54.1	33
	p value	*0.6014*	*0.7735*	*0.5342*

Values in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly significance test, CV = coefficient of variation, A = Tillage practice, B = Pre-emergence weed control treatment, C = post-emergence weed control treatment.

Relationship Between Cassava Growth Parameters and Cassava Fresh Root Weight at Ilonga Site

The relationship between cassava growth parameters and cassava fresh root weight is shown in Table 8. The correlation analysis revealed that, there was a highly significant, strong positive relationship ($r = 0.925$, $p < 0.001$) between the cassava stem height and the cassava fresh root weight. Also, there was a significant strong positive relationship ($r = 0.781$, $p < 0.05$) between the cassava stem girth and the cassava fresh root weight.

Table 8: Relationship between cassava stem height and girth and cassava fresh root weight

	Stem girth	Stem height	Fresh root weight
Stem girth	1		
Stem height	0.916***	1	
Fresh root weight	0.781*	0.925***	1

n = 24, df =n-2, *Significant correlation p = 0.05, Significant correlation p = 0.01 and ***Significant correlation p = 0.001

Influence of Tillage Practice, Pre-Emergence and Post-Emergence Weed Control Options on Soil pH, N, P, K, Ca and Mg Nutrient

Results from the study revealed that, the selected weed control treatment combinations had not significantly affected soil pH, amount of N, P, K, Ca and Mg nutrients.

DISCUSSION

Effect of Integrating Tillage and Herbicides Control Option(s) on Weeds Growth

From the study findings, its revealed that, the integration of tillage practice (till + ridge) and the use of pre-emergence herbicide having 290 g/L S-metolachlor and 370 g/L atrazine active ingredient significantly hinders the weeds regrowth for a long period. The reasons for this could be due to tillage exposes the underground seed to the sunlight which kills the exposed weeds while ridging buries the existing weeds thus killing them, these results are in accordance to that of [4] who reported that, farm preparation by tillage exposes the underground weeds and weed seeds to the sunlight which is not favorable for seed germination, thus reducing their ability to germinate.

Also, the use of herbicides made up of 290 g/L S-metolachlor and 370 g/L atrazine kills the weed seedlings as these herbicides are active to the tender weeds. The results are similar to those of Udensi et al. and Godwin et al. [19, 20] who reported 290 g/L S-metolachlor and 370 g/L atrazine are highly effective in controlling early emerged weeds during the starting of the planting season.

Effect of Integrating Tillage and Mechanical Weeding Control Option(s) on Weeds Growth

The study results showed that, integration of tillage practices and mechanical weeding required more than three weeding operations for its maximum weed control. The most commonly weeds observed were *Asclepias syriaca*, *Trichodesma zeylanicum*, *Commelina benghalensis*, *Cyperus rotundus*, *Ocimum sp*, *Echinochloa colona*, *Cynodon species*, *Dactyloctenium aegyptium*, *Digitaria sp* and *Portulaca oleracea*. This was observed as a result of mechanical machines only killed the above ground weed parts and leaving the below ground parts alive, thus stimulating their regrowth as most of these observed weeds have reproductive ability to reproduce both sexually and asexually and their adaptive ability to grow in a wide range of soil. Edensi et al. and Ekeleme et al. [3, 19] also started when mechanical machines like backpack weeder are used, more than four times weeding operations are required in order to control perennial weeds.

Influence of Weed Control Treatments on Cassava Plant Height and Stem Girth At 5 Months After Planting

The results showed that, the integration of weed control option(s) had significant influence on cassava plant height and girth. The observed effect could be probably due to reduced competition on soil nutrients and sunlight between cassava plants and weeds, hence favors the cassava grows and expansion with vigor. These results are in accordance with that of Velmurugan et al. [21] who reported presence of weeds and their management activities can highly affect the growth of cassava stem and girth. Also, [4] showed tillage helps root penetration by loosening the compacted soils and exposes beneath the ground weed seeds to the direct sunlight thus helping the crop to grow and the application of herbicides control weeds that emerged at the time of application or those weed already emerged thus the crop planted in a weed free soil.

Relationship Between Cassava Growth Parameters and Cassava Fresh Root Weight

Results showed that, at Ilonga site, there was a highly significant strong positive relationship between the cassava stem height and the cassava fresh root weight, $r = 0.925$, $p < 0.001$. There was a significant strong positive relationship between the cassava stem girth and the cassava fresh root weight, $r = 0.781$, $p < 0.05$. This profound effect of growth parameter of cassava on the final tuber yield could be due to the fact that, growth parameters tend to show a significant positive contribution to the tuber weight at a maximum vegetative phase of cassava. During this stage, the increase in cassava height and girth goes in accordance to the increase in cassava fresh root weight. Similar results were reported by Edet et al., Amarullah et al. and Misganaw and Bayou [11, 22, 23] who observed the increase in stem height and girt is positively correlated with the increase in fresh root weight and dry matter yield. This occurs at the maximum vegetative phase of cassava.

Reasons for Lower Cassava Fresh Root Weight (tha^{-1}) and Fresh Biomass at The Studied Site

There was a non-significant difference observed in fresh root weight and biomass of cassava at the studied site that may be attributed to the difference in soil characteristics and weather condition during 2019/2020 planting season. At Ilonga there were high rainfall which was not favorable for cassava growth. The high rainfall intensity and distribution usually lead to poor roots formation thus affecting the cassava fresh root weight and its biomass. These results are in agreement with that of [12] who reported that there was a positive influence of optimum rainfall on root yield of many cassava varieties, particularly during the first 4-6 months of growth. Additionally, the soil characteristics of the studied site could be another reason contributing to the poor fresh root yield and biomass obtained. As it was observed that, the soil texture was Silt clay loamy which gives inadequate room for the cassava root expansion. These results were similar to that of Onasanya et al. [24] who indicated that light-textured soil had high cassava root yield compared to soils with high clay content. Also, other soil nutrients at Ilonga site were high above the suitable nutrient range for cassava production thus it ought to cause the toxicity effect toward cassava growth and root formation. Nutrient like Calcium found to be 10.8 $cmol_c kg^{-1}$ while the suitable range for cassava production is between 1.0 and 5.0 $cmol_c kg^{-1}$ thus this could cause the toxicity effect to root yield and cassava growth obtained. The similar results were explained by [17] who explained excess nutrient in the soil could cause reduction in cassava performance as the example of excess Calcium content in the soil reduces cassava root and shoot growth.

CONCLUSION AND RECOMMENDATIONS

From the study findings, its concluded that, integration of weed management option(s) highly helps in controlling weeds in cassava production than the use of single treatment. Results showed the combination of till + ridges, appropriate application of pre-emergence herbicides Primagram Gold (a.i 290 g/L S-metolachlor + 370 g/L atrazine) or Oxfen (a.i Oxyfluorfen 24% EC) and post emergence herbicides Force up (a.i 480 g/L of Glyphosate-Isopropylamine salt) provided significant conducive environment for cassava growth and root formation as compared to the use of mechanical weeding alone. Thus, for maximum cassava production it is recommended that, early land preparation by tillage and ridging, proper use of pre-emergence herbicide made of S-metolachlor and atrazine and proper use of glyphosate as post-emergence herbicide in integrated way could greatly provide ample time for cassava growth and root expansion as they will be free from weeds for a longer period of time. Also, more studies should be conducted on the residue effect of continuous application of herbicides in cassava plant and roots produced.

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