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Effect of tillage and weed control practices on weed density, cassava growth and yield at Mkuranga district, Tanzania

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Abstract

Poor and improper weeding in cassava production has been reported to cause cassava yield losses ranging from 40% to 90%. A study was carried out in 2019/2020 planting season at Kiimbwanindi village, Mkuranga, Tanzania to identify common weeds available in the selected cassava field and then the effect of different integrated weed control options was studied. 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. Data on weed species, weed density, cassava height, girth and fresh root yield and soil were collected. By using Thomas methodology, perennial weeds Cyperus rotundus, Reissantia sp, Mucuna pruriens and Commelina benghalensis found to be the mostly and abundantly occurred weed species. The combination of tillage practices and pre-emergence herbicides application increased number of days' weeds took to reemerge. The integrated weed control options significantly affected cassava fresh root weight and biomass, $p = 0.019$ and $p = 0.026$, respectively. The correlation analysis showed a non-significant positive relationship between cassava stem height and cassava fresh root weight ($r = 0.389$, $p > 0.05$), and cassava stem girth and cassava fresh root weight ($r = 0.055$, $p > 0.05$). The study concluded that, the combination of till + ridges, application of pre-emergence herbicide (S-metolachlor + atrazine) and post emergence herbicides (glyphosate) can effectively control weeds and provided favorable environment for cassava growth and root formation as compared to other treatment options.

Keywords: *Cassava Biomass, Fresh root weight, Manihot esculenta, Weeds, weed control options, weed density*

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Introduction

Weeds are the major pests that hinders cassava production as they cause competition for light, water and plant nutrient, also weeds could be a host for insects and disease pathogens for cassava (Islami *et al*., 2017). Weeds have the following characteristics; they have long seed life in soil, they are quick in emergence, they have ability to survive and prosper under the disturbed conditions of a cropped field, they have rapid

early growth and they do not have any special environmental requirements for their seeds to germination (Ekeleme *et al*., 2016; Conrad *et al*., 2018).

Cassava (*Manihot esculenta* Crantz) is one among the most consumed perennial woody plants in the world (Edit *et al*., 2015; Amaarullah *et al*., 2017). According to FAOSAT, world's cassava production in 2012 was estimated to be 250 million tons (FAO, 2014; Reincke *et al*., 2018) where Tanzania with annual production of 4.7 million tons per year were the seventh producer among the African countries. According to Mtunguja *et al*. (2019), this annual cassava production in Tanzania is estimated to support 37% of rural farmers who depend on it as the major source of food.

In cassava production, weed control within the first several weeks after planting is critical in order to avoid yield loss. Poor and improper weeding has been reported to cause cassava root yield losses ranging from 40% to 90% (Chikoye *et al*., 2001; Islami *et al*., 2017; Ekeleme *et al*., 2019). Due to that, various weed control options have been used in cassava production, those control methods are preventative, cultural, mechanical and chemical by which are most effective if applied at the proper time (Islami *et al*., 2017; Sims *et al*., 2018). Tillage is the one of the weed control techniques which alters the soil physical properties, thus exposing weed seeds to conditions unfavorable for germinations that result in reducing weed germination ability and therefore, seedbank reduction. Schwartz-Lazaro and Copes (2019), indicated tillage system and type of tillage have influence on the specific composition and density of the weed seedbank in the soil. Also, researches show that intense tillage highly reduces weed seedbank and weed population (Schwartz-Lazaro & Copes, 2019). However, it has been reported that, excessive tillage results to very loose soil which makes the soil very prone to erosion and nutrients leaching (Ferreras *et al*., 2000; Jongruaysup *et al*., 2007; Figueiredo *et al*., 2017).

Herbicides are effective in controlling weeds if applied at a proper timing, appropriate rate specifically for weed and crop growth stages and for a specific weed type and crop present in the field (Schwartz-Lazaro & Copes, 2019). Some herbicides are soil applied (pre-emergence herbicides) which control weeds as seeds germinate, and reduce early-season weed competition. The important factors to consider during application of these herbicides include soil type, environmental impacts such as leaching or runoff potential, target weeds and objectives of the application (Kraehmer *et al*., 2014; Ekeleme *et al*., 2016). Other herbicides are post-emergence herbicide whose applications target weed species not controlled by soil applications. These herbicides can either control weeds emerged at the time of application or already emerged weeds and provide residual activity against later emerging weeds (Kraehmer *et al*., 2014). Weed control using herbicides in cassava cultivation has been reported by Gianessi and Williams (2016) and Islami *et al*. (2017) to be of benefit to both soil and the crop as it could improve soil quality and reduce soil erosion. Further, other studies revealed that excessive and/or improper use of herbicide can also create many detrimental effects such as environmental pollution, affect human health and evolution of resistant weeds (Islami *et al*., 2017; Westwood *et al*., 2018).

However, some of these methods require a huge labor force and a lot of time. For instance, hoe weeding requires 50 to 80% of the total labor budget in production and as many as 200 to 500 hours of labor per hectare resulting in delaying in weeding activity thus reduction in cassava root yield to about 20 to 50% (Reshma *et al*., 2016; Sims *et al*., 2018; Ekeleme *et al*., 2019). Reshma *et al*. (2016) reported 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 program depends largely on timeliness of its application during this period. When the field is kept free from weeds for the first several weeks after planting, it gives the cassava a competitive edge that allows it to shade out and out compete weeds that would emerge later in the season. Therefore, this study was conducted to identify the common weeds available in the selected cassava field and then to determine the best package of weed control techniques from different integrated weed control techniques

which will keep cassava farm free from weeds for a long period of time and resulting to optimum cassava root yield production.

Materials and methods

Description of the study sites

The study was conducted in Eastern zone of Tanzania at Kiimbwanindi village, Mkuranga district, Coastal region (7°12'19" S, 39°20'38" E, 93.87 MASL). The site experiences an average monthly temperature ranged from a low of around 18.8 °C during the coolest months of July and August to the highest monthly means of 31.9 °C to 32.6 °C during the hot season from December to March. Relative humidity ranges from 67-70 % from August to October, increasing to 82 % during the wettest months of April. The average annual rainfall is 1,073 mm (ranging from 585 mm to 1,536 mm). The district experiencing bi-modal rainfall pattern; March to May (main wet season) with about 550 mm of rain and November to December (short rains) with 235 mm of rain (Mkuranga, 2009; RCO, 2011).

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 treatment was applied at planting. Post emergence weed control treatments were applied when weed population reached 30% (three to four leaves stage) within a plot as per IITA (ACAI project) protocol. Cassava (Kiroba variety) planted at a population of 10 000 plants ha^{-1} was used.

Data collection

Cassava crop data collected were:

Sprout count: Number of cassava stalks that emerged 4 weeks after planting (WAP) were recorded.

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

Harvest data: On the 10th 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 the 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 Edet *et al*., (2015) were recorded. Dry matter content was estimated after the oven dry at 105°C for 24 hours according to Ntawuruhunga and Dixon, (2010). All 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 were: Weed density, weed species and 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 re-emergence as per Moeini *et al*. (2008) procedure.

Weed sampling procedure: A total of 24 quadrats (1 m × 1 m) were placed in a selected field at random, distance from one quadrat to the other was ten meters. In each quadrat all available weed species were identified to a species level, counted and recorded.

Soil data collected were: Soil samples were collected at the depth of 0 – 20 cm and 21 – 50 cm before land preparation to allow the assessment of the initial soil fertility status. A total of five samples were collected in a zigzag pattern at each depth to make a composite sample and then this sample was used to make a single sample (Jones, 2012).

Data analysis

Weed data: For the determination of mean field density of each weed species, the Thomas method was used (Thomas, 1985). *Weed density* of each

weed species was obtained by taking the total number of real plants in each quadrat divided by the number of quadrats. Thus

$$D_{ki} = \frac{\Sigma \quad zj}{n} \qquad \text{(i)}$$

Where by

D_{ki} = density (number of plants or spikes/panicles/m²) of the species k in field i

Z_j = number of plants/spikes/panicles in each 1 m² sample/quadrat

n = number of quadrats

Cassava crop data: 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.

Soil data: The soil physical and chemical characteristics were analysed in the laboratory following procedures by Jones (2012).

Results

Physical and chemical characteristics of the studied area

Soil chemical characteristics and particle size class (0 to 20 cm and 21 to 50 cm deep) at the experimental site in 2019 are shown in Table 1. The soil was found to be loamy sand (12% clay, 3% silt and 85% sand) with sufficient available phosphorus, total nitrogen and exchangeable potassium and pH of 5.47. This soil condition was optimal hence the locations support the cassava production (Soil staff, 1993).

Table 1: Soil characteristics of the studied site

Parameter	Method used	Kiimbwanindi village		Range suitable for cassava production	Rated according to:
		0-20 cm	21-50 cm		
pH (in H_2O)	pH meter	5.47	5.24	4.5 - 7.0	CIAT (2011)
OC (%)	Walkley - Black	0.66	0.3	4.0 - 10.0	Landon (2014)
P ($mgkg^{-1}$)	Bray 1	10.79	5.86	< 4.2	Howeler (2002)
N (%)	Kjeldahl	0.25	0.2	0.20 - 0.50	Landon (2014)
Ca ($cmol_c kg^{-1}$)	Ammonium Acetate Extraction pH 7.0	2.21	0.93	1.0 - 5.0	CIAT (2011)
Mg ($cmol_c kg^{-1}$)		0.9	0.32	0.40 - 1.00	CIAT (2011)
K ($cmol_c kg^{-1}$)		0.23	0.17	0.15 - 0.25	CIAT (2011)
Na ($cmol_c kg^{-1}$)		0.04	0.03	< 2	Howeler (2002)
Cu ($mgkg^{-1}$)	DTPA Extraction pH 7.3	0.6	0.83	0.3 - 0.8	Motsara and Roy (2008)
Zn ($mgkg^{-1}$)		2.07	1.18	1.0 - 3.0	Motsara and Roy (2008)
Mn ($mgkg^{-1}$)		26.61	26.92	1.2 - 3.5	Motsara and Roy (2008)
Fe ($mgkg^{-1}$)		20	22.39	4.0 - 6.0	Motsara and Roy (2008)
Textural class	Hydrometer	LS	SL		

LS = loamy sand soil and SL= sandy loam soil

Weed species, families, lifecycle, morphology and their mean field density

The results of the occurred weeds in the survey fields are presented in Table 2. The weeds' mean field density was calculated according to Thomas methodology. A total of 8 different weed species belonging to 6 families were identified. These 6 weed families include Poaceae with two species, Fabaceae with two species and Commelinaceae, Convolvulaceae, Cyperaceae and Celastraceae had one species. Out of these identified weed species, 5 were broadleaf weeds, 2 grassy weeds and 1 sedge weed.

Reissantia sp occurred in highest mean field densities followed by *Mucuna pruriens* while other weed species found to be very minimal. *Reissantia* sp, *Mucuna pruriens, Cyperus rotundus*

and *Commelina benghalensis* were the highest occurred and the most disturbing weed species at this site.

Table 2: Weed species, families, life cycle, morphology and mean field density (MFD) as found at Kiimbwanindi village, Mkuranga during the 2019/2020 planting season

Sn	Scientific name	Family	Life cycle	Morphology	MFD plant m^{-2}
1	*Commelina benghalensis*	Commelinaceae	Perennial	Broad leaves	2.46
2	*Cynodon plectostachyus*	Poaceae	Perennial	Grass	0.17
3	*Cyperus rotundus*	Cyperaceae	Perennial	Sedge	1.75
4	*Digitaria* sp	Poaceae	Annual	Grass	0.42
5	*Ipomoea* sp	Convolvulaceae	Perennial	Broad leaves	0.13
6	*Mucuna pruriens*	Fabaceae	Annual	Broad leaves	5.00
7	*Reissantia* sp	Celastraceae	Perennial	Broad leaves	6.17
8	*Tephrosia* sp	Fabaceae	Perennial	Broad leaves	0.17

Influence of tillage practice, pre-emergence weed control and post emergence weed control treatments on weed growth

Days to first post emergence weed control application

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 are shown in Table 3. There was highly significant (P<0.001) effect of tillage practice on the number of days to first post emergence weed control treatments application. The application of tillage and ridging resulted in the highest number of days to first post emergence weed control treatments application.

Table 3: Influence of Tillage practice, Pre emergence weed control and Post emergence weed control treatments on weed growth at Kiimbwanindi village, Mkuranga

Treatment factors		Days to 1st PEWC	Days to 2nd PEWC
Factor A	Till	30.17b	55.50b
(Tillage practice)	Till and Ridge	45.33a	70.00a
	Mean	*37.75*	*62.75*
	p value	*<.0001*	*<.0001*
Factor B	Oxfen	33.37b	60.92b
(Pre emergence treatment)	Primagram	41.83a	64.58a
	Mean	*37.6*	*62.75*
	p value	*<.0001*	*0.0009*
Factor C	Force up	38.67a	69.25a
(Post emergence treatment)	Mechanical weeding	36.83b	56.25b
	Mean	*37.75*	*62.75*
	p value	*0.0322*	*<.0001*

Values in the same column, respectively, 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.

Also, there was a highly significant (P<0.001) effect of pre-emergence weed control treatments on number of days to weeds emergence. The application of Primagram gold as pre-emergence herbicide showed the highest number of days to weed emergence.

There was a significant (P<0.05) effect of post emergence treatment application on the days to weeds emergence. The application of Force up herbicide as a post-emergence treatment led to the highest number of days that weed took to reemerge and reach the three leaves stage.

Days to second post emergence weed control

Table 3 shows the results on effect of tillage practice, pre-emergence weed control and post emergence weed control treatments on weed emergence 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 were by till and ridge showed highest number of days to second post emergence weed control treatments application.

There was a highly significant (P<0.001) effect of pre-emergence weed control treatments on days to second post emergence weed control treatments application. The application of Primagram gold as pre-emergence herbicide showed the highest number of days to second post emergence weed control treatment application.

Also, 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 second post emergence weed control treatments application.

Interaction's effect of weed control treatments toward weeds growth

Days to first post emergence weed control application

The results on the weed control treatment interaction on the number of days to first post emergence weed control treatment application are shown in Table 4.

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

The combination of tillage practices and post emergence weed control showed no significant (P>0.05) increase on 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 at the studied site. 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 lowest 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 at the studied sites. 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.

Table 4: Interaction effect of weed control treatments on weed growth at Kiimbwanindi village, Mkuranga

Treatment factors		**Days to 1st PEWC**	**Days to 2nd PEWC**
A × B	Till × Oxfen	28.00d	55.17c
	Till × Primagram	32.33c	55.83c
	Till and Ridge × Oxfen	39.33b	66.67b
	Till and Ridge × Primagram	51.33a	73.33a
	p value	*0.0002*	*0.0044*

A × C	Till × Force up	30.33c	59.67b
	Till × Mechanical weeding	30.00c	51.33c
	Till and Ridge × Force up	47.00a	78.83a
	Till and Ridge × Mechanical weeding	43.67b	61.17b
	p value	*0.073*	*<.0001*
B × C	Oxfen × Force up	34.33b	67.17b
	Oxfen × Mechanical weeding	33.00b	54.67c
	Primagram × Force up	43.00a	71.33a
	Primagram × Mechanical weeding	40.67a	57.67c
	p value	*0.5315*	*0.5883*
A × B × C	Till × Oxfen × Force up	28.00d	59.33c
	Till × Oxfen × Mechanical weeding	28.00d	51.00d
	Till × Primagram × Force up	32.67cd	60.00c
	Till × Primagram × Mechanical weeding	32.00d	51.67d
	Till and Ridge × Oxfen × Force up	40.67b	75.00b
	Till and Ridge × Oxfen × Mechanical weeding	38.00bc	58.33c
	Till and Ridge × Primagram × Force up	53.33a	82.67a
	Till and Ridge × Primagram × Mechanical weeding	49.33a	64.00c
	Mean	37.75	62.75
	CV%	5.4	3.5
	p value	*0.8339*	*0.5883*

Values in the same column, respectively, 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.

Days to second post emergence weed control

The results on effect of tillage practice, pre-emergence weed control and post emergence weed control treatment interactions on days to second post emergence weed control treatment application are shown in Table 4. 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 × Oxfen treatment combinations were applied showed the lowest number of days at the studied site.

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 at a site. Till and ridge × Force up herbicide treatment combinations-controlled weeds for more days. The plots where till × mechanical weeding 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) increased the number of days to second post emergence weed control treatment application at the studied sites. Primagram herbicide × Force up herbicide treatment combination-controlled weeds for more days. The plots where Oxfen × 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 did not significantly (P>0.05) increase the average number of days to second post emergence weed control treatment application at the site. Till and ridge × Primagram × Force up treatment combinations showed the highest number of days followed by Till and ridge × Oxfen × Force up treatment combinations and till × Primagram × mechanical weeding and

till × Oxfen × mechanical weeding had the lowest number of days.

During this stage of post emergence treatment application, perennial weeds; *Cyperus rotundus*, *Cynodon species* and *Reissantia sp* were predominant at the field.

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

Treatment interactions		Kiimbwanindi village	
		Stem Height (cm)	**Stem Girth (cm)**
A × B	Till × Oxfen	200.17a	10.58a
	Till × Primagram	182.08a	9.5a
	Till and Ridge × Oxfen	198.17a	10.02a
	Till and Ridge × Primagram	190.67a	10.35a
	p value	*0.5461*	*0.1168*
A × C	Till × Force up	190.5a	10.63a
	Till × Mechanical weeding	191.75a	9.45a
	Till and Ridge × Force up	188.00a	9.48a
	Till and Ridge × Mechanical weeding	200.83a	10.88a
	p value	*0.5093*	*0.0081*
B × C	Oxfen × Force up	193.83a	10.4a
	Oxfen × Mechanical weeding	204.5a	10.2a
	Primagram × Force up	184.67a	9.72a
	Primagram × Mechanical weeding	188.08a	10.13a
	p value	*0.6783*	*0.4809*
A×B×C	Till × Oxfen × Force up	189.17a	11.3a
	Till × Oxfen × Mechanical weeding	211.17a	9.87a
	Till × Primagram × Force up	191.83a	9.97a
	Till × Primagram × Mechanical weeding	172.33a	9.03a
	Till and Ridge × Oxfen × Force up	198.5a	9.5a
	Till and Ridge × Oxfen × Mechanical weeding	197.83a	10.53a
	Till and Ridge × Primagram × Force up	177.5a	9.47a
	Till and Ridge × Primagram × Mechanical weeding	203.83a	11.23a
	Mean	192.8	10.11
	CV%	9	8.3
	p value	*0.0633*	*0.8931*

Values in the same column, respectively, 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.

Influence of tillage practice, pre-emergence weed control and post emergence weed control treatments on cassava stem height and stem girth at 5 months after planting

The results in figure 1 and figure 2 showed that there was no significant (P>0.005) influence of tillage practices on cassava plant height and stem girth, respectively at five months after planting between treatments. The highest plant height and stem girth was on the till and ridge treatment.

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 for the studied site. Oxfen herbicide 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. Mechanical weeding treatment applied as post emergence weed control showed the highest stem height and stem girth while.

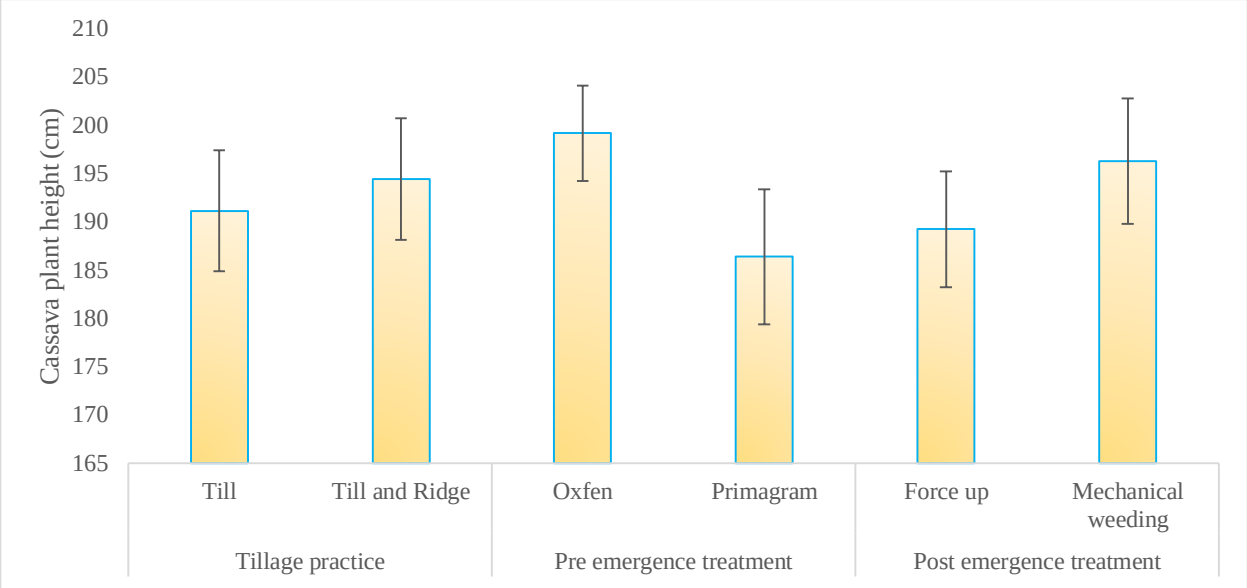

Figure 1: Influence of Tillage practice, Pre emergence weed control and Post emergence weed control treatments on cassava stem height (cm) at 5 months after planting at Kiimbwanindi village

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 × Oxfen treatment combinations led to the highest stem height. 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 × Mechanical weeding treatment combinations showed the highest stem height. Also, plots where Till and ridge × Force up herbicide treatment combinations were applied showed the lowest stem height.

The combinations of pre-emergence weed control and post emergence weed control treatments did not significantly (P>0.05) affect the stem height. Oxfen × mechanical weeding treatment combination showed the highest stem height while Primagram × Force up herbicides' treatment combination showed the lowest stem height.

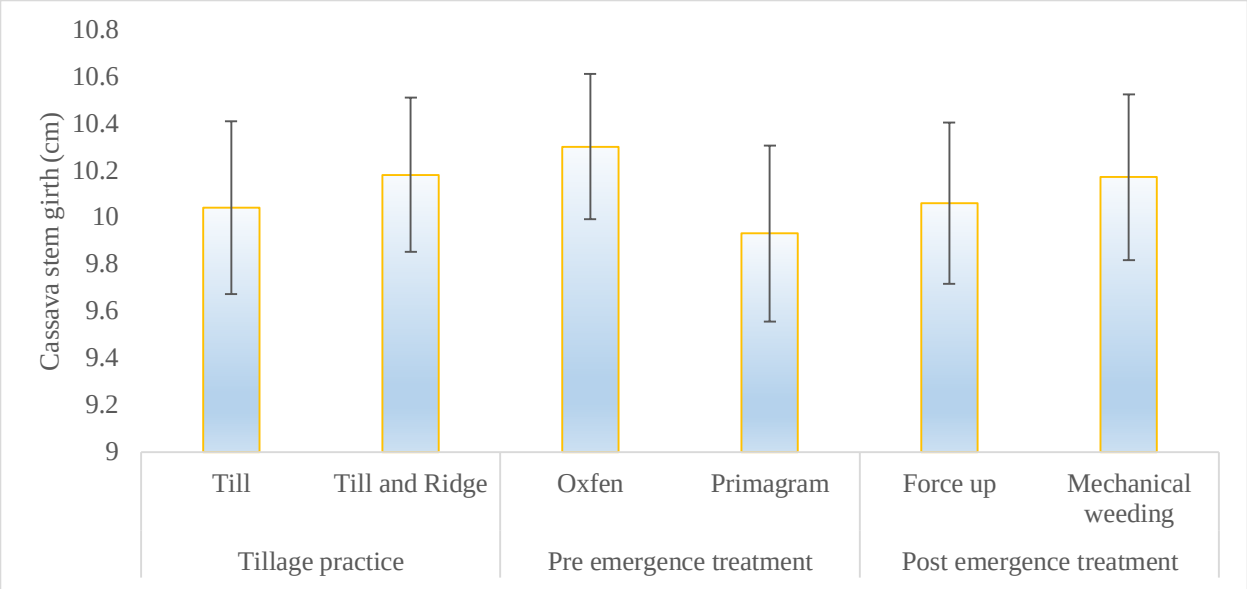

Figure 2: Influence of Tillage practice, Pre emergence weed control and Post emergence weed control treatments on cassava stem girth (cm) at 5 months after planting at Kiimbwanindi village

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. The till × Oxfen × mechanical weeding treatment combinations had the highest stem height followed by Till and ridge × Primagram × mechanical weeding. The lowest stem height was observed in plants grown in a till × Primagram × mechanical weeding treatment combination.

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, whereby, till × Oxfen treatment combinations led to the highest stem girth. 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 significantly (P<0.05) affect the stem girth. 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 weed control and post emergence weed control did not significantly (P>0.05) affect the stem girth. Oxfen × Force up herbicide treatment combinations showed the highest stem girth while Primagram × Force up herbicides' 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. Cassava plants under the till × Oxfen × Force up and Till and Ridge × Primagram × Mechanical weeding treatment combinations had the highest stem girth while till × Primagram × Mechanical weeding treatment combination had the lowest stem girth.

The influence of tillage practice, pre-emergence weed control and post emergence weed control treatments on cassava yield, biomass and dry matter content

Results on the influence of tillage practices and weed control methods 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 did not significantly (P>0.05)

influence the cassava fresh root weight and cassava biomass while significantly (P≤0.05) influenced the cassava dry weight. Till treatment showed the highest cassava fresh root weight, biomass and dry weight as compared to the till and ridge treatment which were used as standard.

Pre emergence treatments and post emergence treatments did not significantly (P>0.05) affect the cassava fresh root weight, biomass and dry weight. Oxfen treatment led to highest cassava fresh root weight, biomass and lowest dry weight while mechanical weeding led to highest cassava fresh root weight, biomass and dry weight as compared to force up herbicide which showed the lowest cassava fresh root weight, biomass and dry weight even though it was used as the standard in post emergence weed control 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

Treatment factors		**Fresh root weight (t ha^{-1})**	**Cassava biomass (t ha^{-1})**	**Cassava dry weight (g)/ 500 g sample**
Factor A	Till	38.56a	75.81a	199.17a
(Tillage practice)	Till and Ridge	36.61a	69.54a	159.58b
	Mean	*37.59*	*72.68*	*179.38*
	p value	*0.6705*	*0.3332*	*0.0348*
Factor B	Oxfen	38.00a	74.19a	177.50a
(Pre emergence treatment)	Primagram	37.17a	71.16a	181.25a
	Mean	*37.59*	*72.68*	*179.38*
	p value	*0.8558*	*0.6352*	*0.8298*
Factor C	Force up	34.53a	65.76b	173.33a
(Post emergence treatment)	Mechanical weeding	40.64a	79.59a	185.42a
	Mean	*37.59*	*72.68*	*179.38*
	p value	*0.1944*	*0.0426*	*0.4914*

Values in the same column, respectively, 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. The combinations of tillage practices and pre-emergence weed control treatments did not significantly (P>0.05) affect the cassava fresh weight, cassava biomass and cassava dry weight. Till × Primagram treatment combinations showed the highest cassava fresh weight, cassava biomass and cassava dry weight. The till and Ridge × Primagram herbicide treatment combinations showed the lowest cassava fresh weight and cassava biomass while Till and Ridge × Oxfen herbicide treatment combination showed the lowest cassava 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 × Mechanical weeding treatment combinations showed the highest cassava fresh weight and cassava biomass while till × Mechanical weeding treatment combinations showed the highest cassava dry weight. Also, Till and Ridge × Force up herbicide treatment combinations showed the lowest cassava fresh weight, cassava biomass and cassava dry weight.

The treatment combinations of pre-emergence

weed control and post emergence weed control treatments did not significantly (P>0.05) affect the cassava fresh weight, cassava biomass and cassava dry weight. Oxfen × Mechanical weeding treatment combinations showed the highest cassava fresh weight and cassava biomass, while Primagram herbicide × Mechanical weeding treatment combinations showed the highest cassava dry weight. Also, Oxfen × Force up treatment combinations showed the lowest cassava fresh weight and cassava dry weight, while Primagram × Force up treatment combinations showed the lowest cassava biomass.

The application of tillage practice, pre-emergence herbicides and post emergence weed control treatment combinations significantly (P≤0.05) affected both cassava fresh root weight and cassava biomass at the studied site. Till and Ridge × Oxfen × Mechanical weeding treatment combinations gave the highest fresh root weight and biomass while Till and Rigde × Oxfen × Force up treatment combination recorded 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

Treatment interactions		**Fresh root weight (t ha^{-1})**	**Cassava biomass (t ha^{-1})**	**Cassava dry weight (g)/ 500 g sample**
A × B	Till × Oxfen	35.87a	71.74a	195.83a
	Till × Primagram	41.25a	79.87a	202.50a
	Till and Ridge × Oxfen	40.12a	76.64a	159.17a
	Till and Ridge × Primagram	33.08a	62.44a	160.00a
	p value	*0.1876*	*0.0944*	*0.8672*
A × C	Till × Force up	38.06a	72.38a	189.17a
	Till × Mechanical weeding	39.07a	79.23a	209.17a
	Till and Ridge × Force up	31.00a	59.14a	157.50a
	Till and Ridge × Mechanical weeding	42.21a	79.95a	161.67a
	p value	*0.275*	*0.2826*	*0.6507*
B × C	Oxfen × Force up	33.73a	66.20a	171.67a
	Oxfen × Mechanical weeding	42.27a	82.19a	183.33a
	Primagram × Force up	35.33a	65.32a	175.00a
	Primagram × Mechanical weeding	39.01a	76.99a	187.50a
	p value	*0.5971*	*0.7355*	*0.9809*
A×B×C	Till × Oxfen × Force up	40.10a	75.48a	186.67a
	Till × Oxfen × Mechanical weeding	31.64a	68.01a	205.00a
	Till × Primagram × Force up	36.01a	69.29a	191.67a
	Till × Primagram × Mechanical weeding	46.49a	90.46a	213.33a
	Till and Ridge × Oxfen × Force up	27.36a	56.92a	156.67a
	Till and Ridge × Oxfen × Mechanical weeding	52.90a	96.37a	161.67a
	Till and Ridge × Primagram × Force up	34.64a	61.36a	158.33a
	Till and Ridge × Primagram × Mechanical weeding	31.52a	63.53a	161.67a
	Mean	37.58	72.68	179.4
	CV%	29.4	22.3	24.8
	p value	*0.0179*	*0.0184*	*0.9428*

Values in the same column, respectively, 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 the studied site

The results on the relationship between cassava growth parameters and cassava fresh root weight are shown in Table 8. The correlation analysis showed that, there was a non-significant positive relationship (r = 0.389, p > 0.05) between the cassava stem height and the cassava fresh root weight. Also, there was non-significant positive relationship (r = 0.055, p > 0.05) between the cassava stem girth and the cassava fresh root weight.

Table 8: Relationship between cassava growth parameters and cassava fresh root weight at Kiimbwanindi site

	Stem girth	Stem height	Fresh root weight
Stem girth	1		
Stem height	0.452	1	
Fresh root weight	0.055	0.389	1

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

Discussion

Weed density, uniformity, frequency and relative abundance from the studied sites

In the studied site where cassava was grown, perennial weeds, *Cyperus rotundus*, *Commelina benghalensis*, *Cynodon plectostachyus*, *Reissantia* sp and *Tephrosia* sp tend to dominate with high mean field density as compared to annual weeds. This might be attributed by the reproductive ability of these perennial species as they can reproduce both asexually and sexually, their ability to make use of the available resources in the soil and history of previous cropping systems and weed management practices. Similar results were reported by Olorunmaiye *et al*. (2013) who reported the high presence of perennial weeds in cassava fields due to their ability to grow over a high range of soil types. Also, Webster *et al*., (2005) reported the ability of perennial weeds to reproduce both sexually and asexually and highly adapted on the areas having temperature ranging from 30° C to 35° C (Webster *et al*., 2005) is the other reason for their success at the studied site.

Effect of integrated tillage, pre-emergence and post emergence weed control options toward weeds growth

The current study findings revealed that, till + ridge × primagram gold (a.i 290 g/L S-metolachlor and 370 g/L atrazine) as a pre-emergence weed control herbicide significantly hinders the growth of weed for a long period of time up to 53 days after planting. This could possibly be due to ridges burry weed seeds below the surface and the combination of 290 g/L S-metolachlor and 370 g/L atrazine kills the exposed seedlings or shoots of germinating weeds before emergence or shortly after emergence. Similar findings were reported by Schwartz-Lazaro and Copes (2019) who observed that, weed seedbank and weed population is highly reduced as tillage intensity increases as a result it exposes weed seeds to conditions that do not favor their growth. Also, Godwin *et al*. (2017) reported pre-emergence herbicides help in controlling weeds for up to four weeks after cassava planting. Only weeds managed to reemerge after pre-emergence herbicides application were *Commelina benghalensis*, *Cyperus rotundus*, *Mucuna pruriens*, *Cynodon species* and *Reissantia sp.*

For the plots where mechanical weeding was applied, more than three weeding operations were required due to the presence of perennial

weeds. This could be due to the ability of perennial weeds (*Cyperus rotundus*, *Cynodon species* and *Reissantia* sp) to regrow faster as compared to annual weeds as the mechanical weeder only killed the above ground plant parts while the below parts remained alive. Other researchers have shown that, more than two weeding operations are required for effectively control of perennial weeds (Ekeleme *et al*., 2019).

For those plots where glyphosate was applied as post emergence weed control treatment, weeds were significantly controlled because glyphosate is a systematic, non-selective herbicide therefore it kills all grown weeds during the time of its application. Udensi *et al*. (2012) reported that, herbicide use in ridged farm is more efficient in controlling weeds as compared to the use of mechanical weeder.

Influence of weed control treatments on cassava plant height and stem girth at 5 months after planting

The results obtained from the study showed the combination of tillage, pre-emergence and post emergence weed control treatments had influence on cassava plant height and girth. This might be due to the fact that, as the combination of these treatments gives the free space for the cassava to grow and expand in dimensions. Similar results were explained by Velmurugan *et al*. (2017), who reported that weed management activities affect the growth of cassava stem and girth. Also, Kraehmer *et al*. (2014) and Schwartz-Lazaro and Copes (2019), showed the effect of tillage as it gives free space for the crop to grow and the application of herbicides can either control weeds that emerged at the time of application or those weed already emerged thus giving free space for the crop to grow.

Relationship between cassava growth parameters and cassava fresh root weight

Results showed that, there was a non-significant positive relationship between the cassava stem height and the cassava fresh root weight. Also, there was non-significant positive relationship between the cassava stem girth and the cassava fresh root weight. This profound non-significance relationship between the pronounced parameters is likely attributed to the high sand proportion of soil at the studied field which give free space for unlimited increase in cassava roots. These results confirmed report by Onasanya *et al*. (2021), which indicated that on light-textured soil, there is highly increase in cassava root yield. Also, Misganaw and Bayou (2020) reported that, environmental factors like rainfall and soil characteristics could affects cassava growth and root yield.

Conclusion and Recommendation

The study played an important role in identifying common weed species that are mostly found in cassava field at Mkuranga district, Tanzania, and hence proven that, perennial weeds *Cyperus rotundus*, *Reissantia sp*, *Mucuna pruriens* and *Commelina benghalensis* are the mostly and abundantly occurring weed species with intrinsic adaptive characteristics compared to other species. Thus, this study documents probably the first-time common weed and its behavior as they are associated with cassava production systems in Mkuranga district.

Also, the study concludes that integrated weed management option is more effective 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 favorable environment for cassava growth and root formation as compared to the use of mechanical weeding alone.
Thus, it is recommended that, integration of proper tillage and ridging before cassava planting, use of pre-emergence herbicide made of S-metolachlor and atrazine and proper use of glyphosate as post emergence herbicide is highly recommended for weed control in cassava farms. Also, farmers should be trained on weed management practices for increased cassava yield to optimum level and lastly, further studies should be conducted on a regular basis to identify possible weed population shifts and also further studies on the residue effect of continuous

application of herbicides in cassava plant, roots produced and soil quality.

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