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World Encyclopedia, 2008). Cassava is adapted to low pH, exchangeable Aluminium (Howeler, 2002) and low available Phosphorus but fertile soils can enhance tuber yields inspite the projected negative effects on tuber taste. The plant parts used as food are the storage root tubers and leaves.

Cassava plays five important roles in African development: famine-reserve crop, rural staple food, cash crop for both rural and urban households and, to a minor extent, raw material for feed and chemical industries (Nweke, 2000). However, studies show that famine rarely occurs in areas where cassava is widely grown (Nweke *et al*., 2002). On the other hand, cassava production potential has not been exhausted. This could be attributed to poor technology adoption by farmers, low yielding varieties and competition with weeds (Cardoso *et al.*, 2013).

Studies have revealed that weed in cassava cultivation is one of the main factors affecting crop yield. Root yield can be reduced by more than 90% in absence of weed control (Alves JMA *et al.*, 2008). Cassava being a longer duration crop, the competition between crop and weed and cost of weeding is a major constraint in cassava production. Farmers have a common tendency to delay carrying out first weeding at two months after planting.. Yield reduction in cassava is mainly due to a slow initial growth of cassava plants, which facilitates weed species development, favoring the competition for water, light, nutrients, carbon dioxide and physical space (Alves JMA *et al.*, 2008). Due to weed competition, farmers employ high human manual labour requirements for weeding which increase cost of production. Apart from manual labour weeds can be controlled using herbicides and cultural methods. Many research programmes have shown that efficient weed management strategies can be achieved through the application of herbicides in cassava as in other crops (Fermont et al., 2009). Chemical weed control is the most effective method of controlling weeds in cassava for producing higher tuber yields(Abdullahi *et*

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al., 2014). Hand hoe weeding four times is more expensive than using herbicides. Weeding consumes about 30% of the total labour input and about 150-200 man days ha^{-1} (Melifonwu, 1994; Melifonwu *et al*., 2000; Nedunchezhiyan *et al.* 2013). Because of long cultivation and the soil partial covering by the plant, several weed infestations can occur within the planting area, what might increase crop yield losses (Alves JMA *et al.*, 2008).

The extent of interference of weeds in the crops depends on factors related to the crop such as, the weed community, the environment and the period in which they coexist (Silva *et al*., 2007). In this process, one of the factors more easily controllable, in practice, is the length of the coexistence period between crop and weeds (Alves JMA *et al.*, 2008). The degree of this competition depends on the species, the population density and, mainly, the period in which they remain growing together (Alves JMA *et al.*, 2008). Thus, identification of the most frequent species of weed is necessary because each one, according to the potential to establish in the area and the aggressiveness, can interfere differently with the cassava plant (Alves JMA *et al.*, 2008). Cassava harvest can occur up to two years after planting, when roots are delivered to processing industry (Alves JMA *et al.*, 2008).

Cassava and sorghum which are especially important staple foods contain cyanogenic glucosides. Cyanogenic glycosides are potentially toxic and release poisonous hydrogen cyanide upon hydrolysis (Nzwalo, H., 2011). Cases of acute cyanide intoxication results to a common cassava cyanide health disorder called konzo which is an irreversible paralysis of legs (Nzwalo, H., 2011). The people who are at risk are the rural poor cassava dependent communities in particular. Researchers attribute the increase in cyanogenic glucoside levels to water stress from prolonged droughts that coincide with most epidemics of konzo. Continuous ingestion of cyanogenic glucosides from improperly processed cassava products often results in cases of

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cassava cyanide intoxication (Bellotti and Riis, 2003). It is believed that cyanogens confer protection to the cassava plant against attack by some herbivores (Bellotti and Riis, 2003).

Bitterness in cassava could as well be associated with planting of bitter cassava varieties which are preferred by many farmers (Oluwole. O, 2007). There are a number of varieties of cassava: sweet cassava and bitter cassava. The term "bitter" cassava, as opposed to sweet cassava, refers to the taste of the root parenchyma. Bitterness is associated with higher levels of cyanogenic glucosides (Cock, 2000). Bitter cassava varieties have cyanide levels higher than the FAO/ WHO (2000) recommendations which are < 10 mg cyanide equivalents/kg DM (Bellotti and Riis, 2003). Bitter cassava varieties are more drought resistant and thus more readily available and cheaper (Chijindu and Boateng, 2008). The naturally high cyanogenic glucoside content of bitter cassava varieties are further increased by water stress. During the dry season, cassava cyanogen levels can increase by 9–10 times their normal levels (Sriroth K, *et al.,* 2001). With respect to soil fertility, fertilizer application may increase or decrease cyanide potential of cassava (Rolinda *et al.,* 2008). As leaf and tuber cyanide potential demonstrated a strong positive correlation in field-grown cassava (Mahungu, 1994), findings by Jørgensen *et al*. (2005) could suggest that N and K fertilization or their high indigenous levels in the soil may increase tuber cyanide content. Further, the hydrocyanic acid content of cassava tubers in a field trial was observed to increase with potassium fertilization rates (Attala et al., 2001). Tuber bitterness in cassava has an increasing trend with reduced frequency of weeding or more weed pressure due to increased competition for soil water and nutrients in weedy plots (Bokanga, 2004). Weeds deplete soil water thus induce soil water stress or drought which has been linked to root or tuber bitterness (Okogbenin *et al*., 2003). Traditional cultivation of cassava entails no weeding at maturity because of good canopy which sufficiently smoothers weeds. Effective weed management

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should be considered in improving the taste of tubers at harvesting. Farmers experience loss of starch in cassava harvested immediately after weeding. This study aims at investigating the effects of weed intensity on bitterness in cassava. The results of the study are important to cassava farmers in particular since they can be applied to enhance production and quality of cassava.

MATERIALS AND METHOD

Research design

The design used in the experiment was Randomized Complete Block Design (RCBD**)** with four replications. The weed treatments were randomized in the plots against cassava varieties using tables of random numbers.

Field establishment of cassava

The cassava experiment was performed in two sites. The first site was Voroni village of Matuga and the second site was Golini village of Kwale Town. Each of the two sites was divided into four blocks which were further divided into plots after proper cultivation of the field. The four cassava varieties used in the experiment were *Kibandameno*, *Nzalauka*, *Karembo* and *Tajirika*. These varieties were planted in plots measuring 3 metres × 4 metres. The length of each cassava cutting was 15 centimetres. The cassava cuttings were planted in rows at a spacing of 1 metre × 1 metre, giving a plant population of twelve plants per plot. In this experiment, no chemical was used to avoid tampering with the soil chemistry. The experiment aimed at investigating the effects of weeds on bitterness of cassava root tubers.

Sampling and data collection

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Weeds are classified as either broadleaved or grasses. The four varieties of cassava used in the study were subjected to three weeding treatments. In the first weeding treatment, cassava plants were allowed to grow in weedy plots for the entire growth period. No weeding was done at all to these plots. The second weeding treatment involved intensive weeding to eliminate all weeds in the plots throughout the duration of the experiment. In the third weeding treatment, plots were weeded at four weeks interval. Samples of cassava root tissues were collected from the cassava plants under the various weeding treatments for cyanide content analysis. Collection of the cassava root tissues from the field involved destructive sample collection procedure other than piece meal harvesting procedure. The collected cassava root samples were then taken to laboratory for analysis to determine cyanide content in cassava root tissues (mg/kg) across the three weeding treatments. Cassava root tissue collection for laboratory analysis was done at three weeks interval. Samples of cassava roots collected for laboratory analysis were immediately preserved in a cooling box in the field to minimize cyanide losses since cyanide is volatile. Still at the laboratory, the cassava tissues had to be preserved in deep freezers to curb cyanide losses. The first cassava samples were collected six months after cassava establishment. The amounts of cyanogenic glycosides in the cassava roots collected under the different weeding treatments were determined using Alkaline Titration method (Titrimetric technique). The collected row data from all the experiment treatments was then analyzed to get analysis of variance (ANOVA). Mean separation was done in the event of significant differences in means ($p<0.05$). The weeds x varieties interaction was also determined to establish the level of significance.

Determination of cyanide by titration

In this experiment, 20 g of the cassava root (parenchyma) was grounded using a blender. The sample was then transferred into a distillation flask and left to stand for 3 hrs. It was then

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distilled until 150 cm^3 of the distillate was collected; 20 cm3 of 0.02 M sodium hydroxide was added to the distillate and the volume completed to 250 cm^3 in a volumetric flask using distilled water. Three aliquots, two of 100 ml each and one of 50 ml were obtained; 8 cm3 of 6 M ammonium solution and 2 cm^3 of 5% potassium iodide were added to th*e* 100 ml aliquots, 4 cm3 and 1 cm3 were added to the 50 ml aliquot. This was titrated using 0.02 M silver nitrate, using the 50 ml aliquot as the trial and readings recorded; 5% Potassium Iodide was used as the indicator and the end point of the titration was reached when the solution changed from a clear solution to a faint turbid solution. The equation below was used to get HCN in mg.

1 ml of 0.02 M silver nitrate = 1.08 mg HCN according to AOAC (1990).

Data analysis

The Statistical Package for the Social Sciences (SPSS) and Genstat softwares were used in data analysis to get analysis of variance (ANOVA).

RESULTS

Effect of weeding intensity on cyanide content of cassava roots

Results revealed that cassava plants growing in weedy plots for the entire growth period produced the highest cyanide content (79.2 mg kg^{-1}) compared to cassava from weed- free plots which produced the least cyanide content (53.5 mg kg^{-1}) (Table1). The highest cyanide content in the weedy plots was found in *Tajirika* variety while the least cyanide content came from *Kibandameno* variety. Results also showed that the amount of cyanide produced by cassava was variety-specific. From the results, the weedy treatment produced 64.6 mg kg^{-1} cyanide in *kibandameno* variety while in *Nzalauka* and *karembo* varieties the same weedy treatment produced 65.3 mg kg^{-1} and 66.2 mg kg^{-1} respectively. Cyanide content figures from cassava

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weeded after every four weeks fell in between weed-free treatments and very weedy treatment figures (Table1).

Table 1: Effect of weeding intensity on cyanide content (mg kg^{-1}) per variety of cassava

	Variety			
Weeding level	V_1= *Kibandameno*	V_2 = *Nzalauka*	V_3= *Karembo*	V_4 = *Tajirika*
W_1= Very weedy/No weeding	64.6	65.3	66.2	79.2
W_2 = Intensive weeding / No weeds	53.5	68.5	70.3	67.5
W_3 = Weeding at 4-weeks intervals	64.2	68.1	64.2	64.9

The results of the study showed that weeding was significant($P\leq0.05$) on cassava roots cyanide content (Table 2). The mean cyanide content of cassava roots from plots which were not weeded at all was 71.3 mg kg^{-1} while that of cassava maintained weed-free was 68.1 mg kg^{-1}.

There was no significant difference in cyanide content between cassava kept weed-free and that weeded after every three weeks (Table 2).

Table 2: Effect of weeding intensity on cyanide content (mg kg^{-1}) of cassava roots

Weeding regime	**Mean**	**Minimum**	**Maximum**	**Range**
No weeding	71.3^{a}	64.6	79.0	14.4
No weeds	68.1^{b}	53.5	70.3	16.8
Weeding at 4-weeks intervals	67.1^{b}	64.2	68.1	3.9

Means followed by the same superscript are not significant at $P\leq0.05$

Weeding x variety interaction in cassava root cyanide contents

Results from the analysis showed that weeds x variety interactions are highly significant ($p < 0.05$) (Table3).

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Table3: Weeding by Variety interaction effects on cassava root cyanide content

Treatment by variety interaction	P-value	Remarks
Weeds x variety interaction	<.001	Highly significant

DISCUSSION

Effect of weeding intensity on cyanide content of cassava roots

The study findings showed that weeding in cassava was significant ($P \leq 0.05$). Weeds are a big concern to farmers. Weeds compete with cultivated plants for nutrients, water, space and light. Weeds carry pests and diseases which they might transmit to cultivated plants such as cassava. Tuber bitterness in cassava increases with weeds pressure. This was demonstrated in this study in plots which were left with weeds indefinitely. The amount of cyanide produced in weedy plots cassava was significantly higher (71.3^{a}) compared to that in weed-free plots (68.1^{b}). These findings are in line with work done by Okogbenin *et al.*, (2003) who reported that weeds deplete soil water and induced soil water stress which is linked to cassava tuber bitterness. Similar observations were reported by Alou IN, *et al*., (2014) that delayed weeding or no weeding at maturity had been found to result in increased cassava root bitterness. Weed free plots seemed to have experienced least water stress from weed competition hence the least cyanide content in cassava harvested from these plots (Table 1). Bitterness in cassava is shown to be an attribute of a variety involved. Results demonstrate that at every level of treatment still one finds minor differences in cyanide content across the four cassava varieties. In this experiment, the amount of cyanide in *Karembo* variety in both weedy and weed–free plots outweighed the amount in

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Kibandameno variety(Table 1). The result confirms Isaac N. A *et al* (2014) work that cyanogenic potential indicative of tuber bitterness is inherent of cassava genotypes.

Cassava is slow to establish its canopy hence early weed control is crucial. Farmers sometimes practice peacemeal harvest for consumption when cassava is mature. Peacemeal harvesting involves harvesting cassava at a time without uprooting the mother plant. Farmers claimed that the stock left behind after peacemeal harvesting eventually turns bitter. This observation could be attributed to the fast active growing young tubers left behind after harvest which accumulates higher cyanide levels.

Factor such as drought, temperature, nutrient concentrations in the soil can individually influence cassava quality. Although these parameters alone can significantly influence the growth, nutrition and cyanogenesis of cassava, it will be the interactions between these factors which are likely to be most important. Results in this study indicated that the weed x variety interaction is highly significant (Table 3).

CONCLUSION AND RECOMMENDATIONS

Conclusion

The following conclusions were made following the results obtained from this research work:

Weeds have a significant effect ($p < 0.05$) on cyanide concentration in cassava roots.

Recommendations

i. The public should be sensitized and made aware on the critical HCN equivalents/ kg as compared with WHO preference standards.

ii. Campaign mobilization work should be carried out to give farmers a complete weeding package in order to manage good quality cassava root tubers.

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iii. Cassava processing is essential. Farmers must be sensitized on effective cassava processing techniques to improve cassava quality before consumption.

Acknowledgements

My thanks to the Department of Horticulture (Pwani University) for advice and guidance during my study. I kindly appreciate the support of my supervisors Dr. Saha, H.M, and Dr. Mwololo, J in this project.

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