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An evaluation of the efficacies of four (4) selected herbicides in controlling herbicide resistant weeds in cassava cultivation in Bebi Obanliku, cross river state, Nigeria

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Abstract

A two year (2024 and 2025) trial was conducted at the Teaching and Research farm of the Federal College of Education Obudu, (Bebi Campus) Cross River State. The main objective was to compare the efficacies of four (4) selected herbicides in controlling noxious/herbicide resistant weeds in cassava varieties. The design of the experiment was a Completely Randomized Design (CRD) on a four by four (4 x 4) factorial layout. The main plot treatments were the cassava varieties; TMS. 60444, TMS. 30555, TMS. 30572 and TMS. 60506. The subplot treatments were the herbicide types; Paraquat, Glyphosate, Atrazine, and Ametryn, all applied at 3.0 kg/ha. Application was done two weeks after planting of the cassava varieties. Data for percentage establishment of cassava were taken at four (4) weeks after planting (4WAP). Herbicide toxicity (injury) on the cassava and the weed control efficiency were recorded six (6) weeks after planting (6WAP). Tuber yield in tons per hectare (t/ha) were recorded at six (6) months after planting (6MAP) all data generated were subjected to analysis of variance (ANOVA) and the means were separated using Least Significant Difference (LSD) at 5 % level of probability. Results showed that herbicide toxicity rating on the cassava was higher in Atrazine> Glyphosate> Paraquat> Ametryn. Weed control efficiency rating of herbicides was Paraquat (97.40 %)> Glyphosate (85.87 %)> Ametryn (83.83 %)> Atrazine (62.07 %). The highest yields in t/ha were recorded in TMS. 30572 (4.30 t/ha) in application of Paraquat and (3.88 t/ha) in application of Glyphosate. Glyphosate and Ametryn gave significantly higher yields in almost all the varieties. Therefore it was recommended that Paraquat applied at 3.0 kg ai/ha should be the correct approach to dealing with noxious/herbicide resistant weeds. Two varieties of cassava TMS. 30572 and TMS. 30555 were also recommended to farmers.

Keywords: Paraquat; Glyphosate; Efficacy; Mortality; Herbicide; Noxious

1. Introduction

Cassava is an important tuber crop which is widely produced in Nigeria. The economic importance of the crop, greatly as a major source of industrial starch and as a staple food crop in rural communities cannot be overemphasized. Like any other crop, cassava is susceptible to weed competition despite its high adaptations to adverse environmental conditions. The impact of the weed competition is most adversely felt by the crop during its first 30 to 120 days of planting. In effect, it means that the cassava farms must be kept weed free during the early life of the crop.

Common weeds in the tropic always found in cassava farms include; *Pteridium aquilinum* L Kuhn, *Imperata cylindrical* L. Beauv, *Sida acuta* Bum F, *Melinis ninutiflora* Beau, *cyperus rotundus* L, *Commelina diffusa* Burn F., *Ageratum conyzoids* L., *Portulaca oleraceae* L, *Alternenthera sessilis* L, *Mimosa invisa* Mart, *Digitaria horyontalis* wild, and *Panicum* maximum Jacq, National Root Crop Research [1].

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Predominant weeds at the study area included, *Imperata cylindrica,* L. Beauv*, Sida acuta* Bum F*., Cyperus rotundus* L*, Commelina diffusa* Burm F*., Ageratum conyzoides* L*, Digitaria horizontalis* Willd, etc. These weeds belong to families like Malvacea, Poaceae, Convolvulaceae, Euphobiaceae etc. They constitute a group of devastating weeds of cassava in many parts of tropical Africa, including Nigeria. Causing 40 to 45 % losses of the total cassava tuber output in West Africa, International Institute of Tropical Agriculture [2]. Weeds like *Imperata cylindrical* cause damage to cassava tubers and other root crops by piercing through the roots and tubers with their racemes which are dense, tight, cylindrical and spikelike. This inflict severe damage to the tubers thereby reducing their quality, yield and market value. This condition does not only render them unacceptable for human consumption, but also rejected in the international market. Most of the holes created on the tubers by these racemes will eventually become entry point for most fungal root rot, and bacterial diseases that will further destroy the tubers. Weeds generally compete with crops for light, water, space and nutrients,

1.1. Statement of the problem

The control of weeds manually by farmers in the study area is characterized by drudgery, time wasting and often does not yield good results. Most weeds like *Imperata cylindrica*, *Sida acuta*, *Cyperus rotundus* etc, are becoming resistant to some herbicides. They are becoming stubborn and resilient, making it very difficult to control by the farmers.

Despite the environmental hazards said to be associated with the continuous use of chemicals in agricultural production, and the persistent agitations for their ban, their use remains the best and reliable solution to weed problem in crops. Herbicides used for weed control are highly effective, as they rapidly reduce large populations of weeds. However, if herbicides are excessively used or misused, will often lead to environmental degradation, toxicity injuries on the crops and poisonous effects on the user and consumers of the crops.

It has become necessary that in using herbicides, appropriate selection of the right herbicides for a particular weed situation should be made in order to avoid herbicide misuse and reduce environmental degradation. Selecting the most suitable herbicide will also reduce herbicide resistant affect by weeks.

1.2. Objective of the study

The purpose of the study is to eliminate herbicides misuse and reduce environmental degradation. The specific objectives include to:

- Establish and recommend appropriate herbicides that will have the efficacy of controlling weeds that are stubborn and resistant to control measure.
- Evolve a more sustainable method of managing stubborn and herbicide resistant weeds in order to avoid excessive use and misuse of herbicides
- Increase cassava production, based on the concept of low external inputs and sustainable agriculture (LEISA). Under this concept, the recommended herbicide(s) will be applied only at low levels yet achieving results.

2. Materials and methods

The experiment was conducted at Bebi Campus of Federal College of Education Obudu, Cross River State, during the 2024 and 2025 planting seasons. Obudu experiences both the guinea savanna climate and the rainforest climate. Generally, the climate is characterised by a long wet season starting in March every year and last till October, followed by a long dry season from November to March of the following year. This weather is accompanied by harmattan which is cool, and misty in the morning hours disappearing as the sun rises in the day.

The experimental design was a Randomized Complete Design (RCD) on a four by four factorial in three replicates with five (5) subplots in each block. One subplot in each block represented control, while the remaining four (4) subplots were treatments, according to the four (4) herbicides used in the experiment. Herbicides used included, Atrazine, Ametryn, Gramoxone (Paraquat) and Glyphosate. All were applied at 3.0 kg ai/ha. Ridges were constructed five (5) metres long and one (1) metre wide with fifty (50 cm) distance between ridges. The space between two blocks was 1.5 metres. There were three (3) replicates in the experiment with a space of two (2) metres between two (2) replicates. The entire experimental farm was measuring 19 x 25 metres. The main plot treatments were the cassava cultivars (TMS. 60506, TMS 60444, TMS 30555 and TMS. 30572). The subplot treatment were the treatments with the four herbicides, applied at two (2) weeks after planting (2 WAP).

2.1. Data collection and analysis

Data for the Physico-chemical properties of the soil at the experimental site before planting, were taken immediately after clearing the field. Percentage establishment of the cassava varieties was determined by counting the number of germinated stands and expressed as a percentage of total number of cuttings planted per sub plot. Visual ratings were taken for herbicide toxicity (injury) levels on the crop plants and their control, using the methods of [3]. Ratings were done as follows; (i) Toxicity (injury) in which less than 10 % of the crops was killed (Mortality) was insignificant (ii) Toxicity (injury) was slight where 10-29 % of the crops was killed (Mortality) (iii) Toxicity (injury) level of 30-70 % was regarded as moderate, while (iv) toxicity (injury) level of 70-100 % was considered as severe.

In assessing herbicide weed control efficiency, a scale was used thus (i) If less than 10 % of weeds emerged after spraying, then the rating was regarded as very good (ii) if 10-49 % of weeds emerged, the rating was regarded as good (iii) if 50-79 % of weeds emerged, it was fair, while (iv) if 80-100 % of weeds emerged, the rating was considered poor. Both toxicity (injury) levels of the herbicides on the crop and control levels were determined at six (6) weeks after application of the herbicides, both in 2024 and 2025.

Tuber yields were obtained from each plot by weighing in kgs and later expressed in tons per hectare (t/h) at six (6) months after planting (6MAP). Tuber yields were determined when the mean of the two seasons (2024 and 2025) were pooled together and the average calculated.

All data collected were subjected to analysis of variance using Genstat statistical software (version 13) and significant means were compared using Least Significant Difference (LSD) at 5 % level of probability.

3. Result

3.1. Physico-Chemical Properties of the soil at the experimental site

Table 1 Physical and chemical properties of the soil at the experimental site before planting

S/N	Soil properties	2024	Soil	Depth	2025
		0-15	15-30	0-15	15-30
1	Soil P^H (H_2O)	5.52	5.22	5.62	5.25
2	Organic matter (%)	2.55	2.32	5.60	5.33
3	Total Nitrogen (%)	0.25	0.22	0.21	0.20
4	Available P (Mg/kg)	156.34	144.22	165.62	152.22
5	Exchangeable Cations				
	Ca (Meg/100g)	4.62	3.25	6.61	6.22
	Mg (Meg/100g)	2.25	2.22	2.45	2.44
	Na (Meg/100g)	0.06	0.06	0.04	0.04
	K (Meg/100g)	0.22	0.20	1.05	0.05
6	Exchangeable Acidity	0.62	0.51	0.56	0.46
	Al (cmol/kg)	0.62	0.51	0.56	0.46
	H (cmol/kg)	0.42	0.43	0.43	0.12
	EcEc (cmol/kg)	8.32	6.56	10.32	9.43
7	Particle size distribution %				
	Sand	89.60	88.60	88.60	88.60
	Silt	5.52	5.67	5.50	6.22
	Clay	4.80	4.75	4.86	4.88
	Soil texture	Sandy-Loam			

Pre-planting soil analysis revealed the following physico-chemical characteristics: P^H in water 5.25, organic matter 5.33 %, total nitrogen 0.20 %, available P 152.22 (mg/kg) while exchangeable bases were 0.05, 6.22 and 2.44 for K, Ca and Mg respectively. The soil particle distribution was, sand 88.60 %, silt 6.22 % and clay 4.88 %.

3.2. Plant establishment, crop mortality rating and weed control efficiency

Cassava percentage establishment at 4 weeks after planting (4 WAP) did not differ significantly ($p>0.05$) amongst the crop varieties (Table 2). However, herbicide type significantly ($p<0.05$) affected the plant (cassava) establishment.

This means that the type of herbicide applied affected the percentage establishment and the mortality rate of the crops. This was demonstrated by the high percentage establishment of the cassava plants in plots treated with Paraquat and Glyphosate. This was in comparism with the high mortality rate as recorded in plots treated with Atrazine and Ametryn. The interaction effects between the herbicide type and the cassava varieties were equally significant ($p<0.05$), with the trend indicating that Paraquat and Glyphosate favoured plant establishment with adequate weed control (Table 2)

Table 2 Effects of selected herbicides on percentage establishment of some cassava varieties at 4 weeks after planting

S/N	Cassava variety	Herbicide	2024	2025	Mean
1	TIMS 60506	control	85.52	88.32	86.74
		Atrazine	65.22	70.36	67.74
		Ametryn	70.35	82.22	76.28
		Paraquat	90.25	91.60	90.93
		Glyphosate	92.51	91.72	92.10
		Mean	80.77	84.82	82.79
2	TMS 60444	Control	90.04	88.65	89.35
		Atrazine	66.52	80.22	73.37
		Ametryn	72.23	70.66	71.45
		Paraquat	92.55	96.22	94.40
		Glyphosate	90.63	95.21	92.92
		Mean	82.40	86.20	84.30
3	TMS. 30555	Control	86.25	90.22	88.24
		Atrazine	60.22	68.23	64.22
		Ametryn	68.56	71.34	69.95
		Paraquat	92.74	95.66	94.20
		Glyphosate	90.55	94.26	92.41
		Mean	79.66	83.94	81.81
4	TMS. 30572	Control	89.27	86.79	88.03
		Atrazine	65.63	80.55	73.09
		Ametryn	70.28	76.36	73.32
		Paraquat	93.65	92.53	93.09
		Glyphosate	91.21	90.31	90.76
		Mean	82.01	85.31	83.65
	LSD (p=0.05)				
		Variety	NS	NS	

		Herbicide	5.62	5.36	
		Variety x herbicide type	22.40	26.20	

Key: NS = Not Significant

Percentage crop establishment for cassava in Paraquat treated plots was higher than in all other plots, irrespective of the cassava variety. The next higher plant establishment was recorded in plots treated with Glyphosate. Significant differences ($p<0.05$) were observed in the injury (Mortality) rating of the type of herbicide applied, as seen in (Table 3).

Atrazine appeared to be more lethal to the cassava plant than the other herbicides used here. Plant establishment was low in all the varieties treated with Atrazine. Weed control efficiency rating differed significantly ($p<0.05$) amongst the different herbicides used and the control (Table 4). Paraquat was the most efficient in controlling the noxious weeds in this experimental farm. This was followed by glyphosate, with Atrazine least in controlling the weeds, thereby resulting in low plant establishment (Table 2).

Table 3 Injury Rating (%) Of Selected Herbicides on Some Cassava Varieties At Two Weeks After Planting/Application

Treatment	2024	2025	Mean
Control	1.20	0.72	0.96
Paraquat	3.22	4.52	3.87
Atrazine	70.34	67.36	68.85
Glyphosate	5.21	4.68	4.95
Ametryn	6.43	6.32	3.37
Mean	17.28	16.72	16.40
LSD = (0.05)	5.42		4.22

No significant difference ($_P>0.05$) was recorded in the mortality rate amongst the cassava varieties as well as for the weed control efficiency rating and the interaction effect between the herbicide type and the cassava variety.

Table 4 Weed control Efficiency Rating (%) of some selected herbicides at six weeks after planting (6 WAP)

Treatment	2024	2025	Mean
Control	80.12	75.62	77.87
Paraquat	98.23	96.52	97.40
Atrazine	62.32	61.82	62.07
Glyphosate	86.51	85.24	85.87
Ametryn	85.23	82.43	83.83
Mean	82.50	80.33	81.41
LSD = (0.05)	5.42	4.64	

Tuber yield did not differ significantly ($p>0.05$) amongst the cassava varieties (Table 5). However, on the basis of average yield for both 2024 and 2025, the trend was in the following order, TMS. 30572 (3.77 t/ha^{-1})> TMS. 30555 (3.37 t/ha^{-1})> TMS. 60506 (3.00 t/ha^{-1})> TMS. 60444 (2.55 t/ha^{-1}). Tuber yield differed significantly ($p<0.05$) amongst the herbicide type applied, notwithstanding the variety of cassava. Although no clear trend was established, average of the efficiency rating of the herbicides in the two year cultivation was as follows; Paraquat (97.40 %) > Glyphosate (85.87 %)> Ametryn (81.41 %)> Atrazine (62.07 %) (Table 4).

Paraquat promoted higher yields in TMS. 30572, TMS. 30555 and TMS. 60506 (Table 5). The interaction effects between the cassava varieties and the herbicide type was significant ($p<0.05$) with Paraquat and Glyposate highly favoured in TMS. 30572 and TMS. 30555 (Table 5)

Table 5 Effects of Selected Herbicides on the yields of cassava varieties at six (6) months after planting (6MAP)

Cassava variety	**Herbicide**	**Tuber yield (t/ha^{-1})**		
		2024	2025	Mean
TMS. 60506	Control	3.20	2.50	2.85
	Atrazine	2.64	3.20	2.92
	Ametryn	3.10	3.15	3.13
	Paraquat	3.24	3.20	3.22
	Glyphosate	2.82	3.00	2.91
	Mean	3.00	3.01	3.00
TMS. 60444	Control	2.85	2.88	2.86
	Atrazine	2.76	2.64	2.70
	Ametryn	3.00	2.95	2.97
	Paraquat	3.83	3.87	3.85
	Glyphosate	3.15	3.36	3.25
	Mean	3.11	3.21	2.55
TMS. 30555	Control	2.86	2.88	2.87
	Atrazine	2.87	3.02	2.95
	Ametryn	2.88	3.25	3.10
	Paraquat	3.95	4.12	4.04
	Glyphosate	3.88	3.96	3.92
	Mean	3.30	2.79	3.37
TMS. 30572	Control	2.86	3.25	3.10
	Atrazine	3.66	3.85	3.75
	Ametryn	3.72	3.92	3.82
	Paraquat	4.20	4.35	4.30
	Glyphosate	3.88	3.86	3.88
	Mean	3.66	3.85	3.77
	LSD (p=0.05			
	Cassava variety		NS	NS
	Herbicide		3.52	3.71
	Variety x Herbicide		3.61	3.48

4. Discussion

The significant difference ($p<0.05$) in percentage establishment and morality rate of the cassava varieties in respect to the herbicide type used here was obvious (Table 2). There is an indication that some herbicides are toxic to both the weeds and the crops when applied in higher levels of up to 3.0 kg/ha. [4] had earlier on observed that most herbicides

at lower levels of applications are less toxic to plants. He recommends applications at 2 to 2.5 kg/ha as the ideal rates. This view has been supported by [3] who reported that most pre-emergence herbicides applied at lower concentrations or rates of 1.5 to 2.0 kgai/ha will record lower mortality rate on crops.

In this experiment, cassava establishment percentage was lower in plots treated with Atrazine due to herbicide toxicity on the cassava plants. [4] had also reported that Atrazine has a lower biodegradable ability and persist longer in the soil. Plots treated with atrazine here, recorded a main injury (toxicity) rating of 68.85 % against 3.87 % and 4.95 % for Paraquat and Glyphosate respectively (Table 3). Both Atrazine and Ametryn are trizine family compounds requiring a long 'back plant period' (a period after application before crops are planted), especially when used as pre-emergence herbicide [5]. Farmers are usually advised to consider the time of application of herbicides when controlling weeds in farms. Proper timing of herbicide application and the knowledge of the appropriate herbicide to be used are essential in effective weed management [4].

Cassava like most other crops, suffers weed stress mostly at early stage of growth. Therefore, proper timing of herbicide application is important. [6] observed that cassava dies of weed infestation and stress at the early stage of growth. Early weed control strategies are necessary. Paraquat, Glyphosate and Ametryn recorded significantly greater weed control efficiency ratings of (97.40, 85.87, and 83.83) % respectively as against 62.07 % for Atrazine treated plots (Table 4). The three herbicides appeared to be the best herbicides for used in weed management in cassava production, especially in dealing with herbicide resistant weeds (noxious weeds).

Tuber yield differ significantly ($p<0.05$) amongst the cassava varieties in respect to the herbicide type applied (Table 5). The highest yields of cassava tubers were obtained in plots treated with Paraquat and Glyphosate in the variety TMS. 30572 (4.30 and 3.88) t/ha respectively. There was a significantly high yield in TMS. 30555 too, with Paraquat, Glyphosate and Ametryn (4.04, 3.92 and 3.10) t/ha respectively. However, tuber yields in varieties TMS 60506 and TMS 60444 were equally significantly higher in plots treated with Paraquat, Glyphosate and Ametryn, though not as high as in TMS. 30572 and TMS. 30555 (TMS. 60506, 3.22, 2.91 and 3.13) t/ha respectively, (TMS 60444, 3.8, 3.25, 2.97) t/ha respectively (Table 5). The effective control of weeds here by Paraquat, Glyphosate and Ametryn is in line with the report of [7] who reported that most Dichlorides and Organochloride herbicides are very effective in dealing with noxious weeds of crops. Similarly, [6] reported the use of Paraquat in controlling spear grass, one of the most stubborn weeds of tuber crops. [8] also reported the use of a combination of Glyphosate and Ametryn in dealing with herbicide resistant weeds in legumes.

5. Conclusion and recommendations

Based on the findings of this research, it was concluded that using Paraquat for the control of noxious weeds in tuber crops was economical and leads to higher yields of the tuber crops such s cassava. Where Paraquat is not available, Glyphosate or Ametryn can be used as the best way of handling herbicide resistant weeds. In view of the high toxicity levels of the herbicides (Paraquat and Glyphosate) to weeds, it is always advisable that they should be used at low dosages of 2 to 3 kg ai/ha.

The following recommendations were made on the basis of the research outcome;

- Paraquat is highly recommended for managing herbicide resistant weeds in farms,
- Where Paraquat is not available, Glyphosate or Ametryn could be used as substitute,
- Application of these herbicides should be at low dosages of 2.0 or 2.50 kg/ha or at most 3.0 kg ai/ha.
- Proper timing of herbicide application is very essential. In cassava, application at the early stage of growth of the crop will lead to higher yields of the crop,
- Cassava varieties TMS. 30572 and TMS. 30555 are high yielding varieties, therefore they are highly recommended for cultivation.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

The conduct of the experiment was in accordance with all ethical standards. Experts were brought in at different stages of the research work to ensure accuracy.

Statement of informed consent

The researchers ensured that the Land allocation committee of Federal College of Education Obudu, Cross River State consented to the use of a portion of land at the institution's teaching and research farm before the experimental work commenced.

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