

Full Length Research Paper

Response of two potato (*Solanum tuberosum* L.) plant varieties to different types of herbicides under field conditions

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The present study was aimed to study the response of two potato plant varieties to different types of herbicides in Jos Plateau State, Nigeria. The experiment was laid out in a randomized complete block design (RCBD). There were 8 treatment combinations consisting of two potato varieties (Marabel and Rumba) and 4 types of herbicides (Atrazine, Paraquat, a combination of Paraquat and Atrazine and control (without)) replicated 3 times. The result showed that variety had significant effect on the growth and yield of the potato plants. While variety Marabel yielded 2.71 kg/m², Variety Rumber yielded 0.93 kg/m². In addition, the herbicide type had significant effect on potato performance. Treatment with a combination of herbicides and Atrazine was significantly higher than Paraquat. Herbicides used did not have significant effect on

establishment count (EC) at 4 WAP, number of leaves at all sampling dates, total number of tubers, number of ware of tubers, number of seed tubers and yield of seed tubers. There was significant interaction of variety and herbicides on number of leaves, plant height at 10 WAP, number of ware tubers, and number of seed, total yield and yield of ware tubers. There was no significant interaction of variety and herbicides on EC, number of ground stems, total number of tubers formed and yield of seed tubers. This result suggests that weed control with a combination of herbicides (Atrazine and Paraquat), and sole use of Atrazine enhanced the growth and yield of potato crop.

Keywords: Potato yield, weed control, herbicides

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the third most important food security crop in the world after rice and wheat (Haverkort *et al.*, 2009). Potato serves as a major food source (Lachman *et al.*, 2001). It is very low in fat with high content of carbohydrates (Muhinyuza *et al.*, 2016). It has significant amounts of good quality protein such as lysine, substantial amounts of vitamins especially vitamin C, B, and A (Dale *et al.*, 2003), such important nutritional value makes potato an efficient crop in combating malnutrition (FAO, 2008).

Weeds deplete crops environment of nutrients, water and light. In addition, weeds cause spread of several

disease and pest (Pandey, 2000). Weeds compete with potato for light, nutrient, and water (Jan *et al.*, 2004). Intense weed competition is one of the constraints in realizing potential yield of potato resulting in substantial reduction in yield (Singh *et al.*, 1984). Weeds lead to reduction in yield by 36-80% (Neild and Proctor, 1962; Nelson and Thoreson, 1981). Weed competition has been reported to increase the percentage of smaller tubers (Nelson and Thoreson, 1981). The quality of potato is also reduced by weed infestation (Pandey, 2000). Manual weeding is costly, time consuming and sometimes not possible due to non-availability of labour

(Khan *et al.*, 2008). Before the advent of herbicides, controlling weeds require hard physical labour such as hoeing (Kraehmer *et al.*, 2014). In modern agricultural practices, the application of herbicides in weed control plays great importance. Herbicides provide efficient and prompt protection, much longer-term than other agricultural practices (Jovovic *et al.*, 2012). Broad spectrum herbicides such as Paraquat and Atrazine has been reported to have accelerated the use of reduced-tillage measures in Agriculture and helped prevent soil erosion (Kraehmer *et al.*, 2014).

The aim of this research was to study the response of two potato (*Solanum tuberosum* L.) varieties to different types of herbicides under field conditions.

MATERIALS AND METHODS

The field experiment was carried out during the 2016 raining season to study the response of two potato (*Solanum tuberosum* L.) plant varieties to different types of herbicides under field conditions at the National Root Crops Research Institute (NRCRI) Kuru, Jos, Plateau State, Nigeria (Longitude 08° 41'E, Latitude 09° 44'N and an Altitude of 1,239 metres above sea level).

Two potato varieties viz: Marabel and Rumba were obtained from the NRCRI, Kuru, and two types of herbicides were obtained from the Plateau Agricultural Development Programme (PADP). A randomized complete block design (RCBD) was used. There were 8 treatment combinations consisting of 2 potato varieties and 4 types of herbicides (Atrazine, Paraquat, combination and control) replicated 3 times. Land preparation was done using tractor. One seed tuber was planted per hill at an intra-row spacing of 0.3 m (30 cm) and inter-row spacing of 1 m (100 cm) on the 27th May, 2016. Herbicide mixtures were carried out as follows: For sole Atrazine treatment, 30 g of atrazine was dissolved in 3 litres of water; for sole paraquat treatment, 50 mls of paraquat was mixed with 3 litres of water. While for the combination treatment, 30 g of atrazine and 50mls of paraquat were mixed into 3 litres of water. The different herbicide mixtures were evenly sprayed on the appropriate treatment plots on 4th June, 2016. Fertilizer N₁₅P₁₅K₁₅ was applied in bands at the rate of 100 Kg/ha at three weeks after planting (WAP).

The following parameters were assessed: emergence/ establishment count at 4 and 6 weeks after planting, plant height (Fort nightly), number of above ground stems at 6, and 8 WAP, number of leaves (Fort nightly), total number of tubers formed/m², number of ware (saleable) tubers formed/m², number of seed sized tubers formed/ plot, total yield of tubers (kg/m²), yield of ware tubers (kg/m²), yield of seed sized tubers (kg/m²). At harvest, weed sampling was carried out by throwing 3 quadrats on each treatment plot to evaluate the types of weeds that grew after the herbicide treatment. The number of each type

weed was recorded and expressed as a percentage. The data collected were subjected to analysis of variance (ANOVA) and the means were separated using LSD using the SAS Software.

RESULTS

Establishment count

The main effect of variety on establishment count was significant at 4 and 6 weeks after planting (WAP). Variety Marabel resulted in significantly higher establishment count (15.42 and 16.25 %) than variety Rumba (2.92 and 9.42 %) at 4 and 6 WAP respectively at 5% level of probability (Table 1). The main effect of herbicides used for weed control on establishment of potato crop in the field was not significant ($P < 0.05$) at 4 WAP but was significant at 6 WAP. Treatment with a combination of herbicides resulted in significantly higher EC (15%) than treatment with herbicide paraquat (11.50%) (Table 1). There was no significant ($P < 0.05$) interaction of variety and herbicide on percentage establishment count (Table 1).

Above ground stems

The number of above ground stems formed was significantly ($P < 0.05$) affected by varieties (Table 1). Variety Marabel resulted in significantly higher ($P < 0.05$) mean number above ground stems formed (1.83 and 1.92) than variety Rumba (1.31 and 1.15) at 6 and 8 WAP respectively (Table 1). The number of above ground stems formed was significantly ($P < 0.05$) affected by herbicides at 6 WAP. The control resulted in significantly higher mean number of above ground stems (1.63) than Atrazine (1.27), although the control was similar to Paraquat and treatment with a combination of Paraquat and Atrazine (Table 1). At 8 WAP, all the herbicides treatment resulted in a similar mean number of above ground stems (Table 1). There was no significant interaction of variety and herbicides treatment on mean number of above ground stems (Table 1).

Number of leaves

The number of leaves formed increased from 6 WAP to 10 WAP (Table 2). The effect of variety on mean number of leaves formed was significant ($P < 0.05$) (Table 2). Variety Marabel resulted in significantly higher mean number of leaves (37.70, 43.50 and 48.20) than variety Rumba (18.12, 22.73 and 39.07) at 6, 8 and 10 WAP respectively (Table 2). Weed control with different types of herbicides did not affect the number of leaves formed by potato plants significantly ($P < 0.05$) at all the sampling

Table 1. Effect of variety and herbicide on establishment count (%) and number of above ground stems formed during 2016 rainy season in Jos.

Treatment	Establishment count WAP (%)		Number of above ground stems formed / tuber	
	4	6	6	8
Variety				
Marabel	15.42 ^a	16.25 ^a	1.83 ^a	1.92 ^a
Rumba	2.92 ^b	9.42 ^b	1.31 ^b	1.15 ^b
LS	*	*	*	*
LSD _{0.05}	1.64	2.00	0.24	0.25
Herbicide				
Control	8.17 ^a	12.33 ^{ab}	1.63 ^a	1.57 ^a
Atrazine	8.83 ^a	12.50 ^{ab}	1.27 ^b	1.40 ^a
Paraquat	10.33 ^a	11.50 ^b	1.57 ^{ab}	1.60 ^a
Combination	9.33 ^a	15.00 ^a	1.47 ^{ab}	1.57 ^a
LS	NS	*	*	NS
LSD _{0.05}	2.32	2.78	0.34	0.35
Interaction				
Variety X Herbicide	NS	NS	NS	NS

Table 2. Effect of variety and Herbicide on mean number of leaves and plant height (cm) of potato/ plant during the 2016 rainy season in Jos.

Treatment	Number of leaves WAP			Plant height (cm) WAP		
	6	8	10	6	8	10
Variety						
Marabel	37.70 ^a	43.50 ^a	48.20 ^a	22.40 ^a	33.73 ^a	41.46 ^a
Rumba	18.12 ^b	22.73 ^b	39.07 ^b	17.89 ^a	18.73 ^b	33.98 ^b
LS	*	*	*	NS	*	*
LSD _{0.05}	8.33	7.72	6.74	4.68	3.96	6.04
Herbicide						
Control	27.40 ^a	31.57 ^a	48.07 ^a	15.12 ^b	27.30 ^a	41.72 ^a
Atrazine	32.00 ^a	26.93 ^a	42.12 ^a	25.27 ^a	23.51 ^a	35.28 ^a
Paraquat	25.17 ^a	27.53 ^a	42.67 ^a	15.50 ^b	26.20 ^a	37.90 ^a
Combination	36.30 ^a	37.20 ^a	40.68 ^a	24.70 ^a	27.92 ^a	35.97 ^a
LS	NS	NS	NS	*	NS	NS
LSD _{0.05}	11.78	10.91	9.54	6.61	5.60	8.54
Interaction						
Variety X Herbicide	*	*	*	NS	NS	*

dates. Although treatment with a combination of Atrazine and Paraquat resulted in highest mean number of leaves at 6 and 8 WAP while the control (without herbicide) resulted in highest number of leaves at 10 WAP (Table 2). The interaction of variety and herbicides on mean number of leaves produced per plant is presented on Table 3. At 6 WAP, variety Marabel resulted in highest number of leaves on plots treated with a combination of herbicides (Atrazine and Paraquat), while variety Rumba produced a similar mean number of leaves with all the treatments. A similar pattern was repeated at 8 WAP. At 10 WAP, variety Marabel produced a similar mean number of leaves in all the herbicide treatments (Table 3).

Plant height

Plant height increased from 6 to 10 WAP (Table 2). The main effect of variety on plant height was significant at 8 to 10 WAP, but was not significant at 6 WAP. Variety Marabel had significantly ($P < 0.05$) higher mean plant height (33.73 and 41.46) than variety Rumba (18.73 and 33.98) at 8 and 10 WAP respectively (Table 2). The main effect of herbicide treatment was significant ($P < 0.05$) at 6 WAP. Treatment with Atrazine and a combination (Atrazine and Paraquat) resulted in significantly ($P < 0.05$) higher mean plant height than weed control with Paraquat and the control. At 8 and 10 WAP, all the herbicides used for weed control resulted in similar mean

Table 3. Interaction of variety and herbicide on mean number of leaves formed and plant height (cm) of potato/ plant during the 2016 rainy season in Jos.

Treatment	Number of leaves						Plant height (cm)	
	6 WAP		8 WAP		10 WAP		10 WAP	
	Variety		Variety		Variety		Variety	
	Marabel	Rumba	Marabel	Rumba	Marabel	Rumba	Marabel	Rumba
Herbicide								
Control	43.13ab	20.00a	33.40ab	21.40a	49.40a	46.73a	44.60a	38.83a
Atrazine	38.67b	15.20a	38.47ab	25.53a	51.20a	33.03b	39.33a	31.23ab
Paraquat	36.93b	18.13a	30.33b	20.00a	45.40a	41.93ab	36.70a	39.10a
Combination	55.27a	19.19a	48.60a	24.00a	46.80a	35.57ab	45.20a	26.73b
LSD _{0.05}	15.43		16.66		13.49		9.35	

Table 4. Effect of variety and herbicide on mean number of leaves and plant height (cm) of potato/ plant during the 2016 rainy season in Jos.

Treatment	Number of Tubers/ m ²			Yield of Tubers/ m ²		
	Total Number of tubers formed	Number of ware tubers	Number of seed tubers	Total	Ware	Seeds
Variety						
Marabel	50.00 ^a	8.67 ^a	41.33 ^a	2.71 ^a	0.99 ^a	1.63 ^a
Rumba	24.50 ^b	4.50 ^b	19.67 ^b	0.93 ^b	0.36 ^b	0.58 ^b
LS	*	*	*	*	*	*
LSD _{0.05}	9.49	2.80	7.07	0.45	0.18	0.50
Herbicide type						
Control	37.17 ^a	4.67 ^a	32.50 ^a	1.68 ^{ab}	0.42 ^b	1.31 ^a
Atrazine	39.17 ^a	7.83 ^a	31.33 ^a	1.95 ^{ab}	0.90 ^a	1.01 ^a
Paraquat	31.00 ^a	5.33 ^a	25.00 ^a	1.43 ^b	0.48 ^b	1.09 ^a
Combination	41.67 ^a	8.50 ^a	33.17 ^a	2.22 ^a	0.91 ^a	0.96 ^a
LS	NS	NS	NS	*	*	NS
LSD _{0.05}	13.42	3.95	10.00	0.64	0.26	0.45
Interaction						
Variety X Herbicide	NS	*	*	*	*	NS

plant height of potato (Table 2). The interaction of variety and herbicides on mean plant height is presented in (Table 3). With variety Marabel, treatment with all the herbicides resulted in a similar mean plant height. With variety Rumba, plots treated with Paraquat and the control had the highest mean plant height (Table 3).

Total number of tubers formed

Variety Marabel resulted in significantly ($P < 0.05$) higher total number of tubers formed (50.00) than variety Rumba (24.50) (Table 4). The different types of herbicides used for weed control resulted in a similar mean total number of tubers formed, although treatment with a combination of Atrazine and Paraquat resulted in the highest total number of tubers formed (1.67) (Table 4). The interaction of variety and herbicide on total number of tubers formed was not significant (Table 4)

Number of ware (saleable) tubers formed

Variety Marabel had significantly ($P < 0.05$) higher mean

number of ware tubers formed (8.67) than variety Rumba (4.50) (Table 4). Weed control with different types of herbicides did not affect the number of ware tubers formed significantly ($P < 0.05$) although treatment of a combination of herbicides (Atrazine and Paraquat) resulted in highest mean number of ware tubers formed per m² (8.50) (Table 4). The interaction of variety and herbicide on mean number of ware tubers formed per m² is presented on (Table 5). With variety Marabel, weed control using Atrazine and a combination of herbicides (Atrazine and Paraquat) produced the highest mean number of ware tubers, while the control had the least number of ware tubers. With variety Rumba, all the herbicide treatments and the control had a similar mean number of ware tubers formed (Table 5).

Number of seed tubers formed

Variety Marabel resulted in significantly ($P < 0.05$) higher mean number of seed tubers formed (41.33) than variety Rumba (19.67) (Table 4). All the herbicides use for weed

Table 5. Interaction of variety and herbicide type on mean number of ware tubers, number of seed tubers, total yield of tubers and Yield of ware tubers of potato/ m² during the 2016 rainy season in Jos.

Herbicide type	Number of ware tubers		Number of seed tubers		Total Yield of Tubers		Yield of Ware Tubers	
	Variety		Variety		Variety		Variety	
	Marabel	Rumba	Marabel	Rumba	Marabel	Rumba	Marabel	Rumba
Control	10.00c	7.67a	98.67a	33.67a	2.46b	0.90a	0.50b	0.33a
Atrazine	26.33a	8.67a	76.00b	47.00a	2.85ab	1.05a	1.40a	0.40a
Paraquat	17.00b	6.67a	71.33b	35.67a	2.08b	0.78a	0.67b	0.28a
Combination	24.33a	8.67a	96.33a	43.67a	3.45a	0.98a	1.40a	0.42a
LSD _{0.05}	5.59		14.13		0.89		0.35	

Table 6. Important weed flora identified on the experimental field, in Jos Plateau State Nigeria during the 2016 rainy season.

Common name	Scientific name	Number	Percentage
Day flower	<i>Commelina benghalensis</i>	6009	65
Billy goat weed	<i>Ageratum conyzoides</i> Linn	924	10
Couch grass (short grass)	<i>Digitaria abyssinica</i>	1440	15
Spear grass (tall grass)	<i>Imperata cylindrica</i>	694	7.55
Quack grass (looks like corn)	<i>Elyytrigia repens</i>	106	1.15
Goat weed sp (Yellow flowers)		15	0.16
Bind weed (wild morning glory)		5	0.05
Pig weeds	<i>Amaranthus</i> sp	3	0.03

control resulted in a similar mean number of seed tubers formed although treatment with a combination of herbicides (Atrazine and Paraquat) resulted in the highest mean number of seed tubers formed (Table 4). Table 5 shows the interaction of variety and herbicide on mean number of seed tubers formed. With variety Marabel, the control and treatment with a combination of herbicides (Atrazine and Paraquat) produced the highest mean number of seed tubers. With variety Rumba, the different herbicide treatments and the control produced a similar mean number of seed tubers (Table 5).

Total yield of tubers

Variety Marabel resulted in significantly higher total yield of tubers formed (2.71 kg/m²) than variety Rumba (0.93 kg/m²) (Table 4). The different herbicides used for weed control resulted in significantly (P < 0.05) higher mean total yield of tubers formed. Weed controlled with a combination of herbicides (Atrazine and Paraquat) had the highest total yield of tubers formed (2.22 kg/m²) than treatment with herbicide Paraquat (Table 4). The interaction of variety and herbicides on mean total yield of tubers is presented on Table 5. With variety Marabel, weed control with a combination of herbicides (Atrazine and Paraquat) produced the highest total yield of tubers. With variety Rumba, all the herbicides used and the control had similar total yield of tubers (Table 5).

Yield of ware (saleable) tubers

Variety Marabel had significantly (P < 0.05) higher yield of ware (saleable) tubers formed (0.99 kg/m²) than variety Rumba (0.36 kg/m²) (Table 4). Weed controlled with herbicides resulted in significantly (P < 0.05) different yield of ware tubers. Treatment with Atrazine and with a combination of herbicides (Atrazine and Paraquat) resulted in significantly (P < 0.05) higher yield of ware tubers (0.90 and 0.91 kg/m² respectively) than the control and herbicide Paraquat (Table 4). The interaction of variety and herbicide on yield of ware tubers is presented on (Table 5). With variety Marabel, weed control with Atrazine and a combination of herbicides (Atrazine and Paraquat) produced significantly higher yield of ware tubers than the control and Paraquat (Table 5).

Yield of seed tubers

Variety Marabel resulted in significantly (P < 0.05) higher yield of seed tubers (1.63 kg/m²) than variety Rumba (0.58 kg/m²) (Table 4).

Weed control using different types of herbicides resulted in a similar yield of seed tubers although the control resulted in highest yield of seed tubers (1.31 kg/m²) (Table 4). There was no significant (P < 0.05) interaction of variety and herbicides on the yield of seed tubers (Table 4).

Weed population

Some of the weed population on the experimental field consisted of: Day flower (*Commelina benghalensis*), billy goat weed (*Ageratum conyzoides*), couch grass (*Digitaria abyssinica*), Spear grass (*Imperata cylindrica*), Quack grass (*Elytrigia repens*), Goat weed species with yellow flower, Bind weed (wild morning glory), and pigweed (*Amaranthus* sp). (Table 6). Among these, the most predominant weed species were Day flower (*Commelina benghalensis*), billy goat weed (*Ageratum conyzoides*) and couch grass (*Digitaria abyssinica*) (Table 6).

DISCUSSION

The result showed that establishment count varied with variety. Variety Marabel had the highest establishment count % at both 4 and 6 WAP. This may be due to the genetic composition and physiological condition (number and sprout length) of the tubers at planting. The rate of emergence has been reported to be dependent on sprout length and soil temperature (Headford, 1962; Tantowijoyo and Van de Flirt, 2006), planting date, soil temperature, environmental factors, physiological age and characteristic of a particular cultivar (Johnson, 2008). Jan *et al.* (2004) found that percentage germination was not affected by any of the weed control methods used (hand weeding and herbicides).

The number of above ground stems formed varied with variety. Variety Marabel had more stem number than variety Rumba. The variation in stem number could be a cultivar characteristic. Ostrosky and Struik, (2008) found the number of stems to be significantly affected by cultivar. Beukema and Van Der Zaag, (1990) reported that tubers of various varieties produce a different number of stems per tuber. The main effect of variety on number of leaves was significant. Variety Marabel produced significantly higher mean number of leaves than variety Rumba at all the sampling dates. This variation may be as a result of genetic composition of the varieties. Taylor, (1953) reported varietal differences in the distribution of leaves above ground and stolon below ground. The number of leaves was not significantly affected by herbicide types. The main effect of variety on plant height was significant at 8 and 10 WAP. Variety Marabel was significantly higher than variety Rumba. The differences may be attributed to the genetic composition of the varieties. Cultivar differences in plant height have been reported (Fernandez, 2010). Herbicides significantly affected plant height at 6 WAP with Atrazine and combination (Atrazine and Paraquat) being significantly higher than control and Paraquat. This may be because the herbicides controlled the weeds thus, the potato is not competing for resources with any weed. Jan *et al.* (2004) reported that weeds compete with potato for light, nutrient and water.

Herbicides was not significant at 8 and 10 WAP. This might be because fresh weeds have germinated and grown and are competing with the potato for resources with the potato crop. The main effect of variety on total number, number of ware and number of seed tubers formed was significant. Variety Marabel was significantly higher than Rumba. This may be attributed to genetic composition of the varieties and environmental conditions during crop growth in the field. Number of tuber has been reported to be significantly affected by variety (Razzaque and Ali, 2009). The types of herbicides used did not affect the number of tubers produced significantly. Yield of tubers (total ware and seed) was significantly affected by variety. Variety Marabel was significantly higher than variety Rumba. Yield is a varietal characteristic even though, it is dependent on environmental conditions during seed storage and crop growth in the field. Rosen *et al.* (2011) reported yield to be significantly influence by variety for all tuber size and quality categories.

Herbicides used significantly affected the yield of total and ware tubers but seed tubers was not significant. A combination of herbicides was significantly higher than Paraquat. Jan *et al.* (2004) reported significant increase in yield with the use of hand weeding and weedicides tribunil and sencor over the control. Jan *et al.* (2004) also found unweeded control and herbicide stomp significantly inferior to all the other treatments and resulted in low yield because of heavy weed infestation. Jovovic *et al.* (2013) found that combinations of herbicides recorded significantly higher tuber yield compared to the control. Khan *et al.* (2008) found tuber yield of potato to be significantly influenced by different weed management practices. Untreated control treatment gave the lowest tuber yield of 13.78 t/ha in 2005 - 2006 and 13.30 t/ha in 2006 -2007.

Intense weed competition is one of the constraints in realizing potential yield of potato resulting in substantial reduction in yield (Singh *et al.*, 1984). Pandey, (2000) reported that weeds deplete crops environment of nutrients, water and light, thus yields of potato is reduced considerably. It can be concluded that weed control using herbicides enhanced the growth and yield of potato plants. The use of a combination of herbicides (Atrazine and Paraquat) yielded a better result than the use of Paraquat only. Although the experimental field was sprayed with herbicides some weed seeds still grew in the field, suggesting that some of the weed seeds resisted the herbicides used.

Authors' declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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