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EFFECT OF INTEGRATING CHEMICAL AND MANUAL WEED CONTROL METHODS ON SWEETPOTATO YIELD AND PROFITABILITY IN NIGERIA

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Abstract

One of the main factors responsible for the observed low productivity in sweetpotato is inadequate weed control. A study was therefore conducted to determine the effect of integrating different chemical and manual weed control methods on sweetpotato yield in the rain forest (Umudike) and humid savannah agro-ecologies (Otobi) in 2017 and 2018 cropping seasons. Treatments were arranged in a Randomized Complete Block Design (RCBD) and replicated three times. There were five treatments which includes; Atrazine/metolachlor at 2.5kg ai/ha^{-1}, Diuron at 3.0 kg ai/ha^{-1} + one hand manual weeding at 8 WAP (weeks after planting), Atrazine/metolachlor at 2.5kg ai/ha^{-1} + one hand manual weeding at 8 WAP, Manual weeding at 4 and 8 WAP and unweeded check. Application of Atrazine/metolachlor at 2.5 kg ai/ha^{-1} with manual weeding at 8 WAP enhanced season long weed suppression and also gave the highest root yield of 30.01 t/ha^{-1} and 31.08 t/ha^{-1} in Umudike and Otobi, respectively. Application of Atrazine/metolachlor at 2.5kg ai/ha^{-1} integrated with one manual hand weeding gave a net revenue and cost ratio of N2.05 and N2.10 to every one naira invested at Otobi and Umudike, respectively. The treatment; Atrazine/metolachlor at 2.5 kg ai/ha^{-1} with one manual hand weeding at 8 WAP is therefore, recommended.

Keywords: Weeds, herbicide applications, Sweetpotato production

Introduction

Sweetpotato (*Ipomoea batatas* [L.] Lam) is an important root crop which is extensively cultivated in tropical and sub-tropical zones (Islam *et al.*, 2002). It is cultivated in over 100 countries of the world (Woolfe, 1992), and belongs to the family *Convolvulaceae* (Gill, 1988). Nigeria is the second largest producer of sweetpotato in Africa and third in the world with root production of 4.03 million tonnes cultivated on 1.712 million hectares (FAOSTAT, 2018). However, in recent time, the production rate of sweetpotato has been on the decrease. Some of the main factors believed to be responsible for the decrease in production include; inadequate weed control and poor nutrient status of the soil where it is grown (IITA, 1998). Weed management as indicated by Akobundu (1987) is the ability to manipulate weeds so that they do not interfere with growth, development and economic yield of crops and animals. The practical implementation of weed management is to use the best weed control practices to reduce weed introduction, spread, competition with crops and their adaptation to any habitat. Orkwor *et al.* (1981), while working on metobromuron (galex), reported that four to eight weeks weed control with herbicides was usually sufficient to control weeds in sweetpotato field.

Materials and Methods

Field trials were conducted at the National Root Crops Research Institute experimental farm between May 2017 and November 2018 to determine the effect of integrating different chemical and manual weed control methods on sweetpotato yield at two locations (Umudike – rainforest belt on latitude 05°, 29°N, longitude 07°, 33'E and 122m above sea level; and Otobi – derived "humid" guinea savannah agro-ecology, on latitude 07°,19N, longitude 08°, 32'E and 141m above sea level). The treatments were arranged in Randomized Complete Block Design (RCBD) with 5m x 6m plot size, and each treatment replicated three times and spaced 30cm within and 1m between the rows. The pre-emergence herbicides were applied immediately after planting in the soil. There were five treatments: manual weeding at 4 and 8 weeks after planting (WAP), atrazine/metolachlor at 2.5 kg ai/ha, diuron at 3.0 kg ai/ha + one manual weeding at 8 WAP, Atrazine/metolachlor at 2.5kg ai/ha + one manual weeding at 8WAP and unweeded check. The pre-emergence herbicides were applied using a CP-15 Knapsack sprayer calibrated to deliver 220 litres/ha spray volume and at a pressure of 2.1 bar^{-1} with a red nozzle. Herbicides were applied immediately after planting. Each plant was spaced 30cm within and 1m between the rows to give a plant population of 33,333 plants/ha. Mixed NPK (15:15:15) fertilizer equivalent to 60 kgN/ha, 60kg P_2O_5/ha and 60kgK_2O/ha was applied basally at the recommended rate of 400 kg/ha at 4 weeks after planting (WAP). Sweetpotato variety TIS87/0087 was used as the test crop, and obtained from the National Root Crops Research Institute (NRCRI), Umudike. Soil analysis was carried out to determine the physico-chemical properties of the soil for each cropping season in the two locations. Data on total weed density and weed biomass were obtained at 4, 8 and 12 WAP by throwing a 1m x 1m quadrat randomly and counting the number of weeds and weight of weeds within the quadrat. Total root yield was measured at harvest (4 MAP). The economics of chemical and manual weeding of the enterprise were also determined.

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the two-way ANOVA procedure of Genstat statistical package (Genstat Edition 4 of 2012). Significant treatment means were compared using the Fisher's least significant difference at 5% level of probability. The profitability analysis is specified thus;

NB =GB-TV …… (1)
MRR = NB/TVC …… (2)

Where, NB=Net benefit, measured in naira, GB=Gross farm gate benefit, derived as yield of sweetpotato in tones per hectare, multiplied by the farm gate price measured in naira, TVC =Total variable cost of all inputs and resources used measured in naira, MRR=Marginal rate of return, derived as a ratio of the change in benefit to change in total variable cost of inputs in each treatment expressed in percentage.

Results and Discussion

The soil physico-chemical properties of the experimental sites are presented in Table 1. The particle size distribution analysis showed that soils of the Otobi location were sandy clay loam in both 2017 and 2018, while that of Umudike were sandy loam in both years. The soils were slightly acidic with pH values that ranged from 5.20-5.60 at Umudike and 5.40-5.58 for Otobi. The two year mean values of soil organic matter (SOM) at Umudike and Otobi were 16.7 and 17.6 g kg^{-1}, respectively. The soils of both sites were generally low in total nitrogen (<0.1 g kg^{-1}), while available phosphorous in Umudike soils were medium and ranged from 19.45 - 20.25mg/kg, and high with phosphorus values >30 mg/kg in Otobi. Effective cation exchange capacity values were low in both soils, ranging from 7.93 Cmol/kg in Umudike soils to 18.6 Cmol/kg in Otobi soils. However, the exchangeable acidity was high at both locations in both years due to low pH values of the soil.

Establishment count

Sweetpotato stand establishment (%) as influenced by the various weed control treatments at Umudike and Otobi in 2017 and 2018 seasons are presented in Table 2. The treatments did not significantly affect establishment count of sweetpotato in both locations and seasons. But generally, establishment of sweetpotato in 2017 was lower at Otobi (ranged between 78 and 90%) than at Umudike with a range of 90.7 and 100%.

Weed Density

The results of the various weed control methods on weed density evaluated at Umudike (rainforest belt) and Otobi (humid savannah) in the 2017 and 2018 rainy seasons are presented in Table 3. The treatments significantly ($p<0.05$) affected weed density at 4, 8 and 12 WAP at Umudike and Otobi in 2017 and 2018. The weed population density ranged from 1.5 to 217.7 and 3.2 to 153.0 at Umudike and Otobi in 2017, and 1.4 to 260.3 and 2.66 to 109.3 at Umudike and Otobi in the 2018 season, respectively. The least weed density at 4 WAP in Umudike was observed in plots weeded at 4 and 8 WAP, which did not differ significantly from weed density from other treatments except the unweeded check in 2017 and 2018 seasons. Observations at 8 WAP of sweetpotato also revealed that combining atrazine and metolachlor 2.5kg ai ha^{-1} + manual weeding at 8 WAP (2.3-11.3 and 2.51-10.12) was statistically similar to weeding twice at 4 and 8 WAP (1.5-14.5 and1.40 - 12.50), while both gave significantly lower weed density compared to other treatments at 8 WAP in 2017 and 2018 seasons. Whereas, at 12 WAP of sweetpotato at Umudike, the least weed density was observed in plot of integration of atrazine/ metolachlor 2.5kg al/ha + manual weeding once at 8 WAP, which was similar to weed densities from plots treated to atrazine/ metolachlor 2.5kg ai ha^{-1} in 2017and the twice manual weeding plot in 2017 and 2018 respectively at Umudike, while the unweeded plots gave the highest weed densities in both seasons. In Umudike,weed density was lower in plots treated with atrazine/metolachlor 2.5 kg ai ha^{-1} +manual weeding at 8WAP after weeds were sampled at 12 WAP.

At the Otobi location, the effect of weed management treatments showed similar trend as Umudike, such that observation at 4 WAP showed that plots weeded twice had the least weed density which did not differ from plots treated with integrated atrazine/metolachlor 2.5kg ai ha^{-1} + manual weeding once at 8 WAP in 2017 and 2018 each. For observations taken at 8 WAP at Otobi, treatments atrazine/metolachlor 2.5kg ai ha^{-1} + manual weeding once at 8 WAP and twice weeding at 4 and 8 WAP with weed densities of 16.80 and 10.70 in 2017 and 14.90 and 8.69 in 2018, were significantly lower than other treatments. Same trend was observed at 12 WAP with atrazine/metolachlor 2.5kg ai ha^{-1} + manual weeding once at 8 WAP and twice weeding at 4 and 8 WAP with weed densities of 11.00 and 14.00 in 2017, and 12.11 and 14.90 in 2018, respectively.

Weed Biomass

Weed biomass in sweetpotato plots as influenced by weed control treatments at Umudike and Otobi in 2017 and 2018 seasons are presented in Table 4. The treatments significantly ($p < 0.05$) affected weed biomass at 4, 8, and 12 WAP at Umudike and Otobi in 2017 and 2018 seasons. Generally, the highest weed biomass in sweetpotato plots were observed at 12 WAP in the unweeded plots at both locations and seasons. At 8 and 12 WAP in both locations and years, integration of atrazine and metolachlor 2.5kg ai ha^{-1} + manual weeding at 8 WAP gave the least weed biomass of 0.13g/plot. At Otobi, observation at 8 and 12 WAP of sweetpotato showed that plot treated with integration of atrazine and metolachlor 2.5kg ai ha^{-1} + manual weeding once, gave significantly lower weed biomass than those treated with integration of diuron 3.0kg ai ha^{-1} + manual weeding once in 2017 and 2018 seasons. Also, plots that received atrazine and metolachlor 2.5kg ai ha^{-1} without supplementary weeding gave significantly higher weed biomass than those that received atrazine and metolachlor 2.5kg ai ha^{-1} with supplementary weeding (integration) at 12 WAP at Umudike in 2018 and at Otobi in 2017 and 2018 seasons each. However, the unweeded plot gave highest weed biomass at 4, 8 and 12 WAP in both locations and sessions.

Total Root Yield

The effects of the various weed control methods on total root yield of sweetpotato in Umudike and Otobi in 2017 and 2018 are presented in Table 5. The results revealed that total root yield was significantly ($p<0.05$) influenced by the weed management options adopted in both locations and years. At Umudike in 2017, atrazine and metolachlor 2.5 kgai ha^{-1} and manual weeding at 8 WAP gave the highest total root yield in 2017 and 2018 (25.90 and 26.46 t/ha), followed by manual weeding at 4 and 8 WAP (20.20 and 20.19 t/ha) when compared with unweeded treatments (7.90 and 6.54 t/ha), respectively. At Otobi, atrazine and metolachlor 2.5 kgai ha^{-1} + manual weeding at 8 WAP gave the highest sweetpotato total root yield of 24.31 and 26.80 t/ha in 2017 and 2018, followed by manual weeding at 4 and 8 WAP (18.4 and 21.66 t/ha), when compared to untreated plots (6.4 and 4.93 t/ha) that had the least total root yield.

Total Number of Roots

The effect of integration of atrazine and metolachlor 2.5 kgai ha^{-1}, diuron 3.0kgai ha^{-1} with manual weeding once on the total number of roots per hectare of sweetpotato at Umudike and Otobi in 2017 and 2018 is presented in Table 5. The result revealed that total number of sweetpotato root per hectare was significantly influenced by the weed management options adopted at both locatios. At Umudike, plots treated with manual weeding at 4 and 8 WAP gave the highest total number of roots (47325/ha and 48437/ha) in 2017 and 2018 respectively, and followed by plots treated with atrazine and metolachlor at 2.5 kg a i/ha + manual weeding at 8 WAP (46502/ha and 47718/ha). When compared with the untreated plots (24897/ha and 23345/ha), that had the lowest total number of roots/ha. At Otobi, plots treated with diuron at 3.0 kg ai /ha + manual weeding at 8 WAP gave the highest total number of roots /ha (33128/ha and 40187 /ha) in 2017and 2018 respectively, followed by plots treated with atrazine and metolachlor at 2.5kg ai/ha +Manual weeding at 8 WAP (31070/ha and 32167/ha) when compared with untreated plots that had the lowest total number of roots/ha (24486 and 18975/ha) in that order.

Table 1: Pre-planting physico-chemical properties of the soils taken from the experimental fields in the 2017 and 2018 cropping seasons

	Location			
	Umudike 2017	**Otobi 2017**	**Umudike 2018**	**Otobi 2018**
Particle size analysis:				
Sand %	78.40	51.40	74.45	58.45
Silt %	12.40	29.40	12.38	22.90
Clay %	9.20	19.20	13.17	18.65
Soil texture				
pH	5.40	5.60	5.40	5.56
Organic matter (gkg^{-1})	1.66	1.76	1.68	1.76
Total Nitrogen (gkg^{-1})	0.08	0.09	0.08	0.09
Available P ($mgkg^{-1}$)	19.45	34.65	20.25	33.65
Calcium ($cmolkg^{-1}$)	3.40	4.20	3.44	4.2
Magnesium ($cmolkg^{-1}$)	2.00	2.60	2.01	2.67
Sodium ($cmolkg^{-1}$)	0.11	0.13	0.11	0.13
Potassium ($cmolkg^{-1}$)	0.09	0.08	0.06	0.09
Exchangeable acidity ($cmolkg^{-1)}$	1.04	1.12	1.06	1.16
Organic carbon(g/kg^{-1}) ($cmolkg^{-1}$)	9.6	10.2	9.4	10.3
Cation exchange capacity ($cmolkg^{-1}$)	6.46	8.13	5.60	8.18
Base saturation (%)	84.38	85.66	83.50	86.71

Keywords: SL=Sandyloam; L=loam; SCL = Sandy clay loam; ECEC=Effective cation exchange capacity

Table 2: Sweetpotato establishment (%) as influenced by chemical and manual weed control methods at Umudike and Otobi in 2017 and 2018 cropping seasons

	Umudike Establishment %		Otobi Establishment %	
Treatment	**2017**	**2018**	**2017**	**2018**
ATR/MET 2.5	97.3	89.20	78.00	81.00
ATR/MET 2.5 +8MW	95.7	100.00	84.00	99.00
DIU 3.0 + 8MW	100.00	95.00	88.00	100.00
MW 4 + 8MW	100.00	100.00	83.00	95.50
Unweeded	90.70	100.00	90.00	100.00
LSD (P<0.05)	Ns	Ns	Ns	Ns

**** ATR/MET 2.5 = Atrazine/Metolachlor At 2.5kgai/ha***

**** ATR/MET 2.5+8MW = Atrazine/Metolachlor at 2.5kgai/ha + manual weeding at 8 WAP***

**** DIU 3.0 + 8MW = Diuron at 3.0kgai/ha + Manual Weeding at 8 WAP***

**** MW 4 + 8MW = Manual Weeding at 4 and 8 WAP, respectively***

Table 3: Weed density (No/m^2) as influenced by chemical and manual weed control methods at Umudike and Otobi in 2017and 2018 cropping seasons (WAP)

	Umudike						Otobi					
	2017			2018			2017			2018		
Treatment	4	8	12	4	8	12	4	8	12	4	8	12
ATR/MET 2.5	3.8	19.5	19.3	4.12	20.61	22.15	12.70	19.3	22.0	8.16	15.01	25.60
ATR/MET 2.5 +8MW	**2.3**	**11.3**	**5.2**	**2.51**	10.12	**4.66**	**3.20**	**10.7**	**11.0**	**4.10**	**8.69**	**14.90**
DIU 3.0 + 8MW	4.8	25.8	50.0	4.90	35.20	62.90	12.30	33.5	43.0	18.25	49.60	54.09
MW 4 + 8MW	**1.5**	**10.2**	**14.5**	**1.40**	**8.36**	**12.50**	**3.80**	**16.8**	**14.0**	**2.66**	**14.90**	**12.11**
Unweeded	21.3	114.0	217.7	28.33	120.11	260.30	31.5	106.2	153.0	52.01	109.33	75.36
LSD (P<0.05)	3.65	6.63	47.34	2.61	7.18	14.88	10.85	4.60	9.40	4.76	6.99	7.33

**** ATR/MET 2.5 = Atrazine/Metolachlor at 2.5kgai/ha***
**** ATR/MET 2.5+8MW = Atrazine/Metolachlor at 2.5kgai/ha + manual weeding at 8 WAP***
**** DIU 3.0 + 8MW = Diuron at 3.0kgai/ha + manual weeding at 8 WAP***

Table 4: Weed biomass (g) as influenced by chemical and manual weed control at Umudike and Otobi in 2017 and 2018 cropping seasons

	Umudike						Otobi					
	2017			2018			2017			2018		
Treatment	**4WAP**	**8WAP**	**12WAP**	**4WAP**	**8 WAP**	**12WAP**	**4WAP**	**8 WAP**	**12WAP**	**4WAP**	**8 WAP**	**12WAP**
ATR/MET 2.5	0.61	0.81	0.91	0.63	0.70	0.95	0.27	0.60	0.94	0.25	0.57	1.09
ATR/MET 2.5 +8MW	0.27	0.16	0.13	0.23	0.10	0.11	0.15	0.29	0.12	0.17	0.35	0.18
DIU 3.0 + 8MW	1.06	0.94	0.71	1.02	0.75	0.75	0.21	1.33	1.39	0.24	1.08	1.29
MW 4 + 8MW	0.20	0.41	0.35	0.21	0.41	0.35	0.20	0.67	0.37	0.20	0.61	0.25
Unweeded	1.31	3.23	5.00	1.36	3.85	6.75	2.90	5.01	6.12	3.40	8.25	8.85
LSD (P<0.05)	0.79	0.93	0.94	0.35	0.55	0.73	0.86	0.73	0.33	0.48	0.49	0.65

**** ATR/MET 2.5 = Atrazine/Metolachlor At 2.5kgai ha^{-1}***
**** ATR/MET 2.5+8MW = Atrazine/Metolachlor at 2.5kgai ha^{-1} + manual weeding at 8 WAP***
**** DIU 3.0 + 8MW = Diuron at 3.0kgai/ha + Manual Weeding at 8 WAP***

Table 5: Effect of integrated atrazine/metolachlor, diuron and manual weeding on total root yield and total number of roots/h a in 2017 and 2018 seasons

	Total root yield (t/ha)				Total number of roots/ha			
	Umudike		Otobi		Umudike		Otobi	
	2017	2018	2017	2018	2017	2018	2017	2018
ATR/MET 2.5	16.20	17.36	16.7	15.07	34979	35756	29630	29110
ATR/MET/2.5+8MW	25.90	26.46	24.31	26.80	46502	47718	31070	32167
DIU3.0+8MW	13.5	13.26	14.1	21.25	41152	42160	33128	40187
MW4+8MW	20.20	20.19	18.4	21.66	47325	48437	26749	27850
Unweeded	7.90	6.54	6.4	4.93	24897	23345	24486	18975
LSD (0.05)	3.43	4.69	3.54	3.17	4970	4300	2968	10631

ATR/MET 2.5 = Atrazine/metolachlor 2.5kgai ha^{-1}

*** ATR/MET 2.5 + 8MW = Atrazine/metolachlor 2.5 kgai ha^{-1} + manual weeding at 8 WAP***

*** DIU 3.0 + 8MW = Diuron 3.0 kgai ha^{-1} + manual weeding at 8 WAP***

*** MW4 + 8 MW = Manual weeding at 4 and 8 WAP***

Table 6: Economics of chemical and manual weeding regimes in sweetpotato production in 2017 and 2018 at Otobi (humid savannah ecology)

Treatments	Mean Yield t/ha	Total Variable Cost (TVC) (₦/ha)	Price of Root (₦/ton)	Gross Revenue (₦/ha)	Gross Margin (₦ /ha)	Return per Naira Invested	Ranking
Atrazine/Metolachlor at 2.5kg a.i/ha	19.785	239,500	20,000	395700	156,200	1.65	2
Atrazine/Metolachlor at 2.5kg a.i/ha + 8WAP	31.085	303,500	20,000	621700	318,200	2.05	1
Manual weeding at 4 and 8WAP	22.335	363,000	20,000	446700	83,700	1.23	3
Diuron at 3.0kga.i/ha + 8WAP	17.265	304,400	20,000	345300	40,900	1.13	4
Unweeded check	7.865	251,000	20,000	157300	-93,700	-1.37	5

Table 7: Economics of chemical and manual weeding regimes in sweetpotato production, 2017and 2018 at Umudike

Treatments	Mean Yield t/ha	Total Variable Cost (TVC) (₦ /ha)	Price of Root (₦ /ton)	Gross Revenue (₦ /ha)	Gross Margin (₦ /ha)	Return per Naira Invested	Ranking
Atrazine/Metolachlor at 2.5kg a.i ha^{-1}	19.85	239,500	20,000	397,000	157,500	1.66	2
Atrazine/Metolachlor at 2.5kg a.i ha^{-1}+8WAP	30.17	287,500	20,000	603,400	315,900	2.10	1
Manual weeding at 4 and 8WAP	22.9	347,000	20,000	458,000	111,000	1.32	3
Diuron at 3.0kga.i/ha + 8WAP	16.64	288,400	20,000	332,800	44,400	1.15	4
Unweeded check	7.34	251,000	20,000	146,800	-104,200	-1.42	5

Economic Analysis of the Integration of Chemical and Manual Control Methods in Sweetpotato at Otobi in 2017 and 2018 Seasons

The economic benefit analysis of the use chemical and manual weed control measures in sweetpotato production at Otobi in 2017 and 2018 seasons is presented in Table 6. The analysis showed total variable cost (TVC) ranged from N239,500 (obtained from the plot of atrazine and metolachlor 2.5 kgai ha^{-1} without manual weeding) to N363,000 (obtained from the plot weeded twice manually). Integrated treatments of atrazine / metolachlor 2.5 kgai ha^{-1} with manual weeding at 8 WAP posted a gross margin of N318,200 per hectare and a return of two naira and five kobo (₦2.05) to every one naira invested in Otobi location. This was followed by atrazine/ metolachlor 2.5 kgai ha^{-1} without manual weeding that gave an income of N156,200 and a return of one naira, sixty-five kobo (₦1.65) to every one naira invested in sweetpotato production. As expected, the unweeded plots gave the least gross margin of ₦93,700, which was a loss, and a return of ₦-1.37 on every one naira invested.

Economic Analysis of the Integration of Chemical and Manual Control Methods in Sweetpotato at Umudike in 2017 and 2018 Seasons

The economic analysis of the use of chemical and manual weed control methods in sweetpotato production at Umudike in 2017 and 2018 seasons is presented in Table 7. The analysis showed total variable cost (TVC) ranged from N239,5000 (obtained from the plot of atrazine/ metolachlor kgai/ha without manual weeding) to N347,000 (obtained from the plot weeded manually twice). Treatment integration of atrazine / metolachlor 2.5 kgai/ha with manual weeding at 8 WAP gave the highest gross revenue of N603,400 and a profit of N315,900/ha, returning two naira ten kobo to every one naira invested in sweetpotato production at Umudike to rank first amongst the treatments. This was followed by atrazine/ metolachlor 2.5 kgai ha^{-1} without manual weeding that posted a gross margin of N157,501 with return of one naira, sixty-six kobo to every one naira invested in the sweetpotato production. Unweeded plots gave the least performance with a negative gross margin of ₦-104,200 and a negative return per one naira invested of ₦-1.42.

Application of atrazine / metolachlor (Primextra) at 2.5 kgaiha^{-1} with or without supplementary hand weeding at 4 WAP, and diuron at 3.0 kgai ha^{-1} resulted to lower weed densities and biomass in both locations and years than the unweeded (control) treatment in this study. This observation is predicated upon the opinion of various authors, that herbicide treatments ensure timely and effective weed control, through early (initial) potency and wide spectrum of weed control (Rao, 2004; Kolo, 2004). The observed lower weed densities at 8 and 12 WAP given by atrazine and metolachlor at 2.5 kgai^{-1} compared to diuron at 3.0 kgai ha^{-1} was because Primextra, which consists of atrazine / metolachlor have been reported to have a wider spectrum of weed control as these two active ingredients act on annual grasses and broadleaves, respectively. Metolahclor is active against broadleaf weeds as the seedlings and germinating seeds of the broadleaf weeds absorb the chemical through their roots and shoot, while atrazine is more efficient in controlling annual grasses. Hence, primextra was formulated to exhibit wide spectrum of control over annual broadleaf and grass weeds (Melifonwu and Ikeorgu, 2001).

The lack of treatment effects at 4 WAP on weed population and biomass in both locations and years shows that the observed differences in weed density and biomass could be explained by the effectiveness of land preparation and other heterogeneous factors of the soil rather than the applied weed control treatments. Mechanical disturbance of the soil surface during tillage is known to stimulate weed seed germination and ensures uniformity of chemical application which often leads to increased effectiveness of pre-emergence soil-applied herbicide (Akobundu, 1987). While at 12 WAP, the effectiveness of weed suppression of atrazine/ metolachlor at 2.5 kagi ha^{-1} integrated with one hand weeding was similar to that of twice hand-weeded plots, probably due to the supplementary hoe weeding, as primextra is not known to confer season long weed control as a result of its short persistence (Olorunmaiye and Olorunmaiye, 2009). This result emphasizes the need for supplementary hoe weeding in plots treated with Primextra, and also confirms the earlier study of Akobundu (1987) who reported that most pre-emergence herbicides give early weed control of emerging weed seedlings but easily lose their efficacy with time, resulting in later weed emergence and vigorous weed growth to gain ground. This is also similar to the observation of Aladesanwa and Adigun (2008) who reported decrease in weed density and biomass and an increase in maize grain yield when melon live-mulch was supplemented by one hoe weeding.

In all the studies, the unweeded plots produced the highest weed density and biomass. This could be attributed to the accumulation of favourable resources overtime. This accumulation of biomass is proportional to carbohydrate synthesis which depends on environmental resources (light, nutrient, water and carbon iv oxide) extracted by the weeds as observed by Tanaka and Sekioka (2010). Weeds in crop production have been described as the most important but the most under-estimated pests in tropical agriculture (Akobundu, 1987). The economics of integrated weed management indicated that application of atrazine/ metolachlor at 2.5 kg ai ha^{-1} integrated with one hand weeding attracted N2.05 and N2.10 to every one naira invested at Otobi and Umudike, respectively.

Conclusion

Based on the findings of these trials, the application of atrazine/metolachlor at 2.5 kg ai/ha integrated with manual weeding at 8 WAP is an effective weed control method that will ensure reduced weed infestation and weed biomass and an enhanced sweetpotato root yield.

The use of this recommended pre-emergence herbicide supplemented with weeding at 8 WAP will lead to a minimum of return of two naira on every one naira spent on sweetpotato production. Therefore, the application of atrazine/metolachlor at 2.5 kg a i/ha integrated with manual weeding at 8 WAP is recommended for sweetpotato root production in both derived guinea savanna and rain forest agro-ecological zones of Nigeria.

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