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**ECONOMIC ASSESSMENT OF TILLAGE METHODS AND INTEGRATED WEED
MANAGEMENT FOR MAIZE PRODUCTION IN A NORTHERN GUINEA SAVANNA
OF NIGERIA**

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ABSTRACT

A field experiment was conducted in 2008 and 2009 at Jalingo, to evaluate the economics of integrated use of low-dose (25% rates) of selected herbicides mixtures (atrazine-pendimethalin (AP₁) or Primextra (PX₁) and covercrops (CC, a vegetable cowpea, "Akidi" (A), Melon (M) and Sweet potato (S) planted sole or mixed at 20,000 stands/ha (1) or 40,000 stands/ha (3) under manual (MT) and tractor tillage (TT) methods on weed management in maize using split plot arrangement in a randomized complete block design. Tillage operations were the main plots while, herbicide-covercrop integrated weed management (IWM) treatments AP₁A₁, AP₁AS₁, AP₁S₃, AP₁MS₃, AP₁AMS₃, PX₁A₁, PX₁AS₁, PX₁S₃, PX₁MS₃, PX₁AMS₃, weeding (at 3 and 6 Weeks After Planting) and weedy check were sub-plots. Partial budget analysis was used to obtain the level of profitability of each weed management system. Gross benefit was 18% higher in TT than MT in both years. Averaged over the two years, net profit showed AP₁S₃ (₦208,478.00) and PX₁S₃ (₦176,877.00) in TT while AP₁S₃ (₦114,353.00) and PX₁S₃ (₦121,718.00) in MT system. The Marginal Rate of Returns (MRR) showed that most IWM treatments in MT had MRR greater than 1.0 while in TT, AP₁A₁ and AP₁S₃, PX₁S₃ had MRR above 2.0. Net benefit in AP-CC, PX-CC and C₁ was 404.7, 334.1 and 347.5 % higher than unweeded respectively. The most profitable treatment was atrazine + pendimethalin at 25 % + 40,000 stands/ha sweet potato (AP₁S₃) and thus recommended.

Key words: Profitability, Tillage, Herbicide-mixture, Integrated weed management, Maize, Cover crop mixtures

Highlights

- Use of 25% recommended dose of selected herbicide mixture could be enhanced by cover crop mixtures for higher profitability.
- Use of tractor tillage once is more profitable than use of manual hand ridging in maize production.
- Application of atrazine + pendimethalin with cover crop mixtures is more profitable than Primextra in maize production.
- System with higher sweet potato is more profitable than other cover crops.

INTRODUCTION

Maize is the highest yielding cereal crop and plays a significant role in sustaining livelihoods in developing countries like Nigeria. Its contribution to domestic and national economy as a rich source of food, feed, fodder and industrial raw material is well established in the country. The economics of weed control in maize has been reported for maize in many Agro-ecologies of Nigeria and elsewhere (Baba *et al.*, 2015, Omovbude and Udensi, 2012, Maxwell *et al.*, 2019).

Adoption of a sustainable weed management technique by farmers must be back up with a viable economic analyses (SARE, 2019). Amin *et al.* (2008) observed that Primextra greatly reduced weed density and biomass 25 and 75 days after sowing and was the most economical. Mixed herbicide is more effective against weed than single herbicide (Amin *et al.*, 2008, Janak and Grichar, 2016). Mncube and Banda, (2018) in their evaluation of ten weed control practices reported that manual weeding in combination with other weed management will enhance effectiveness and that herbicide needs to be supplemented with other weed control practices to obtain acceptable weed control. This supplementary weed control could be achieved using hoe weeding and/or cover cropping. Sustainable agriculture requires the limiting use of herbicides either by reducing application rates (Zhang *et al.*, 2013), herbicide rotation, use of selective narrow spectrum products or using alternative soil and crop management method. Herbicides with more than one active ingredients were effective than single active ingredient (Janak and Grichar, 2016).

Weed management is a major factor that determines the level of profitability in maize production, as it influences the growth and yield of maize Shrivastar *et al.* (2015) Weeds are omnipresent and substantially reduce yield and quality of crops. Worldwide yield losses in maize due to weeds are estimated around 37%. It is reported that weed infestation is one of the major causes that leads 20 to 80% reduction in maize yield

Shrestha *et al.* (2019). Yield losses of between 60–80% have been attributed to uncontrolled weed infestation in maize (Lagoke, Adeosun, Elemo, Chude, & Shebayan, 1998) and this finding was confirmed by Imoloame and Omolaiye (2016), who reported 89% yield loss in maize as a result of uncontrolled weed infestation. In the economic evaluation of weed management strategies in cowpea cultivation, Osipitan *et al.* (2018) observed that total variable cost of production was significantly influenced by the cost of weed control. Increase in weed control input, such as, dosage of herbicide or plant population or frequency of operations did not necessarily increase net benefit. Integrated weed management (IWM) treatment gave higher gross and net returns compared to non-integrated approaches (Olorunmaiye, 2011, Kumar and Singh, 2017). Osipitan *et al.* (2018) equally reported that a single input of hand weeding resulted in higher cost of weed control than a single input of pre-herbicide for weed management in cowpea.

Integrated weed management is being advocated as none of the single weed control approach can provide complete solution. However, if various components of integrated weed management are implemented in a systematic manner, it can provide complete weed control with higher economic returns. Therefore, it is suggested to adopt IWM approach that can contribute to reduced use of herbicides and focus on sustainable crop production (Shrestha *et al.*, 2019).

Integration of cultivation and half herbicide rates was viable for sugarbeet grown for biofuel. Cultivation improved control of cool-season weeds, but the effect largely independent of control provided by herbicides (Johnson *et al.*, 2018).

One method of weed control cannot provide adequate weed control for maize growth cycle, ensures maximum crop yield and profitability for the grower (Westwood *et al.*, 2018). The food value of selected creepers, akidi, melon and sweet potato make them more adoptable to farmers across Nigeria

and their weed suppression potentials have been established (Frick and Johnson, 2018; Kaur, 2017, Ahom *et al.*, 2017). Therefore, appropriate IWM system which integrates crop competitiveness of akidi, melon and sweet potato with low herbicidal mixture in an effectively tilled land could control weed longer in maize, increase yield effectively without environmental pollution and soil erosion (Alizade *et al.*, 2007).

The objective of the study therefore was to evaluate the economics of integrated use of 25% rates of selected herbicides mixtures applied on different densities of cover crops and tillage methods on weed control and performance of maize.

MATERIALS AND METHODS

Experimental Site

The Field trials were conducted at the Teaching and Research Farm of Taraba State College of Agriculture (08° 50' N, 11° 50' E) Jalingo in the northern Guinea savanna ecological zone. Jalingo has a wet and dry tropical climate with rainy season of about 150 days and an average annual rainfall of about 700 mm – 1000 mm. Mean annual temperature of Jalingo is about 28°C with maximum temperature ranges between 30 °C and 39.4°C and minimum temperature range between 15°C to 23°C. Annual rainfall was 808.9 and 1063.2 mm for 2008 and 2009, respectively. The rainy season is between May and October while the dry season is from November to April.

Experimental materials

Maize variety 95-TZEE-W1, an open pollinated and Extra early maturing used as the test crop was obtained from International Institute of Tropical Agriculture (IITA), Ibadan.

Experimental design and layout

The experiment was laid out in a randomized complete block design with a split plot arrangement and replicated three times. Tillage methods (Tractor Tillage (TT) and Manual Tillage (MT) were the main plots. The sub-plot factors were various integrated weed

management treatments viz: AP₁A₁, AP₁AS₁, AP₁S₃, AP₁MS₃, AP₁AMS₃, PX₁A₁, PX₁AS₁, PX₁S₃, PX₁MS₃, PX₁AMS₃, hand-weeded at 3 and 6 WAP(C₁) and weedy check (C₂) treatments were subplots (Table 1).

Field establishment

The field was cleared manually using cutlass to reduce shrubs on the land. The fields were laid out in two strips, Manual Tillage (MT) and Tractor Tillage (TT). Ploughing was done on strips in alternate replicates. Manual tillage was accomplished using big hand-held hoes to make 4 ridges per plots of 4m x 4m.

Maize seeds (95-TZEE-W1, an open pollinated and extra early maturing variety was obtained from International Institute of Tropical Agriculture (IITA), Ibadan.) were sown on 30th and 13th June in 2008 and 2009 respectively, three seeds per hole at 25cm x 100cm spacing, to give a population of 40,000 plants/ha in all the plots and the seedlings were latter thinned to one plant per stand.

Cover crops were planted in 8 rows (2 rows of cover crop to 1 row of maize). Akidi and melon seeds were sown 4 seeds/hole, while 2-3 sweet potato vines/hole, spaced 50 cm x 100 cm and latter thinned to give the required population densities of 20,000 or 40,000 plants/ha. The number of rows or stands was shared evenly in the mixed cover crop plots. However, sweet potato vines were planted after 48 hours of application of the herbicides.

Herbicide Application

Atrazine (6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine) formulation used was 50% SC (500g/L), pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) 500 EC and Primextra (atrazine (290g/L) + metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)-acetamide (370g/L)) 660g a.i./L. were used. Low rate (25% of recommended rates) of the preemergence herbicides, 0.5 + 0.5 kg a.i./ha atrazine +pendimethalin (AP₁) or 0.625 kg a.i./ha Primextra (PX₁) was applied to appropriate plots within 48 hours of planting of maize, akidi and melon with a CP 15 knapsack

sprayer calibrated to deliver 300 L ha⁻¹ spray solution.

Trial management and harvesting

Manual weeding was carried out twice at 3 and 6 WAP on hoe-weeded control plots, other treatments were not weeded at all.

Fertilizer was applied to maize at 120 kgN/ha in two splits at 5 and 7 WAP. NPK 20-10-10 and Urea were used. Maize cobs were harvested dry on 12th (14 WAP) and 2nd (16 WAP) October of 2008 and 2009, respectively and shelled.

Table 1: Tillage and integrated weed management treatments

Tillage	IWM Treatment	Symbols
Manual	25 % atrazine + pendimethalin + Akidi at 20,000 plants/ha	AP ₁ A ₁
Manual	25 % atrazine + pendimethalin + Sweet potato at 40,000 plants/ha	AP ₁ S ₃
Manual	25 % atrazine+pendimethalin + Akidi/Sweet potato at 20,000 plants/ha	AP ₁ AS ₁
Manual	25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants/ha	AP ₁ MS ₃
Manual	25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants/ha	AP ₁ AMS ₃
Manual	25 % Primextra + Akidi at 20,000 plants/ha	PX ₁ A ₁
Manual	25 % Primextra + Sweet potato at 40,000 plants/ha	PX ₁ S ₃
Manual	25 % Primextra + Akidi/Sweet potato at 20,000 plants/ha	PX ₁ AS ₁
Manual	25 % Primextra + Melon/Sweet potato at 40,000 plants/ha	PX ₁ MS ₃
Manual	25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha	PX ₁ AMS ₃
Manual	Hand-weeded control	C ₁
Manual	Unweeded control	C ₂
Tractor	25 % atrazine + pendimethalin + Akidi at 20,000 plants/ha	AP ₁ A ₁
Tractor	25 % atrazine + pendimethalin + Sweet potato at 40,000 plants/ha	AP ₁ S ₃
Tractor	25 % atrazine+pendimethalin + Akidi/Sweet potato at 20,000 plants/ha	AP ₁ AS ₁
Tractor	25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants/ha	AP ₁ MS ₃
Tractor	25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants/ha	AP ₁ AMS ₃
Tractor	25 % Primextra + Akidi at 20,000 plants/ha	PX ₁ A ₁
Tractor	25 % Primextra + Sweet potato at 40,000 plants/ha	PX ₁ S ₃
Tractor	25 % Primextra + Akidi/Sweet potato at 20,000 plants/ha	PX ₁ AS ₁
Tractor	25 % Primextra + Melon/Sweet potato at 40,000 plants/ha	PX ₁ MS ₃
Tractor	25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha	PX ₁ AMS ₃
Tractor	Hand-weeded control	C ₁
Tractor	Unweeded control	C ₂

Data collection and analysis

Maize grain yield was estimated from 10 tagged plants on sampled in the middle of each plot (a net plot of 2.5m²), cover crop yield was from 3 and 6 stands of each cover crop per plot in 2 way and 3-way mixtures respectively.

Crop Enterprise Budget Technique (Wesley *et al.*, 1993) was used for the economic analysis of maize production under each tillage and integrated weed management treatments yearly.

The cost of inputs, various farming operations and crop prices were the average prices prevailing in the study area during the experimental periods. The budget preparations included calculation of the:

- (i) Average yield of maize ($t\ ha^{-1}$)
- (ii) Gross benefit (Naira/ha) based on prices of maize and or cover crop

$$\text{Gross benefit (N/ha)} = (\text{yield of maize} \times \text{price}) + (\text{yield of cover crop} \times \text{price})$$
- (iii) Total variable cost (N/ha) for each treatment which comprised of cost of land preparation, planting materials and labour (for planting, weeding, harvesting and processing).
- (iv) Net benefit (NB) (N/ha) under each treatment

$$\text{Net benefit (N/ha)} = \text{Gross benefit} - \text{Total variable cost.}$$
- (v) The marginal rate of return (%) that compared the extra (marginal) costs with the extra (marginal) net benefit

$$\text{Marginal Rate of Return (MRR)} = \frac{\text{Extra benefit from weed management}}{\text{Extra investment in the weed management}} \times 100$$
- (vi) Relative profitability was assessed with :
 (a) Net benefit relative to hand-weeded control (C_1) ($NBRC_1$)

$$NBRC_1 = \frac{\text{Net benefit from a given weed management treatment}}{\text{Net benefit from hand-weeded control (C}_1\text{)}}$$

 (b) Net benefit relative to the unweeded (C_2) ($NBRC_2$)

$$NBRC_2 = \frac{\text{Net benefit from a given weed management treatment}}{\text{Net benefit from the unweeded control (C}_2\text{)}}$$

(c) Percentage Net Benefit Gain (%NBG)

$$\%NBG = \frac{(\text{Net benefit from a given weed management treatment} - \text{Net benefit from unweeded})}{\text{Net benefit from the unweeded control (C}_2\text{)}} \times 100$$

(vii) Weed control efficiency

$$WCE = \frac{\text{Weed population in unweeded control} - \text{Weed in treated plot}}{\text{Weed population on unweeded ccontrol}} \times 100 \text{ (Singh et al., 2017)}$$

All the data collected were analysed with simple descriptive statistics and means were compared using standard error of difference (SED).

RESULTS

Cost of production

The cost of production (CP) of integrated weed management as influenced by tillage methods in maize production is presented in Table 2. Generally, cost of production was higher in MT than TT for both years. Averaged over the two years, ₦70,390 and ₦63,740 was used for producing maize in MT and TT respectively. Across the tillage, the CP in AP-CC system ranged from ₦57,330 (AP_1A_1) to ₦92,000 (AP_1S_3), while

cost of production was highest (₦92,000) for AP_1S_3 followed by PX_1S_3 (₦90,660) per hectare. Treatments having sweet potato recorded higher cost of production when compared with those without or low stands of sweet potato, particularly in hand weeded plots (₦56,810) and unweeded plots (₦43,930 naira). The highest CP was recorded in AP_1S_3 under MT (₦96,290), while the least CP was in unweeded plots in TT (₦39,660). In PX-CC, it ranges from ₦54,210 (PX_1A_1) to ₦90,660 (PX_1S_3). The cost of production in

AP system was slightly higher than the PX system.

Gross benefit

The highest gross benefit from tillage and IWM treatments were obtained from PX_1MS_3 and AP_1S_3 in TT in 2008 and 2009 respectively, while the least was from unweeded in TT and MT in 2008 and 2009 respectively (Table 3). Gross benefit was generally higher in TT than MT in both years. Averaged over the two years, gross benefits in TT was about 18% higher than in MT. All weed control treatments recorded higher gross benefits than the unweeded. Across the tillage methods, treatments AP_1S_3 (N253,410), AP_1MS_3 (N161,080), PX_1S_3 (N239,950), PX_1AS_1 (N163,440) recorded significantly higher gross benefits than the recommended hand weeding, C_1 . Other treatments were at par with hand weeded plots except PX_1A_1 and PX_1AMS_3 . Gross benefit in AP-CC (N143,230 – N253,410) was higher than PX-CC (N109,120 – N239,950).

Net benefit

Net benefit followed same trend as the gross benefit. Averaged over the two years, AP_1S_3 (N208,478.00) and PX_1S_3 (N176,877.00) resulted in the highest net benefit in TT while AP_1S_3 (N114,353.00) and PX_1S_3 (N121,718.00) in MT system (Table 4). Net benefit in AP-CC, PX-CC and C_1 was 404.7, 334.1 and 347.5 % higher than

unweeded. This support the finding of Patel *et al.*, (2006) who concluded that application of combination of atrazine and pendimethalin which showed similar result with atrazine and metolachlor combination created highest net income of US\$ 222.97/ha with benefit cost ratio of 2.71. The order of average net profit was $S_3 > A_1 > MS_3 > AS_1 > AMS_3$ and $S_3 > AS_1 > MS_3 > A_1 > AMS_3$ in AP_1 and PX_1 treated plots respectively. Generally gross benefit and net profit increased over time in both tillage systems. Irrespective of the weed control treatments, net benefit in TT was 45.5% higher than in MT.

Marginal Rate of Returns

The Marginal Rate of Returns (MRR) show that most IWM treatments in MT had MRR greater than 1.0 (except AP_1AMS_3 , PX_1A_1 , PX_1MS_3 , PX_1AMS_3), which were comparable to C_1 (1.3). However, in TT, AP_1A_1 , AP_1S_3 and PX_1S_3 had MRR above 2.0, which was higher than in C_1 (1.84). Others had MRR that ranged between 0.53 in PX_1AMS_3 to 1.78 in PX_1AS_1 (Table 5).

Across the tillage systems, all the IWM treatments except PX_1AMS_3 had MRR > 1.0, which were better than in unweeded (0.45) and comparable with C_1 (1.55). Using tractor tillage, resulted in significantly higher MRR (1.53) than MT (0.96). MRR in AP-CC (1.13 – 1.76) and PX-CC (0.76 – 1.65) were comparable with C_1 .

Table 2. Effect of integrated weed management on Cost of Production of Maize (2008 and 2009)

Trts	2008			2009			Average		
	MT (N' 000)	TT (N' 000)	MEA N (N' 000)	MT (N' 000)	TT (N' 000)	MEA N (N' 000)	MT (N' 000)	TT (N' 000)	MEAN (N' 000)
AP ₁ A ₁	59.47	51.65	55.56	59.36	58.83	59.09	59.41	55.24	57.33
AP ₁ S ₃	96.17	88.51	92.34	96.41	86.89	91.65	96.29	87.70	92.00
AP ₁ AS ₁	69.79	63.60	66.70	68.70	62.89	65.79	69.24	63.24	66.24
AP ₁ MS ₃	78.65	68.95	73.80	76.16	68.92	72.54	77.41	68.94	73.17
AP ₁ AMS ₃	69.11	64.64		70.39	65.01				
			66.87			67.70	69.75	64.82	67.29
PX ₁ A ₁	57.73	53.67	55.70	55.14	50.29	52.71	56.43	51.98	54.21
PX ₁ S ₃	96.66	84.38	90.52	93.72	87.88	90.80	95.19	86.13	90.66
PX ₁ AS ₁	67.94	64.95	66.45	67.85	62.84	65.34	67.90	63.90	65.90
PX ₁ MS ₃	75.51	72.29	73.90	73.11	67.61	70.36	74.31	69.95	72.13
PX ₁ AMS ₃	70.29	60.38		69.20	60.64				
			65.33			64.92	69.74	60.51	65.13
C ₁	60.88	52.85	56.86	60.64	52.86	56.75	60.76	52.85	56.81
C ₂	49.76	38.95	44.36	46.64	40.36	43.50	48.20	39.66	43.93
SED	3.95	3.85	3.88	3.98	3.77	3.86	3.96	3.78	3.86

MT= Manual tillage TT= Tractor tillage ,AP₁A₁ -25 % atrazine + pendimethalin + Akidi at 20,000 plants/ha, AP₁S₃ = 25 % atrazine + pendimethalin + Sweet potato at 40,000 plants/ha, AP₁AS₁-25 % atrazine+pendimethalin + Akidi/Sweet potato at 20,000 plants/ha, AP₁MS₃- 25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants/ha, AP₁AMS₃-25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants/ha, PX₁A₁ = 25 % Primextra + Akidi at 20,000 plants/ha, PX₁S₃ = 25 % Primextra + Sweet potato at 40,000 plants/ha, PX₁AS₁ = 25 % Primextra + Akidi/Sweet potato at 20,000 plants/ha, PX₁MS₃ = 25 % Primextra + Melon/Sweet potato at 40,000 plants/ha, PX₁AMS₃ = 25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha, C₁=weeded control, C₂=unweeded control

Table 3. Effect of integrated weed management on Gross benefit of Maize (2008 and 2009)

Trts	2008			2009			Average		
	MT (N' 000)	TT (N' 000)	MEAN (N' 000)	MT (N' 000)	TT (N' 000)	MEAN (N' 000)	MT (N' 000)	TT (N' 000)	MEAN (N' 000)
AP ₁ A ₁	121.24	116.78	119.01	118.66	226.42	172.54	119.95	171.60	145.78
AP ₁ S ₃	183.29	182.89	183.09	238.00	409.47	323.73	210.64	296.18	253.41
AP ₁ AS ₁	121.60	145.86	133.73	177.47	153.31	165.39	149.53	149.59	149.56
AP ₁ MS ₃	182.06	133.38	157.72	177.62	151.26	164.44	179.84	142.32	161.08
AP ₁ AMS ₃	93.69	152.00	122.84	140.92	186.32	163.62	117.30	169.16	143.23
PX ₁ A ₁	105.82	161.76	133.79	63.52	105.38	84.45	84.67	133.57	109.12
PX ₁ S ₃	159.56	175.72	167.64	274.25	350.30	312.27	216.90	263.01	239.95
PX ₁ AS ₁	103.25	196.31	149.78	197.60	156.61	177.10	150.43	176.46	163.44
PX ₁ MS ₃	139.12	224.88	182.00	109.07	137.22	123.14	124.09	181.05	152.57
PX ₁ AMS ₃	132.59	82.93	107.76	123.79	102.40	113.09	128.19	92.67	110.43
C ₁	142.00	149.80	145.90	138.00	150.00	144.00	140.00	149.90	144.95
C ₂	90.00	51.50	70.75	38.00	75.00	56.50	64.00	63.25	63.63
SED	8.74	13.22	8.93	18.74	27.78	22.08	12.59	17.64	14.38

MT= Manual tillage TT= Tractor tillage ,AP₁A₁ =25 % atrazine + pendimethalin + Akidi at 20,000 plants/ha, AP₁S₃ = 25 % atrazine + pendimethalin + Sweet potato at 40,000 plants/ha, AP₁AS₁=25 % atrazine+pendimethalin + Akidi/Sweet potato at 20,000 plants/ha, AP₁MS₃= 25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants/ha, AP₁AMS₃=25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants/ha, PX₁A₁ = 25 % Primextra + Akidi at 20,000 plants/ha, PX₁S₃ = 25 % Primextra + Sweet potato at 40,000 plants/ha, PX₁AS₁ = 25 % Primextra + Akidi/Sweet potato at 20,000 plants/ha, PX₁MS₃ = 25 % Primextra + Melon/Sweet potato at 40,000 plants/ha, PX₁AMS₃ = 25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha, C₁=weeded control, C₂=unweeded control

Table 5: Effect of integrated weed management on Marginal rate of returns of Maize

Treatment	2008			2009			Average		
	MT	TT	MEAN	MT	TT	MEAN	MT	TT	MEAN
	(N' 000)	(N' 000)	(N' 000)	(N' 000)	(N' 000)	(N' 000)	(N' 000)	(N' 000)	(N' 000)
AP ₁ A ₁	1.04	1.26	1.14	1	2.85	1.92	1.02	2.05	1.53
AP ₁ S ₃	0.91	1.07	0.98	1.47	3.71	2.53	1.19	2.39	1.76
AP ₁ AS ₁	0.74	1.29	1.01	1.58	1.44	1.51	1.16	1.37	1.26
AP ₁ MS ₃	1.31	0.93	1.14	1.33	1.19	1.27	1.32	1.06	1.2
AP ₁ AMS ₃	0.36	1.35	0.84	1	1.87	1.42	0.68	1.61	1.13
PX ₁ A ₁	0.83	2.01	1.4	0.15	1.1	0.6	0.49	1.55	1
PX ₁ S ₃	0.65	1.08	0.85	1.93	2.99	2.44	1.29	2.03	1.65
PX ₁ AS ₁	0.52	2.02	1.25	1.91	1.49	1.71	1.22	1.76	1.48
PX ₁ MS ₃	0.84	2.11	1.46	0.49	1.03	0.75	0.67	1.57	1.11
PX ₁ AMS ₃	0.89	0.37	0.65	0.79	0.69	0.74	0.84	0.53	0.7
C ₁	1.33	1.83	1.57	1.28	1.84	1.54	1.3	1.84	1.55
C ₂	0.81	0.32	0.6	-0.19	0.86	0.3	0.31	0.59	0.45
SED	0.08	0.17	0.09	0.18	0.26	0.2	0.1	0.16	0.11

MT= Manual tillage TT= Tractor tillage ,AP₁A₁ =25 % atrazine + pendimethalin + Akidi at 20,000 plants/ha, AP₁S₃ = 25 % atrazine + pendimethalin + Sweet potato at 40,000 plants/ha, AP₁AS₁=25 % atrazine+pendimethalin + Akidi/Sweet potato at 20,000 plants/ha, AP₁MS₃= 25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants/ha, AP₁AMS₃=25 % atrazine + pendimethalin + Akidi/Melon/Sweet potato at 40,000 plants/ha, PX₁A₁ = 25 % Primextra + Akidi at 20,000 plants/ha, PX₁S₃ = 25 % Primextra + Sweet potato at 40,000 plants/ha, PX₁AS₁ = 25 % Primextra + Akidi/Sweet potato at 20,000 plants/ha, PX₁MS₃ = 25 % Primextra + Melon/Sweet potato at 40,000 plants/ha, PX₁AMS₃ = 25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha, C₁=weeded control, C₂=unweeded control

Table 6. Relative profitability of tillage methods and integrated weed management in maize

Ttrs	WCE (%)	MT			TT			MEAN							
		NB	NBRC ₁	NBRC ₂	%NBG (x100)	WCE	NB	NBRC ₁	NBRC ₂	%NBG (x100)					
AP ₁ A ₁	0.28	60.54	76.40	383.16	283.16	0.33	116.36	119.90	493.05	393.05	0.31	88.45	100.35	448.98	348.98
AP ₁ S ₃	0.62	114.35	144.31	723.73	623.73	0.53	208.48	214.82	883.39	783.39	0.57	161.42	183.14	819.39	719.39
AP ₁ AS ₁	0.42	80.29	101.33	508.16	408.16	0.46	86.34	88.96	365.85	265.85	0.44	83.32	94.53	422.94	322.94
AP ₁ MS ₃	0.39	102.43	129.27	648.29	548.29	0.54	73.38	75.61	310.93	210.93	0.48	87.91	99.74	446.24	346.24
AP ₁ AMS ₃	0.70	47.55	60.01	300.95	200.95	0.50	104.33	107.50	442.08	342.08	0.58	75.94	86.16	385.48	285.48
PX ₁ A ₁	0.64	28.24	35.64	178.73	78.73	0.56	81.59	84.07	345.72	245.72	0.59	54.91	62.30	278.73	178.73
PX ₁ S ₃	0.63	121.72	153.61	770.38	670.38	0.39	176.88	182.26	749.49	649.49	0.49	149.3	169.39	757.87	657.87
PX ₁ AS ₁	0.61	82.53	104.15	522.34	422.34	0.61	112.56	115.98	476.95	376.95	0.61	97.55	110.68	495.18	395.18
PX ₁ MS ₃	0.70	49.79	62.83	315.13	215.13	0.36	111.1	114.48	470.76	370.76	0.50	80.44	91.26	408.32	308.32
PX ₁ AMS ₃	0.55	58.44	73.75	369.87	269.87	0.70	32.16	33.14	136.27	36.27	0.64	45.3	51.40	229.95	129.95
C ₁	0.48	79.24	100.00	501.52	401.52	0.40	97.05	100.00	411.23	311.23	0.44	88.14	100.00	447.41	347.41
C ₂	0.00	15.8	19.94	100.00	0.00	0.00	23.6	24.32	100.00	0.00	0.00	19.7	22.35	100.00	0.00
SED	0.06	9.08	11.45	57.44	57.44	0.05	14.41	14.84	61.04	61.04	0.05	10.87	12.33	55.16	55.16

MT= Manual tillage TT= Tractor tillage AP₁A₁-25 % atrazine + pendimethalin + Akidi at 20,000 plants/ha, AP₁S₃-25 % atrazine + pendimethalin + Sweet potato at 40,000 plants/ha, AP₁AS₁-25 % atrazine+pendimethalin + Akidi/Sweet potato at 20,000 plants/ha, AP₁MS₃-25 % atrazine + pendimethalin + Melon/Sweet potato at 40,000 plants/ha, PX₁A₁-25 % Primextra + Akidi at 20,000 plants/ha, PX₁S₃-25 % Primextra + Sweet potato at 40,000 plants/ha, PX₁AS₁-25 % Primextra + Akidi/Sweet potato at 20,000 plants/ha, PX₁MS₃-25 % Primextra + Melon/Sweet potato at 40,000 plants/ha, PX₁AMS₃-25 % Primextra+ Akidi/Melon/Sweet potato at 40,000 plants/ha, C₁=weeded control, C₂=unweeded control

Relative profitability

The weed control efficiency and relative profitability of using various integrated weed management and tillage methods in maize production is shown in Table 6. The weed control efficiency was higher in MT than TT. The WCE in PX-CC plots (0.50 in PX₁MS₃ - 0.64 in PX₁AMS₃), were higher the hand weeded plot C₁. The WCE in AP-CC was slightly lower (0.31 in AP₁A₁ to 0.58 in AP₁AMS₃).

The relative profitability followed the same trend as the net benefit. Profitability relative to the recommended hand weeding shows that the net benefit ratio in TT (N49,900) was slightly higher than MT (N31,440). Across the tillage methods, maize grown in AP -CC and PX-CC plots were 113% and 97% as profitable as the hand weeded plot. Relative to the unweeded, all IWM treated plots were more profitable. Similar trend was observed for net benefit gain. The order of % NBG was AP₁S₃ > PX₁S₃ > PX₁AS₁ > AP₁A₁ > C₁. All others had %NBG less than that of C₁.

DISCUSSION

The higher cost of production in 40,000 sweet potato stands per ha (S₃) irrespective of herbicide and tillage is attributed to the cost of purchasing the vines and planting. The planting was more demanding and quantity of the vines was higher compared to Akidi and Melon seeds. The higher cost of production in manually tilled system is attributed to the high cost of human labour required for making ridges when compared with the cost of single ploughing in tractor tillage. This is in support of the findings of Mafongoya *et al.* (2015) and Buah *et al.* (2017) who reported that no tillage system with minimal soil pulverization was more profitable than the conventional tillage method in maize production. The number of persons involved in manual tillage was much higher, hence the increased cost. The CP in AP treated plots was higher because, the cost of the two separate products, atrazine and pendimethalin, was more than the cost of the single product, Primextra.

The higher gross and net benefit in TT could be as result of the low cost of tractor services compared to manual hoe ridging. The low dose herbicide and cover crop effectively suppressed weeds resulting in higher maize grain yield and additional income from cover crop makes all the treated plots have higher gross benefits when compared to the unweeded. Weeds compete with crops for growth resources, thereby limiting the growth and subsequently the yield. Hence, the least gross benefit from the unweeded plots. Though, the hand weeding managed weed effectively, however, its gross benefit was significantly less than plots with maximum sweet potato because of the additional benefit obtained from the sales of the sweet potato and Akidi. The root yield of sweet potato was highly appreciable, marketable and supplemented the returns made from the sales of maize. This is in line with the report of Michael and Tijani-Eniola (2012) Michael (2015) and Chukudi (2020) who reported higher returns in plots planted with sweet-potato alone or mixed with other cover crops.

The higher gross benefits obtained in AP-CC when compared with PX-CC could be attributed to a number of factors: the AP mixture was freshly constituted and utilized enhancing growth and subsequent yield. This is in contrast to Amin *et al.* (2008) who reported higher profitability of Primextra gold. Though the main target crop was maize, the overall cost of production, gross return and net profits were higher in plots with sweet potato because appreciable root yield were harvested, while the absence of sweet potato in A₁ plot caused them to have the low economic value.

The MRR suggests that for every N1 investment, the farmer earned N1.53 and N0.96 in TT and MT, respectively. These reflected the high net benefit as a result of low cost of TT compared to MT. The highest MRR obtained in AP₁S₃ and PX₁S₃ both reflected the additional benefit from sweet potato (Michael, 2015).

The substantial tuber yields of sweet potato obtained in the AP₁S₃ and PX₁S₃ resulted in higher gross and net benefit, which the yields from other plots with less stands of sweet potato could not offset.

The higher net benefit ratio relative to C₁, C₂ as well as NBG in TT compared to MT reflected the low cost of single plough tillage resulting in higher benefit. The cost of MT was multiples of that of TT. The profitability of PX-CC over AP-CC reflected the lower cost of procuring the single constituted Primextra which was cheaper than the combined cost of atrazine and pendimethalin. The observed better relative profitability indices of all weed control treatments compared with the unweeded is a reflection of weed control efficiency of the various treatments and additional profit from the sales of the complementary cover crop. Unweeded

plot, generally reduced growth and maize grain yield. There was a consistently enhanced efficacy of low rates of the herbicide by tillage.

The high rainfall which favoured sweet potato growth and production was also to the disadvantage of akidi and melon, causing them to produce little or no harvestable yields.

CONCLUSION

Cover crop(s) enhanced the effectiveness of low dosage of herbicides in maize production. Using TT was more profitable than MT irrespective of the herbicide-cover crop weed management options. AP-CC was more profitable than recommended hand weeding and PX-CC.

The most profitable treatment was atrazine + pendimethalin at 25 % + 40,000 stands/ha sweet potato (AP₁S₃) and thus recommended.

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