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Economic assessment of biological weed control using cover crop mixtures in maize production

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The economics of using mixtures of a vegetable cowpea, Vigna unguiculata subsp. sesquipedalis L., known locally as 'Akidi' (A) in Eastern Nigeria, melon (M) and sweet potato (S) Ipomea batatas for weed management in maize were evaluated between 2007 and 2009 in Taraba State, College of Agriculture Teaching and Research Farm, Jalingo, Treatments include 20,000($_1$), 30,000($_2$) and 40,000($_3$) stands/ha of AM (AM$_1$, AM$_2$, AM$_3$), AS (AS$_1$, AS$_2$, AS$_3$), MS (MS$_1$, MS$_2$, MS$_3$) and AMS (AMS$_1$, AMS$_2$, AMS$_3$). Weeded (3+6 WAP) (C$_1$) and unweeded (C$_2$) checks served as control replicated three times in a randomized complete block design. Partial budget analysis was used to obtain the level of profitability. The cost of production in all the mixtures having sweet potato was slightly higher (₦61,740 .00-₦67,340.00) than the AM treated plots (₦51,460.00-₦52,880.00) in the three year production. The gross benefit of ₦205,490.00, ₦199,920.00, ₦164,940.00 and ₦130,270.00 was realized respectively from MS, AS, AMS and AM treated plots compared with ₦154,980 in the hand weeded plots. Over the three years, the net benefit was in the order MS> AS> AMS > C$_1$>AM , which resulted in 24.33, 23.22, 18.1, 17.57 and 13.67 times net profit when compared to the unweeded, respectively.

Key words: Profitability, biological weed management, maize, cover crop mixtures.

INTRODUCTION

The decision to use non-chemical weed management options including cover crops, either as sole or mixed by farmers is a business decision (SARE, 2019). The economics of weed control in maize has been reported for maize in many parts of Nigeria and elsewhere (Baba et al., 2015; Omovbude and Udensi, 2012; Maxwel et al., 2019). These studies emphazised use of non-food cover crops planted singly or with herbicdes expecially in forest-savannah transition zones. If any weed control option is not cutting cost or raising value, it is not lkely to be adopted (SARE, 2019). 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). SARE (2019) observed adopting cover cropping, which is a conservative practice with high resilience may take several year period to have significant economic value if non- food cover crops are used. Therefore, the decision to adopt cover crop mixtures requires an economic

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outlook for sustainable usage. The profitability of weed management technologies for maize production (Saleh and Oyinbo, 2017) is indespensible to compliment the usual research focus on agronomic and productivity aspects of maize-cover crops intercrop system. The economic aspects of using cover crop mixtures has not been adequately addressed in the study area, thereby limiting research-based decisions of the farmers. Thus, this study compares the profitability of several mixed cover crops aimed primarily for weed suppression in maize production.

The impact of cover crops mixture in a production system is to reduce soil erosion and suppress weed. However, Maxwel et al. (2019) reported that in the US, planting and establishing a decent stand before winter are major challenges. This calls for a holistic perspective in appraising the benefit of such farms. The need for farmers to make several management changes that compliment the productivity of the target or primary crop of interest like maize and maximize the overall economic efficiency calls for the assessment of benefits derivable from the chosen weed control option. This is the essence of this study.

The potentials of vegetable cowpea (*Vigna unguiculata subsp. sesquipedalis* L), melon (*Citrullus lanatus*) and sweet potato (*Ipomea batatas*) to suppress weed in maize have been reported (Okpara, 2000; Ahom et al., 2017; Michael, 2015). Weed density reduction in maize field by sole planted akidi (A), melon (M) and sweetpotato (S) was 72-80, 55-63% and 60-71% in Northern Guinea Savanna of Nigeria, while the mixed cover AM, AS, MS, AMS reduced weed density by 61-66%, 67-71%, 56-65% and 59-66% more than the un-weeded (Michael, 2015). Herbicide free weed management practices could be cultural, mechanical and biological (Kaur, 2017) useful at initial emergence stage of weed or when weed population is below the economic threshold level. Some cover crop species also release chemicals from roots or decaying residue, which can inhibit weed seed germination (DeAnn and Anita, 2016).

The possibility of using cover crop mixtures for weed management has been suggested and used (Michael, 2015; Michael and Tijani-Eniola, 2013; Scott and Burt, 1985; Anuebunwa, 1991). Bunch (1995) suggested the potentials latent in new as yet untried species, like Akidi (*Vigna unguiculata subsp. sesquipedalis* L), including trees and non legumes, and the value to be derived from using combination of green manures and cover crops rather than individual species be harnessed (Frick and Johnson, 2018). Abdin et al. (2000) in their evaluation of cover crops for weed control in maize in Canada used a mixture of red clover and ryegrass, and white clover and ryegrass at 1:1 proportion. In their studies, the combination of cover crops and cultivation controlled 77-80% of weed. The red clover/ryegrass and white clover/ryegrass gave 21.3 and 32.4 gm^{-2} of weed respectively, which significantly reduced weed weight when compared with weedy control (89.8 gm^{-2}).

In California, a mixture of melon and cowpea together with herbicide grow vigorously and out competed weed (Sullivan, 2003). Abdin et al. (2000) working on 12 cover crops in Canada observed that the mixtures ryegass, and clover at 1:1 plant population gave good ground cover, reduce weed weight, and have yield comparable to hand and chemically weeded treatment. The rationale for using cover crop mixture in weed suppression includes:

(i) Enhancement of biodiversity with consequent biological, physical, chemical input on the soil and environment.
(ii) Reduction in pest/disease attack
(iii) Reducing the yield depressive effect of some effective non leguminous cover crops like sweet potato and pumpkin in crops like cocoyam, plantain and maize. (Akinyemi, 1989; Nwagwu et al., 2000)
(iv) Possibility of regulating rate and duration of decomposition and subsequent nutrient supply.
(v) The nature of traditional farming culture, where farmers grow a number of such cover crops without observing their effects of weed control.

Gianessi and Reigner (2007) reported that though herbicides are used to control weed populations on 87 million ha of cropland in the United States; the major reason that organic crop hectarage totals only 565,600 ha is the difficulty of weed control without herbicides. Kyle et al. (2015) observed that enhanced agricultural productivity in developing country is hindered by the failure of farmers to adopt new technology and improved agricultural practices. Farmers cited financial constraints and need for specialized skills were some reasons for not adopting chemical weed control (Adedzwa and Ortese, 2004; Eni et al., 2013).

Organic crop growers cite weed control as their greatest difficulty in crop production because they are not permitted to use chemical herbicides. They substitute hand weeding and cultivation for herbicides at a greatly increased cost and with reduced effectiveness. The possibility of reducing herbicide use by roughly 50% by planting cover crops which enhances moisture retention and weed control (Winslow, 2018). The cover crop protected the soil from erosion and provided about a 50% reduction in weed biomass in the fall compared to bare fallow (Frick and Johnson, 2018).

Seeding a blend of cover crop species is often more effective than seeding a mono cropping system. Some species grow quickly and die during the winter, while others take longer to establish then living into the spring. A mix of species that collectively provides continuous living vegetation is often recommended – though not always critical – for increased weed suppression (Winslow, 2018).

Weed scientists must find cost-effective, ecologically based methods to manage undesirable plants. Economic

Table 1. Cover crop mixtures weed management treatments.

S/N	Treatment	Plant population/ha
1	AM_1	Akidi + Melon at 10,000 each (20,000)
2	AM_2	Akidi + Melon at 15,000 each (30,000)
3	AM_3	Akidi + Melon at 20,000 each (40,000)
4	AS_1	Akidi + Sweet potato at 10,000 each (20,000)
5	AS_2	Akidi + Sweet potato at 15,000 each (30,000)
6	AS_3	Akidi + Sweet potato at 20,000 each (40,000)
7	MS_1	Melon + Sweet potato at 10,000 each (20,000)
8	MS_2	Melon + Sweet potato at 15,000 each (30,000)
9	MS_3	Melon + Sweet potato at 20,000 each (40,000)
10	AMS_1	Akidi + Melon + Sweet potato at 6,666 each (20,000)
11	AMS_2	Akidi + Melon + Sweet potato at 10,000 each (30,000)
12	AMS_3	Akidi +Melon + Sweet potato at 13,333 each (40,000)
13	C_1	Hand weeded control (3+6 WAP)
14	C_2	Unweeded control

analyses are needed for management, policy making, and setting research priorities. The fundamental economic principle for weed management is to act only if the benefits exceed the costs. Therefore, the economics of using mixed cover of a vegetable cowpea "akidi" and melon (AM), akidi and sweet potato (AS), Melon and sweet potato (MS), akidi, melon and sweet potato (AMS) at three planting densities 20,000($_1$), 30,000($_2$) and 40,000($_3$) stands/ha for weed management in maize production were evaluated to ascertain their level of profitability.

MATERIALS AND METHODS

Experimental site

Field trials were conducted at the Teaching farm of Taraba State College of Agriculture (08° 50' N, 11° 50' E) in the Northern Guinea Savannah 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- 1000 mm. Mean annual temperature of Jalingo is about 28°C with maximum temperatures ranges between 30 and 39.4°C. The minimum temperatures range between 15to 23°C. The rainy season is between May and October while the dry season is from November to April.

Land preparation

The land used for the experiment was cleared manually using cutlass to reduce the few shrubs scattered on the field. Ploughing was done once using tractor.

Experimental design and layout

The experiment was designed to study the influence of three planting densities of mixtures of akidi/melon (AM), akidi/sweet potato (AS), melon/sweet potato (MS) or akidi/melon/sweet potato (AMS) on weed suppression and performance of maize. The experimental design was a randomized complete block with three replications. There were 14 mixed cover treatments as in Table 1. Each plot measured 4m × 4m with 1m space between plots and 2 m border separating blocks. The total land area was (69 m × 16 m) 1104 m^2.

Planting and trial management

Planting of maize was done on 16th June, 2007; 30th June, 2008 and 13th June, 2009. Cover crops were planted within 24 h. Maize was sown three seeds per hole at 25 cm × 100 cm 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. The plot size was 4 m × 4 m. There were 64 stands of maize per plot (4 rows of 16 stands/ row).

Akidi and melon seeds were sown 4/hole, while 2-3 sweet potato vines/hole, spaced 50 cm × 100 cm and latter thinned to give the required population densities of 20,000 (One stand/hill); 30,000 (One and two stands in altenate hills) or 40,000 (two stands/hill) plants/ha. All cover crop treated plots were weeded once at 3 weeks after planting to enhance establishment and spread.

In each of the cover crop mixtures, cover crops were planted at 1:1 ratio in two way mixture and 1:1:1 in three way mixture. The cover crops were planted in alternate rows/hills. Field management was similar for all the treatments till harvesting.

Data collection and analysis

Maize grain yield was estimated from 10 tagged plants sampled in the middle of each plot; 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 of the mixed cover crops 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 th e:

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

Table 2. Cost of production and gross benefit of using cover crop mixtures to manage weed in maize production 2007 – 2009.

Treatment	2007		2008		2009		Average	
	CP (₦' 000)	GB (₦' 000)	CP (₦' 000)	GB (₦' 000)	CP (₦' 000)	GB (₦' 000)	CP (₦' 000)	GB (₦' 000)
AM_1	49.48	123.43	51.61	117.72	53.28	136.92	51.46	126.02
AM_2	49.85	113.59	53.96	148.82	53.17	127.28	52.33	129.90
AM_3	50.55	121.68	56.14	178.74	51.96	104.24	52.88	134.89
AM	49.96	119.57	53.91	148.43	52.80	122.81	52.22	130.27
AS_1	63.11	200.50	65.08	141.45	64.56	157.47	64.25	166.47
AS_2	66.96	209.50	69.47	159.05	65.88	243.10	67.44	203.88
AS_3	69.75	322.42	71.99	153.28	69.26	212.53	70.33	229.41
AS	66.61	244.14	68.85	151.26	66.57	204.37	67.34	199.92
MS_1	63.22	233.00	63.30	135.76	62.15	159.79	62.89	176.18
MS_2	64.96	229.43	67.69	188.83	66.96	272.40	66.54	230.22
MS_3	71.52	329.43	71.59	169.00	67.71	131.81	70.27	210.08
MS	66.56	263.95	67.53	164.53	65.61	188.00	66.57	205.49
AMS_1	57.87	155.05	60.27	160.31	58.86	124.90	59.00	146.75
AMS_2	59.63	151.61	62.41	155.12	62.76	167.85	61.60	158.19
AMS_3	64.97	222.52	64.38	137.20	64.51	209.89	64.62	189.87
AMS	60.82	176.39	62.35	150.88	62.04	167.54	61.74	164.94
C_1	52.44	118.05	55.17	163.55	56.36	183.35	54.66	154.98
C_2	40.39	50.50	39.99	43.75	39.95	43.20	40.11	45.82

AM=Akidi + Melon, AS =Akidi + Sweet potato, MS = Melon + Sweet potato, AMS= Akidi + Melon + Sweet potatoC_1=weeded control, C_2=unweeded control 1=20,000 stands/ha , 2=30,000 stands/ha, 3=40,000 stands/ha. CP: cost of production, GB: gross benefit.

Gross benefit (₦/ha) = (yield of maize x price) + (yield of cover crop x price)

(iii) Total variable cost (₦/ha) for each treatment comprising cost of land preparation, planting materials and labour (for planting, weeding, harvesting and processing).

(iv) Net benefit (NB) (₦/ha) under each treatment

Net benefit (₦/ha) = Gross benefit – Total variable cost.

(v) The marginal rate of return (%) that compared the extra (marginal) costs with the extra (marginal) net benefit

$$\text{Marginal Rate of Return (MRR)} = \frac{\text{Extra benefit from weed management}}{\text{Extra investment in the weed management}} \times \frac{100}{1}$$

(vi) Relative profitability was assessed with :

(a) Net benefit relative to hand-weeded control (C_1) ($NBRC_1$)

$$NBRC_1 = \frac{\text{Net benefit from a given weed management treatment}}{\text{Net benefit from hand-weeded control } (C_1)}$$

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

$$NBRC_2 = \frac{\text{Net benefit from a given weed management treatment}}{\text{Net benefit from the unweeded control } (C_2)}$$

(c) Percentage Net Benefit Gain (%NBG)

$$\%NBG = \frac{(\text{Net benefit from a given weed management treatment} - \text{Net benefit from unweeded}) \times 100}{\text{Net benefit from the unweeded control } (C_2)}$$

(vii) Weed control efficiency

$$WCE = \frac{\text{Weed population in unweeded control} - \text{Weed in treated plot} \times 100}{\text{Weed population on unweeded control}}$$

RESULTS

The cost of production in all the mixtures having sweet potato were slightly higher (₦61,740 .00-₦67,340.00) than the AM treated plots (₦51,460.00-₦52,880.00) on the three year average (Table 2).The gross benefit fluctuated over time in most treatments. It generally declined between 2007 and 2008, and later appreciated in 2009. On the average ₦205,490.00, ₦199,920.00, ₦164,940.00 and ₦130,270.00 were realized respectively from MS, AS, AMS and AM treated plots compared with ₦154,980 from the hand weeded plots.

The net benefit followed the trend of the gross revenue. Averaged over the three years, net benefit increased with planting populations in all the covercrop mixture groups except in MS where MS_2 recorded the highest net profit of ₦163,680.00. The order MS> AS> AMS > C_1>AM was established, which resulted in 24.33, 23.22, 18.1, 17.57 and 13.67 times net profit when compared to unweeded respectively. The marginal rates of return of AS_2 (2.02), AS_3 (2.26), MS_2 (2.46),and AMS_3 (1.94) were higher than that of C_1 (1.82), while the rest were less. The

Table 3. Net benefit and marginal rate of return for using cover crop mixtures to manage weed in maize production 2007 - 2009.

Treatment	2007		2008		2009		Average	
	NB (₦' 000)	MRR	NB (₦' 000)	MRR	NB (₦' 000)	MRR	NB (₦' 000)	MRR
AM_1	73.96	1.49	66.11	1.28	83.64	1.57	74.57	1.45
AM_2	63.74	1.28	94.86	1.76	74.11	1.39	77.57	1.48
AM_3	71.13	1.41	122.60	2.18	52.28	1.01	82.00	1.53
AM	69.61	1.39	94.52	1.75	70.01	1.33	78.05	1.49
AS_1	137.38	2.18	76.37	1.17	92.91	1.44	102.22	1.60
AS_2	142.53	2.13	89.58	1.29	177.22	2.69	136.44	2.04
AS_3	252.67	3.62	81.29	1.13	143.27	2.07	159.08	2.27
AS	177.53	2.67	82.41	1.20	137.80	2.07	132.58	1.98
MS_1	169.78	2.69	72.47	1.14	97.64	1.57	113.30	1.80
MS_2	164.47	2.53	121.14	1.79	205.44	3.07	163.68	2.46
MS_3	257.92	3.61	97.41	1.36	64.10	0.95	139.81	1.97
MS	197.39	2.97	97.00	1.44	122.39	1.87	138.93	2.09
AMS_1	97.18	1.68	100.05	1.66	66.04	1.12	87.75	1.49
AMS_2	91.98	1.54	92.71	1.49	105.09	1.67	96.59	1.57
AMS_3	157.55	2.42	72.82	1.13	145.37	2.25	125.25	1.94
AMS	115.57	1.90	88.53	1.42	105.50	1.70	103.20	1.67
C_1	65.61	1.25	108.38	1.96	126.99	2.25	100.32	1.82
C_2	10.11	0.25	3.77	0.09	3.25	0.08	5.71	0.14

AM=Akidi + Melon, AS =Akidi + Sweet potato,MS = Melon + Sweet potato, AMS= Akidi + Melon + Sweet potatoC_1=weeded control, C_2=unweeded control 1=20,000 stands/ha , 2=30,000 stands/ha, 3=40,000 stands/ha. NB: Net benefit.

MRR increased with planting density in all group except in MS (Table 3).

The weed control efficiency and relative profitability of using various cover crop mixtures for weed management in maize is shown in Table 4. Though the weed control efficiency was highest of hand weeded (0.72), it was comparable with AS (0.70), AMS, AM (0.63 each), followed by MS (0.60). Profitability relative to the recommended hand weeding shows that the net benefit ratio of AS (1.02-1.59) and MS (1.13-1.63) treated plots was higher than the hand weeded while those of AM plots and AMS treated plots except at 40,000 stands/ha (AMS_3) were less. Relative to the unweeded, all the cover crop mixtures were more profitable, 13.06-28.67 times more profitable than the unweeded plots. Similar trend was observed for net benefit gain

DISCUSSION

The economics of maize production under various cover crop mixture reflected the productivity of the component crops and not just the grain yield of maize (Michael, 2015). 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 tuber yields were harvested, while the absence of sweet potato in AM plot caused them to have the lowest economic value. The net profit of sole cover akidi, melon, or sweet potato reflected the impact of extra cash benefit derivable from the sale of cover crop in association with maize as well as the planting density. This observed efficacy of sole planted cover crops comparable with hand weeded plot is confirmed in this study (Michael and Tijani-Eniola, 2014). Among the cover crop mixture treated plots with melon had the least cost of production, gross revenue and net benefit when compared with mixtures having akidi and/or sweet potato because melon could not reach maturity and no harvestable yields were obtained throughout the experimental periods, simillar to the observation in melon/plantain system (Akinyemi and Tijani–Eniola 1997). Omovbude and Udensi (2012) reported that use of melon plus hoe weeding recorded the lowest financial return when compared with mulched or herbicides treated plots in a forest-savannah transition zone of Edo state, Nigeria. Anuebunwa (1991) reported that egusi melon (*Colocythis citrillus*. L) at 40,000 stands/ha in association with yam in Umudike grew vegetatively with no pod formation. This was the experience in this trial. Mixtures having sweet potato had higher economic value because of the yield obtained from the tuber. Before increasing seeding rates to enhance weed suppression, the economic benefit of higher seeding rates should be

Table 4. Weed control efficiency and relative profitability of using cover crop mixtures for weed management in maize.

Treatment	WCE	NB (₦' 000)	$NBRC_1$	$NBRC_2$	%NBG (x100)
AM_1	0.62	74.57	0.74	13.06	12.06
AM_2	0.61	77.57	0.77	13.58	12.58
AM_3	0.66	82.00	0.82	14.36	13.36
AM	0.63	78.05	0.78	13.67	12.67
AS_1	0.67	102.22	1.02	17.90	16.90
AS_2	0.71	136.44	1.36	23.89	22.89
AS_3	0.71	159.08	1.59	27.86	26.86
AS	0.70	132.58	1.32	23.22	22.22
MS_1	0.56	113.30	1.13	19.84	18.84
MS_2	0.58	163.68	1.63	28.67	27.67
MS_3	0.65	139.81	1.39	24.49	23.49
MS	0.60	138.93	1.38	24.33	23.33
AMS_1	0.63	87.75	0.87	15.37	14.37
AMS_2	0.59	96.59	0.96	16.92	15.92
AMS_3	0.65	125.25	1.25	21.94	20.94
AMS	0.63	103.20	1.03	18.07	17.07
C_1	0.72	100.32	1.00	17.57	16.57
C_2	0.00	5.71	0.06	1.00	0.00

considered because increased seed fee costs may exceed the benefits in weed suppression (Nice et al., 2001; Renner and Mickelson, 1997). Similarly, the substantial tuber yields of sweet potato obtained in the S plots resulted in higher gross and net benefit in which the yields from other plots having less stands of sweet potato could not offset. 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

The net benefit was in the order MS (Melon/Sweetpotato) > AS (Akidi/Sweetpotato) > AMS (Akidi/Melon/ Sweetpotato) > C_1 (Hand weeding) > AM (Akidi/Melon), which resulted in 24.33, 23.22, 18.1, 17.57 and 13.67 times net profit when compared to the unweeded, respectively. Organic weed management using melon/ sweet potato, akidi/sweet potato or akidi/melon/sweet potato mixtures is more profitable than the recommended hand weeding.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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