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Effects of pre-rice cassava/legume intercrops and weed management practices on weed dynamics and yield of low land rice in Badeggi, Nigeria

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The effects of cassava/legume intercrop-rice relay and weed management practices on weed infestation, growth and yield of rice were investigated at Badeggi, Southern Guinea Savanna of Nigeria in 2011 to 2013 cropping seasons. The treatments consisted of factorial combination of cassava (IIT 427) intercrop with: Mucuna or Velvet bean [*Mucuna pruriens* (L.) DC.], Cowpea [*Vigna unguiculata* (L.) Walp.], Soybean [*Glycine max* (L.) Merr.], Hyacinth bean [*Lablab purpureus* (L.) Sweet.] and Porcupine Jointvetch (*Aeschynomene histrix* Poir.) and weed management practices: (i) application of propanil at 1.44 kg a.i ha^{-1} plus 2,4-D at 0.80 kg a.i ha^{-1} (Orizo Plus®) at the rate of 2.24 kg a.i ha^{-1} at three weeks after transplanting (WAT) rice followed by hoeing at 6 WAT, (ii) two hoeing at 3 and 6 WAT, (iii) one hoeing at 3 WAT, and (iv) weedy check with sole cassava and natural fallow as control laid in a split plot arranged in a randomized complete block with three replications. Across cassava/legumes intercrops, cassava/mucuna had lower weed density and dry matter, cassava/*Aeschynomene* and cassava/cowpea produced comparable taller rice plants, more rice panicles and paddy yield, and cassava/*Aeschynomene* produced greater number of rice tillers. Irrespective of the weed management practices, two hoeing at 3 and 6 WAT gave better weed control, taller rice plants, greater number of tillers and panicles, and higher paddy yield comparable to application of Orizo Plus® at 3 WAT followed by one hoeing at 6 WAT. This study suggests that sustainable weed control with *Mucuna* intercrop and rice productivity with *Aeschynomene* and cowpea intercrops can be achieved with two hoeing at 3 and 6 WAT or application of Orizo Plus® at 3 WAT followed by hoeing at 6 WAT in this agro-ecology of Nigeria.

Key words: Intercrops, legumes, *Oryza sativa* L., paddy yield, weed suppression.

INTRODUCTION

Weeds are a major biotic constraint to increased rice production worldwide. Its occurrence is a constant component of the ecosystem in comparison with the epidemic nature of other pests which makes farmers

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unaware of the significant losses they incur from their infestation (Ismaila et al., 2015). Farmers can spend over US $400 ha^{-1}, or 20% of their production costs to control weeds during the growing cycle (Islam et al., 2005). Weeds can cause serious yield reduction in rice production worldwide. Losses caused by weeds vary from one country to another, depending on the predominant weed flora and the control methods practised by the farmers (Mishra et al., 2016). The extent of loss varies depending upon cultural methods, rice cultivars, weed species and the density and duration of competition. For example, uncontrolled weed growth is reported to have caused 28 to 74% yield losses in transplanted lowland rice, 28 to 89% in direct-seeded lowland rice, and 48 to 100% in upland ecosystems (Rodenburg and Johnson, 2009). The potential yield loss from weed is less in transplanted rice than in dry-seeded rice (Joshi et al., 2013).

However, improved weed control has been estimated to increase rice yields by 15 to 23%, depending on production system in the ecosystem (Rodenburg and Johnson, 2009). It is rare, however, for farmers not to undertake some form of weed control and therefore losses on farmer' fields are likely to be less depending on the control measures adopted. Common weed management practices in rice-based cropping systems include soil tillage, clearance by fire, hand- or hoe-weeding, herbicides, flooding, fallow and crop rotations, and these are often used in combinations (Rodenburg and Johnson, 2009). Good cultural practices cannot be underestimated in their importance to weed management. Most, if not all of these cultural methods should be a necessary part of crop management procedures in controlling weeds (Gbanguba et al., 2011).

The management of weeds requires integrated strategies to be successful. The combination of direct weed control methods, such as herbicides or hand weeding, with indirect methods such as land preparation, flooding and competitive crops, can suppress weed growth. The optimum combination of weed control methods will depend on the farming system, economic conditions, and farmers' resource and knowledge base (Johnson, 2009). During the off-season, rain fed rice lands are typically fallowed (Gbanguba et al., 2014). The straw and fallow weed vegetation are subjected to grazing by livestock. In a minor fraction of the area with conducive residual soil water-holding capacity, and/or a high ground water table, upland crops, including legumes, are grown in the post-rice season. This practice is most common in well-drained rice lands. In this case, upland crops are grown prior to rice during the dry-to-wet season transition period. Very short duration crops are advantageous to permit maturity before the soil becomes waterlogged. Rotating crops with different planting dates and growth periods, contrasting competitive characteristics and dissimilar management practices can be used to disrupt the regeneration niche of different weed species in rice field. For example, Liebman and Davis (2000) reported that *Bromus tectorum* (L.) density remained relatively stable when winter wheat (*Triticum aestivum* L.) was rotated with oilseed rape (*Brassica napus* L.), whereas the density of the weed increased rapidly when wheat was grown continuously. Also, Liebman and Davis (2000) mentioned that *Setaria faberi* Herrm. seedling density tended to be greatest in continuous maize, intermediate in a two year maize/soybean rotation and lowest in a three year maize/soybean/winter wheat rotation. A well-planned crop rotation system can help producers avoid many of the problems associated with weeds, particularly perennial weeds (Mohler, 2012). Crop rotation is an effective practice for controlling weeds because it affects weed growth and reproduction negatively and in turn reduces weed density (Sims et al., 2018). In a previous study, Filizadeh et al. (2007) found that rice yields in rotation with soybean were higher by 17 to 21% compared with continuous rice. Anders et al. (2004) reported higher yield of rice in rice grown after soybean than in rice wheat rotation. Toomsan et al. (2000) recorded 50% higher rice yields in rice followed cover crop green mixtures than rice in bare fallow rotation. The grain yield of rice preceded by a legume fallow had been reported to be on average 0.2 kg ha^{-1} or 30% greater than that preceded by a natural weedy fallow control (Gbanguba et al., 2014).

In Nigeria, cassava/legume intercropping preceding rice production is a common practice among farmers in the Southern Guinea agro-ecology. But it is not known, how this practice under varying weed control methods affects weed growth, growth and yield of rice in this region. Thus, this study was aimed at evaluating the effect of one year rotation of pre-rice cropping with cassava/legume intercrops and weed management practices on weed suppression, growth and yield of low land rice.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in 2011 to 2013 growing seasons at the lowland experimental field of the National Cereals Research Institute, Badeggi (latitude 09° 45′N, longitude 06° 70′E, elevation 70.57 m above sea level). The area is located in the Southern Guinea Savanna zone of Nigeria with mean annual rainfall of 2066.3, 1163.6 and 899.7 mm distributed between April and October in 2011, 2012 and 2013, respectively. The average maximum and minimum air temperature was 30 to 38°C and 14 to 26°C, respectively. The soil texture of the experimental site was sandy clay. All the soils were moderately acidic with a pH (H_20) around 5.24.

Treatments and experimental design

The treatments were a factorial combination of Cassava (IIT 427) intercrop with Mucuna or Velvet bean [*Mucuna pruriens* (L.) DC.], Cowpea [*Vigna unguiculata* (L.) Walp.], Soybean [*Glycine max* (L.)

Table 1. Influence of cassava/legume intercrops on some soil nutrient status.

Cassava/Legume intercrop	Organic carbon (g kg^{-1})			Total nitrogen (g kg^{-1})			Available phosphorus (mg kg^{-1})		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Cassava/Mucuna	2.8^b	2.9^b	3.1^a	0.14	0.16^a	0.20^a	30.8^a	32.1^a	32.4^b
Cassava/Cowpea	3.2^a	3.1^a	3.2^a	0.18	0.18^a	0.20^a	31.3^a	31.6^a	34.1^a
Cassava/Soybean	3.2^a	3.1^a	3.1^a	0.14	0.14^b	0.20^a	30.8^a	31.1^a	32.4^b
Cassava/*Lablab*	2.9^b	2.9^b	2.7^b	0.12	0.13^b	0.10^a	29.7^a	30.5^b	31.9^b
Cassava/*Aeschynomene*	3.3^a	3.2^a	3.3^a	0.18	0.18^a	0.20^a	31.4^a	32.0^a	32.7^b
Sole Cassava	2.2^c	2.1^c	2.2^c	0.10	0.08^c	0.05^b	20.5^c	21.8^c	23.3d
Natural Fallow	2.0^c	2.0^c	2.1^c	0.10	0.04^c	0.04^b	28.4^b	29.1^b	29.2^c
SE±	0.04	0.10	0.02	0.40	0.01	0.04	0.30	0.50	0.90

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT).

Merr.], Hyacinth bean [*Lablab purpureus* (L.) Sweet.] and Porcupine Jointvetch (*Aeschynomene histrix* Poir.) legumes, sole cassava and natural fallow. The weed management practices were (i) application of propanil at 1.44 kg a.i. ha^{-1} plus 2, 4 D at 0.80 kg a.i ha^{-1} (Orizo plus^{R})) at the rate of 2.24 kg a.i ha^{-1} at 3 weeks after transplanting (WAT) followed by hand weeding at 6 WAT, (ii) two hand weedings at 3 and 6 WAT, (iii) one hand weeding at 3 WAT, and (iv) weedy check. Cassava/Legume intercrop was assigned to the main plot, while weed management practices were assigned to the sub plot. The trial was laid out in a split plot arranged in a randomized complete block with three replications. Main plot size was 12.5 × 5 m and sub plot size was 3 × 5 m replicated three times.

Cultural practices

The experiment was initiated by intercropping of cassava with the legumes in January in 2011, 2012 and 2013 on manually prepared raised beds (2.5 m × 0.5 m × 0.75 m) using residual moisture. Beds were spaced 0.5 m. Cassava (IIT 427) was planted on the top side of the bed in two rows at intra-row spacing of 0.5 m (ten stands per bed) and legumes were planted by the side of the beds at intra-row spacing of 0.25 m, except for soybean (TGX 1019EN) which was drilled at 5 cm intra row immediately the beds were constructed. Cassava cutting and soybean varieties were sourced from the International Institute of Tropical Agriculture, Ibadan. Among the other legumes, *Aeschynomene histrix* was sourced from the International Institute of Tropical Agriculture, Kubwa-Abuja, and cowpea (IAR 48) and *Mucuna* seeds were obtained from the Institute for Agricultural Research, Samaru-Zaria. The cassava/ legume cropping lasted till August when cassava was harvested. Superimposition of rice (Faro 52) variety obtained from seed unit of National Cereals Research Institute, Badeggi, on the plots previously cropped with cassava/legume intercrops were levelled for rice cultivation on 6, 5 and 9th August of 2011, 2012 and 2013, respectively. Rice was transplanted at rate of two seedlings per hill at a spacing of 20 cm × 20 cm. Weeding was carried out as per the treatments. Orizo Plus® was applied with a CP3 knapsack sprayer using a spray volume of 250 L ha^{-1} at 206 kPa. Fertilizer application was done by broadcasting in split application of NPK 40: 60: 60 as basal, while N 40 kg ha^{-1} was applied as top dressing. Harvesting was achieved by using sickle. Drying, threshing and winnowing were manually carried out.

Data collection

Before the superimposition of the rice seedling, soil samples were taken from three randomly selected spots from each cassava/ legume intercrop plot, bulked and used to determine organic carbon, total nitrogen, and available phosphorous. The method of Walkley and Black (Anderson and Ingram, 1993) was used to determine the organic carbon. Total nitrogen was determined by the macro Kjeldahl method (Jackson, 1962). Available phosphorous was determined by the Olsen method (Okalebo et al., 2002).

Weed samples were collected from 1 m^{-2} quadrant randomly placed in each plot in each year at 9 WAT for determination of weed density, dry weight and control efficiency. All the weed species in each quadrat were counted and clipped above the soil surface; oven dried at 70°C to a constant weight for weed dry weight determination. Rice plant height, tiller and panicle numbers were determined by collecting rice samples from the 1 m^2 quadrat used for weed sampling at 9 WAT. Rice grain yield was obtained from tillers harvested from 2 × 4 m net plot. Tillers were harvested at physiological maturity and manually threshed and winnowed. Grains obtained from the tillers were measured and converted to kg ha^{-1}. Data collected were subjected to analysis of variance (ANOVA) and differences between means were separated using Duncan Multiple Range Test (DMRT) at P≤ 0.05 using M-Stat-C software (M-Stat-C Version 1.3).

RESULTS

Some soil nutrient status after cassava/legume intercrop

A significant effect of cassava/legume intercrop was observed on organic carbon, total nitrogen and available phosphorous in this study (Table). Cassava/Cowpea, ca ssava/soybean and cassava/*Aeschynomene* intercrops in each year and cassava/*Mucuna* intercrop in 2013 added more organic carbon to the soil than all other treatments. Total nitrogen was the highest and comparable in cassava/*Mucuna*, cassava/cowpea and cassava/ *Aeschynomene* intercrops in 2012 and 2013, and cassava/soybean or *Lablab* intercrops in 2013 than all other treatments. In terms of available phosphorous, cassava/cowpea intercrops significantly contributed more of this nutrient, which was comparable to cassava/ *Mucuna*, cassava/soybean and cassava/*Aeschynomene* intercrops in 2011 and 2012, and cassava/*Lablab* intercrop in 2011 only.

Table 2. Effects of pre-rice cassava/legume intercropping and weed management practices on weed density in rice at 9 WAT.

Treatment	Weed density (no^{-2})		
	2011	2012	2013
Cassava/legume intercrop (I)			
Cassava/*Mucuna*	71.0^{f}	139^{d}	129^{f}
Cassava/Cowpea	102.5^{e}	171^{c}	156^{e}
Cassava/Soybean	123.3^{d}	188^{c}	169^{cd}
Cassava/*Lablab*	137.4^{c}	200^{b}	178^{c}
Cassava/*Aeschynomene*	126.4^{d}	188^{c}	152de
Sole cassava	165.0^{b}	224^{b}	218^{b}
Natural fallow	`199.8^{a}	325^{a}	377^{a}
SE±	2.9	6.1	4.4
Weed management practices (W)			
Orizo Plus fb hoeing at 6 WAT	170^{c}	172^{c}	172^{c}
Two hoeing at 3 and 6 WAT	165^{c}	168^{c}	152^{c}
One hoeing at 3 WAT	223^{b}	225^{b}	210^{b}
Weedy check	266^{a}	229^{a}	246^{a}
SE±	2.2	4.6	3.3
Interaction			
I × W	*	*	*

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). *Significant at 5% level of probability. fb: follow by; WAT: weeks after transplanting.

Weed density

Rice grown after cassava/*Mucuna* intercrop produced the least weed density compared with other intercrops in each year of the study (Table 2). Furthermore, weed density produced in rice after cassava/legume intercrops and natural fallow ranged from 29.5 to 47.2%. Rice grown after natural fallow consistently had the highest weed density followed by sole cassava.

On weed management practices, application of Orizo Plus fb hoeing at 6 WAT and two hoeing at 3 and 6 WAT produced similar lower weed densities in 2011, 2012 and 2013 rainy seasons (Table 2). Weedy check accounted for the highest weed density in both years of the study which ranged between 30.0 and 38.0% over Orizo Plus fb hoeing at 6 WAT, and two hoeing at 3 and 6 WAT.

A significant ($p \leq 0.05$) interaction between cassava/legume intercrops and weed management practices was recorded for weed density in each year in this study (Table 3). In 2011, weed density was significantly ($p \leq 0.05$) lowest in cassava/*Mucuna* intercrop in combination with each of the weed management options. Furthermore, in 2012 and 2013, cassava/*Mucuna* in combination with Orizo Plus fb hoeing at 6 WAT and two hoes weeding at 3 and 6 WAT caused similar significant decrease in weed density. Similarly, reduction of weed density by cassava/*Mucuna* intercrop in combination with one hoe weeding at 3 WAT was comparable to that recorded in cassava/cowpea intercrop in 2012 and 2013. Irrespective of the weed management practice, the highest weed density was observed in natural fallow which were similar for each weed management practice in the three years of the study.

Weed dry matter

Table 4 shows that the lowest weed dry matter was obtained in rice grown after cassava/*Mucun*a intercrop compared with others throughout the period of study. Weed dry matter production in rice grown after sole cassava and natural fallow was found to be 16.7 to 56.9% and 31.2 to 64.5% more than that of the intercrops, respectively.

Considering weed management practices effects, application of Orizo Plus fb hoe weeding at 6 WAT and hoe weeding at 3 and 6 WAT had similar lowest weed dry matter, than the other treatments in the study period (Table 4).

Irrespective of the weed management practice, maximum weed dry matter was recorded in combination natural fallow with each of the weed management option

Table 3. Interaction between cassava/legume intercrops and weeds management practice on weed density at 9 WAT.

Treatment	Orizo Plus fb hoeing at 6 WAT	Two hoeing at 3 and 6 WAT	One hoeing at 3 WAT	Weedy check
		2011 Rainy season		
Cassava/*Mucuna*	111.0^{q}	111.0^{q}	178.0^{jkl}	223.0^{f}
Cassava/Cowpea	139.0^{op}	139.0^{op}	197.0^{ghi}	240.0^{e}
Cassava/Soybean	160.0^{mn}	160.0^{mn}	204.0^{gh}	246.0^{de}
Cassava/*Lablab*	173.0^{j-m}	173.0^{j-m}	209.0^{fg}	262.0^{cd}
Cassava/*Aeschynomene*	166.0^{l-n}	166.0^{lmn}	203.0^{gh}	246.0^{de}
Sole cassava	187.0^{hij}	187.0^{hi}	251.0^{de}	270.0^{c}
Natural fallow	258.0^{cd}	258.0^{cd}	322.0^{b}	375.0^{a}
SE±	3.82			
		2012 Rainy season		
Cassava/*Mucuna*	111.0^{op}	98.0^{p}	159.0^{j-m}	221.0^{fgh}
Cassava/Cowpea	240.0^{def}	134.0^{n}	184.0^{ijk}	221.0^{fgh}
Cassava/Soybean	174.0^{ijk}	166.0^{i-m}	270.0^{cd}	248.0^{ef}
Cassava/*Lablab*	158.0^{k-n}	150.0^{lmn}	187.0^{h-k}	227.0^{efg}
Cassava/*Aeschynomene*	158.0^{k-n}	150.0^{lmn}	187.0^{h-k}	227.0^{efg}
Sole cassava	195.0^{ghi}	193.0^{g-j}	246.0^{def}	264.0^{cd}
Natural fallow	264.0^{cd}	282.0^{c}	337.0^{b}	426.0^{a}
SE±	4.6			
		2013 Rainy season		
Cassava/*Mucuna*	100.0^{q}	96.0^{q}	163.3^{j-n}	187.0^{k-o}
Cassava/Cowpea	133.0^{op}	129.0^{p}	165.0^{j-m}	198.0^{fgh}
Cassava/Soybean	150.0^{l-o}	145.0^{mno}	173.0^{h-l}	210.0^{efg}
Cassava/*Lablab*	161.0^{k-n}	155.0^{k-n}	179.0^{h-k}	219.0^{ef}
Cassava/*Aeschynomene*	143.0^{mno}	139.0^{nop}	172.0^{i-l}	197.0^{f-i}
Sole cassava	191.0^{ghi}	187.0^{ghij}	234.0^{f}	259.0^{d}
Natural fallow	327.0^{c}	315.0^{c}	384.0^{b}	484.0^{a}
SE±	3.3			

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT).

in each year in this study. The lowest weed dry matter was obtained from cassava/*Mucuna* intercrop irrespective of the weed management practice in each year of study (Table 5). Contrarily, optimum weed dry matter was produced in natural fallow.

Rice plant height

Table 6 shows that rice plant height differed between cassava/legume intercrops, such that cassava/*Mucuna*, cassava/cowpea and cassava/*Aeschynomene* in 2011 and 2012 produced similarly taller plants. The natural fallow plots had the shortest plants.

Two hoe weeded plots consistently produced taller plants (Table 6). Similar taller plants were observed in plots with application of Orizo Plus fb hoeing at 6 WAT, and one hoeing at 3 WAT in 2011 only.

There was significant interaction between cassava/ legume intercrop and weed management practices on rice plant height in 2012 and 2013 (Table 7). The use of cassava/cowpea intercrop in combination with the weed management practices generally had taller rice plants in 2012. Similarly, in 2013, irrespective of the weed management practice, rice plant height was tallest under cassava/cowpea, and cassava/*Aeschynomene*.

Rice tiller number

Table 8 shows that more tiller were recorded in cassava/*Aeschynomene* in 2011, 2012 and 2013 rainy seasons, which was at par with cassava/*Mucuna* in 2011 and 2012. It was observed that greater number of tillers

Table 4. Effect of pre-rice cassava/legume intercropping and weed management practices on weed dry matter in rice at 9 WAT.

Treatment	Weed dry matter (g^{-2})		
	2011	2012	2013
Cassava/Legume Intercrop (I)			
Cassava/*Mucuna*	155^{f}	139^{d}	129^{f}
Cassava/Cowpea	177^{e}	171^{c}	156^{e}
Cassava/Soybean	190^{d}	188^{c}	169^{cd}
Cassava/*Lablab*	202^{c}	200^{b}	178^{c}
Cassava/*Aeschynomene*	192^{d}	188^{c}	152^{de}
Sole cassava	223^{b}	224^{b}	218^{b}
Natural fallow	302^{a}	325^{a}	377^{a}
SE±	1.9	6.1	4.4
Weed management practices (W)			
Orizo Plus fb hoeing at 6 WAT	80.9^{c}	172^{c}	172^{c}
Two hoeing at 3 and 6 WAT	81.8^{c}	168^{c}	152^{c}
One hoeing at 3 WAT	137.4^{b}	225^{b}	210^{b}
Weedy check	223.6^{a}	229^{a}	246^{a}
SE±	1.4	4.6	3.3
Interaction			
I × W	*	*	*

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). *Significant at 5% level of probability. fb: follow by; WAT: weeks after transplanting.

was recorded in two hoe weeded plots in the three years of investigation (Table 8).

The interaction between pre-rice cropping of cassava/ legume intercrops and weed management practices on rice tiller per stand was significant in each year of study (Table 9). The use of cassava/*Mucuna* and cassava/*Aeschynomene* with each weed management practice had greater number of tillers per stand in 2011. In 2012, the use of cassava/*Aeschynomene* in combination with each of the weed management practice, had higher number of tillers per stand than other treatment combinations. In 2013, the use of cassava/ *Aeschynomene* under each weed management practice generally produced greater number of rice tillers per stand than other combinations.

Rice panicle count

More rice panicles were recorded in cassava/cowpea and *Aeschynomene* intercrops throughout the period of study and cassava/*Mucuna* plots in 2011 and 2012 only (Table 10). In contrast, natural fallow consistently gave the lowest number of panicles in each year of the study.

Weed management with two hoeing at 3 and 6 WAT in each year of the study, and application of Orizo Plus fb hoeing at 6 WAT in 2012 and 2013 only, resulted in greater number of panicles (Table 10).

The interaction between pre-rice cassava/legume intercrop and weed management practice showed that rice panicle count were least in cassava/*Lablab* intercrops irrespective of the weed management practice in 2011 and 2012, and in addition to cassava/soybean in 2013 (Table 11). Rice panicle number was consistently the lowest in the natural fallow treatment.

Rice paddy yield

Rice paddy yield was significantly (P≤0.05) higher in cassava/Cowpea and cassava/*Aeschynomene* intercrop throughout the study and in 2012 and 2013, respectively (Table 12). Rice yield was consistently significantly lower in the natural fallow treatment.

In terms of weed management, two hoes weeding had the greatest paddy yield followed by use of Orizo Plus and one hoe weeding (Table 12).

DISCUSSION

The high organic carbon added to the soil by cassava with cowpea, soybean and *A. histrix* Poir., was due to the high rate of growth and the bushiness of the legumes

Table 5. Interaction between cassava/legume intercrops and weeds management practice on weed dry matter at 9 WAT.

Treatment	Orizo Plus fb hoeing at 6 WAT	Two hoeing at 3 and 6 WAT	One hoeing at 3 WAT	Weedy check
		2011 Rainy season		
Cassava/*Mucuna*	42.2[n]	42.2[n]	81.9[kl]	117.6[h]
Cassava/Cowpea	59.1[m]	58.4[m]	97.2[ij]	195.4[d]
Cassava/Soybean	75.6[l]	74.3[l]	127.4[gh]	216.1[c]
Cassava/*Lablab*	88.1[jk]	87.8[jk]	147.8[f]	225.8[c]
Cassava/*Aeschynomene*	75.9[l]	75.1[l]	135.7[g]	218.8[c]
Sole cassava	102.1[i]	99.4[i]	171.[e1]	287.3[b]
Natural fallow	129.9[g]	129.1[g]	200.3[d]	339.2[a]
SE±	3.9			
		2012 Rainy season		
Cassava/*Mucuna*	34.7[t]	32.2[t]	55.2[rs]	109.3[lm]
Cassava/Cowpea	53.6[rs]	52.0[s]	78.5[n]	184.1[g]
Cassava/Soybean	67.1[pq]	60.2[qr]	121.8[k]	197.8[f]
Cassava/*Lablab*	76.7[no]	70.3[op]	130.8[j]	224.3[d]
Cassava/*Aeschynomene*	65.2[pq]	60.2[qr]	108.1[m]	190.0[g]
Sole cassava	115.8[kl]	113.0[lm]	211.1[e]	311.4[b]
Natural fallow	148.6[h]	140.2[i]	243.3[c]	390.3[a]
SE±	0.9			
		2013 Rainy season		
Cassava/*Mucuna*	32.2[p]	29.2[p]	50.1[no]	104.4[i]
Cassava/cowpea	54.0[mno]	49.2[o]	74.7[k]	183.5[e]
Cassava/soybean	62.4[lm]	58.6[mn]	115.5[gh]	191.8[e]
Cassava/*Lablab*	73.9[k]	69.3[kl]	122.6[g]	217.4[d]
Cassava/*Aeschynomene*	59.1[mn]	55.9[mno]	86.5[j]	165.8[f]
Sole cassava	113.2[hi]	112.0hi	214.3[d]	315.4[b]
Natural fallow	164.5[f]	160.1[f]	272.0[c]	467.5[a]
SE±	1.2			

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT).

compared with other species. These translated into high leaf litter production and its subsequent decomposition. In a previous study, Osundare (2015) reported a significant increase in soil carbon content in *Centrosema pubescens* (Bentham) Kuntze; planted fallow compared to continuous maize cultivation.

The increase in soil total nitrogen in all cassava/legume intercrops, was probably due to greater addition of Nitrogen (N) as a result of leaf litter decomposition and atmospheric fixation. This finding is in agreement with the work of Matata et al*.* (2017) who reported high total nitrogen content in the biomass of *M. pruriens* (L.) DC., and *Canavalia ensiformis* (L.) DC., cropping systems relative to no fertilizer application.

In the present study, the intercropped legumes generally contributed more phosphorus than natural fallow. However, the highest addition of available phosphorus by cowpea intercrop in each year in this study could be tied to the high organic carbon added to the soil. In a previous study, Matata et al. (2017) reported that soil organic matter enhances the plant nutrients supply compared to treatments without crop residues.

The result of the present study demonstrated that in terms of weed density reduction, cassava/*Mucuna* intercrop was best. This observation corroborated with the findings of Liebman and Davis (2000) who reported that cover crops can suppress weed establishment and growth. This in turn reduced the number of weed seeds and vegetative propagules that could infest succeeding crops. The ability of cassava/*Mucuna* intercrop to effectively suppress weed growth (weed dry matter produced) the most, might be attributed to the allelopathic effect of the intercrop residues. These residues might have hindered subsequent weed seed germination and growth. This is consistent with the findings of Mhlanga et al. (2015) who noted that effectiveness of intercrops or

Table 6. Effect of pre-rice cassava/legume intercropping and weed management practices on rice plant height at 9 WAT.

Treatment	Rice plant height (cm)		
	2011	2012	2013
Cassava/Legume Intercrop (I)			
Cassava/*Mucuna*	57.5^{a}	63.4^{a}	70.3^{b}
Cassava/cowpea	57.7^{a}	64.0^{a}	72.2^{a}
Cassava/soybean	57.6^{a}	61.7^{b}	68.5^{c}
Cassava/*Lablab*	52.3^{b}	61.1^{b}	67.4^{c}
Cassava/*Aeschynomene*	56.3^{a}	64.0^{a}	71.4^{ab}
Sole cassava	50.9^{bc}	53.3^{c}	54.0^{d}
Natural fallow	47.5^{c}	49.5^{d}	48.7^{e}
SE±	1.3	0.6	0.5
Weed management practices (W)			
Orizo Plus fb hoeing at 6 WAT	59.8^{a}	65.9^{b}	71.9^{b}
Two hoeing at 3 and 6 WAT	61.8^{a}	77.3^{a}	77.9^{a}
One hoeing at 3 WAT	61.8^{a}	63.7^{c}	69.0^{c}
Weedy check	33.9^{b}	36.9^{d}	39.8^{d}
SE±	1.0	0.4	0.4
Interaction			
I × W	NS	*	*

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). *Significant at 5% level of probability. fb: follow by; NS: not significant; WAT: weeks after transplanting.

Table 7. Interaction effect of cassava/legume intercrop and weed management practices on rice plant height at 9 WAT in 2012-2013 rainy season.

Treatment	Orizo Plus fb hoeing at 6 WAT	Two hoeing at 3 and 6 WAT	One hoeing at 3WAT	Weedy check
		2012 Rainy season		
Cassava/*Mucuna*	70.0^{cd}	77.3^{a}	70.0^{cd}	77.3^{a}
Cassava/Cowpea	71.1^{ab}	77.8^{a}	71.1^{ab}	77.8^{a}
Cassava/Soybean	67.3^{de}	76.5^{ab}	67.3^{de}	76.5^{ab}
Cassava/*Lablab*	65.3^{ef}	74.5^{ab}	65.3^{ef}	74.5^{ab}
Cassava/*Aeschynomene*	70.0^{cd}	78.0^{a}	70.0^{cd}	78.0^{a}
Sole cassava	40.7^{j}	59.8^{gh}	40.7^{j}	59.8^{gh}
Natural fallow	57.6^{hi}	55.5^{hi}	57.6^{hi}	55.5^{hi}
SE±	0.43		0.43	
		2013 Rainy season		
Cassava/*Mucuna*	104.1^{c}	111.9^{b}	104.1^{c}	111.9^{b}
Cassava/Cowpea	113.1^{b}	118.4^{a}	113.1^{b}	118.4^{a}
Cassava/Soybean	98.5^{de}	106.7^{c}	98.5^{de}	106.7^{c}
Cassava/*Lablab*	96.6^{e}	100.2^{d}	96.6^{e}	100.2^{d}
Cassava/*Aeschynomene*	112.5^{b}	118.1^{a}	112.5^{b}	118.1^{a}
Sole cassava	78.0^{hi}	80.7^{gh}	78.0^{hi}	80.7^{gh}
Natural fallow	66.4^{k}	67.7^{k}	66.4^{k}	67.7^{k}
SE±	1.23		1.23	

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). fb: Follow by.

Table 8. Effect of cassava/legume intercrop and weed management practices on rice tiller per stand.

Treatment	Number of rice tillers per stand		
	2011	2012	2013
Cassava/Legume Intercrop (I)			
Cassava/*Mucuna*	19.0[a]	25.0[a]	27.0[d]
Cassava/Cowpea	18.0[b]	23.0[b]	32.0[b]
Cassava/Soybean	16.0[c]	22.0[c]	28.0[c]
Cassava/*Lablab*	15.0[d]	21.0[d]	28.0[c]
Cassava/*Aeschynomene*	20.0[a]	26.0[a]	34.0[a]
Sole cassava	12.5[e]	14.5[e]	18.0[e]
Natural fallow	9.3[f]	9.0[f]	7.0[f]
SE±	0.2	0.3	0.2
Weed management practices (W)			
Orizo Plus fb hoeing at 6 WAT	18.0[b]	24.0[b]	30.0[b]
Two hoeing at 3 and 6 WAT	22.0[a]	27.0[a]	31.0[a]
One hoeing at 3 WAT	14.0[c]	16.0[c]	24.0[c]
Weedy check	9.0[d]	11.0[c]	15.0[d]
SE±	0.1	0.2	0.2
Interaction			
I × W	*	*	*

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). *Significant at 5% level of probability. fb: follow by; WAT: weeks after transplanting.

smother crops may in part depend on their allelopathic ability. The decomposition of products of organic mulches and cover crops residues may continue to prove toxic to weeds in subsequent crops (Silva and Rezende, 2016).

Application of Orizo Plus fb hoeing at 6 WAT and two hoeing at 3 and 6 WAT effectively reduced weed growth, in terms of weed density and dry matter. Weeds were adequately controlled thereby reducing their quantity of soil seed shedding for the succeeding year's infestation. The present results are consistent with the findings of Hasanuzzam et al. (2007) who reported that application of pre-emergence herbicide followed by one hoeing can effectively reduce weed growth in rice production. Also, Ansari et al. (2018) observed an effective reduction in weed growth when hoe weeding was carried out twice at 20 and 45 DAS in rice production.

The significant interaction between cassava/legume intercrop and weed management practices for weed density and dry matter produced suggest that reduction in weed growth among the cassava/legume intercrops responded differently to weed management practice for these parameters. The best reduction in weed growth (density and biomass) from cassava/*Mucuna* in combination with application of Orizo Plus fb hoeing at 6 WAT and two hoeing at 3 and 6 WAT would be attributable to the shading effect and competitive stress produced by the canopy of the *Mucuna* legume. This legume produced high biomass which reduced weed seed germination in preceding cropping, and reduced weed seed number in subsequent rice. This result is in agreement with Choudhary et al. (2014) who noted that the main factor enhancing weed suppression in an intercrop system is the shading effect by the crop canopy.

In this study, cassava/cowpea and cassava/*Aeschynomene* intercrop gave taller rice plants than all the other intercrop practices. These intercrops also gave comparable taller rice plants in some years with cassava/*Mucuna* and cassava/soybean intercrops than all others. This observation might be an indication of greater addition of some plant nutrients by the legumes in the intercrops especially N, which in turn enhanced rice growth. This result agrees with the findings of Morteza et al. (2008) who observed variation in rice height planted after different legumes.

It was also obvious that two hoeing at 3 and 6 WAT, gave taller rice plants than the other weed management treatments, though comparable to application of Orizo Plus fb hoeing at 6 WAT, and one hoeing at 3 WAT. The improvement in rice growth in terms of the increased height suggest the effectiveness of these weed management treatments in reducing weed-crop competition, and providing condition for better resource availability which ultimately enhanced rice growth (Khaliq et al., 2013).

The interactions between cassava/legume intercrops and weed management practice on plant height revealed

Table 9. Interaction effect of cassava/legume intercrop and weed management practices on rice tiller/stand in 2011-2013 rainy seasons.

Treatment	Orizo Plus fb hoeing at 6 WAT	Two hoeing at 3 and 6 WAT	One hoeing at 3 WAT	Weedy check
		2011 Rainy season		
Cassava/*Mucuna*	23.0^{cd}	26.0^{a}	18.0f^{g}	11.0^{klm}
Cassava/Cowpea	21.0^{e}	24.0^{abc}	16.0^{h}	9.0^{no}
Cassava/Soybean	19.0^{fg}	24.0^{bcd}	14.0^{i}	9.0^{no}
Cassava/*Lablab*	18.0f^{g}	23.0^{c}	12.0^{jk}	9.0^{no}
Cassava/*Aeschynomene*	23.0^{cd}	25.0^{ab}	19.0^{fg}	11.0^{kl}
Sole cassava	14.0^{ij}	18.0^{fg}	10.0^{lmn}	7.0^{pq}
Natural fallow	10.0^{lmn}	12.0^{k}	8.0^{op}	6.0^{q}
SE±	0.53			
		2012 Rainy season		
Cassava/*Mucuna*	28.0^{ef}	31.0^{bc}	20.0^{g}	14.0^{lm}
Cassava/Cowpea	28.0^{ef}	34.0^{a}	19.0^{gh}	13.0^{mno}
Cassava/Soybean	28.0^{ef}	30.0^{cd}	18.0^{hi}	12.0^{op}
Cassava/*Lablab*	27.0^{f}	29.0^{de}	17.0^{ij}	17.0^{ij}
Cassava/*Aeschynomene*	32.0^{b}	35.0^{a}	20.0^{g}	16.0^{jk}
Sole cassava	15.0^{kl}	20.0^{g}	14.0^{lmn}	9.0q
Natural fallow	11.0^{p}	12.0^{no}	7.0^{r}	5.0^{s}
SE±	0.22			
		2013 Rainy season		
Cassava/*Mucuna*	33.0^{d}	35.0^{c}	25.0^{f}	15.0^{jk}
Cassava/Cowpea	39.0^{b}	40.0^{ab}	33.0^{d}	17.0^{i}
Cassava/Soybean	34.0^{cd}	35.0^{c}	27.0^{e}	17.0^{i}
Cassava/*Lablab*	34.0^{cd}	35.0^{c}	27.0^{e}	17.0^{i}
Cassava/*Aeschynomene*	41.0^{ab}	42.0^{a}	33.0^{d}	19.0^{h}
Sole cassava	22.0^{g}	22.0^{g}	15.0^{k}	13.0^{l}
Natural fallow	9.0^{m}	9.0^{m}	7.0^{n}	5.0^{o}
SE±	0.52			

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). fb: Follow by.

that cassava/*Mucuna*, cassava/cowpea, cassava/*Aeschynomene* in combination with two hoeing at 3 and 6 WAT resulted in producing taller rice plants. This could be attributed to efficient weed control observed, which might have supported the uptake of essential nutrients by the rice plant and translated into enhanced vegetative growth (Nadeem et al*.,* 2011).

Cassava/*Aeschynomene* intercrop gave greater number of rice tillers per stand than all the other intercrops, but compared with cassava/*Mucuna* intercrop. This intercrop practice was able to provide season long weed control, which in turn provided favourable condition for enhanced crop growth and production of yield attributes of rice. This finding is in agreement with the work of Anders et al*.* (2004) who observed higher rice yield in rice grown after soybean than in rice-wheat rotation.

The practice of two hoeing at 3 and 6 WAT gave greater number of rice tillers, suggesting that this treatment gave efficient weed control, which provided good crop yield attributes. Kolo and Umaru (2012) and Hakim et al. (2013) also observed the production of more rice tillers in weed free plots that received two or three hoe weedings.

The significant interaction between cassava/legume intercrop on number of rice tillers per stand affirmed that the combined use of cassava/*Mucuna*, cassava/*Aeschynomene* intercrops with two hoeing at 3 and 6 WAT probably gave rise to better weed control and soil nutrient availability and utilization.

The greater number of rice panicles per plant produced by two hoeing at 3 and 6 WAT than the other weed management treatments, though comparable to application of Orizo Plus fb hoeing at 6 WAT was due to efficient weed control. This provided conditions for better

Table 10. Effect of cassava/legume intercrop and weed management practices on number of rice panicle.

Treatment	Number of rice panicle (m^{-2})		
	2011	2012	2013
Cassava/Legume Intercrop (I)			
Cassava/*Mucuna*	273.0^{a}	291.0^{a}	307.0^{b}
Cassava/Cowpea	273.0^{a}	297.0^{a}	326^{a}
Cassava/Soybean	268.0^{b}	276.0^{b}	298.0^{b}
Cassava/*Lablab*	225.0^{c}	250.0^{c}	298.0^{b}
Cassava/*Aeschynomene*	272.0^{a}	298.1^{a}	327.0^{a}
Sole cassava	193.0^{d}	180.0^{d}	188.0^{c}
Natural fallow	118.0^{e}	116.0^{e}	144.0^{d}
SE±	1.1	4.5	4.5
Weed management practices (W)			
Orizo Plus fb hoeing at 6 WAT	299.0^{b}	313.0^{a}	341.0^{a}
Two hoeing at 3 and 6 WAT	305.0^{a}	319.0^{a}	344.0^{a}
One hoeing at 3 WAT	218.0c	231.0^{b}	259.0^{b}
Weedy check	105.0d	113.0^{c}	114.0^{c}
SE±	0.8	3.4	3.4
Interaction			
I × W	*	*	*

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). *Significant at 5% level of probability. fb: follow by; WAT: weeks after transplanting.

Table 11. Interaction between cassava/legume intercrops and weed management practices on number of rice panicle (m^{-2}) in 2011-2013 rainy seasons.

Treatment	Orizo Plus Two fb hoeing at 6 WAT	Herbicide + hand weeding	One hand weeding	Weedy check
		2011 Rainy season		
Cassava/*Mucuna*	354.0^{ab}	357.0^{a}	262.0^{ef}	120.0^{l}
Cassava/Cowpea	353.0^{ab}	358.0^{a}	260.0^{ef}	120.0^{l}
Cassava/Soybean	348.0^{ab}	353.0^{b}	$256,0^{fg}$	117.0^{l}
Cassava/*Lablab*	298.0^{d}	308.0^{c}	194.0^{i}	100.0^{n}
Cassava/*Aeschynomene*	349.0^{b}	354.0^{ab}	263.0^{e}	121.0^{l}
Sole cassava	243.0^{h}	252.0^{g}	186.0^{j}	93.0^{o}
Natural fallow	150.0^{k}	155.0^{k}	107.0m	61.0^{p}
SE±	2.24			
		2012 Rainy season		
Cassava/*Mucuna*	371.0^{ab}	376.0^{ab}	286.0^{d}	132.0^{hi}
Cassava/Cowpea	378.0^{ab}	385.0^{ab}	291.0^{d}	134.0^{hi}
Cassava/Soybean	361.0^{bc}	368.0^{ab}	254.0^{e}	120.0^{ij}
Cassava/*Lablab*	340.0^{c}	340.0^{c}	208.0^{fg}	113.0^{ij}
Cassava/*Aeschynomene*	379.0^{ab}	388.0^{a}	289.0^{d}	135.0^{hi}
Sole cassava	214.0^{f}	222.0^{f}	188.0^{g}	98.0^{j}
Natural fallow	149.0^{h}	152.0^{h}	103.0^{j}	60.0^{k}
SE±	3.44			

Table 11. contd.

	2013 Rainy season			
Cassava/*Mucuna*	399.0^{cd}	400.0^{bcd}	295.0^{e}	134.0^{h-k}
Cassava/Cowpea	420.0^{abc}	425.0^{ab}	318.0^{e}	141.0^{hij}
Cassava/Soybean	386.0^{d}	390.0^{d}	296.0^{e}	122.0^{jkl}
Cassava/*Lablab*	385.0^{d}	389.0^{d}	296.0^{e}	122.0^{jkl}
Cassava/*Aeschynomene*	425.0^{ab}	427.0^{a}	314.0^{e}	225.0^{f}
Sole cassava	226.0^{f}	144.0^{hij}	194.0^{g}	110.0^{kl}
Natural fallow	147.0^{hi}	151.0^{h}	99.0^{l}	62.0^{m}
SE±	9.03			

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT).

Table 12. Effect of cassava/legume intercrop and weed management practices on rice paddy yield.

Treatment	Rice paddy yield (kg ha^{-1})		
	2011	**2012**	**2013**
Cassava/Legume intercrop (I)			
Cassava/*Mucuna*	2733.3^{b}	4565.6^{b}	4684.0^{b}
Cassava/Cowpea	2933.3^{a}	4836.9^{a}	5039.6^{a}
Cassava/Soybean	2200.0^{c}	3963.5^{c}	4329.5^{c}
Cassava/*Lablab*	2066.7^{d}	3558.6^{d}	3821.7^{d}
Cassava/*Aeschynomene*	2800.0^{b}	4718.5^{a}	5000.0^{a}
Sole cassava	1466.7^{e}	2576.5^{e}	2670.0^{e}
Natural fallow	1096.7^{f}	1042.5^{f}	1005.0^{f}
SE±	66.7	49.2	77.1
Weed management practices (W)			
Orizo Plus fb hoeing at 6 WAT	2733.3^{b}	4921.2^{b}	5196.8^{a}
Two hoeing at 3 and 6 WAT	3200.0^{a}	5219.8^{a}	5330.9^{a}
One hoeing at 3 WAT	1666.7^{c}	2732.9^{c}	2848.8^{b}
Weedy check	866.7^{d}	852.1^{d}	843.3^{c}
SE±	20.0	37.2	58.3
Interaction			
I × W	NS	NS	NS

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (DMRT). NS: Not significant; fb: follow by; WAT: weeks after transplanting.

crop yield. The present result is consistent with previous studies in which plots weeded twice at 15 and 30 DAS, increased number of rice panicles, and comparable to plots given bispyribac-sodium or ethoxysulfuron fb manual weeding at 30 DAS (Ihsan et al*.,* 2014).

The interaction between cassava/legume intercrop and weed management practice on number of rice panicle revealed that cassava/*Mucun*a, cassava/cowpea, cassava/*Aeschynom*e intercrops with two hoeing at 3 and 6 WAT produced similar highest number of rice panicles per unit area. This could be attributed to the greater number of tillers produced per stand, which might have produced more panicles per unit area (Maite et al., 2015). The greater number of rice panicles per plant from cassava/cowpea and cassava/*Aeschynomene* intercrops compared with cassava/*Mucuna* intercrops could be attributed to effective weed growth reduction, which translated into enhanced crop yield attributes. Mobasser et al. (2007) also observed that greater number of panicles m^{-2} gave higher grain yield.

In this study, cassava/cowpea intercrop gave the highest paddy yield than the other intercrop practices, though comparable to cassava/*Aeschynomene*. These intercrop practices gave taller rice plants and more rice panicles, thereby provided conditions for enhanced rice growth and yield.

Expectedly, paddy yield of rice was more in plots given two hoeing at 3 and 6 WAT, because it gave the best weed control (reduced weed density and biomass), produced taller plants, greater number of tillers and panicles per stand which translated into enhanced paddy yield of rice. Conversely, the highest paddy yield recorded with two hoeing at 3 and 6 WAT was comparable with application of Orizo Plus fb hoeing at 6 WAT. This may be attributed to efficient weed control which suggests reduced nutrients depletion by the weeds, which in turn enhanced rice growth, yield and yield attributes. Similar results have been reported in a previous study in Pakistan in which paddy yield of rice was increased with two hoeing at 15 and 30 DAS, which was comparable to application of bispyribac sodium or ethoxysulfuron ethyl followed by one manual weeding at 30 DAS (Ihsan et al., 2014).

Conclusion

Based on the results of the present investigation, it can be concluded that in terms of weed management, the best treatments were cassava/*Mucuna* intercrop under two hoeing at 3 and 6 WAT, or Orizo Plus fb hoeing at 6 WAT. Increased growth and yield of rice can be realized in this agro ecology with cassava/cowpea, cassava/ *Aeschynomene* intercrop in combination with two hoeing at 3 and 6 WAT or with application of Orizo Plus fb hoeing at 6 WAT.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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