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Effect of cassava-sweet potato intercrops patterns and weed control methods on weed suppression.

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ABSTRACT

Field trials were conducted to investigate complementary weed control potential of sweet potato on cassava in 2015, 2016 and 2017 cropping seasons at the National Cereal Research Institutes' farm, (NCRI), Amakama (07˚29′N latitude and 05˚28´E longitude), South Eastern Nigeria. The study was laid out in a split plot arrangement in a Randomized Complete Block Design (RCBD) with three replicates. The main plots consisted of intercrop patterns which included two populations of sweet potato (10,000 and 20,000 plants ha-1) between rows of cassava, planted at 0, 4 and 8 weeks after planting cassava (WAP), sole cassava (SC) and sole sweet potato (SS), The sub-plots were four weed control treatments viz pre-emergence application of S-metolachlor+atrazine at 1.16+1.48 kg a.i ha-1 alone (P), S-metolachlor+atrazine at 1.16+1.48 kg a.i ha-1 followed by supplementary hoe weeding at 8WAP (PHW1), three hoe weedings at 4, 8 and 12 WAP (3HW) and a weedy check (0W). Results indicated that Cassava intercropped at the same time with sweet potato at 20,000 plant ha-1 (CS200) significantly reduced weed density and dry matter compared with SC which gave the poorest weed control. Weed density and dry matter were higher with cassava+sweet potato introduced at 8 WAP at both populations (CS108 and CS208) comparable to SC. There were statistically significant differences in weed growth between the different weed control methods. PHW1 significantly suppressed weed growth as effectively as 3HW when compared to 0W. The weedy check (0W) and P recorded the poorest weed control and performance of these crops at harvest. Although weed density and drymatter was significantly reduced by CS200 and PHW1 independently, results from this study suggested that CS200 combined PHW1 could provide a sustainable integrated weed management system than sole cassava, introducing the sweet potato at 8 WAP or herbicide treatment alone in the study area.

1. INTRODUCTION

Majority of tropical farmers often adopt hoe weeding, thrice in cassava-based intercrop (Umanah, 2005). This approach is costly, cumbersome and unreliable (Lavabare, 1991). The drudgery associated with this makes traditional farming unattractive and uneconomical, particularly by the younger generation of farmers because weed limits the area of land that can be cultivated as weed infestation is heavy and its reinfestation and growth are rapid allowing no breathing space for the farmer (Akinpelu *et al.,* 2006).

Weed interference reduces yield and yield components by competition with crops for growth resources which are in limited supply (Ahmed and Moody, 1980). Cassava competes well with weeds once its canopy has fully been formed. However, its ability to compete with weeds depends to some extent how long the crop stays weed free after planting before the canopy covers the ground. Several studies have reported that most pre emergence herbicides could only control weeds satisfactorily for 8 WAP and thereafter, only frequent hand weeding operations or intercropping gave satisfactory control of weeds for the remaining life of the crop (Olorunmaiye and Olorunmaiye, 2009; Iyagba and Ayeni, 2000a; b; Imoloame, 2014; Ekpo *et al.*, 2012). For instance, Olorunmaiye and Olorunmaiye (2009) reported lower weed biomass and higher yield with atrazine+metolachlor (2.5 kg a.i. ha^{-1}) supplemented with 2 hoe weeding as atrazine+metolachlor (2.5 kg a.i. ha^{-1}) alone gave satisfactory weed control only for about 6 WAP but failed to give long season weed control. Good shading of the ground is obtained in an intercropping system by growing crops with different architecture. Apart from the production of higher total yield from a given area of land, insurance against crop failure, reduction in the levels of insect pests, diseases and better use of growth resources among others (Njoku and Muoneke 2008; Isoken, 2000), one benefit of intercropping is the ability to suppress weed better than a sole crop (Taiwo and Ekeleme, 2008; Okeleye *et al.,* 1999; Imeokparia, 1999; Eneji *et al.,* 1995).Akobundu (1987) showed that both sweet potato and egusi melon are good substitute for repeated hand weeding in maize/cassava, maize/yam and maize/yam/cassava intercropping systems. There is need to characterize integrated weed management system involving time of planting and population of sweet potato, reduced rate of herbicide and hoe weeding in cassava-sweet potato-based intercrop system. Such information will be useful in mitigating the drudgery associated with repeated hoe weeding in cassava production. Therefore, this study evaluated different cassava/sweet potato cropping patterns and weed control methods in order to determine the best combination that will give most effective weed control and result in higher productivity of cassava.

2. MATERIALS AND METHOD

2.1. Experimental site

The experiment was conducted at the National Cereal Research Institute (NCRI) farm Amakama Nigeria (Latitude 05°27´ N, longitude 07°29´ E and an altitude of 161m above sea level) in the 2015, 2016 and 2017 cropping seasons. The climate of the experimental site showed a typical rainforest with a bimodal rainfall distribution (Table 1). The soil of the experimental area was a deep, well drained sandy loam classified as Haplic Nitosol (Onyekwere *et al*., 2012) with pH (4.6 to 5.06), Organic matter (1.18 – 1.32), total Nitrogen N (0.05 - 0. 33), Phosphorus (12.50 to 19.6 mg/kg ha^{-1}),exchangeable Potassium (0.081 to 0.25cmolkg^{-1}), Calcium (2.45 - 8.00 cmol kg^{-1}), Magnessium (1.20 to 2.00 cmolkg^{-1}) Sodium (0.145 to 0.365), and Effective Cation Exchange Capacity (6.355 and 10.62) during the cropping seasons.

Table 1: Monthly and average annual rainfall (mm) at, Amakama, Abia State during the cropping seasons.

Month/Year	Cropping Season and Average Annual Rainfall (mm)		
	2015	**2016**	**2017**
January	2.1	0.0	34.3
February	33.4	59.5	0.0
March	138.8	109.9	102.5
April	280	181.3	130.0
May	294.4	276.2	125.4
June	395.0	276.2	284.7
July	239.4	212.5	433.9
August	341.3	543.3	367.9
September	341.4	501.1	306.0
October	350.3	225.1	160.3
November	62.5	74.4	26.2
December	0.0	5.2	0.0
Total	2226.1	2462.7	1971
Mean	185.5	205.3	164.2

Source: National cereals Research Institute, Amakama (2015, 2016 and 2917)

2.2. Experimental design and treatments

The experiment was set up in a split plot arrangement in a Randomized Complete Block Design (RCBD) with three replicates. Cassava/sweet potato intercrop systems involving two different populations of sweet potato (10,000 and 20,000 plantsha^{-1}) and three different times of introduction of sweet potato (0, 4 and 8 weeks after planting cassava (WAP)) formed the main plot treatments while weed control methods formed the sub plot trearments. The main plot treatments were sole cassava cropping (SC), cassava+sweet potato planted together at 10,000 plantsha^{-1}(CS100), cassava+sweet potato planted together at 20,000plants ha^{-1}(CS200), cassava+sweet potato planted 4 WAP at 10,000 plantsha^{-1}(CS104), cassava+sweet potato planted 4WAP at 20,000 plants ha^{-1}(CS204),cassava+sweet potato planted 8 WAP at 10,000 plantsha^{-1} (CS108), cassava+sweet potato planted 8 at WAP 20,000 plants ha^{-1} (CS208), and sole sweet potato plot (SS). The sub plot treatments included S-metolachlor+atrazine at 1.16+1.48 kg a.i. ha^{-1} (P),S-metolachlor+atrazine at 1.16+1.48 kg a.i. ha^{-1} plus one hoe weeding at 8 WAP (PW1), Three hand weeding at 4, 8 and 12WAP (3HW) and an unweeded plot (0W). Each main plot measured 19m x 4m (76m^2) and was separated by a 1m alley while the replicates were separated by a 2 m alley giving a total area of 64m x 40m (0.2624ha). The sub plot treatments measured 4m x 4m (16m^2) each and separated by a 1m alley.

Planting of cassava and sweet potato (first introduction) was done on the 23rd ,17th and 6th June in 2015, 2016 and 2017 respectively, the second introduction of sweet potato at 4 WAP was done on 20th, 16th and 6th July while the 3rd introduction at 8WAP was on the 17th, 13th and 3rd August in the three years respectively. Cassava cuttings was planted at 1m x 1m spacing by placing the cutting at an angle of 45° on the crest of the ridge to give a plant population of 16 plants per plot (10,000plantsha^{-1}). The sweet potato vines were planted mid way to the side of the ridge at 1m x 1m and 1m x 0.5 m to give a plant population of 10,000 and 20,000 plants ha^{-1} respectively for the cassava sweet potato intercrop systems. The sole sweet potato plot was planted on the crest of the ridge at 1m x 0.3m spacing giving a plant population of 33,000plants ha^{-1} (Korieocha, 2015). In order to maintain a uniform and optimum population of crops in all seasons, diseased, dead or unviable planted materials were supplied at 2 WAP. Compound fertilizer (NPK 15:15:15) was applied for both crops at 4 WAP at the rate of 400kgha^{-1} for cassava and 200kgha^{-1} for sweet potato. Fertilizer application was by side banding at a single dose. There was a 2m alley between the borders of the entire field and other fields or bushes which was kept weed free through out the experiment in the three years of study. Ridge bars were erected in each block and in areas that were prone to flooding to prevent erosion.

2.3. Experimental procedure and statistical analysis

Weed density was assessed at 4, 8 and 12WAP just before weeding operations using two quadrants (1m x 0.5m) placed halfway on top of the ridge in such a way that the furrow is half way covered in each plot. Weeds within the quadrants were counted to obtain the weed density (plants m^{-2}), cut above ground, bulked into a tagged brown khaki envelope for each plot for proper identification and then oven dried at a temperature of 105℃ for 72hours to obtain a constant dry matter weight of the weeds using a digital sensitive balance for the assessment of dry matter (g m^{-2}). The final weed density and dry matter was assessed at harvest (10 MAP). Other yield contributing characters were recocorded. Data collected were compiled and subjected to Analysis of Variance (ANOVA) using the GenStat Release 12.1(2012) edition and differences between two treatment means were compared using least significant difference (LSD) at 5% level of probability.

3.0. RESULTS AND DISCUSSION

3.1. Weed composition

The experimental field was dominated by broad leaves 60%, grasses 28.6% and sedges 11.4% in 2015 whereas in 2016 and 2017, the ratio of broad leaves, grasses and sedges where 54.9%, 11%, 29.1% and 49.6%, 38.5% and17.5% respectively. The prominent weed species were *Panicum maximum, Oldenladia corymbosa, Spermacoce verticillata, Lindernia antipoda, Cyperus sp., Killinga bulbosa, Charmaecrista rotundufolia* and *Digitaria horizontalis* (Table2).

Table 2. Weed species composition at the experimental field in 2015, 2016 and 2017 cropping seasons.

Weed species	Family	Life span	Degree of occurrence		
			2015	2016	2017
Broadleaves					
Spermacoce verticillata	Rubiaceae	A	+	+++	+ +
Lindernia antipoda	Scrophulariaceae	**A**	+	++	+
Oldenlandia corymbosa	Rubiaceae	A	+++	+	++
Platostoma africanum	Lamiaceae	A	+	+	+
Phyllantus niruri var. *amarus*	Euphorbiaceae	A	+	+	+
Ageratum conyzoides	Asteraceae	A	-	+	+
Cleome viscose	Capparidaceae	A	+	+	+
Ipomoea involucrata	Convulvulaceae	P	+	+	+
Chamaecrista rotundifolia	Leguminosae	P	++	+	+
Commelina benghalensis	Combretaceae	A	-	+	+
Tridax procumbiens	Tiliaceae	A	+	+	-
Calapogonum mucunoides	Leguminoseae	A	+	+	+
Sessemia indicum	Pedaliaceae	A	+	-	-
Aspilia africana	Euphorbiaceae	A	+	-	-
Chromolaena odorata	Asteraceae	P	+	-	-
Sida acuta	Malvaceae	P	+	-	-
Croton lobata	Euphorbiaceae	A	-	+	-
Talinum triangulea	Portulacaceae	P	-	+	-
Diodia scandens	Rubiaceae	P	-	+	-
Mimosa invisa	Leguminoseae	P	-	+	-
Grasses					
Panicum maximum	Poaceae	P	+++	+	+++
Imperata cylindrica	Poaceae	P	-	+	-
Digitaria horizontalis	Poaceae	A	+	+	+
Paspalum conjugatum	Poaceae	A	+	+	+
Brachari alata	Poaceae	A	+	+	+
Sedges					
Killinga bulbosa	Cyperaceae	P	+	+++	+
Fimbristylis littoralis	Cyperaceae	P	+	+	+
Cyperus sp	Cyperaceae	P	++	+	+

*A=Annual, P=Perrenial

Similar trends in weed class composition have been documented for cassava farms in different zones in Nigeria and Africa (Usman *et al.,* 2013; Toure *et al*., 2013; Sharma and Dairo, 1981; Onochie, 1975; Ekeleme *et al.,* 2004).The prevalence of broad-leaved weeds over grasses and sedges agreed with Watanabe *et al.* (1998) who reported that broadleaves emerge over a longer period of time within a growing season.

3.2. Effect of cropping pattern and weed control methods on weed density

Weed density was similar among the cropping patterns at 4 WAP and 8 WAP in the three years of study (Table 3). However, at 12WAP in 2015 and 2017 cropping seasons, weed density was similar and significantly higher in CS100 (74.2 and 57.0 plants m^{-2}) and CS200 (50.2, 57.6 plants m^{-2}) when compared with sole cassava (42.2 and 33.8 plants m^{-2}). This may be attributed to the fairly moist environment created by the sweet potato ground cover. Factors such as reduced light intensity, temperature and soil evapotranspiration individually or in combination can delay, reduced or increase weed seedling germination and emergence (Teasedale and Mohler, 1993). Contrary to this trend at 12 WAP in 2016, these plots had the lowest weed density of 13.7 plant m^{-2} and 21.5 plant m^{-2} respectively compared to the other treatments except with CS204 which had similar (P≥0.05) weed density (24.0 plants m^{-2}). This may be attributed to the longer fallow status of the experimental site used in 2016 which agreed with reports of Szott *et al.*(1991) and Moody (1975) that weed seed bank is generally low in the season after opening of land that have been under fallow. The extra ground cover provided by the vigorously growing sweet potato created unfavorable conditions for some of the weeds to germinate.

At 10MAP in 2015 and 2016, weed density was significantly higher in sole cassava when compared to CS100, CS200 and CS204 but was at par with the other treatments (Table 3). However, in 2017, sole sweet potato had a significantly higher weed density than the rest of the cropping patterns at 10 MAP. Weed density was similar in sole cassava, CS108 and CS208 across the years at 10 MAP (P≥0.05). Averaged over the three years at 10 MAP, weed suppression followed the order SS < SC < CS208 < CS108 < C 104 < CS204 < CS100 < CS200 (Table 2). The lower weed density observed in the intercrops especially CS200 and CS100 indicated a better weed control due to good and early ground cover in these treatments. This result agreed with the findings of Amosun and Modupe (2016) who reported a better weed suppression due to higher plant population and better ground cover in cassava groundnut-based intercrop system. Similarly, Olatasan *et al.* (1996) reported that cassava-based intercrop reduced light penetration to the soil through better soil coverage, thus reducing weed growth. The higher weed density observed in SS at 10 MAP in 2017 might be attributed to the harvest of sweet potato at 4 MAP which exposed the plot to longer time of light transmission and weed growth at cassava harvest. The similarity in weed density between SC, CS108 and C208 may be attributed to the time of introduction of the sweet potato (8 WAP) which extended its growing period to a time of reduced rainfall and soil moisture (Oct. - Nov., Table 1). It has been reported that sweet potato requires adequate rainfall to achieve good sprouting and growth (Ramirez, 1992).

Weed density was significantly reduced by P and PHW1 at 4 WAP in the three years of study compared to the weedy check (Table 3). At 8 WAP in 2015, weed density was significantly lower in 3HW (15.7 plant m^{-2}) compared to the other treatments while 0W recorded the highest weed density (99.0 plant m^{-2}). However in 2016 and 2017 at 8 WAP, weed density was similar and significantly reduced in P and PHW1 when compared with 0W. Weed density values from these treatments (P and PHW1) were statistically similar (P≥0.05) to that of 3HW which recorded the lowest weed density (27.1 plant m^{-2}) at 8 WAP in 2017. This result agreed with the findings of Olorunmaiye and Olorunmaiye (2009) and Akinyemiju (1992) that Primextra gold (a mixture of atrazine and metolachlor) is able to suppress weed growth only for the first 4 WAP – 8WAP. At 12 WAP in the three years, weed density was similar and significantly reduced in PHW1 and 3HW compared to the weedy check (0W). Weed density was also significantly higher in P at 12 WAP compared to PHW1 and 3HW but was significantly lower when compared with 0W in 2015 and 2017 (Table 3). The same trend was observed at 10 MAP in the three years of study with 3HW having the lowest weed density whereas 0W had a significantly higher weed density comparable to P but differed from the other treatments. Weed density obtained from PHW1 was similar to those of 3HW in 2015 and 2017 but was significantly lower compared to P and 0W at 10 MAP in the three years of study. These results indicated poor weed control with P alone (Table 3). Ekpo *et al*. (2012) and Olorunmaiye (2010) had previously demonstrated that S-metolachlor+atrazine applied without supplementary weeding did not sufficiently control weeds up to 12 WAP. Olorunmaiye and Olorunmaiye (2009) recommended that S-metolachlor+atrazine at 2.5 kg a.i ha^{-1} should be supplemented with two hoe weeding at 6 WAP and 12 WAP to give adequate long season weed control in cassava maize intercrop system. This was true in this study because, even at 10 MAP, PHW1 maintained a significantly lower weed density comparable to 3HW, whereas a higher weed density that was similar to that of the weedy check was recorded in P. The order of weed suppression in the three years of study at 10 MAP was 3HW > PHW1 > P > 0W. Similar results have been reported in maize by Chikoye *et al*. (2009) that plots treated with S-metolachlor+atrazine at 2.5 kg a.i ha^{-1} without supplementary hoe weeding was similar in weed density to unweeded treatment at crop harvest.

Table 3: Effect of cropping pattern and weed control methods on weed density in 2015, 2016 and 2017 cropping seasons.

	Weed density (plants m^{-2}),Weeks after planting (WAP) and Cropping season											
	4WAP			8WAP			12WAP			10MAP		
Treatments	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
Cropping Pattern (CP)												
SC	43.2	3.2	24.7	48.0	30.8	41.6	42.2	34.2	33.8	51.7	28.42	26.8
CS100	46.7	1.5	25.0	58.7	35.7	49.3	74.2	13.7	50.2	32.3	12.9	17.9
CS200	36.0	1.92	31.8	51.8	30.5	46.7	57.0	21.5	57.6	26.6	11.8	17.3
CS104	33.1	2.75	31.0	42.2	30.5	46.6	47.9	33.2	46.8	41.4	25.3	20.2
CS204	36.5	3.58	22.6	53.2	25.4	36.3	50.5	24.0	38.8	31.7	13.8	19.5
CS108	38.5	2.25	23.2	54.2	23.4	41.8	43.1	35.0	44.0	48.7	23.8	24.0
CS208	39.7	2.26	21.4	54.8	25.5	44.6	43.4	35.1	42.5	47.8	25.1	26.7
SS	-	-	18.8	-	-	38.8	-	-	48.1	-	-	43.3
LSD (CP)	**13.10**	**1.86**	**12.01**	**20.12**	**14.79**	**14.21**	**18.98**	**15.42**	**13.13**	**17.4**	**9.43**	**7.09**
Weed Control method (WC)												
P	0	0	0	51.0	19.0	30.1	68.4	33.1	54.6	56.7	27.81	28.2
PHW1	1.4	0.86	0	55.3	22.2	28.5	20.9	21.7	18.5	21.3	15.0	17.7
3HW	56.9	4.49	46.4	15.7	35.0	27.1	25.1	20.2	19.5	16.2	7.9	16.5
Weedy check	52.7	5.0	52.9	99.0	33.4	87.1	90.3	37.4	88.3	65.8	29.9	35.5
LSD(WC)	**11.10**	**1.60**	**9.64**	**13.47**	**8.76**	**7.04**	**13.37**	**6.12**	**8.99**	**11.01**	**5.91**	**5.97**
LSD (CP*WC)	**20.0**	**4.01**	**26.01**	**35.84**	**24.16**	**21.17**	**35.09**	**20.10**	**25.09**	**29.76**	**15.45**	**15.96**

* MAP=Months after planting cassava, SC=Sole cassava. SS=Sole sweet potato. CS100=Cassava intercropped with sweet potato at the same time at10,000 plants ha^{-1}, CS200= Cassava intercropped with sweet potato at the same time at 20,000 plants ha^{-1}, CS104= Cassava intercropped with sweet potato 4WAP at 10,000 plants ha^{-1}, CS204= Cassava intercropped with sweet potato 4 WAP at 20,000 plants ha^{-1}, CS108= Cassava intercropped with sweet potato 8 WAP at 10,000 plants ha^{-1}, CS208= Cassava intercropped with sweet potato 8 WAP at 20,000 plants ha^{-1}, LSD=Least significant difference, P=S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1}, PHW1= S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1} followed by one hoe weeding at 8 WAP, 3HW=Three hoe weeding.

3.3. Interactive effect of cropping pattern and weed control methods on weed density

Weed density was significantly reduced by the combination of cropping pattern and weed control methods at 10 MAP in 2015 and in 2017 cropping seasons (Table 4). In 2015, weed density was significantly lower in C200 combined with 3HW (3.0 plants m^{-2}) when compared to the weedy CS108 (102 plants m^{-2}) which had the highest weed density. However, weed density in this treatment combination was comparable to those of other cropping patterns combined with 3HW and PHW1 but differed from other cropping patterns combined with 0W and P alone (Table 4).

The same trend was oberved in 2017 where 3HW and PHW1 significantly reduced weed density ($P \leq 0.05$) when compared with P and 0W across the cropping patterns (Table 4). However, the lowest weed density (5.7 plants m^{-2}) was recorded under CS104 combined with 3HW, whereas SS combined with 0W had the highest weed density. Weed density under weedy SS in 2017 was comparable to SS combined with P, SC combined with 0W and CS208 combined with 0W but differed from those of the other treatments.

Averaged over both years, 3HW generally reduced weed density more than any other weed control method across all the cropping patterns except for plots combined with PHW1 which confirmed that S-metolachlor+atrazine at 2.5 kg a.i ha^{-1} should be supplemented with hoe weeding to efficiently control weeds up to 8 WAP (Olorunmaiye and Olorunmaiye, 2009; Ekpo *et al*., 2012; Akinyemiju, 1992), when weed interference is most critical in cassava. It also confirmed that sweet potato planted in August generally have a lower fodder yield and leaf to stem ratio (Mwanga and Zamora, 1989; Etela and Anyanwu, 2011) which reduces its potential of being a good weed suppressant. This observation may be attributed to the time of introduction of the sweet potato at 8 WAP when weed seedling had a major emergence peak which probably interfered with sweet potato growth. The higher weed density observed in the sole sweet potato plot across all the weed control methods at 10 MAP was probably due to the removal of sweet potato cover as a result of crop harvest which predisposed the plot to more light transmission and more vigorous weed growth.

3.4. Effect of cropping pattern and weed control methods on weed dry matter

Weed dry matter was significantly influenced by cropping patterns ($P \leq 0.05$) in the three years of the study at 12 WAP and 10 MAP. However, in 2016, weed dry matter was also significantly influenced by cropping pattern at 8 WAP (Table 5). At 12 WAP in 2015 and 2016, CS200 significantly reduced weed dry matter when compared with SC. Weed dry matter in CS200 was 46.0 and 1.85 gm^{-2} while SC recorded 96.2, 13.6 and 30.5gm^{-2} (Table 5). In 2017, weed dry matter was significantly lower in SS at 12 WAP (14.0 gm^{-2}) than the other treatments except with CS100 (18.2 gm^{-2}) and CS200 (16.4 gm^{-2}). The same trend was observed at 10 MAP in 2015, 2016 and 2017 with the same treatment (CS200) having significantly lower weed dry matter (38.4, 16.6 and 43.9 gm^{-2}) when compared with those of SC, CS208 and CS108. Weed dry matter recorded under CS200 and those of CS100 and CS204 were similar ($P \geq 0.05$) at both sampling dates and years. The lower weed dry matter obtained in CS200 at 12 WAP and 10 MAP may be attributed to good sweet potato ground cover in this treatment which reduced light transmission and prevented emerged weed seedlings from vigorous growth and dry matter accumulation. According to Olatasan *et al.* (1996), intercropping cassava with maize reduced radiation and soil temperature compared to sole cassava. Plant population and planting date of the sweet potato may be responsible for the lower weed dry matter in CS200 comparable to SS which was significantly different ($P \leq 0.05$) from sole cassava. This finding agreed with Amosun and Modupe (2016) who reported greater weed control with increased groundnut population from 40,000 plant ha^{-1} to 160,000 plants ha^{-1} in cassava-groundnut based intercrop. At 10 MAP in 2017, weed dry matter was significantly higher in SS than those in other treatments due to sweet potato harvest which exposed the plots to light transmission. At all sampling dates in the three years of study, weed dry matter was significantly similar in SC, CS108 and CS208 possibly due to the time of introduction of sweet potato which gave room for excessive weed emergence and growth. There was significantly poor sweet potato ground cover in these cropping patterns up to 16 WAP compared to the other intercropped plots. Weed competition occurred at the early growth stage of cassava due to its slow initial growth in the first 4 – 12 WAP (Onochie, 1978; Akobundu, 1987). Sweet potato developed rapid canopy from 8 WAP reaching its maximum at 16 WAP. Therefore, introducing sweet potato at 8 WAP delayed its canopy formation till after 16 weeks after planting cassava thereby allowing luxuriant weed growth in these plots. The critical period of weed interference in cassava have been reported to be between 4 WAP and 12 WAP (Melifonwu, 1992). The high weed dry matter recorded under SC confirmed the findings of Okeleye *et al*. (1999) and Eneji *et al*. (1995) that weed dry matter was significantly reduced in plots planted with sweet potato than in sole crop. Similarly, Taiwo and Ekeleme (2008) have also reported that sweet potato cover at 10,000 plants ha^{-1} was effective in suppressing speargrass in soybean intercrop.

Table 4: Interactive effect of cropping pattern and weed control methods on weed density at 10 MAP in 2015, 2016 and 2017 cropping seasons.

	Weed density (plants m^{-2}), Weedcontrol methods (WC) and Cropping season														
	P			PHW1			3HW			0W			Mean		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
Cropping Pattern (CP)															
SC	**78.3**	39.67	**33.33**	**20.7**	26.67	**13.0**	**10.7**	11.0	**17.7**	**97.0**	36.3	**43.0**	**51.7**	**28.42**	**26.8**
CS100	**43.3**	16.33	**17.7**	**24.3**	8.0	**10.3**	**14.0**	5.7	**9.7**	**45.7**	21.67	**34.0**	**32.3**	**12.92**	**17.9**
CS200	**53.3**	11.67	**29.0**	**3.7**	13.33	**24.3**	**10.3**	8.3	**8.3**	**46.3**	14.0	**7.7**	**26.6**	**11.8**	**17.3**
CS104	**72.0**	38.67	**33.7**	**29.7**	15.33	**10.3**	**22.7**	7.0	**5.7**	**41.3**	40.3	**31.3**	**41.4**	**25.3**	**20.2**
CS204	**52.0**	19.67	**20.7**	**23.7**	9.67	**15.7**	**18.0**	6.3	**10.0**	**33.3**	19.6	**31.7**	**31.7**	**13.9**	**19.5**
CS108	**46.7**	29.3	**20.7**	**26.7**	19.00	**10.3**	**18.3**	11.3	**35.7**	**102.3**	35.3	**29.3**	**48.4**	**23.8**	**24.0**
CS208	**49.0**	39.3	**26.0**	**20.7**	13.00	**22.0**	**26.7**	5.7	**11.0**	**95.0**	42.3	**47.7**	**47.8**	**25.0**	**26.8**
SS	**-**	-	**44.7**	**-**	-	**35.3**	**-**	-	**33.7**	**-**	-	**59.7**	**-**	**-**	**43.3**
Mean	**56.7**	**27.8**	**28.2**	**21.3**	**15.0**	**17.7**	**16.2**	**7.90**	**16.5**	**65.8**	**29.95**	**35.5**	**-**	**-**	**-**
LSD (CP)	**17.4**	**9.48**	**7.09**												
LSD (WC)	**11.0**	**5.59**	**5.97**												
LSD (CP*WC)	**29.8**	**15.45**	**15.96**												

* MAP=Months after planting cassava, SC=Sole cassava. SS=Sole sweet potato. CS100=Cassava intercropped with sweet potato at the same time at10,000 plants ha^{-1}, CS200= Cassava intercropped with sweet potato at the same time at 20,000 plants ha^{-1}, CS104= Cassava intercropped with sweet potato 4WAP at 10,000 plants ha^{-1}, CS204= Cassava intercropped with sweet potato 4 WAP at 20,000 plants ha^{-1}, CS108= Cassava intercropped with sweet potato 8 WAP at 10,000 plants ha^{-1}, CS208= Cassava intercropped with sweet potato 8 WAP at 20,000 plants ha^{-1}, LSD=Least significant difference, P=S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1}, PHW1= S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1} followed by one hoe weeding at 8 WAP, 3HW=Three hoe weeding.

Weed dry matter significantly varied (P≤0.05) among the weed control methods across all the sampling dates in the three years of study (Table 5). At 4 WAP in the three years, weed dry matter was significantly reduced by P and PHW1 when compared with the weedy check (0W) and 3HW. At 8 WAP, weed dry matter was significantly lower in 3HW compared to the weedy check. However, weed dry matter from 3HW was similar to those of P and PHW1 at 8 WAP in 2016 and 2017 (Table 5). At 12 WAP and 10 MAP in the three years, weed dry matter was similar with 3HW and PHW1 both of which were significantly lower than values obtained from P and 0W. At all sampling dates and years, weed dry matter was significantly higher in the weedy check compared to the other treatments except at 10 MAP where it was similar (P≥0.05) to P. PHW1 and 3HW provided adequate long season weed control as significantly lower weed dry matter was observed in these treatments compared with other weed control methods. Similar results have been reported by Ekpo *et al.* (2012), Olorunmaiye and Olorunmaiye (2009) and Chikoye *et al.* (2005). According to these authors, S-metolachlor+atrazine at 2.5 kg a.i. ha^{-1} plus supplementary hoe weeding gave good weed control. Olorunmaiye and Olorunmaiye (2009) particularly noted that the effect of this S-metolachor+atrazine at 2.5 kg a.i. ha^{-1} with supplementary by 2 hoe weedings treatment was visible up to 20 WAP stating that P without supplementary weeding was similar to weedy plots at cassava harvest. These results further confirm the earlier report of Akobundu (1987) that most herbicide treatments gave an early season weed control and soon loose their efficacy as observed in the plots treated with P alone. Short soil persistence of S-metolachlor and atrazine have been well documented (Weller and Owen, 2016).

Generally, weed dry matter was lower in 2016 compared to 2015 and 2017. This might be attributed to the lower weed density in 2016 probably as a result of the fallow status of the experimental site before establishment of trials. This observation is in line with the report of Szott *et al.* (1991) that fallow reduces weed seed bank in the year after opening of the land. Another reason for this might be due to the minor status of grasses like *Panicum maximum* which accumulates greater dry matter compared to *Spermacoce verticillata* and *Lindernia antipoda.*

3.5. Interactive effect of cropping pattern and weed control methods on weed dry matter

Weed dry matter was significantly (P≤0.05) influenced by cropping pattern and weed control method combination at 12 WAP in the three years of the study (Table 7), at 8 WAP in 2016 (Table 6) and at 10 MAP in 2015 (Table 8). At 8 WAP in 2016 weed dry matter was similar and significantly higher in CS108 (1.0 and 2.23 gm^{-2}), CS208 (1.77 and 2.50 gm^{-2}) and SC (1.87 and 1.87 gm^{-2}) combined with P and 0W than the other treatments (Table 6). Weed dry matter was significantly reduced by CS100 combined with 3HW (0.27 gm^{-2}) when compared with the weedy sole cassava, CS108 and CS208. However, weed dry matter in this treatment combination was similar to those of the other cropping patterns combined with 3HW and PHW1 except with CS104 at 8 WAP in 2016. Similarly, at 12 WAP across the years, the same trend followed with the weedy SC, CS108 and CS208 having a significantly higher weed dry matter compared with the other treatment combinations (Tables 7). At 10 MAP in 2015, weed dry matter was significantly higher with SC combined with 0W (Table 8). Weed dry matter recorded under this treatment combination (208.7 gm^{-2}) was similar to those obtained from C combined with P and weedy CS108 but differed from the rest of the treatment combinations. The lowest weed dry matter was recorded under CS108 combined with 3HW (0.0 gm^{-2}). However, weed dry matter was similar and significantly lower under all cropping patterns combined with 3HW and PHW1. Apart from SC combined with P and 0W, CS208 combined with P and 0W and CS108 combined with 0W which had significantly higher weed dry matter. Weed dry matter was similar (P≥0.05) in all cropping patterns combined with either P or 0W at 10 MAP in 2015 (Table 8). Among the weed control methods, 3HW and PHW1 maintained similar and significantly lower weed dry matter under the entire cropping pattern across the years of study when compared with 0W and P which had higher weed dry matter under SC, CS108 and CS208. This result is in agreement with the report of Kassasian and Seeyave (1967) who stated that weed competition occurred between 4 WAP and 8 WAP in sweet potato mono and intercrop systems due to rapid canopy development from 8 WAP, and keeping the field weed free during this period is a must for sweet potato-based cropping system (Nedunchezhiyan *et al.,* 2013). According to Olorunmaiye and Olorunmaiye (2009), S-metolachor+atrazine at 2.5 kg a.i. ha^{-1} treatment alone is only effective in weed control within the first 6 WAP. This explains the lower weed dry matter observed in PHW1 under all the cropping patterns across all sampling dates and years. In these plots, S-metolachor+atrazine at 1.16+1.48 kg a.i. ha^{-1} provided the initial weed free environment within the first 6 WAP while the supplementary weeding at 8 WAP further reduced weed dry matter through out the rest of the sampling period.

Table 5: Effect of cropping pattern and weed control methods on weed dry matter in 2015, 2016 and 2017 cropping seasons.

	Weed dry matter (g m^{-2}), Weeks after planting (WAP) and Cropping season											
	4WAP			8WAP			12WAP			10MAP		
Treatment/ interactions	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
Cropping Pattern (CP)												
SC	1.04	0.11	1.14	20.3	1.18	7.62	96.2	13.6	30.5	104.8	78.8	112.0
CS100	1.99	0.67	1.39	36.3	0.39	7.91	69.7	0.25	18.2	**53.8**	19.6	89.9
CS200	0.77	0.33	1.08	17.1	0.49	7.31	46.0	1.85	16.4	38.4	16.6	43.9
CS104	0.75	0.06	1.50	17.6	1.10	8.98	73.9	7.42	27.8	58.7	64.7	88.3
CS204	0.05	0.68	0.97	19.9	0.85	9.23	57.7	7.82	25.5	53.6	31.3	70.3
CS108	1.09	0.06	1.06	23.2	1.05	10.18	90.0	8.19	28.6	75.0	99.2	96.9
CS208	0.75	0.06	1.17	14.4	1.28	7.83	95.1	11.83	26.1	81.8	84.5	110.1
SS	-	-	1.05	-	-	7.26	-	-	14.0	-	-	233.4
LSD (CP)	1.32	0.08	0.57	27.59	0.52	5.87	34.07	6.52	9.34	22.04	48.52	58.25
Weed Control (WC)												
P	0.08	0.00	0.00	17.5	0.03	2.04	115.0	10.52	27.5	120.8	94.1	173.0
PHW1	0.06	0.02	0.00	15.1	0.74	1.51	2.0	0.75	0.4	6.7	30.1	28.0
3HW	2.26	0.11	2.34	2.2	0.40	1.04	1.3	0.50	0.3	2.5	8.2	25.3
Weedy check	1.86	0.14	2.34	50.1	1.47	28.57	183.8	17.06	65.3	136.2	93.2	196.1
LSD (WC)	0.68	0.06	0.50	14.07	0.33	3.99	22.68	3.66	6.03	16.58	29.78	29.20
LSD (CP*WC)	1.87	0.16	1.32	32.56	0.89	10.94	60.43	10.28	17.07	42.85	81.23	89.67

** MAP=Months after planting cassava, SC=Sole cassava. SS=Sole sweet potato. CS100=Cassava intercropped with sweet potato at the same time at10,000 plants ha^{-1}, CS200= Cassava intercropped with sweet potato at the same time at 20,000 plants ha^{-1}, CS104= Cassava intercropped with sweet potato 4WAP at 10,000 plants ha^{-1}, CS204= Cassava intercropped with sweet potato 4 WAP at 20,000 plants ha^{-1}, CS108= Cassava intercropped with sweet potato 8 WAP at 10,000 plants ha^{-1}, CS208= Cassava intercropped with sweet potato 8 WAP at 20,000 plants ha^{-1}, LSD=Least significant difference, P=S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1}, PHW1= S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1} followed by one hoe weeding at 8 WAP, 3HW=Three hoe weeding.

Table 6: Interactive effect of cropping pattern and weed control methods on weed dry matter at 8 WAP in 2015, 2016 and 2017 cropping seasons.

	Weed dry matter (g m^{-2}), Weed control methods (WC) and Cropping season														
	P			**PHW1**			**3HW**			**0W**			**Mean**		
	2015	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
Cropping Pattern (CP)															
SC	16.4	**1.87**	1.93	13.8	**0.63**	1.33	1.6	**0.37**	1.53	49.6	**1.87**	25.67	20.3	**1.18**	7.62
CS100	12.7	**0.50**	1.30	16.1	**0.37**	0.87	1.4	**0.27**	0.67	48.2	**0.45**	28.80	36.3	**0.39**	7.91
CS200	9.3	**0.57**	2.07	18.6	**0.50**	1.50	4.0	**0.30**	0.33	36.4	**0.60**	25.33	17.1	**0.49**	7.31
CS104	6.4	**0.67**	1.13	15.2	**1.90**	2.53	1.4	**0.43**	1.30	47.2	**1.40**	30.97	17.6	**1.10**	8.98
CS204	15.4	**0.83**	2.93	13.2	**0.67**	1.17	2.1	**0.67**	0.80	48.9	**1.23**	32.03	19.9	**0.85**	9.23
CS108	29.0	**1.00**	2.73	15.1	**0.50**	2.50	3.8	**0.47**	0.87	44.9	**2.23**	34.60	23.2	**1.05**	10.18
CS208	13.6	**1.77**	2.77	14.0	**0.60**	0.87	1.3	**0.27**	1.90	28.9	**2.50**	25.77	14.4	**1.28**	7.83
SS	-	**-**	1.43	**-**	**-**	1.30		**-**	0.90	-	**-**	25.40	-	**-**	7.26
Mean	**14.7**	**0.03**	2.04	**15.1**	**0.74**	1.51	2.2	**0.40**	1.04	43.4	**1.47**	28.57		**-**	
LSD (CP)	**20.14**	**0.52**	**5.86**												
LSD (WC)	**11.73**	**0.33**	**3.89**												
LSD (CP*WC)	**32.56**	**0.89**	**10.94**												

* MAP=Months after planting cassava, SC=Sole cassava. SS=Sole sweet potato. CS100=Cassava intercropped with sweet potato at the same time at10,000 plants ha^{-1}, CS200= Cassava intercropped with sweet potato at the same time at 20,000 plants ha^{-1}, CS104= Cassava intercropped with sweet potato 4WAP at 10,000 plants ha^{-1}, CS204= Cassava intercropped with sweet potato 4 WAP at 20,000 plants ha^{-1}, CS108= Cassava intercropped with sweet potato 8 WAP at 10,000 plants ha^{-1}, CS208= Cassava intercropped with sweet potato 8 WAP at 20,000 plants ha^{-1}, LSD=Least significant difference, P=S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1}, PHW1= S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1} followed by one hoe weeding at 8 WAP, 3HW=Three hoe weeding.

Table 7: Interactive effect of cropping pattern and weed control methods on weed dry matter at 12 WAP in 2015, 2016 and 2017 cropping season.

	Weed dry matter (g m^{-2}), Weed control methods (WC) and Cropping season														
	P			PHW1			3HW			0W			Mean		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
Cropping Pattern (CP)															
SC	153.2	20.0	28.0	2.1	0.53	0.3	1.5	0.60	0.3	227.9	33.63	93.5	96.2	13.69	30.5
CS100	107.5	0.27	22.2	2.5	0.23	0.3	1.8	0.23	0.3	166.9	0.27	49.7	69.7	0.25	18.2
CS200	84.4	0.40	31.6	2.5	0.43	0.2	0.9	0.27	0.2	96.3	6.30	33.4	46	1.85	16.4
CS104	96.1	11.27	26.2	1.1	0.53	0.9	0.9	0.63	0.9	197.5	17.23	83.8	73.9	7.42	27.8
CS204	109.3	10.37	22.4	2.1	2.53	0.8	2.1	0.43	0.8	117.4	15.57	78.4	57.7	7.02	25.5
CS108	130.5	10.87	26.9	2.3	0.57	0.3	0.6	1.13	0.3	226.3	20.20	86.5	90.0	8.19	28.6
CS208	123.4	20.47	39.9	1.7	0.40	0.5	1.1	0.23	0.5	254.1	26.23	63.8	95.1	11.83	26.1
SS	-	-	22.6	-	-	0.0	-	-	0.0	-	-	33.2	-	-	14.0
Mean	115.0	10.52	27.5	2.0	0.75	0.4	1.3	0.50	0.4	183.8	17.06	65.3		-	
LSD (CP)	34.07	6.52	9.34												
LSD (WC)	22.68	3.66	6.03												
LSD (CP*WC)	60.43	10.28	17.07												

* MAP=Months after planting cassava, SC=Sole cassava. SS=Sole sweet potato. CS100=Cassava intercropped with sweet potato at the same time at10,000 plants ha^{-1}, CS200= Cassava intercropped with sweet potato at the same time at 20,000 plants ha^{-1}, CS104= Cassava intercropped with sweet potato 4WAP at 10,000 plants ha^{-1}, CS204= Cassava intercropped with sweet potato 4 WAP at 20,000 plants ha^{-1}, CS108= Cassava intercropped with sweet potato 8 WAP at 10,000 plants ha^{-1}, CS208= Cassava intercropped with sweet potato 8 WAP at 20,000 plants ha^{-1}, LSD=Least significant difference, P=S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1}, PHW1= S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1} followed by one hoe weeding at 8 WAP, 3HW=Three hoe weeding..

Table 8: Interactive effect of cropping pattern and weed control methods on weed dry matter at 10 MAP in 2015, 2016 and 2017 cropping seasons.

	Weed dry matter (g m^{-2}), Weed control methods (WC) and Cropping season														
	P			PHW1			3HW			0W			Mean		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
Cropping Pattern (CP)															
SC	**206**	135.2	245.9	**3.3**	92.0	10.9	**0.4**	13.9	7.7	**208.7**	74.1	183.5	**104.8**	78.8	112.0
CS100	**93.8**	53.2	106.7	**7.0**	3.5	5.0	**6.3**	1.6	2.0	**108.0**	20.2	245.8	**53.8**	19.6	89.9
CS200	**67.4**	18.6	105.2	**10.3**	18.9	2.0	**2.6**	9.3	0.5	**73.3**	19.7	67.9	**38.4**	16.6	43.9
CS104	**110.6**	124.3	153.1	**10.1**	20.1	10.7	**5.8**	3.3	6.1	**108.3**	111.2	183.5	**58.7**	64.7	88.3
CS204	**103.0**	38.7	146.7	**0.3**	11.4	10.2	**1.2**	1.7	4.9	**109.7**	73.5	119.2	**53.6**	31.3	70.3
CS108	**114.2**	144.8	165.2	**2.9**	52.8	8.1	**0.0**	20.0	9.0	**182.8**	179.0	205.2	**75.0**	99.2	96.9
CS208	**150.2**	143.7	209.3	**12.1**	11.9	12.0	**1.4**	7.9	8.3	**162.7**	174.6	210.8	**81.8**	84.5	110.1
SS	**-**	-	251.6	**-**	-	165.1	**-**	-	163.8	**-**	-	352.9	**-**	-	233.4
Mean	**120.8**	94.1	**173.0**	**6.7**	30.1	28.0	**2.5**	8.2	25.3	**136.2**	93.2	196.1			
LSD (CP)	**22.04**	**48.52**	**58.52**												
LSD (WC)	**16.58**	**29.78**	**29.20**												
LSD (CP*WC)	**42.85**	**81.23**	**89.67**												

* MAP=Months after planting cassava, SC=Sole cassava. SS=Sole sweet potato. CS100=Cassava intercropped with sweet potato at the same time at10,000 plants ha^{-1}, CS200= Cassava intercropped with sweet potato at the same time at 20,000 plants ha^{-1}, CS104= Cassava intercropped with sweet potato 4WAP at 10,000 plants ha^{-1}, CS204= Cassava intercropped with sweet potato 4 WAP at 20,000 plants ha^{-1}, CS108= Cassava intercropped with sweet potato 8 WAP at 10,000 plants ha^{-1}, CS208= Cassava intercropped with sweet potato 8 WAP at 20,000 plants ha^{-1}, LSD=Least significant difference, P=S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1}, PHW1= S-metolachlor+atrazine applied pre-emergence at 1.16+1.48 kg a.i. ha^{-1} followed by one hoe weeding at 8 WAP, 3HW=Three hoe weeding.

4. CONCLUSIONS

Though weed density was significantly higher at 12 WAP in CS200 in 2015 and 2017, weed dry matter was significantly lowered by this treatment at all sampling times in the three years of study due to adequate ground cover which prevented the emerged weed seedlings from dry matter accumulation. Sweet potato had a discernible satisfactory to excellent ground cover in CS200 across the three years of study whereas it was low in plots where sweet potato was introduced at 8 WAP (CS108 and CS208). This is an indication of a reduced potential of weed seedling growth and consequently a reduced capacity to replenish the soil seed bank. CS100, CS200 and CS204 cropping patterns were also effective in weed control at 10 MAP in this study. Introducing sweet potato at 8 WAP gave very poor weed cotrol. Weed density and dry matter were significantly reduced by 3HW and PHW1 in the three years of study. P alone resulted in a very poor weed control comparable to the weedy check. Although weed density and drymatter was significantly reduced by CS200, results from this study suggested that CS200 combined with the application of S-metolachor+atrazine at 1.16+1.48 kg a. i. ha^{-1} followed by one hoe weeding at 8WAP could provide a sustainable weed management system than sole cassava or introducing the sweet potato at 8 WAP.

Beacause of the high population of *P. maximum* encountered in 2015 and 2017, this study suggested that adequate measure should be taken prior to field operation for proper control of its seedlings and vegetative stumps which is characterized with prolific growth. However, the low population of *P. maximum* in 2016 cropping season indicated the need for further studies on the effect of natural fallow on its control in this area.

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