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Effects of integrated weed management on tuber yield of cassava (*Manihot esculenta* Crantz)

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ABSTRACT

Field experiments were conducted in 2012 and 2013 at the Teaching and Research Farm of the University of Calabar, Cross River State, Nigeria to determine the effectiveness of integration of Fitsextra® (a solution containing Atrazine and Metolachlor herbicides as active ingredients), egusi melon and hand-weeding on weed management and tuber yield of cassava. The twelve treatments which involved individual and combinations of the above-mentioned weed control methods were laid out in a randomized complete block design and replicated three times. Irrespective of the method adopted, weeding depressed weed density by 57.33 % and 63.99 % in 2012 and 2013, respectively and weed biomass by 81.00 % and 79.64 % within the same period compared with the unweeded check. Integration of Fitsextra with egusi melon and/or hand-weeding significantly ($P<0.05$) suppressed weeds more than the sole use of Fitsextra® or egusi melon. Integration of hand-weeding with Fitsextra and/or egusi melon reduced weed dry matter by 43.46, 87.25, 92.34 and 93.51 % in 2012, and by 53.20, 90.20, 94.61 and 94.56 % in 2013 compared with hand-weeding alone, Fitsextra alone, egusi melon alone and no weeding, respectively. Plots that were hand-weeded thrice and those treated with Fitsextra + hand-weeding twice significantly ($P<0.05$) produced the highest fresh tuber yield of 9.73 and 10.23 t/ha, respectively in 2013. No weeding reduced cassava tuber yield by 4.83 t/ha (84.89 %) on a 2-year average, compared with the weeded plots. Conclusively, the results indicated that, three hand-weeding optimized cassava tuber yield, however, the integration of Fitsextra or egusi melon can effectively replace the first hand-weeding.

Introduction

Cassava (*Manihot esculenta* Crantz) is widely grown in sub-Saharan Africa (Arubalueze et al. 2017), where over 600 million people depend on it for their food and livelihood (Ezebuiro et al. 2016). Cassava has been reported to be the second most commonly produced tuber crop after yam in Africa (Bouaguimbeck, 2011). The ability of cassava to withstand drought and thrive in marginal

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soils has ranked it a food security crop in sub-Saharan Africa (Sayre et al. 2011), especially in Nigeria (Mazza et al. 2017). Nigeria is the world's largest producer of cassava followed by Thailand, Brazil, Indonesia and Ghana (Factfish, 2016). Cassava produces more food calories per unit area as a dietary energy source than any other lowland crops in Nigeria (Nweke, 2004). Cassava has become a major source of income (Odoemenem and Otanwa, 2011) and employment, for small-holder farmers who constitute the bulk of its growers in Nigeria. Furthermore, government's initiative of multiplying and distributing Vitamin A-fortified cassava, the substitution of cereal flour with that of cassava and the thrust for exportation of cassava chips, have increased the potential demand for cassava in Nigeria (Ikwelle et al. 2003; Ugwu and Ukpabi, 2002). However, the productivity of cassava in sub-Saharan Africa (including Nigeria) remains low, between 5 and 8 tonnes of fresh root tuber yield per hectare (Bouaguimbeck, 2011), compared to the world yield average of 12.5 tonnes per hectare, or to a national yield average of 34.8 tonnes per hectare in India in 2010 (FAOSTAT, 2011). In Nigeria, weed infestation in cassava-based cropping systems remains a major constraint to the resource-poor farmers (Eke-Okoro et al. 2016). The slow initial development of cassava sprouts makes all cassava cultivars susceptible to weed interference during the first three to four months after planting (Melifonwu, 1994). Root tuber reduction of between 40 and 90 % attributed to weed interference in cassava has been reported (Oerke et al. 1994; Ekanayake et al. 1997). Effective weed management is therefore inevitable for increased cassava production (Fadayomi, 2001).

Cultural weed control by hand-weeding remains the predominant weed control method by small-holder farmers. Presently, farmers weed cassava farms about three times in Eastern Nigeria (Eke-Okoro et al. 2016) using hand-held hoe and a fourth weeding by hand-slashing with machete may follow before harvest. However, the attendant problems of high cost (Doll et al. 1977), untimeliness (Iyagba, 2010), drudgery, unavailability of labour at peak periods (Akobundu, 1987), the need for repeated operations (PAN, 2009), and health and environmental concerns (Law, 1994), have made hand-weeding unfashionable to farmers as a sole method of weed control. Many herbicides can be used safely in cassava production in Nigeria (Akobundu, 1977, IITA, 1977). However, relying on herbicides for long-term weed control may not be sustainable due to environmental, ecological and economic concerns (PAN, 2017). It has therefore been advocated that integrating chemical, cultural and physical measures may be the best option for achieving effective weed suppression and enhanced yield of cassava (Reshma et al. 2016; Chikoye et al .2002). Besides, pre-emergence herbicides alone may not offer effective, all-season weed control in long-gestation annual crops like cassava, thereby necessitating supplementary weed control measures (Olorunmaiye and Olorunmaiye, 2009). Thus, no one weed control method is adequate to tackle the

weed problems in any crop at all times (Akobundu, 1987), as weeds tend to evolve with weed management techniques adopted (Buhler et al. 2000). Integrated weed control, which combines two or more weed control practices at lower inputs has been identified as a panacea for effective weed control in small-holder farms (Sindel and Coleman, 2010). Nigerian farmers readily accept intercropping cassava with egusi-melon because the melon suppresses weeds and provides them additional food/income (Iyagba, 2010). The objective of this study was to evaluate the integrated use of a pre-emergence herbicide (Fitsextra®), egusi-melon (*Citrullus colocynthis* L.), and hand-weeding in weed control and their effects on fresh root tuber yield of cassava in Calabar, Southeastern Nigeria.

Materials and methods

Experimental site

The study was conducted at the Teaching and Research Farm of the University of Calabar, Calabar in the southeastern rainforest zone of Nigeria during the 2012 and 2013 cropping seasons. The average annual rainfall ranges from 3000 mm -3500 mm with a bimodal distribution pattern, separated by a short dry spell usually in August, thereby giving rise to two distinct cropping seasons – the early (March – July) and late- (September – December) seasons (CRBRDA, 1995). The site was under a two-year bush fallow with *Panicum maximum* Jacq., *Centrosema pubescens* Bent., *Commelina diffusa* Burn and *Mimosa pudica* Linn as the predominant weeds.

Experimental design and layout

The experiment was conducted as a randomized complete block design and replicated three times. There were twelve weed management methods comprising hand-weeding once (A), hand-weeding twice (B), hand-weeding thrice (C), Fitsextra only (D), Fitsextra plus hand-weeding once (E), Fitsextra plus hand-weeding twice (F), Fitsextra plus egusi-melon plus hand-weeding once (G), Fitsextra plus egusi-melon (H), egusi-melon plus hand-weeding once (I), egusi-melon plus hand-weeding twice (J), egusi-melon only (K), and unweeded check without melon (L). Each plot measured 6 m x 6 m, while the net plot from which cassava harvested was 4 m x 4 m with two meters paths separating between plots and between blocks.

Planting and weed management

The sites were manually cleared with machete and tilled with spade. Planting was done on 10th August in 2012 and 5th September in 2013. The cassava variety used was TMS 98/0510 sourced

from the National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria. Cassava stem cuttings (25 cm long) with seven functional nodes (James et al. 2000) were planted on flat seedbeds at 1 m x 1 m spacing, giving a population of 10,000 plants per hectare (36 plants/plot). egusi melon seeds were planted four per stand, at a spacing of 1 m x 1 m same day. The egusi melon seedlings were thinned to two per stand at two weeks after planting (WAP), to give a population of 20,000 plants per hectare (72 plants/plot). Hand-weeding was done using a hand-held hoe. The first, second and third hand-weeding were done at 4, 12 and 20 WAP, respectively (Uguru, 2011) in plots that received no additional management measures. The first and second weeding were carried out at 12 and 20 WAP, respectively, in plots integrated with Fitsextra and/or melon. Fitsextra, a systemic and residual proprietary herbicide mixture containing 370 g atrazine [2-chloro-4-(ethylamino)-6-isopropylamino)-s-triazone] and 290 g metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxyl-l-methyl ethyl) acetamide] per liter of formulation, was applied five days pre-plant using a CP-15 knapsack sprayer in a spray volume of 200 liters of water at the rate of 1.5 kg a.i atrazine + 1.2 kg a.i metolachlor /ha.

Data collection and analyses

Weed density, weed flora count and weed biomass were assessed at 4, 12, 20 and 36 WAP using a 1 m x 1 m quadrate randomly placed on two locations in a plot. The fresh weed samples were oven-dried at 72 0C to a constant weight. Cassava root tuber yield was determined at 11 months after planting in each year. All data collected were subjected to analysis of variance (ANOVA) using the GenStat Statistical Package (GenStat, 2005) and means were compared by the Tukey's Honest Significant Differences at 5 % level of probability.

Results and discussion

Effect of weed management methods on weed density

Weed management methods significantly ($P<0.05$) reduced weed density at all sampling periods in both years except 4 WAP in 2013 (Table 1). Irrespective of the method adopted, weeding depressed weed density by 57.33 % and 63.99 % in 2012 and 2013, respectively relative to the unweeded check which had the highest weed density throughout the duration of study. This could be attributed to the wide spacing (1 m x 1m) and slow early growth of cassava (Melifonwu, 1994), which must have created niches for more weeds to establish and thrive undisturbed in the unweeded plots. It has been noted that, weeds have the potential to occupy sites disturbed by man and establish their populations rapidly on crop farms if unchecked (Lingenfelter and Hartwig, 2013;

Melifonwu et al. 2000). The reduction in weed density in the weeded plots underscores the efficacy of the adopted weed control methods, though to varying degrees. The lowest weed density was obtained in the Fitsextra + egusi melon + hand-weeding once at 12 WAP 2012, and in egusi melon+hand-weeding once at 20 WAP in 2013. Cumulatively, Fitsextra+hand-weeding once, Fitsextra+hand-weeding twice, Fitsextra+egusi melon+hand-weeding once and egusi melon+hand-weeding twice produced statistically lower weed density compared to sole applications of hand-weeding, Fitsextra, egusi melon, and the unweeded check. These results indicate that, integration of a pre-emergence herbicide (Fitsextra) with egusi melon (a cover crop) and/or hand weeding could be more effective in weed suppression than applying either of the three alone and is consistent with the findings of Okoleye et al. (1999).

Table 1. Effect of integrated weed management on weed density (no/m2) in cassava at different periods in 2012 and 2013.

Treatments	Weed density (no/m2)									
	2012 Weeks after planting					2013 Weeks after planting				
	4	12	20	36	Total	4	12	20	36	Total
A	66.30b*	44.30cd	54.00cdPe	83.72ab	248.32bc	52.57a	44.71cd	39.60de	125.35bc	262.23cd
B	65.70b	52.67c	58.70cd	60.32bcde	237.39bc	59.00a	62.62bc	116.04abc	127.33bc	364.99b
C	73.00b	47.00cd	51.04cde	58.71cde	229.75cd	49.90a	48.13bc	81.05bcd	17.00f	196.08de
D	39.21cd	52.00c	79.30bc	81.70abc	252.21bc	39.10a	71.20b	134.32ab	72.51de	317.13bc
E	35.33d	22.32e	26.74ef	37.24ef	121.63e	26.73a	14.04e	13.11e	20.32f	74.20g
F	37.33cd	34.30de	34.03def	37.30ef	142.96e	35.50a	49.61bc	38.71de	45.33ef	169.15ef
G	30.31d	16.30e	22.02f	32.00f	100.63e	46.51a	12.32e	12.63e	14.24f	85.70fg
H	30.30d	24.70e	45.71def	53.70def	154.41de	29.43a	20.60de	55.02de	25.02f	130.07efg
I	39.30d	25.70e	28.01ef	61.02bcd	154.03de	32.02a	6.01e	5.11e	20.21f	63.35g
J	37.30d	22.51e	22.02f	32.72f	114.55e	35.52a	10.06e	7.61e	23.01f	76.20g
K	56.04bc	73.13b	94.06ab	86.74a	309.97b	36.04a	71.74b	73.93cd	99.24cd	280.95bcd
L	102.23a	119.32a	117.05a	99.37a	437.97a	53.55a	173.70a	148.68a	134.06a	509.99a

*Means in the same column with the same letter(s) are not significantly different from each other at 5 % level of probability according to Turkey's Honest Significant Difference.

Buhler (2002) noted that, cover crops play an important role in weed control by being able to displace weed from harvested crop through resource competition. egusi melon has fast early growth and spreading ability that enable it to occupy niches that would have been colonized by weeds and can also smother existing ones (Nwagwu et al. 2000). Irrespective of the method

adopted, weeding depressed weed density by 57.33 % and 63.99 % in 2012 and 2013, respectively compared with the unweeded check.

Effect of weed management methods on weed flora count

Weed management methods had significant (P<0.05) effect on the number of weed floras present at 12 WAP in 2012 and at all sampling periods in 2013 (Table 2). In both years, all weeded plots except those hand-weeded once significantly (P<0.05) had lower weed flora at 12 WAP, compared with the unweeded check. This result implies that, the weed management methods employed was able to suppress the emergence and/or establishment of some weed species at 12 WAP. Cheruiyot et al. (2003) noted that, hand-hoeing indirectly reduces weed interference in following crops by checking build-up of weed seed thereby resulting in lower number of weed species in managed compared to unmanaged weedy fallow.

Table 2. Effect of integrated weed management on number of weed flora present in cassava at different periods in 2012 and 2013.

Treatments	Weed flora present (no/m²)									
	2012					2013				
	Weeks after planting					Weeks after planting				
	4	12	20	36	Total	4	12	20	36	Total
A	7.30a*	7.73ab	5.60a	5.20a	25.83a	5.33abcd	5.23ab	4.00ab	3.67abcd	18.23abcd
B	5.61a	5.70bcde	4.72a	5.81a	21.84a	7.70a	3.65bc	5.71a	4.30abcd	21.36ab
C	6.52a	6.31b	5.61a	6.01a	24.45a	5.30abcd	4.31bc	4.50ab	4.600abc	18.71abcd
D	6.61a	5.42bcde	6.00a	6.80a	24.83a	5.61abc	3.42bc	5.00ab	5.61a	19.64abc
E	6.82a	6.50b	4.80a	4.21a	23.33a	2.82d	4.31bc	3.11ab	2.43d	12.67cd
F	7.80a	5.00cde	4.90a	5.32a	23.02a	5.06abcd	3.67bc	3.82ab	3.01bcd	15.56abcd
G	6.64a	5.21cde	4.31a	4.60a	20.76a	3.93bcd	3.52bc	3.01ab	3.12bcd	13.58bcd
H	6.00a	3.80e	5.62a	4.40a	19.82a	3.00bcd	2.60c	3.71ab	3.02bcd	12.33cd
I	7.10a	4.31de	5.63a	4.05a	21.09a	3.70bcd	2.41c	2.32b	2.51cd	10.94d
J	6.06a	4.34de	5.34a	5.76a	21.50a	6.00ab	2.11c	2.90ab	2.63cd	13.64bcd
K	7.71a	5.10de	5.01a	6.22a	24.04a	5.22abcd	3.92bc	3.30ab	3.20abcd	15.64abcd
L	7.00a	8.02a	5.02a	4.31a	24.35a	5.31abcd	7.73a	5.20ab	5.00ab	23.24a

*Means in the same column with the same letter(s) are not significantly different from each other at 5 % level of probability according to Turkey's Honest Significant Difference.

While the pre-emergent application of Fitsextra could have resulted in lethality of some weed seeds and seedlings, egusi melon possibly smothered some weed species especially at peak canopy cover (Nwagwu et al. 2000). On the other hand, the unweed check served as a natural fallow with

possibly greater diversity of weed species in the soil seed bank (Cheruiyot et al. 2003). The similarity in number of weed species present at 12 WAP in plots hand-weeded once and the unweeded treatment could be possibly due to the hand-weeding operation triggering the germination and emergence of other weed species after the treatment application at 4 WAP, without further weed management measure. In the same vein, the similarity in number of weed species present across weeded and unweeded treatments at most sampling periods in 2012 and the inconsistent pattern where significant differences were found except 12 WAP in 2013, could be attributed to the prolific and diverse nature of weeds, which enable species not affected by a particular weed management method to thrive under that environment as observed by Hyvonen and Salonen, (2005).

Effect of weed management on weed dry matter

Data on the effect of integrated weed management on weed dry matter are as presented in Table 3. Integrating hand-weeding with Fitsextra or egusi melon significantly reduced weed dry matter compared with hand-weeding alone at 4 WAP in both years.

Table 3- Weed dry matter as affected by integrated weed management in cassava at different periods in 2012 and 2013.

Treatments	Weed dry matter (g/m^2)									
	2012					2013				
	Weeks after planting					Weeks after planting				
	4	12	20	36	Total	4	12	20	36	Total
A	40.91ab*	28.22cd	48.72c	327.01d	444.86b	34.52c	17.80c	156.71d	102.08c	311.11c
B	53.32a	33.71cd	51.70c	61.02de	199.75bcd	93.21a	9.65c	56.02e	55.03c	213.91c
C	53.43a	21.90d	42.62c	55.20de	173.15cd	74.91ab	12.80c	44.33e	41.07c	173.11c
D	37.13bc	94.20b	266.72b	810.40c	1208.45a	91.72a	175.41b	261.03c	583.05b	1111.21b
E	7.42ef	10.33d	22.03c	85.02de	124.80cd	10.90de	7.31c	8.72e	9.00c	35.930c
F	17.62def	10.32d	18.44c	24.21e	70.59d	15.03cde	16.37	14.14e	12.20c	57.74c
G	4.33f	11.31d	19.05c	32.01de	66.70d	3.83e	3.86c	3.63e	3.00c	14.32c
H	20.51de	58.91c	72.70c	188.05de	340.17bc	18.97cde	15.84c	138.32d	94.19c	267.32c
I	20.40de	11.56d	32.31c	125.02de	189.29bcd	25.01cde	4.43c	33.00e	38.00c	100.44c
J	25.33cd	8.07d	49.30c	50.02de	132.72cd	87.11ab	11.92c	43.22e	35.40c	177.65c
K	48.02ab	176.72a	606.02a	1182.31b	2013.07a	32.30cd	205.03a	432.11b	1350.18a	2019.62a
L	49.05a	199.09a	533.21a	1593.34a	2374.69a	64.02b	225.72a	518.31a	1193.01a	2001.06a

*Means in the same column with the same letter(s) are not significantly different from each other at 5 % level of probability according to Turkey's Honest Significant Difference.

This result shows that, the integration of Fitsextra with hand-weeding and/or egusi melon were more effective in early weed suppression than hand-weeding alone where treatment commenced later. One of the drawbacks of hand-weeding is that, it is often applied when weeds have already established, thereby leading to subtle but often severe competition of weeds with crops (Akobundu, 1987). On the other hand, Buhler (2002) noted that, cover crops play an important role in weed control by being able to displace weed from the harvested crop through resource competition. As earlier stated, egusi melon has fast early growth and spreading ability that enable it to occupy niches that would have been colonized by weeds and can also smother existing ones. The unweeded check, egusi melon only and Fitsextra only plots significantly ($P < 0.05$) had higher weed dry matter compared to treatments with combination of methods at 12 and 20 WAP in 2012, and at 12, 20 and 36 WAP in 2013. This indicates that, while the pre-emergence herbicide and egusi melon as a smother crop can offer early-season weed suppression, each may not be relied upon singly for full-season weed control without supplementary measures (Olorunmaiye and Olorunmaiye, 2009). Cumulatively, integration of hand-weeding with Fitsextra and/or egusi melon reduced weed dry matter by 43.46, 87.25, 92.34, and 93.51 % compared with hand-weeding alone, Fitsextra alone, egusi melon alone and no weeding, respectively in 2012. In the same vein, integration of weed management methods reduced weed dry matter by 53.20, 90.20, 94.61 and 94.56 % in comparison with hand-weeding alone, Fitsextra alone, egusi melon alone and no weeding, respectively in 2013. The better weed control recorded in the Fitsextra+ egusi melon treatment, compared to Fitsextra or egusi melon plots alone suggests that, Fitsextra and egusi melon are complementary and can offer better early weed control than either of them alone. This finding is consistent with Olorunmaiye and Olorunmaiye (2009) also reported that, two pre-emergence herbicides – Primexta and Galex were not effective in providing adequate weed control when used alone in maize. Sindel and Coleman (2010) noted that, farmers who have a plan involving the integration of several control methods over time are the ones most likely to have success in controlling weeds.

Effect of weed management method on fresh cassava root tuber yield

Cassava root tuber yield ranged from 0.88 t/ha in plots treated with egusi melon only to 11.17 t/ha in plots hand-weeded thrice in 2012, and from 0.67 t/ha in plots treated with egusi melon only to 10.23 t/ha in plots treated with Fitsextra and hand-weeded twice in 2013 (Table 4). These are similar to yields (2.33 – 9.93 t/ha) reported for ten different elite cassava varieties elsewhere in southern Nigeria (Umeri, 2017). No weeding reduced cassava root tuber yield by 5.29 t/ha (84.89 %) on the 2-year average, compared with the weeded plots, which collaborates the findings of previous researchers (Ekanayake et al., 1997). The finding also tends to validate the assertion

that, total yield loss can result from weeds if unchecked in cassava (Melifonwu, 1994). Elsewhere, cotton equivalent yield, cotton seed yield and soybean yield were all depressed by no weeding compared to all the weed control methods adopted (Jadhav and Bhosle, 2018).

On the two-year average, highest root tuber yield of cassava was obtained from plots hand-weeded thrice (10.45 t/ha) which was statistically similar to plots treated with Fitsextra and hand-weeded twice (9.87 t/ha). This could be attributed to timely and better weed suppression as indicated by the relatively lower weed dry matter recorded in the Fitsextra + hand-weeding twice and hand-weeding thrice treatments. This finding is in agreement with Alabi et al. (1999) who obtained best yield of cassava from plots hand weeded three times followed by plots treated with atrazine + metolachlor at 0.88 + 1.68 kg ai/ha, with no significant differences between the treatments. Eke-Okoro et al. (2016) reported highest cassava fresh root tuber yield (27 t/ha) with application of pre-emergence herbicide and hand-weeding twice followed closely by manual weeding three times which yielded 26 t/ha. Iyagba (2005) reported that, the use of low growing crops such as fluted pumpkin with cassava reduced the three times suggested weeding regime in cassava to two.

Table 4. Effect of integrated weed management on cassava fresh root-tuber yield

Weed Control Treatment	Cassava fresh root-tuber yield (t/ha)		
	2012	2013	Average
Hand-weeding once	4.62ef	5.00d	4.81e
Hand-weeding twice	6.70cd	5.01d	5.86cd
Hand-weeding thrice	11.17a	9.73a	10.45a
Fitsextra only	1.78g	2.07f	1.93g
Fisextra+hand-weeding once	7.30cd	6.15c	6.73c
Fisextra+hand-weeding twice	9.51b	10.23a	9.87a
Fisextra+hand-weeding once+ egusi melon	6.60cd	4.80d	5.70de
Fitsextra+ egusi melon	3.75f	3.50e	3.63f
egusi melon+hand-weeding once	5.57de	4.62d	5.10de
egusi melon+hand-weeding twice	7.73bc	7.73b	7.73b
egusi melon only	0.88g	0.67g	0.78h
No weeding	1.02g	0.70g	0.86h

*Means in the same column with the same letter(s) are not significantly different from each other at 5 % level of probability according to Turkey's Honest Significant Difference

On a 2-year average, the integration of Fitsextra with hand-weeding twice increased fresh root tuber yield by 4.01 t/ha (68.43 %) over hand-weeding twice, while combination of egusi melon with hand-weeding twice increased fresh root tuber yield by 1.92 t/ha (31.91 %) over hand-weeding twice. This finding indicates that, the integration of Fitsextra or egusi melon with hand-weeding twice at 12 and 20 WAP resulted in better weed control and subsequently better cassava yield performance than hand-weeding twice at 4 and 12 WAP. This finding is in agreement with Melifonwu et al. (2000) who noted that, the best way to control weeds in cassava is to combine different strategies. The observed ability of Fitsextra and egusi melon to significantly suppress weeds without adversely affecting cassava yield suggests that, Fitsextra or egusi melon could substitute the first-hand weeding in cassava. Plots hand-weeded once produced significantly ($P < 0.05$) higher cassava root tuber yield than those treated with Fitsextra alone and egusi melon alone in each year. This relatively poor yield performance of cassava in plots treated with Fitsextra or egusi melon without additional weeding can be attributed to the inability of these treatments to suppress weeds effectively on a long-run basis as indicated by the high cumulative weed density and weed biomass recorded for these treatments which is consistent with Olorunmaiye and Olorunmaiye (2009). The appreciable yield of cassava from the plots hand-weeded once in this study (4.62 t/ha and 5.00 t/ha, in 2012 and 2013, respectively), agrees with a previous report that, a single weeding can provide considerable weed suppression in cassava if planting was done in time (Udoh et al., 2005).

Conclusion

The results of this study have shown that, three hand-weedings are necessary to optimize cassava yield in the Calabar humid area of southeastern Nigeria, but the integration of Fitsextra or egusi melon can effectively replace the first hand-weeding, thereby reducing the frequency of manual weeding. The findings further suggest that, neither pre-plant application of Fitsextra nor intercropping with egusi melon as a cover crop should be relied upon alone for full-season weed control in cassava; adequate supplementary measures such as two hand-weedings are necessary for optimal cassava performance.

Conflict of interest

Authors declare no conflict of interest.

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