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

Nwagwu A. Francis *, Udo I. Asukwo

*Department of Crop Science, University of Calabar, P.M.B 1115 Calabar, Cross River State, Nigeria.*

**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.

**KEYWORDS**

Cassava
Fitsextra
Integrated
Melon
Weed
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
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-slaashing 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
weeds 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-triazine] and 290 g metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxyl-1-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°C 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 1 m) 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 | 2012 Weeks after planting | Weed density (no/m²) | 2013 Weeks after planting | Total |
|------------|--------------------------|----------------------|---------------------------|-------|
|            | 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 | 116.04abc | 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          | 39.30cd | 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
Effects of integrated weed management were 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 | 2012 Weeds after planting | 2013 Weeds 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 | 3.93bdc | 3.52bc | 3.01ab | 3.12bdc | 13.58bdc |
| 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 | 3.70bdc | 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 | 2012 Weeks after planting | 2013 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 | 132.72bcd | 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 Oluronmaiye (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 |
| Fitsextra+hand-weeding once                   | 7.30cd | 6.15c | 6.73c |
| Fitsextra+hand-weeding twice                  | 9.51b | 10.23a | 9.87a |
| Fitsextra+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.
References

Assalin M.R, Queiroz S.C, Ferracini V.L, Oliveira T, Vilhena E, Mattos M.L. 2014. A Method for determination of imazapic and imazethapyr residues in soil using an ultrasonic assisted extraction and LC-MS/MS. Bull Environ Contam Toxcol. 93: 360-364.

Akobundu I.O. 1977. Weed control in cassava: Proceedings of the First National Accelerated Food Production Progamme (NAFPP) Cassava workshop, Umudike, Nigeria, March 21 – 26, pp. 1–11.

Akobundu I.O. 1987. Weed Science in the Tropics: Principles and Practices. John Wiley and Sons, New York.

Alabi B.S, Ayeni A.O, Agboola A.A. 1999. Effect of selected herbicides on the control of Thorny Mimosa in cassava. Nig. J. Weed Sci. 12:51-57.

Arubalueze C.U, Muoneke C.O, Remison S.U, Achebe U.A. 2017. Growth and yield of cassava as influenced by maize and cowpea population density in southeastern Nigeria. The Nig. Agric. J. 48(1): 10-16.

Bouaguimbeck H. 2011. Cassava, in: AdeOluwa O.O, Budu O, Ssebunya B. (Eds.), African Organic Agricultural Training Manual Module 9 Crops: Unit 6 Cassava. FIBL, Research Institute of Organic Agriculture, Switzerland: www.organic-africa.net (accessed 27 July, 2014).

Buhler D.D. 2002. Challenges and opportunities of integrated weed management. Weed Sci. 50: 273-280.

Buhler D.D, Liebman M, Obycki J.J. 2000. The theoretical and practical challenges to an IPM approach to weed management. Weed Sci. 48: 274-280.

Cheruiyot E.K, Mumera LM, Nakhone LN, Mwonga SM. 2003. Effect of legume-managed fallow on weeds and soil nitrogen in following maize (Zea mays L.) and Wheat (Triticum aestivum L.) crops in the Rift Valley highlands of Kenya. Australian J. Exp. Agric. 43: 597-604

Chikoye D, Manyong VM, Carsky RJ, Ekeleme F, Gbehounou G, Ahanchede A. 2002. Response of speargrass (Imperata cylindrical) to cover crops integrated with hand-weeding and chemical control in maize and cassava. Crop Protection. 21: 145-156.
CRBRDA (Cross River Basin and Rural Development Authority) 1995. Cross River Basin News, A Biennial Newsletter.1:7.

Doll J.D, Pinstrup-Andersen P, Diaz R. 1977. An agro-economic survey of the weeds and weeding practices in cassava (Manihot esculenta Crantz) in Columbia. Weed Res. 17: 153-160.

Ekanayake I.J, Osiru D.S.O, Porto M.C.M. 1997. Agronomy of Cassava IITA Research Guide No. 60. IITA, Ibadan, Nigeria.

Eke-Okoro O.N, Njoku D.N, Amanze N.J, Mbe J, Eke-Okoro O.C. 2016. Investigation of weeding systems and cost of production in growth and yield of cassava in a cassava breeding programme. The Nig. Agric. J. 47(1): 12 – 19.

Ezebuiro N, Ekumankama O.O, Unamma R.P.A. 2016. Farmers’ conservation practices for cassava genetic resources in southeastern Agroecological zone of Nigeria. The Nig. Agric. J. 47(1): 116 – 124.

Factfish. 2016. Cassava production quantity (tons) for all countries. www.factfish.com/statistic/cassava%2c%20production%20quantity (accessed 5 November, 2018).

Fadayomi R.O. 2001. The role of weed management in poverty alleviation. WSSN 28th Annual Conference 2000 Presidential Address. Nig. J. of Weed Sci. 14: 63 – 65.

FAOSTAT. 2011. Production, crops, cassava 2010 data. http://faostat.fao.org/site/567/DesktopDefault.aspx?pageID=567#ancor). (accessed 24 July, 2013).

GenStat. 2005. GenStat Eighth Edition GenStat Procedure Library Release PL16. Lawes Agricultural Trust (Rothmansted Experimental Station)

Hyvonen T, Salonen J. 2005. Biomass production of weeds in low-input and conventional cropping of cereals. Biol. Agric. Hort. 23:161-173

Ikwele M.C, Zulike T.O, Eke-Okoro O.N. 2003. The contribution of root and tuber crops to the Nigeria economy, in: Akoroda M.O. (Ed.) (2003) Root crops: Proceedings of the Eighth Triennial Symposium of the International Society of Tropical Root Crops- Africa Branch. (ISTRC-AB) held at the International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria, 12 – 16 November 2001, pp. 13 – 18.
International Institute of Tropical Agriculture (IITA). 1977. Farming systems performance. Annual Report. IITA, Ibadan, Nigeria, pp. 59-60.

Iyagba A.G. 2005. Effects of weeding regime on crop yield in cassava/fluted pumpkin intercrop in River States, Nigeria. Nig. J. Hort. Sci. 10: 75-81.

Iyagba A.G. 2010. A review on root and tuber crop production and their weed management among small scale farmers in Nigeria. ARPN J. Agric. & Bio. Sci. 5(4): 52-58.

Jadhav A.S, Bhosle G.P. 2018. Effect of different herbicides on weed control in cotton and soybean intercropping system. J. Res. Weed Sci. 1(2): 123-128.

James B, Yaninek J, Tumanteh A, Maroya N, Salawu R, Dixon, A, Kwarteng J.A. 2000. Starting a Cassava Farm: IPM Field Guide for Extension Agents. ITA, Ibadan, Nigeria. 20pp

Lingenfelter D.D, Hartwig N.L. 2013. Introduction to weeds and herbicides. Penstate Cooperative Extension, College of Agricultural Sciences. Pennsylvania State University. 28p. https://extension.psu.edu/introduction-to-weeds-and-herbicides (assessed 18 October 2018).

Law J.T. 1994. Safe and responsible use of herbicides for homeowners. Proceedings of the 4th Annual California Weed Science Society, held 17th - 19th January.

Mazza M, Agbarevo M.N.B, Ifenkwe G.E. 2017. Effect of National Special Programme on Food Security (NSPFS) on the productivity of small-holder cassava farmers in southeastern Nigeria. The Nig. Agric. J. 48(1): 59-65.

Melifonwu A.B, James K, Aihou S, Awah E, Gbaguidi B. 2000. Weed control in cassava farms: IPM Field Guide for Extension Agents. IITA, Ibadan, Nigeria. 23pp.

Melifonwu A. 1994. Weeds and their control in cassava. African Crop Sci. J. 2(4): 519-530.

Nwagwu F.A, Tijani-Eniola H, Chia H.M. 2000. Influence of tillage and cover crops on weed control in cocoyam field at Ibadan, southwestern Nigeria. Nig. J. Weed Sci. 13: 39-44.

Nweke F.I. 2004. New challenges in the cassava transformation in Nigeria and Ghana. Conference paper No. 8. Paper presented at the INVENT, IFPRI, NEPAD, CTA Conference. Success in African Agriculture, Pretoria, 1, and 3 December, 2003.
Odoemenem I.U, Otanwa L.B. 2011. Economic analysis of cassava production in Benue State, Nigeria. Current Res. J. Soc. Sci. 3(5): 406-411.

Oerke E.G, Dehne H.W, Schonbeck F, Weber A. 1994. Crop production and crop protection: Estimated losses in major food and cash crops. Elsevier, p. 808.

Okoleye K.A, Salawu R.A, Melifonwu A.A, Ikeorgu J. 1999. Use of low growing crop as an alternative weed control measure in cassava-based cropping system in southern Nigeria. Nig. J. Weed Sci. 12: 17-22.

Olorunmaiye P.M, Olorunmaiye K.S. 2009. Effect of integrated weed management on weed control and yield components of maize and cassava intercrop in South Guinea Savanna ecology of Nigeria. Australian J. Crop Sci. 3(3): 129-136.

PAN (Pesticide Action Network). 2009. Field guide to non-chemical pest management in cassava production for small scale farming in the tropics and sub-tropics. PAN, Hamburg, Germany.

PAN (Pesticide Action Network). 2017. Alternative methods in weed management to the use of Glyphosate and other herbicides. https://www.pan-europe.info/sites/pan-europe.info/files/Report_Alternatives%20to%20Glyphosate_July_2018.pdf. (accessed 10 October 2018).

Reshma N, Sindhu P.V, Thomas C.G, Menon M.V. 2016. Integrated weed management in cassava (Manihot esculenta Crantz). J. Root Crops, 42(1): 22-27.

Sindel B, Coloman M. 2010. Weed detection and control on small farms: A guide for owners. University of New England, pp.29.

Sayre R, Beeching J.P, Cahoon E.B, Egesi C, Fauquet C, Fellman J, Fregene M, Gruissem W, Mallowa S, Manary M, Maziya-Dixon B, Mbanaso A, Schachtman D.P, Siritunga D, Taylor N, Vanderschuren H, Zhang P. 2011. The biocassava plus program: Biofortification of cassava for sub-Saharan Africa. Ann. Rev. Plant Bio. 62: 251-72.

Udoh D.J, Ndon B.A, Asuquo P.E, Ndaeyo N.U. 2005. Crop production techniques for the tropics. Concept Publications, Lagos, Nigeria.

Uguru M.I. 2011. Crop production tools, techniques and practice. Fulladu Publishing Company, Nsukka, Nigeria.
Ugwu B.O. Ukpabi U.J. 2002. Potential of soy-cassava flour processing to sustain increasing production in Nigeria. Outlook on Agriculture. 31(21): 129-133.

Umeri C. 2017. Growth and yield performance of some selected cassava varieties in a rainforest zone of Delta State, Nigeria, in: Ndaeyo N.U, Udo I.O, Udom G.N, Bassey E.E, Akpheokhai L.I. (Eds.). Improving a Deregulated Economy through Crop Agriculture. Proceedings of the 4th National Annual Conference of Crop Science Society of Nigeria held September 10-14, 2017 at the University of Uyo, Uyo, Nigeria.

Cite this article as: Nwagwu A. Francis., Udo I. Asukwo. Effects of integrated weed management on tuber yield of cassava (Manihot esculenta Crantz). Journal of Research in Weed Science, 2019, 2(1), 1-15. DOI: 10.26655/JRWEEDSCI.2019.1.1