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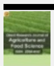

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Cost Implications of i*n Situ Solarization* on Cassava (M*anihot esculenta* Crantz) Production in the Humid Agroecosystem of Southern Nigeria

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ABSTRACT

A two year experiment was conducted in 2019 and 2020 cropping seasons to investigate the cost implications of in situ soil solarization duration using different colours of plastic film in cassava production. Designed as a factorial combination of two plastic colour (transparent and black) and five mulching duration (48, 16, 12, 8 and 0 weeks), arranged in randomized complete block design (RCBD) replicated thrice. The cost implication of the technology was analyzed by computing the production cost, total revenue, net returns, benefit/cost ratio and percentage net returns of each treatment. Results showed a higher production cost and revenue of the solarized plots relative to the unsolarized plot. The highest average percentage net returns of 69.13 % and 69.21 % were obtained from the blocks solarized for 48 weeks using black and transparent plastic, respectively, while the lowest 36.29 % was recorded on the unsolarized plot. In situ solarization for 48 weeks gave the highest economic returns and is therefore recommended.

Keywords: *In situ solarization, plastic colour, Production cost, Revenue, Percentage net returns*

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INTRODUCTION

The passion many have for cassava production is recently being threatened by the surge in the cost of inputs, which makes the need to establish the cash returns of each farming technique relative to production cost to become an urgent necessity. Worldwide, over 800 million people depend on cassava as their staple food (Akpan *et al*., 2019; Ikuemonisan *et al*., 2020; Umunnakwe *et al*., 2023a). In Nigeria, cassava and yam occupy an important position in the agricultural economy and contribute about 46 % of the agricultural gross domestic product. One third (1/3) of Nigerians depend on cassava for their daily caloric intake and the basic means of total survival (Ajayi, 2014). In addition to this over dependent on cassava by many Nigerians as the major source of their livelihood, many industries use it as an essential raw material for their products making the demand for cassava to exceed production (Uwah *et al*., 2013), thus, the need for an improved cultivation techniques that can optimize cassava production at a good cost has become an urgent necessity (Ajah *et al*., 2022; Ajayi, 2014).

Ajayi (2014); Ikuemonisan and Akinbola (2019); Mafimisebi (2008); Nwagwu *et al*. (2023a); Sanchi *et al.* (2022) and Umunnakwe *et al*. (2023a) had listed high input cost as one of the major constraining factors to cassava production across the globe. Akanbi (2019) averred that achieving a cost efficient agricultural system could be the leeway to actualizing the millennial food security goal. Introducing a new cassava production technology and formally analyzing the cost effectiveness may be the much needed turnaround that could revive the lost passion for widespread cassava production. Umunnakwe *et al.* (2023b) and Umunnakwe *et al.* (2003c) had earlier reported that weeds are major threats to cassava production in Nigeria, while Nwagwu *et al*. (2023a) averred that the cost of weed control accounts for over 50 % of cassava production costs. Any environmentally friendly crop production technology that will reduce weed menace while optimizing returns could reduce a higher proportion of cassava production cost (Nwagwu *et al*., 2023a; Umunnakwe *et al*., 2023a; Vissoh *et al*., 2007).

In situ soil solarization, also known as plastic mulching has since its discovery in the early 1930s, become a veritable crop management tool offering many benefits such as promotion of mineralization, higher yields per hectare, cleaner and higher quality produce, more efficient use of water resources and fertilizer inputs, reduced leaching of soil nutrients, reduced erosion, reduced soil compaction and root pruning, better management of soil borne insect pests, reduced soil borne disease incidence, and improved micro-climate by modifying the radiation absorptivity and reflectivity of the surface, thereby enhancing early crop development and reducing weed problems (Aniekwe *et al*., 2004; Kapoor, 2013; 2020). Covering the soil surface with plastic sheet can cause some weed seeds to remain dormant or die after germination probably due to insufficient oxygen and heat stress (Nwagwu *et al.*, 2023b; Nwagwu *et al*., 2023c). Establishing the benefit cost ratio of using different plastic films for *in situ* soil solariztion in cassava production could be the justification that can create the needed awareness for a quick adoption of the technology by farmers. However, there is scarcity of information on cost analysis of *in situ* solarization in cassava production in Nigeria, thus, this research has been conducted to investigate the economic returns of soil solarization in cassava production.

MATERIALS AND METHODS

Location

The field experimentation was carried out during the 2019 and 2020 cropping seasons at the Department of Crop Science, Teaching and Research Farm of the University of Calabar. The location of Calabar is about 39 m above sea level in the rainforest zone of Nigerian agro-ecology at latitude 4° 57' 0" N and longitude 8° 19' 30" E (Otora, 2019). The area is characterized by a relative humidity of 75 % to 88 %, mean annual temperature range of 27 ^{0} C to 35 ^{0} C and a rainfall distribution of 3,000 mm to 3,500 mm range (Efiong, 2011).

Experimental Design and Layout

The field experimentation was designed as a 2 x 5 factorial combinations of black and transparent plastic sheets with 0, 8, 12, 16 and 48 weeks *in situ* solarization periods, which amounted to 10 treatment combinations. Randomized complete block design (RCBD) was adopted in the field layout of these treatments with 3 replications resulting in a total of 30 treatment plots. The dimensions of each experimental unit was a 4 m x 5 m area. Experimental units are separated by a 0.5 m paths, while the blocks are separated by a 1 m paths. The entire experimental area used for the trial was 855.5 m^2 (29 m x 29.5 m).

Treatment Application and Planting

Plastic films of 5.5 m x 4.5 m unit area were spread over the surface of a 5 m x 4 m tilled and pulverized seedbeds on March 9th, 2019 and 2020. To prevent the plastic sheets from being blown away by wind, the edges were buried 10 – 15 cm into the subsoil. A 10 cm radius, circular slit perforations were made at 1 m x 1 m spaces through which the cassava cuttings were inserted into the soil. A 20 – 25 cm stem cuttings with 4 – 7 nodes obtained from TME 419 cassava cultivar, were inserted in a slanting position into the soil. The cuttings were planted one per stand resulting in a population of 20 plants per plot and 10,000 plants per hectare. The plastic sheets were later removed sequentially at 8, 12, 16 and 48 weeks after planting (WAP) for the respective treatments. The plots not covered with plastic sheets were the control.

Crop Management and Field Maintenance

Mixed fertilizer NPK 12:12:17 was ring applied 10 cm from the base of the cassava plant at the rate of 40 g / plant, 0.8 kg / 20 m^2 plot, equivalent to 400 kg / ha recommended by Hauser *et al*. (2014). The fertilizer was applied in two split doses of 20 g / plant at 5 and 12 weeks after planting (WAP). Floor weeding was carried out at the unsolarized plots on the 8th and 16th WAP. While no floor weeding was done inside the *in situ* solarized plots the paths between plots that ere weeded on the 8th and 16th WAP.

Analysis of Production Cost and Returns

The components of production cost and returns used for benefit / cost analysis are total variable cost (production cost), gross revenue and net returns. Percentage net returns was also computed. The costs and returns were calculated on treatment bases and expressed in Naira per hectarage (₦ha^{-1}).

Total variable cost (TVC)

The total expenditure incurred from land preparation through planting to harvesting was worked out and expressed in Naira per hectare (₦ha^{-1}). The cost items included plastic sheets for solarization, cassava stems, fertilizer and labour for bush clearing, tillage, laying of the solarization material, planting, fertilizer application, supplementary weeding, transportation and harvesting. As noted by Itam *et al.* (2018); Nwagwu *et al*. (2023a) and Umunnakwe *et al*. (2023a), total variable cost (TVC) is mathematically expressed as: TVC = cost of materials + cost of labour.

Gross return (total revenue)

The monetary values of the stem and tuber yields of each treatment were estimated and worked out in Naira per hectare (₦ha^{-1}) and recorded on treatment basis.

Net return (gross margin)

This is the difference between the gross farm income (total revenue) and the total variable cost (production cost). The net returns were calculated by subtracting the total variable cost from gross returns and expressed in Naira per hectare (₦ha^{-1}). It is mathematically expressed as:

NR = TR – TVC.

Where;
NR = net returns
TR = total revenue
TVC = total variable cost

Benefit cost ratio

This is the ratio of the total income to the cost of production. The benefit-cost ratio was worked out by dividing the total revenue of each treatment by its total variable cost. It is mathematically expressed as:

BCR = TR / TVC.

Where
BCR = benefit-cost ratio
TR = total revenue
TVC = total variable cost

Percentage net returns

This shows the value of the returns relative to the production cost and is determined by dividing the net returns by total revenue, then multiplying by 100 and the result expressed in percentage, denoted as %.
Mathematically, percentage net returns (% NR) = NR / TR x 100.

RESULTS AND DISCUSSION

Cassava Production Cost, Total Revenue, Gross Income and Benefit/Cost Ratio as Influenced by In Situ Solarization Duration using Different Colours of plastic Film

The influence of *in situ* soil solarization duration and colour of plastic film on total variable cost, total revenue, gross income and benefit/cost ratio of cassava production is displayed in (Table 1). Results showed that higher total variable cost, total revenue, net returns and benefit/cost ratio of cassava production were recorded in the solarized plots in both years of study irrespective of the colour of plastic sheet used compared with the unsolarized plot. The solarized plots recorded 0.34 % and 16.08 % higher total variable cost that the control in 2019 and 2020 cropping seasons respectively. Maximum total revenue, net returns and benefit cost ratio were obtained from the plots covered with the solarization material till crop harvest at 48 weeks after planting (WAP) irrespective of the colour of the plastic sheet used. On the other hand, the lowest total revenue, net returns and benefit cost ratio were obtained from the control plots.

The higher total variable cost incurred in the plots with the *in situ* solarization component relative to the control without solarization material could be attributed to the cost of the solarization material. The 16.08 % increase in the cost of production using *in situ* solarization in 2020 cropping season compared with just 0.34 % in the previous year using the same method could be attributed to a 66 % increase in the cost of solarization material (Appendices 1 and 2) in 2020 caused by the covid-19 pandemic lockdown. On the other hand, the higher total revenue, net returns and benefit/cost ratio obtained from the solarized plots in both cropping seasons relative to the control could be attributed to the higher yields obtained from those plots (Appendices 1 and 2), which

Table 1: Economics of cassava production as influenced by plastic sheet colour and *in situ* solarization duration.

	Total variable cost (₦ha^{-1})		**Gross revenue (₦ha^{-1})**		**Net returns (₦ha^{-1})**		**Benefit cost ratio**	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
PBS$_0$	345,618.20	350,618.20	496,500	606,500	150,881.80	255,881.80	1.44	1.73
PBS$_8$	346,809.10	417,809.10	910,000	956,500	563,190.90	538,690.90	2.62	2.29
PBS$_{12}$	346,809.10	417,809.10	959,500	917,000	612,690.90	499,190.90	2.77	2.19
PBS$_{16}$	346,809.10	417,809.10	1,056,500	1,103,000	709,690.90	685,190.90	3.05	2.64
PBS$_{48}$	346,809.10	417,809.10	1,283,500	1,203,500	936,690.90	785,690.90	3.70	2.88
PWS$_0$	345,618.20	350,618.20	563,000	557,000	217,381.80	206,381.80	1.63	1.59
PWS$_8$	346,809.10	417,809.10	953,500	1,006,500	606,690.90	588,690.90	2.75	2.41
PWS$_{12}$	346,809.10	417,809.10	930,000	1,043,000	583,190.90	625,190.90	2.68	2.50
PWS$_{16}$	346,809.10	417,809.10	1,100,000	1,157,000	753,190.90	739,190.90	3.17	2.77
PWS$_{48}$	346,809.10	417,809.10	1,216,500	1,263,500	869,690.90	845,690.90	3.51	3.02

See appendices for sources of cost and revenue
Note: ₦1,550 = 1USD
KEY:
PB = Black plastic
PW = Transparent plastic
S_0 = Control
S_8 = Eight weeks *in situ* solarization
S_{12} = Twelve weeks *in situ* solarization
S_{16} = sixteen weeks *in situ* solarization
S_{48} = *in situ* solarization till crop harvesting

Table 2: Percentage net returns of cassava production as influenced by plastic sheet colour and *in situ* solarization duration.

Treatments	**Percentage net returns (%)**	
	2019	**2020**
PBS$_0$	30.39	42.19
PBS$_8$	61.89	56.32
PBS$_{12}$	63.86	54.44
PBS$_{16}$	67.17	62.12
PBS$_{48}$	72.98	65.28
PWS$_0$	38.61	37.35
PWS$_8$	63.63	58.49
PWS$_{12}$	62.71	59.94
PWS$_{16}$	68.47	63.89
PWS$_{48}$	71.49	66.93

KEY:
PB = Black plastic
PW = Transparent plastic
S_0 = Unsolarized
S_8 = Eight weeks *in situ* solarization
S_{12} = Twelve weeks *in situ* solarization
S_{16} = sixteen weeks *in situ* solarization
S_{48} = *in situ* solarization till crop harvesting

suggests that the *in situ* solarization treatment had enhanced the soil conditions and made more nutrients available to the cassava crop. Aniekwe *et al.* (2004) had reported similar results when they studied the modulating effect of *in situ* solarization on cassava performance. *In situ* solarization has also been reported to optimize the yield of other crops such as maize (Ali *et al*., 2011), chilli pepper (Ashrafuzzaman *et al*., 2011), cotton (Ahmad *et al*., 2015), okra (Aniekwe, 2015) and sweet potato (Laurie *et al*., 2015; Nwosisi *et al*., 2019).

The Percentage Net Returns of Cassava Production as Affected by In Situ Solarization Duration using Different Colours of plastic Film

The effect of *in situ* solarization duration using different colours of plastic film on percentage net returns of cassava production is as presented in (Table 2). Results showed that higher percentage net returns were recorded in the blocks treated with *in situ* soil solarization irrespective of duration and colour of plastic film relative to the control in both years. *In situ* soil solarization till crop harvest (48 weeks) irrespective of the colour of plastic film used produced the highest percentage net returns in both years of planting. The highest average percentage net return were 69.13 % and 69.21 % obtained from 48 weeks *in situ* soil solarization using black and transparent plastic films respectively. The lowest average percentage net return 36.29 % was obtained was obtained from the control. The relatively higher percentage net returns obtained from the plots treated with *in situ* soil solarization till crop harvest (48 weeks) using any of the black or transparent plastic films suggests higher revenue obtained from the sales of the tubers and stems (Appendices 1 and 2) harvested from those treatments compared to the others. This could be attributed to such factors as the ability of the *in situ soil* solarization to conserve soil moisture, maintain optimum soil temperature, and prevent soil erosion and nutrient leaching, promote the proliferation of beneficial microorganism, promote mineralization by increasing the rate of organic matter decomposition, control soil borne pest and diseases including weeds.

These probably had created a conducive microclimate that made more nutrients available for the cassava crop. This observation corroborates the reports of Aniekwe *et al.* (2004); Kapoor (2020); and Krueger and McSorley (2015). The increased percentage net returns suggests that any technology that boosts production will result in higher revenue and greater gains. This observation agrees with Al-Hattami, Kabra and Lokhande (2020); Egbide-Oladipo *et al*. (2019); Nwagwu *et al*. (2023a); Umunnakwe *et al*. (2023a); Zengin and Ada (2010).

Conclusion

This study on the cost implications of *in situ* soil solarization on cassava production in the humid tropical region of southern Nigeria has shown that *in situ* soil solarization is a promising technology with a very high net returns relative to the cost. Maximum profit was obtained with *in situ* soil solarization till crop harvest. Cassava producers are therefore advised to adopt *in situ* soil solarization till crop harvest using any of black or transparent plastic film.

Conflict of Interest: The authors declare that there are no conflict of interest associated with the study.

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Appendix 1: Components of cost and revenue for polyethylene sheet colour and *in situ* solarization experiment in 2019.

						First planting (2019)						
Input / output	**Unit**	**Price (₦/k)**	**BS_0 (₦/ha)**	**BS_8 (₦/ha)**	**BS_{12} (₦/ha)**	**BS_{16} (₦/ha)**	**BS48 (₦/ha)**	**WS_0 (₦/ha)**	**WS_8 (₦/ha)**	**WS_{12} (₦/ha)**	**WS_{16} (₦/ha)**	**WS_{32} (₦/ha)**
Labour												
Clearing	M^2	4.46	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03
Tillage	M^2	7.22	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07
Planting	MD	2000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Weeding	M^2	4.46	133,809.07	10,000.00	10,000.00	10,000.00	10,000.00	133,809.07	10,000.00	10,000.00	10,000.00	10,000.00
Fertilizer app	MD	2,000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Polyethylene sheet app	MD	2,500	-	15,000.00	15,000.00	15,000.00	15,000.00	-	15,000.00	15,000.00	15,000.00	15,000.00
Transportation	-	5,000	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
Harvesting	MD	2,000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Materials												
Polyethylene sheet	Kg	300	-	100,000.00	100,000.00	100,000.00	100,000.00	-	100,000.00	100,000.00	100,000.00	100,000.00
Stems	Bundle	500	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Fertilizer	Kg	12.5	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00
TVC			345,618.17	346,809.10	346,809.10	346,809.10	346,809.10	345,618.17	346,809.10	346,809.10	346,809.10	346,809.10
Yield												
Tubers	Ton	10,000.00	230,000.00	410,000.00	490,300.00	520,300.00	650,000.00	263,000.00	420,000.00	430,000.00	500,000.00	650,000.00
Stems	Bundle	500.00	266,500.00	500,000.00	466,500	533,500.00	633,500.00	300,000.00	533,500.00	500,000.00	600,000.00	566,500.00
TR			496,500.00	910,000.00	959,500.00	1,056,500.00	1,283,500.00	563,000.00	953,500.00	930,000.00	1,100,000.00	1,216,500.00
Net returns			150,881.80	563,190.90	612,690.90	709,690.90	936,690.90	217,381.80	606,690.90	563,190.90	753,190.90	869,690.90

KEY: B = Black polyethylene sheet; W = Transparent polyethylene sheet; S_0 = No solarization; S_8 = *in situ* solarization for eight weeks; S_{12} = *in situ* solarization for twelve weeks; S_{16} = *in situ* solarization for sixteen weeks; S_{32} = *in situ* solarization till harvest, M^2 = meter square, MD = manday, Kg = kilogramme, TVC = total variable cost, TR = total revenue, Ton = tonnes, ₦/ha = naira per hectare

Appendix 2: Components of cost and revenue for polyethylene sheet colour and *in situ* solarization experiment 2020.

						Second planting (2020)						
Input / output	**Unit**	**Price (₦/k)**	**BS_0 (₦/ha)**	**BS_8 (₦/ha)**	**BS_{12} (₦/ha)**	**BS_{16} (₦/ha)**	**BS48 (₦/ha)**	**WS_0 (₦/ha)**	**WS_8 (₦/ha)**	**WS_{12} (₦/ha)**	**WS_{16} (₦/ha)**	**WS_{32} (₦/ha)**
Labour												
Clearing	M^2	4.46	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03	44,603.03
Tillage	M^2	7.22	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07	72,206.07
Planting	MD	2000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Weeding	M^2	4.46	133,809.07	10,000.00	10,000.00	10,000.00	10,000.00	133,809.07	10,000.00	10,000.00	10,000.00	10,000.00
Fertilizer app	MD	2,000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Polyethylene sheet app	MD	2,500	-	15,000.00	15,000.00	15,000.00	15,000.00	-	15,000.00	15,000.00	15,000.00	15,000.00
Transportation	-	10,000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Harvesting	MD	2,000	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Materials												
Polyethylene sheet	Kg	500	-	166,000.00	166,000.00	166,000.00	166,000.00	-	166,000.00	166,000.00	166,000.00	166,000.00
Stems	Bundle	500	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Fertilizer	Kg	12.5	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00
TVC			350,618.17	417,809.10	417,809.10	417,809.10	417,809.10	350,618.17	417,809.10	417,809.10	417,809.10	417,809.10
Yield												
Tubers	Ton	10,000.00	273,000.00	390,000.00	417,300.00	503,000.00	637,000.00	257,000.00	440,000.00	443,000.00	557000.00	630,000.00
Stems	Bundle	500.00	333,500.00	566,500.00	500,000.00	600,000.00	566,500.00	300,000.00	566,500.00	600,000.00	600,000.00	633,500.00
TR			606,500.00	956,500.00	917,000.00	1,103,000.00	1,203,500.00	557,000.00	1,006,500.00	1,043,500.00	1,157,000.00	1,263,500.00
Net returns			255,881.80	538,690.90	499,190.90	685,190.90	785,690.90	206,381.80	588,690.90	625,190.90	739,190.90	845,690.90

KEY: B = Black polyethylene sheet; W = Transparent polyethylene sheet; S_0 = No solarization; S_8 = *in situ* solarization for eight weeks; S_{12} = *in situ* solarization for twelve weeks; S_{16} = *in situ* solarization for sixteen weeks; S_{32} = *in situ* solarization till harvest, M^2 = meter square, MD = manday, Kg = kilogramme, TVC = total variable cost, TR = total revenue, Ton = tonnes, BD = bundles, ₦/ha = naira per hectare