J Bangladesh Agril Univ 21(4): ***414–420****, 2023* https://doi.org/10.5455/JBAU.159806

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Economics of Cassava (*Manihot esculenta* Crantz) Cultivation under Varying Planting Densities and Pre-planting Soil Solarization Duration

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ARTICLE INFO

Article history
Received: 04 July 2023
Accepted: 13 December 2023
Published: 31 December 2023

Keywords
Cassava production,
Crop density,
Production Cost,
Percentage net returns,
Soil solarization

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ABSTRACT

The cost justification of a new cassava production technology could open the alley for quick adoption by cassava farmers and give extra motivation that will attract new farmers. Soil solarization is a promising cassava production technology that may need extra justification if a widespread adoption is to be achieved. A field trial was carried out during the 2019 and 2020 early cropping seasons to evaluate the cost implications of plant density and soil solarization durations on cassava production. The experiment was a factorial combination of three cassava densities: 17,778 plants ha^{-1} (0.75 m x 0.75 m), 13,333 plants ha^{-1} (0.75 m x 1 m) and 10,000 plants ha^{-1} (1 m x 1 m) and four pre-planting soil solarization durations (0, 4, 7 and 10 weeks), laid out in randomized complete block design (RCBD) with three replications. To analyze the cost implication of the technology, the production cost, total revenue, net returns, benefit/cost ratio and percentage net returns of each treatment were computed and tabulated. Results showed that the percentage net returns increased as cassava density increased from 10,000 stands/ha to 17,778 stands/ha. Similarly, percentage net returns increased as soil solarization duration increased from 0 to 10 weeks. The lowest percentage net returns of 29.39 % was obtained in 2019 from the unsolarized plot integrated with a lower cassava density of 10,000 stands/ha, while the highest percentage net return of 72.85 % was obtained in 2019 from the plot treated with a longer soil solarization duration of 10 weeks integrated with a higher cassava density of 17,778 stands/ha and could therefore be recommended for cost effective and environmental friendly cassava production method in the tropics.

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important root crops of the world, especially in sub-Saharan Africa, where it is widely grown as a major staple food and cash crop (IITA, 2017). Cassava accounts for a daily caloric intake of 30 % of the people in Nigeria and is grown by nearly every farming family (Adeniyan *et al*., 2014). Cassava tuber contains 60 - 65 % moisture, 20 - 31 % carbohydrate, 1 - 2 % crude protein and a comparatively low content of vitamins and minerals. However, new varieties have been developed that are rich in vitamin A. Cassava tubers and hay are used worldwide as animal feed (Furlan *et al*., 2010; Onasanya *et al*., 2021). Cassava hay contains high protein (20 - 27 % crude protein) and condensed tannins of 1.5- 4 % CP, (Lunsin *et al*., 2012). In addition to its usage as a food source, cassava is a vital raw material for the confectionery, gum, medicinal, alcohol, starch, and biodiesel industries (Uwah *et al*., 2013). High input cost is one of the major factors limiting cassava production in Nigeria (Sanchi *et al*., 2022). To encourage farmers to engage more in cassava production, finding a cost effective and environmentally friendly farming technique have recently become a necessity. Analyzing the cost implication of each farming technique employed in cassava production holds the key to finding the cheapest environmentally friendly planting practice for the crop. Among the various production costs, labour cost for weeding has been listed as a factor contributing the highest input cost in cassava production, therefore, any environmentally friendly technology that will reduce the amount of money spent on weeding would resolve a greater percentage of the issues trailing cassava production across the globe (Vissoh *et al*., 2007, Umunnakwe *et al*., 2023ab). Such

Cite This Article
Umunnakwe, O.C., Akpan, J.F., Omadewu, L.I., Bisong, B.O., Awelewa, E.A. and Ebri, B.O. 2023. Economics of Cassava (*Manihot esculenta* Crantz) Cultivation under Varying Planting Densities and Pre-planting Soil Solarization Duration. *Journal of Bangladesh Agricultural University,* 21(4): 414-420. https://doi.org/10.5455/JBAU.159806

farming techniques to be considered in this regard could include crop canopy management and soil solarization.

Cassava yield could be optimized by using appropriate plant density (Hauser and Ekeleme, 2017). Although, 10,000 plants ha^{-1} at 1 m x 1 m spacing is the standard recommendation for cassava, recent reports suggest that higher densities can improve yields (Hauser *et al*., 2014), possibly through more effective weed suppression. It is therefore necessary to determine the plant density that will effectively suppress weeds and enhance yield in non-branching cassava varieties such as TME 419. However, plant canopy management alone cannot guarantee all-season weed control in cassava because of the slow early growth of the crop which predisposes it to severe weed infestation at the first 12 weeks after planting (Nwagwu *et al*., 2023a; Umunnakwe *et al*., 2023ab). Solarization which has been demonstrated to effectively reduce weed growth (Marenco and Lustosa, 2000; Ashrafuzzaman *et al*., 2011) and improve yield of many crops (Golzardi *et al.,* 2014; Nwagwu *et al*., 2023b) could be integrated pre- plant or at planting with other methods such as plant canopy management to enhance the efficacy, timeliness and cost-effectiveness of weed control while optimizing the yield potential of cassava. This research was conducted to determine the cost implications of plant density and duration of soil solarization on cassava production.

Materials and Methods

Location

The field trial was carried out at the Teaching and Research Farm of Crop Science Department at the University of Calabar, Calabar, Nigeria during the 2019 and 2020 cropping seasons. 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 ° C to 35 ° C and a rainfall distribution of 3,000 mm to 3,500 mm range (Efiong, 2011).

Experimental design and layout

The experiment was a 3 x 4 factorial consisting of three levels of crop densities of cassava: 17,778 plants ha^{-1} (0.75 m x 0.75 m), 13,333 plants ha^{-1} (0.75 m x 1 m) and 10,000 plants ha^{-1} (1 m x 1 m) and four levels of pre-planting soil solarization durations (0, 4, 7 and 10 weeks). The twelve treatment combinations were laid out in randomized complete block design (RCBD) and replicated three times bringing the total number of plots to 36. Each experimental unit measured 4 m x 5 m with 0.5 m paths between experimental units and 1 m paths between blocks. An experimental area measuring 38 m x 29.5 m equaling 1121 m^2 was used for the trial.

Procedure for soil solarization:

Transparent polyethylene sheets measuring 5.5 m x 4.5 m were spread over the surface of already prepared seedbeds measuring 5 m x 4 m. The polyethylene sheets were applied at 333 kg ha^{-1}. The edges of the polyethylene sheets were buried 10 – 15 cm into the soil to prevent them from being blown away by the wind. The plots for 10 weeks solarization were laid with polyethylene sheet first, three weeks later, the 7 weeks solarization plots were covered, while the plots for the 4 weeks were covered at the beginning of the seventh week from the inception. Finally, on the tenth week, all the polyethylene sheet materials were removed and the cassava cuttings planted. The unsolarized plots were not covered with polyethylene sheet. The solarization commenced on the 2nd of March and ended on the 11th of May in each year of the trials. Non branching cassava cultivar (TME 419) stem cuttings of 20 – 25 cm length with 4 – 7 nodes each were inserted in a slanting position into the soil, 1 m x 1 m, 1 m x 0.75 m and 0.75 m x 0.75 m apart according to treatments, immediately after the removal of the solarization materials on the 11th of May each year of planting. The cuttings were planted one cutting per stand giving a total of 20, 25 and 35 plants $plot^{-1}$ respectively and 10,000; 13,333 and 17,778 plants ha^{-1}, accordingly. About 40, 53 and 71 bundles of 50 stems of cassava each were used per hectare, accordingly.

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, 32 and 23 g / plant according to plant densities, 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, 16 and 11.5 g / plant accordingly, at 5 and 12 weeks after planting (WAP). Weeding was carried out on the blocks based on incidence and severity. Floor weeding was carried out at the unsolarized plots on the 4th, 8th and 12th WAP. At the 4 and 7 weeks solarization duration plots, floor weeding was done on the 8th and 12th WAP, while no floor weeding was done inside the plots treated with 10 weeks soil solarization duration. However, the paths between plots were weeded on the 8th week after planting. Moisture was provided by natural precipitation. Routine pest and disease surveillance was undertaken every 4 weeks up to the 20th week after planting. No pest or disease of economic importance was observed.

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 were 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 polyethylene 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) and Nwagwu *et al* (2023c), total variable cost (TVC) is mathematically expressed as: TVC = cost of materials + cost of labour.

Total revenue (gross returns):

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 % NR = NR / TR * 100. Where;

% NR = percentage net returns

Results and Discussion

Effect of cassava densities and pre-planting soil solarization duration on production cost, gross revenue, net income and benefit cost ratio of cassava production

Table 1 shows the cultivation cost, gross revenue, net income and benefit cost ratio of cassava as influenced by crop densities and solarization duration. Results showed that total variable cost, gross revenue, net income and benefit-cost ratio of cassava cultivation were generally higher in the treatments with the highest plant density of 17,778 cassava stands/ha in both years of study compared with the corresponding treatments with lower crop densities. These were followed by those with population of 13,333 cassava stands/ha, while the lowest cost and returns were obtained from plots with the lowest density of 10,000 cassava stands/ha. Maximum cost of cultivation was incurred from plots solarized for a shorter duration of 4 – 7 weeks with 17,778 cassava stands/ha in both years. On the other hand, maximum total revenue (1,369,500 ₦ ha^{-1} and 1,256,000 ₦ ha^{-1}), net returns (997,690.90 ₦ ha^{-1} and 813,190.90 ₦ ha^{-1}) and benefit cost ratio (3.69 and 2.84) for 2019 and 2020 planting respectively, were obtained from the plot treated with the integration of 17,778 cassava stands/ha and 10-weeks pre-planting soil solarization duration.

Effect of cassava densities and pre-planting soil solarization duration on percentage net returns of cassava production

Table 2 displays percentage net returns of cassava production as influenced by plant density and soil solarization duration. Results showed that plots treated with a longer soil solarization duration of 10 weeks integrated with a higher cassava density of 17,778 stands/ha produced the highest percentage net returns in both years of planting. This was followed by the integration of soil solarization for 10 weeks with cassava density of 13,333, while the lowest one was obtained from the unsolarized plot with a lower cassava density 10,000 stands/ha. Generally, percentage net returns increased as cassava density increased from 10,000 stands/ha to 17,778 stands/ha. Similarly, percentage net returns increased as soil solarization duration increased from 0 to 10 week. The highest percentage net return of 72.85 % was obtained in 2019 from the plot treated with a longer soil solarization duration of 10 weeks integrated with a higher cassava density of 17,778 stands/ha while the lowest % NR of 29.39 was obtained in 2019 from the unsolarized plot integrated with a lower cassava density of 10,000 stands/ha.

Table 1. Effect of cassava densities and pre-planting soil solarization duration on production cost, gross revenue, net income and benefit cost ratio of cassava production

	Tota variable cost (₦ha^{-1})		Total revenue (₦ ha^{-1})		Net returns (₦ ha^{-1})		Benefit cost ratio	
	2019	2020	2019	2020	2019	2020	2019	2020
D_1S_0	361,618.20	366,618.20	682,000	694,000	320,381.80	327,381.80	1.89	1.89
D_1S_4	392,412.13	463,412.13	794,000	889,500	401,587.90	426,087.90	2.02	1.92
D_1S_7	392,412.13	463,412.13	1,120,000	1,096,500	727,587.90	633,087.90	2.85	2.37
D_1S_{10}	371,809.10	442,809.10	1,369,500	1,256,000	997,690.90	813,190.90	3.68	2.84
D_2S_0	352,618.20	358,618.20	564,000	617,500	211,381.80	258,881.80	1.60	1.72
D_2S_4	383,412.13	454,412.13	698,000	749,500	314,587.90	295,087.90	1.82	1.69
D_2S_7	383,412.13	454,412.13	929,000	947,000	545,587.90	492,587.90	2.42	2.08
D_2S_{10}	362,809.10	433,809.10	1,170,000	1,109,500	807,190.90	675,690.90	3.22	2.56
D_3S_0	345,618.20	350,618.20	489,500	550,000	143,881.80	199,381.80	1.42	1.57
D_3S_4	376,412.13	447,412.13	690,000	669,500	313,587.90	222,087.90	1.83	1.50
D_3S_7	376,412.13	447,412.13	889,500	906,500	513,087.90	459,087.90	2.36	2.02
D_3S_{10}	355,809.10	426,809.10	1,067,000	1,043,500	711,190.90	616,698.90	3.00	2.44

See appendices for sources of costs and revenue

Note: ₦957 = 1 USD ($)

KEY:

D_1 = Cassava @ 17,778 plants/ha — S_0 = No solarization
D_2 = Cassava @ 13,333 plants/ha — S_4 = 4 weeks solarization
D_3 = Cassava @ 10,000 plants/ha — S_7 = 7 weeks solarization
S_{10} = 10 weeks solarization

Table 2. Effect of cassava densities and pre-planting soil solarization duration on percentage net returns of cassava production

Treatments	Percentage net returns (%)	
	2019	2020
D_1S_0	46.98	47.17
D_1S_4	50.58	47.90
D_1S_7	64.96	57.74
D_1S_{10}	72.85	64.75
D_2S_0	37.48	41.92
D_2S_4	45.06	39.37
D_2S_7	58.73	52.02
D_2S_{10}	68.99	60.90
D_3S_0	29.39	36.25
D_3S_4	45.45	33.17
D_3S_7	57.68	50.64
D_3S_{10}	66.65	59.10

KEY:

D_1 = Cassava @ 17,778 plants/ha — S_0 = No solarization
D_2 = Cassava @ 13,333 plants/ha — S_4 = 4 weeks solarization
D_3 = Cassava @ 10,000 plants/ha — S_7 = 7 weeks solarization
S_{10} = 10 weeks solarization

Discussion

The higher cost incurred by increasing the plant population per hectare was as a result of purchasing extra stems to meet up with the extra cuttings requirement for higher plant density. Similarly, the maximum cost incurred in plots solarized for a shorter duration of 4 – 7 weeks was as a result of extra cost incurred on supplementary wedding (Appendices A and B). This suggests that solarization durations of 4 - 7 weeks are insufficient for effective weed control in cassava. Previously, Nwagwu *et al*. (2023b) had observed that shorter solarization duration of 4 weeks was insufficient to effectively control weeds in maize. On the other hand, the reduction of total variable cost by increasing the duration of solarization to 10 weeks was because no supplementary wedding was needed in those plots, which may be attributed to the delay of the emergence of weed seedlings up to 12 WAP. At this time, the cassava had developed enough canopy to suppress the weeds emerging later. This observation is in agreement with Albuquerque *et al*. (2012) Golzardi *et al*., (2014), Krueger and McSorley (2015), Chauhan (2020), Kapoor (2020) and Nwagwu *et al*. (2023a). The higher cost incurred in the plots with solarization components compared with those without solarization in the second year of planting was as result of a 66 % increase in the cost of the solarization material due to the covid-19 pandemic lockdown. The higher gross revenue, net income and benefit cost ratio obtained when 17,778 cassava plants/ha were sown in the plots solarized for 10 weeks may be attributed to a number of factors. The treatment combination was able to control weeds better, resulting in the reduction of extra cost that would have been incurred on supplementary weeding and also, the higher number of plants stands per hectare, had translated to higher tuber and stem yields on hectare basis.

The higher percentage net returns obtained from the plot treated with the integration of a higher cassava density of 17,778 stands/ha and a longer soil solarization duration of 10 weeks, suggests higher productivity of this treatment relative to the others. This could be attributed to a number of factors. Firstly, the treatment probably enhanced the conditions of the rhizosphere soil during the soil solarization process leading to the availability of more nutrients for improved growth and, higher stem and tuber yield of the cassava crop (Appendices A and B). Previously, soil solarization has been reported to improve the soil conditions through weed seedbank reduction (Kapoor, 2020; Umunnakwe *et al*., 2023b), mineralization (Krueger and McSorley, 2015), and reduction in soil borne pest and diseases (Kapoor, 2013; Nwagwu *et al*., 2023b). Also, the longer solarization duration had resulted in the desiccation of weed propagules in the soil leading to early dominance and optimum utilization of available growth resources by the cassava plants. This observation is in consonance with the reports of Marenco and Lustosa (2000), Ashrafuzzaman *et al*. (2011), Horowitz *et al*. (2020) and Kapoor (2020). The lower percentage net returns observed in 2020, especially in the plots that received solarization treatments irrespective of cassava density, could be attributed to higher cost of production incurred in 2020 relative to 2019, suggesting that when input cost increases, percentage net returns tend to decline. This observation conforms with Zengin and Ada (2010), Tepper (2017), Egbide *et al*. (2019), Al-Hattami *et al.* (2020), Sanchi *et al*. (2022) and Nwagwu *et al* (2023c).

Conclusion

The findings of this research have shown that solarizing the soil for 10 weeks and planting a non-branching cassava cultivar such as TME 419 at a density of 17,778 plants ha^{-1}, resulted in profit maximization, evident in the higher total revenue, percentage net returns and benefit cost ratio obtained from that treatment block across the two planting seasons. By implication, this study has shown that soil solarization and optimum cropping density reduce weed severity, thereby reducing weeding frequency, consequently reducing the cost of weeding. Also, solarization improves the conditions of the rhizosphere soil leading to higher yields thereby increasing the revenue. Further research on the impact of this technology on weed species and soil microbial dynamism is highly recommended.

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APPENDIX A. Components of cost and revenue for crop density and soil solarization experiment in 2019

				First planting											
s/n	Input / output	Unit	Price (₦/k)	D_1S_0 (₦/ha)	D_1S_4 (₦/ha)	D_1S_7 (₦/ha)	D_1S_{10} (₦/ha)	D_2S_0 (₦/ha)	D_2S_4 (₦/ha)	D_2S_7 (₦/ha)	D_2S_{10} (₦/ha)	D_3S_0 (₦/ha)	D_3S_4 (₦/ha)	D_3S_7 (₦/ha)	D_3S_{10} (₦/ha)
	Labour														
1	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	44,603.03	44,603.03
2	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	72,206.07	72,206.07
3	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	10,000.00	10,000.00
4	Weeding	M^2	4.46	133,809.07	49,603.03	49,603.03	29,000.00	133,809.07	49,603.03	49,603.03	29,000.00	133,809.07	49,603.03	49,603.03	29,000.00
5	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	10,000.00	10,000.00
6	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	15,000.00
7	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	5,000.00	5,000.00
8	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	10,000.00	10,000.00
	Materials														
9	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	100,000.00
10	Stems	BD	500	36,000.00	36,000.00	36,000.00	36,000.00	27,000.00	27,000.00	27,000.00	27,000.00	20,000.00	20,000.00	20,000.00	20,000.00
11	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	40,000.00	40,000.00
	TVC			361,618.20	392,412.13	392,412.13	371,809.10	352,618.20	383,412.13	383,412.13	362,809.10	345,628.20	376,412.13	376,412.13	355,809.10
	Yield														
12	Tubers	Ton	10,000.00	267,000.00	320,000.00	468,000.00	599,000.00	253,000.00	298,000.00	440,000.00	596,000.00	223,000.00	290,000.00	423,000.00	567,000.00
13	Stems	BD	500.00	415,000.00	474,000.00	652,000.00	770,500.00	311,000.00	400,000.00	489,000.00	574,500.00	266,500.00	400,000.00	466,500.00	500,000.00
	TR			682,000.00	794,000.00	1,120,000.00	1,369,500.00	564,000.00	698,000.00	929,000.00	1,170,000.00	489,500.00	690,000.00	889,500.00	1,067,000.00
	Net returns			320,381.80	401,587.87	727,587.87	997,690.90	211,381.80	314,587.87	545,587.87	807,190.90	143,881.80	313,587.87	513,087.87	711,190.90

Note: ₦957 = 1 USD ($)

KEY: D_1 = cassava @ 17,778 plants/ha; D_2 = cassava @ 13,333 plants/ha; D_3 = cassava @ 10,000 plants/ha; S_0 = No solarization; S_4 = 4 weeks solarization; S_8 = 8 weeks solarization; S_{10} = 10 weeks solarization, M^2 = meter square, MD = manday, Kg = kilogramme, TVC = total variable cost, TR = total revenue, Ton = tonnes, BD = bundles, ₦/ha = naira per hectare

APPENDIX B. Components of cost and revenue for crop density and soil solarization experiment in 2020

				Second planting (2020)											
s/n	Input / output	Unit	Price (₦/k)	D_1S_0 (₦/ha)	D_1S_4 (₦/ha)	D_1S_7 (₦/ha)	D_1S_{10} (₦/ha)	D_2S_0 (₦/ha)	D_2S_4 (₦/ha)	D_2S_7 (₦/ha)	D_2S_{10} (₦/ha)	D_3S_0 (₦/ha)	D_3S_4 (₦/ha)	D_3S_7 (₦/ha)	D_3S_{10} (₦/ha)
	Labour														
1	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	44,603.03	44,603.03
2	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	72,206.07	72,206.07
3	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	10,000.00	10,000.00
4	Weeding	M^2	4.46	133,809.07	49,603.03	49,603.03	29,000.00	133,809.07	49,603.03	49,603.03	29,000.00	133,809.07	49,603.03	49,603.03	29,000.00
5	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	10,000.00	10,000.00
6	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	15,000.00
7	Transportation	-	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	10,000.00	10,000.00	10,000.00
8	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	10,000.00	10,000.00
	Materials														
9	Polyethylene sheet	Kg	300	-	166,000.00	166,000.00	166,000.00	-	166,000.00	166,000.00	166,000.00	-	166,000.00	166,000.00	166,000.00
10	Stems	BD	500	36,000.00	36,000.00	36,000.00	36,000.00	27,000.00	27,000.00	27,000.00	27,000.00	20,000.00	20,000.00	20,000.00	20,000.00
11	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	40,000.00	40,000.00
	TVC			366,618.20	463,412.13	463,412.13	442,809.10	358,618.20	454,412.13	454,412.13	433,809.10	350,628.20	447,412.13	447,412.13	426,809.10
	Yield														
12	Tubers	Ton	10,000.00	279,000.00	356,000.00	504,000.00	604,000.00	262,000.00	324,000.00	458,000.00	576,000.00	250,000.00	303,000.00	440,000.00	577,000.00
13	Stems	BD	500.00	415,000.00	533,500.00	592,500.00	652,000.00	355,500.00	425,500.00	489,000.00	533,500.00	300,000.00	366,500.00	466,500.00	466,500.00
	TR			694,000.00	889,500.00	1,096,500.00	1,156,000.00	617,500.00	749,500.00	947,000.00	1,109,500.00	550,000.00	669,000.00	906,500.00	1,043,500.00
	Net returns			327,381.80	426,087.87	633,087.87	813,190.90	258,881.80	295,087.87	492,587.87	675,690.90	199,381.80	222,087.87	459,087.87	616,698.90

Note: ₦957 = 1 USD ($)

KEY: D_1 = cassava @ 17,778 plants/ha; D_2 = cassava @ 13,333 plants/ha; D_3 = cassava @ 10,000 plants/ha; S_0 = No solarization; S_4 = 4 weeks solarization; S_8 = 8 weeks solarization; S_{10} = 10 weeks solarization, M^2 = meter square, MD = manday, Kg = kilogramme, TVC = total variable cost, TR = total revenue, Ton = tonnes, BD = bundles, ₦/ha = naira per hectare