Agricultural Socio-Economics Journal
Volume 22, Number 3 (2022): 151-158

P-ISSN: 1421-1425
E-ISSN: 2252-6757

PROFITABILITY AND TIME CONSUMPTION AS INFLUENCED BY VARIOUS WEED CONTROL METHODS IN CURCUMA AMADA ROXB.

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Abstract To determine the profitability and time consumption of various weed control options in mango ginger, the field trials were conducted at the Teaching and Research Farm, Federal University of Agriculture Abeokuta (07° 20 N, 3° 23 E, 159 m above sea level) in the forest – savannah transition agroecology of Nigeria in the early cropping seasons of 2016 and 2017. Randomized complete block design (RCBD) was used to evaluate ten weed control strategies and replicated three times. Data collected on weed cover, plant biomass, and rhizome yield were analyzed using ANOVA, and treatment means were separated using the least significant difference at p0.05. Results indicated that the highest man days in weeding was observed on the plots weeded five times at 4, 8, 12, 16 and 20 weeks after planting (WAP), while application of pre emergence herbicides generally reduced time spend on weeding. Despite the fact that weeding at 4, 8, 12, 16, and 20 WAP had the maximum rhizome production and yielded the highest gross return, application of oxyfluorfen (oxyf) at 0.24 kg a.i/ha as a pre and post emergence herbicide yielded the highest benefit cost ratio.

Keywords: *gross return, herbicide, mango ginger, oxyfluorfen, rhizome yield*

http://dx.doi.org/10.21776/ub.agrise.2022.022.3.1

Received 28 March 2022
Accepted 28 July 2022
Available online 31 July 2022

INTRODUCTION

Mango ginger (*Curcuma amada* Roxb.) is a peculiar spice that has a ginger-like appearance and raw mango flavor (Sasikumar, 2005). *Curcuma amada* is a perpetual spice native to Asia and frequently grown beacuase of its mango-flavored rhizomes (Chatterjee et al., 2012). The crop has long leaves, oblong-lanceolate with petiole, and its aerial shoot can reach 90cm above ground level, according to Samant (2012). Curcuma amada is very useful in Ayurvedic medicine to treat conditions like jaundice, bleeding, colic, and its leaves are utilized in mainstream medicine to eliminate cancer cells (Vishnupriya et al., 2012). Mango ginger is a well-known spice that's used as a flavoring, and its golden color may be visible in drinks (Vishnupriya et al., 2012).

Chandarana et al. (2005) reported that mango ginger organic solvent and aqueous extracts are antibiotic against Bacillus subtilis, Escherichia coli and Staphylococcus aureus. Bacillus subtilis, B. cereus, Micrococcus luteus, Listeria monocytogenes, Staphylococcus aureus, Enterococcus fecalis, and Salmonella typhi are all highly antibacterial in extracts such as chloroform,

CITATION: Osunleti, S. O., Lagoke, S. T. O., Olorunmaiye, P. M., Adeyemi, O. R., Olatunde, E. O., Ajani, A. O., Olaogun, O., (2022). THE ROLE OF HUMAN CAPITAL AND SOCIAL CAPITAL IN AGRICULTURAL INSTITUTIONAL DEVELOPMENT IN RURAL AREAS, Agricultural Socio-Economics Journal, 22(3), 151-158 DOI: http://dx.doi.org/10.21776/ub.agrise.2022.022.3.1

ethyacetate, hexane, acetone, and methanol (Policegoudra et al. 2007a; 2007b).

Weeds have been described to be the most common pests in crop production in the humid and subtropical tropics, with adequate precipitation, temperature, sunlight, and relative humidity promote crop development (Nedunchezhiyan et al. 2013). Weed infestation causes severe yield losses, which can reach 100% in the early stages (Ambe et al. 1992). Weed has been describded as one of the most significant constraints in crop production. Weeding takes approximately 30 percent of total labour requirement and 150 - 200 man days/ha. Farmers in India weed up to five times in cassava under irrigation (Ravindran and Ravi 2009). Weeding with chemicals can reduce the need for weeding using hoe. Herbicides usage are likely to turn out to be an unavoidable way of controlling weeds, particularly where labour is scanty or highly-priced, or where farm sizes are huge (Agahiu et al. 2011).

Weed competing with crops had been identified as a limiting factor in root and tuber crops (Unamma, 1984). Weeds reduce crop yield and add to the total labor cost in crop production. Weeds, according to Akobundu (1987), reduce root and tuber crop yield by 65 percent and account for 25 percent of total labor use in production.

As reported by All India Coordinated Research Project on Weed Control, uncontrolled weed growth can result in up to 45 percent reduction in ginger yield (KAU, 2006), and Osunleti et al. (2021b) reported a 92.2 percent mango ginger yield loss due to uncontrolled weed growth. The current study's goal was thus to assess the profitability and time consumption of various weed control options in mango ginger.

RESEARCH METHODS

The trials were carried out on the field of Federal University of Agriculture, Abeokuta, Ogun State, Nigeria (70 15' N, 30 23' E, 159 m above sea level) between June and December of 2016 and 2017. The experimental site was located in the south-western Nigerian forest-savanna transition zone. In 2016, and 2017, the site received 1146.3 mm and 839.7 mm of rain, respectively (Table 1). In 2016 and 2017, the average monthly temperature is between 22.5 °C to 25.2 °C to 30.3 °C and 30.2 °C, respectively (Table 1). The experiment comprised of ten different treatments in both years and arranged in a RCBD with three replicates.

The ten treatments used are: oxyfluorfen (oxyf) at 0.36 kg a.iha-1 alone at planting (TT1); oxyf at 0.36 kg a.i ha-1 at planting plus oxyf at 0.24 kg a.i ha-1 at 8 WAP (TT2); oxyf at 0.36 kg a.i ha-1 at planting plus hoe weeding at 8 WAP (TT3); oxyf at 0.24 kg a.i ha-1 alone at planting (TT4); oxyf at 0.24 kg a.i ha-1 at planting plus oxyf at 0.24 kg a.i ha-1 at 8 WAP (TT5); oxyf at 0.24 kg a.i ha-1 at planting plus hoe weeding at 8 WAP (TT6); hoe weeding (HW) at 4, 8, 12 weeks after planting (WAP) (TT7); HW at 4, 8, 12, 16 WAP (TT8); HW at 4, 8, 12, 16, 20 WAP (TT9) and weedy check (TT10). All post emergence treatments were applied at 8 WAP in all the plots).

In each year, the experimental site was ploughed and harrowed after two weeks to give weed-free tilth soil. The field was laid out and beds of 3 m 3 m were manually formed with a hoe after removing of weed stumps and debris. The rhizomes of mango ginger were planted one per hole per stand at 0.20 m 0.20 m for a plant density of 250,000 plants ha^{-1}. On each treatment plot, weeding operation was preceded by a visual rating of the weeds, and was documented as a weed cover score on a scale of 10 to 100, with 10 indicating no weed cover, 20 to 30 indicating minimal weed cover, 40 to 60 indicating moderate weed cover, 70 to 90 indicating acute weed cover, and 100 indicating absolute weed cover (Osunleti et al. 2021).

To deduce the level of significance of the treatments, data on weed cover, plant biomass, and fresh rhizome yield were subjected to analysis of variance (ANOVA) using Genstat 12th edition. The treatment means were separated based on a 5% least significant difference (LSD). The number of hours spent weeding (whether manual weeding with a hoe or applying pre and post emergence herbicides) was recorded for each plot and treatment and converted to man days using Equation 1. Data on weeding time and economics were compiled over the course of two years. The economics of the treatments were calculated using current market prices for the inputs used and the rhizomes produced.

Man day = H/T (1) (Alabi and Esobhawan 2016)
Where H = the total mean in hours of labour
T = A time span of 8 hours

Table 1: Monthly and annual total rainfall distributions, mean temperature, and relative humidity at the experimental site, 2016 and 2017.

Month	2016			2017		
	Total rainfall (mm)	Mean temperature (°C)	Relative Humidity (%)	Total rainfall (mm)	Mean temperature (°C)	Relative Humidity (%)
January	32.0	28.1	56.2	15.9	28.9	69.5
February	0.0	30.3	56.7	0.0	30.2	70.7
March	150.3	29.5	59.1	34.3	30.0	68.1
April	68.2	29.2	63.1	112.8	29.1	73.8
May	226.2	29.0	73.6	146	27.8	80.8
June	150.5	26.7	72	111	26.7	80.8
July	65.2	26.3	72.7	156	25.7	85.5
August	63.6	25.7	72.8	90.0	25.5	81
September	229.0	26.9	68.9	52.0	25.2	77.3
October	155.4	28.0	65.3	90.2	27.6	82.2
November	5.9	22.5	65.3	45.6	28.6	75.5
December	0.0	28.1	56.6	15.9	28.9	77.3
Average		27.5	56.2		27.9	69.5
Total	1146.3			839.7		

RESULTS AND DISCUSSION

Weed Cover Score.

At 4 WAP in both years, oxyfluorfen (Oxyf) applications of 0.24 kg a.i/ha and 0.36 kg a.i/ha at planting caused significant reduction in weed cover compared to the non-treated plots. Similarly, oxyfluorfen (Oxyf) applications of 0.24 kg a.i/ha and 0.36 kg a.i/ha at 8 WAP in both years caused significant reduction in weed coverage compared to when weeding was done at 4 WAP and the weedy check. Furthermore, weeding once at 4 WAP caused significant reduction in weed coverage compared to the weedy check at 8 WAP (Table 2). Regardless of follow-up treatments in both years, the weedy check plots and plots with Oxyf application had the highest and lowest weed cover at 12 WAP. Oxyf at 0.24 kg a.i/ha and 0.36 kg a.i/ha alone at planting gaved higher weed cover than oxyf at 0.24 kg a.i/ha plus hoe weeding (Table 2). Generally, pre-emergence herbicide application gave significantly lower weed cover score at 4 WAP compared to when hoe weeding was done and weedy check. The lower weed coverage on the herbicide applied plots is due to the application of pre-emergence herbicides used at planting, the herbicide stormed the weed seeds and prevents their germination. These findings support the earlier report of Imoloame (2014) and Osunleti et al (2021c), who found that herbicide-treated plots had better weed control than untreated plots. The combined effect of the herbicide and hoeing manually with hoe resulted in lower weed coverage with pre-emergence herbicide followed by hoe weeding at 12 WAP.

Table 2: Effect of various weed control options on weed cover score

Treatments	Weed Cover Score					
	4 WAP		8 WAP		12 WAP	
	2016	2017	2016	2017	2016	2017
TT1	10.0	10.0	28.8	26.6	51.7	50.0
TT2	11.7	10.0	23.3	23.3	20.0	20.0
TT3	11.7	10.0	21.6	23.3	15.0	15.0
TT4	11.7	13.3	26.6	30.0	53.3	55.5
TT5	11.7	13.3	23.3	31.6	20.0	20.0
TT6	11.7	11.1	23.3	31.6	15.5	16.6
TT7	21.7	21.1	33.3	36.6	20.0	20.0
TT8	23.3	23.3	33.3	31.6	20.0	20.0
TT9	20.0	20.0	33.3	36.6	20.0	20.0
TT10	21.7	21.1	60.0	68.8	78.3	83.3
Lsd	4.58	3.941	6.806	6.264	2.811	2.334
p value	<.001	<.001	<.001	<.001	<.001	<.001

Oxyf – oxyfluorfen; WAP – weeks after planting; HW – how weeding

Plant Biomass and Rhizome Yield

Mango ginger biomass was significantly lower on the weedy check plots in both years and at 16 and 20 WAP than on various weed control methods (Table 3). Mango ginger rhizome yield was highest when plots were weeded at 4, 8, 12, 16, and 20 WAP (29, 789 kg/ha and 32,746 kg/ha, respectively) in 2016 and 2017. (Table 3). In 2016, and 2017, the lowest rhizome yield was observed on the weedy check plots (2356 kg/ha and 2590 kg/ha, respectively). With the application of only pre-emergence herbicide, rhizome yield was lower than when it was followed by a post-emergence herbicide or hoe weeding (Table 3). The higher yield on the five-times-weeded plots at 4, 8, 12, 16, and 20 WAP could be attributed to the plots' long-seasoned weed control, which makes environmental resources and soil nutrients available to the crop alone. This means that mango ginger, as a long-season crop, requires longer weed-free situation to reach its full capacity. This study confirmed the findings of Sivakumar et al. 2019, who found that frequent hoe weeding increased ginger rhizome yield. Weed-crop competition throughout the crop life cycle resulted in continuous competition for soil nutrients and environmental resources, resulting in the lowest yield on the weedy check. This result is related to that of Habetewold et al. (2015), who reported a 93.2 percent yield loss in ginger, and Osunleti et al. (2021b), who previously reported an 85.1 percent to 92.2 percent rhizome yield loss in mango ginger when the crop is left weed infested throughout the crop life cycle. Lower yields on plots treated with only pre-emergence herbicide may be credited to succeeding weed infestation, which also leads to crop-weed competition. This suggests that because mango ginger is a long-season crop, it necessitates long-season weed control. Our findings revealed that after being sprayed with a pre-emergence herbicide, mango ginger requires a post-emergence treatment for increased productivity. Sivakumar et al. (2019) expressed similar sentiments and conveyed higher rhizome yield with integrated herbicide use and hand weeding. These findings are consistent with those reported by Eshetu and Addisu (2015), Dinesh et al, (2017) and Ratnam et al., (2012).

Table 3: Effect of various weed control options on plant biomass and fresh rhizome yield of mango ginger

Treatments	Plant biomass (g/plant)				Rhizome Yield (kg/ha)	
	16 WAP		20 WAP			
	2016	2017	2016	2017	2016	2017
TT1	80.6	83.8	131.5	151.2	11540	12288
TT2	84.1	90.0	144.9	156.9	20003	21942
TT3	84.2	88.4	144.9	157.0	18233	18683
TT4	78.6	86.4	130.2	152.2	12012	12589
TT5	84.4	93.6	145.3	157.3	23192	25554
TT6	76.1	84.5	144.0	143.3	25003	27464
TT7	83.6	92.8	128.4	137.0	15083	15777
TT8	84.0	93.2	144.6	157.3	24519	26989
TT9	84.2	93.5	145.1	157.1	29789	32746
TT10	57.1	63.4	80.2	77.3	2356	2590
Lsd	9.89	11.12	16.17	21.84	9210.9	10344
p value	<.001	<.001	<.001	<.001	<.001	<.001

Oxyf – oxyfluorfen; WAP – weeks after planting; HW – how weeding

Time Spent on Weeding

In both years, 0.58 man days/ha were required to spray pre-emergence herbicide at planting, while neither the hoe weeded nor weedy check plots were weeded (Table 4). At 4 WAP, 23.15 man days/ha were required to carry out hoe weeding on hoe weeded plots, whereas no weeding activity was carried out on pre-emergence herbicide-treated plots (Table 4). At 8 WAP, plots weeded at 4, 8, 12 WAP; 4, 8, 12, 16 WAP; and 4, 8, 12, 16, 20 WAP required more days (34.73 man days/ha) than plots treated with oxyfluorfen at both rates irrespective of the follow up treatments (2.69 man days/ha to 28.94 man days/ha). The shorter number of days on herbicide-treated plots is due to less weed pressure on the plots. Our findings revealed that as weed pressure on the plots increased, so did the time spent weeding. Furthermore, on the herbicide-treated plots, lower man days were recorded with post-emergence herbicide application (2.69 man days/ha) than with hoe weeding as post-emergence treatment (28.94 man days/ha) (Table 4). This could be

attributed to the fact that spraying herbicide over a unit area of land is faster and easier than using a hoe over the same unit while controlling weeds. The plots that had been weeded five times at 4, 8, 12, 16, and 20 WAP had the most days to weed (111.69 man days/ha), while the fewest days were recorded with application of only pre-emergence herbicide (0.58 man days/ha). This implies that manual weeding with a hoe takes a long time and a lot of resources. Our findings revealed a 74 percent to 99 percent reduction in man days when pre-emergence herbicide was used in comparison to manually weeding plots with a hoe (Figure 1). Herbicide use required approximately 2 hours of labour in one hectare, while hand weeding is evaluated to take 400 hours per hectare (Gouse et al., 2006).

Table 4: Effect of various weed control options on time spent weeding (man days) in mango ginger in both years

Treatments	At Planting	4 WAP	8 WAP	12 WAP	16 WAP	20 WAP	Total
TT1	0.58	0.00	0.00	0.00	0.00	0.00	0.58
TT2	0.58	0.00	2.69	0.00	0.00	0.00	3.26
TT3	0.58	0.00	28.94	0.00	0.00	0.00	29.51
TT4	0.58	0.00	0.00	0.00	0.00	0.00	0.58
TT5	0.58	0.00	2.69	0.00	0.00	0.00	3.26
TT6	0.58	0.00	28.94	0.00	0.00	0.00	29.51
TT7	0.00	23.15	34.73	19.09	0.00	0.00	76.96
TT8	0.00	23.15	34.73	19.09	17.36	0.00	94.33
TT9	0.00	23.15	34.73	19.09	17.36	17.36	111.69
TT10	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Oxyf – oxyfluorfen; WAP – weeks after planting; HW – how weeding

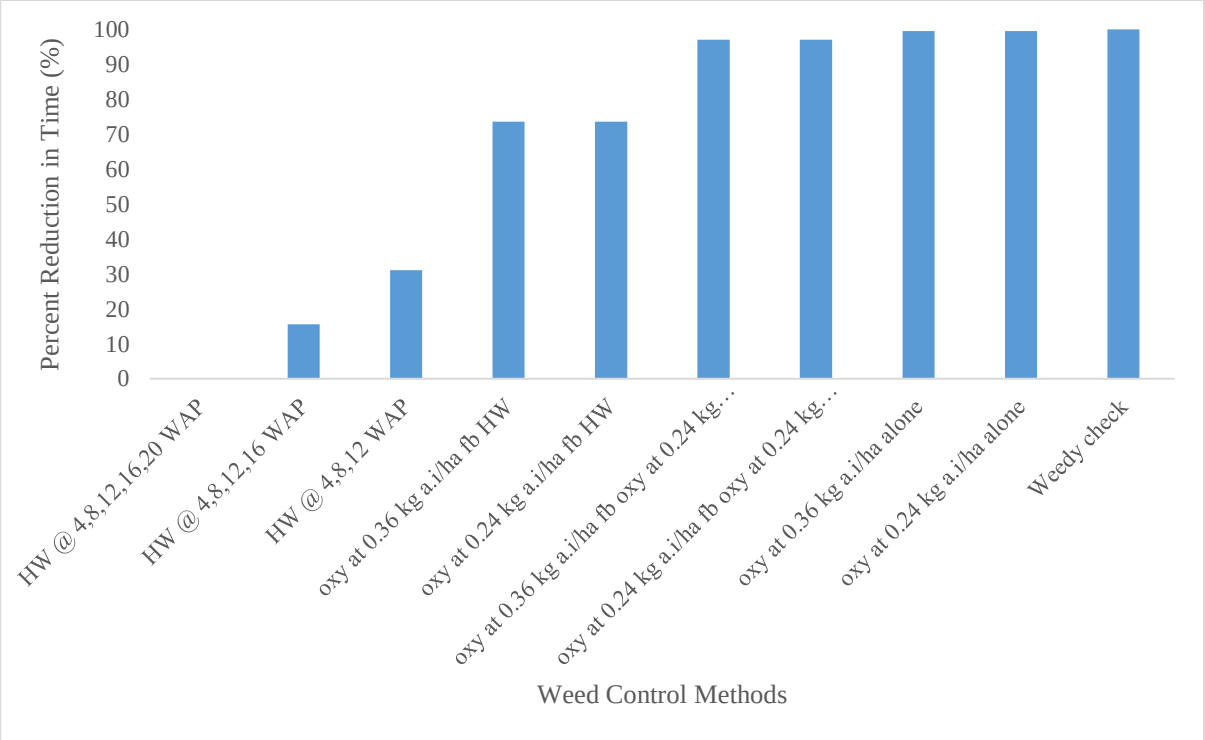

Figure 1: Reduction in time spent to weed relative to weeding five times at 4, 8, 12, 16 and 20 WAP.

Economics

Using only pre-emergence herbicide resulted in a lower cultivation cost (N 1,225,980 to N 1,226,850) than using pre-emergence herbicide along side with either hoe weeding or post-emergence herbicide (N 1,232,720 to N 1,506,415). The lower cost incurred on the plots with only pre-emergence herbicide could be ascribed to the reduction in labour required for only pre-emergence

herbicide versus additional labour required for the post-emergence treatment. Upasani and Barla 2019 previously reported lower cultivation costs on plots treated only with pre-emergence herbicides versus hand weeding combined with pre-emergence herbicide. The cultivation cost increased proportionally to the number of manual weedings performed on the plots, with the highest cost recorded when plots were weeded five times at 4, 8, 12, 16, and 20 WAP (N 2, 997,500). The higher cost of cultivation on hoe weeded plots compared to herbicide weeded plots may be traceable to higher weed cover on the plots, the number of times the plots must be weeded, and the stretch of time required to weed the plots. According to an earlier report, using herbicide lowers overall production costs because it reduces labor requirements when compared to hoe weeding (Overfield et al., 2001).

The highest gross and net returns (N 9,380,250 and N 6,382,750, respectively) were documented on plots weeded five times at 4, 8, 12, 16, and 20 WAP (Table 5). This could be attributed to long-term weed control, which resulted in higher yield and, thus, the highest gross return in this study. Despite higher yields and gross returns on plots weeded five times at 4, 8, 12, 16, and 20 WAP, the net return on the plot is comparable to oxyfluorfen pre-emergence application at 0.24 kg a.i/ha followed by hoe weeding and had a lower benefit-cost ratio than most herbicide-treated plots. This means that the high yield, gross return, and net return on plots weeded at 4, 8, 12, 16, and 20 WAP were offset by the high cost of cultivation due to the longer weeding periods, which necessitated more labor. As a result of this, the plots produced a lower benefit-cost ratio. The application of oxyf at 0.24 kg a.i/ha as a pre and post emergence herbicide yielded the highest benefit-cost ratio (4.93), followed by the application of oxyfluorfen at 0.24 kg a.i/ha and hoe weeding (4.23) (Table 5) The higher benefit-to-cost ratio on herbicide-treated plots is due to less time spent controlling weeds, less labor required, and lower cultivation costs, all while yielding optimal results. These findings are consistent with those of Wibawa et al. (2010) and Jaya Suria et al. (2011), who discovered that using an appropriate herbicide outperformed manual hoe weeding for weed control.

Table 5: Effect of various weed control options on economics (Naira) in mango ginger in both years

Treatments	Cost of Cultivation	Gross Return	Net Return	B:C Ratio
TT1	1226850	3574200	2347350	1.91
TT2	1234025	6291750	5057725	4.10
TT3	1506415	5537400	4030985	2.68
TT4	1225980	3690150	2464170	2.01
TT5	1232720	7311900	6079180	4.93
TT6	1505110	7870050	6364940	4.23
TT7	2397500	4629000	2231500	0.93
TT8	2697500	7726200	5028700	1.86
TT9	2997500	9380250	6382750	2.13
TT10	1197500	741900	-455600	-0.38

Oxyf – oxyfluorfen; WAP – weeks after planting; HW – how weeding

CONCLUSION

The study discovered that differen weed control methods had varied effects on weed cover score, rhizome yield, weeding time, and the economics of mango ginger cultivation. When pre-emergence herbicide was used in weed control instead of manual weeding with a hoe, there was a 74 to 99 percent reduction in man days. While plots weeded at 4, 8, 12, 16, and 20 WAP produced the highest yield and gross benefit, plots treated with pre and post emergence herbicide produced the highest benefit cost ratio. Our research found that using a pre-emergence herbicide to control weeds saves time and resources while increasing the benefit-to-cost ratio in mango ginger.

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