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Original Paper

Influence of organo-mineral ferilizer rates and weeding frequency on mango ginger (*Curcuma amada* Roxb.)

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The initial slow growth of mango ginger makes them highly vulnerable to weed interference with high yield losses. Timely weeding and adequate fertilization therefore is a necessity for enhanced productivity of mango ginger. Field trials were conducted in the early cropping seasons of 2016 and 2017 at the Teaching and Research Farm of the Federal University of Agriculture Abeokuta, Ogun State, Nigeria to evaluate the effect of weeding frequency under different application rates of organo-mineral fertilizer on growth and productivity of mango ginger. Treatments were laid out in split plot arrangement in a randomized complete block design with three replications. Main plot treatments were three levels of organo-mineral fertilizer at 0 t ha^{-1}, 2.4 t ha^{-1} and 3.6 t ha^{-1} while sub plots treatments consisted of six weeding frequencies viz: weeding at 3, 6, 9, 12, 15 weeks after planting (WAP); Weeding at 4, 8, 12, 16, 20 WAP; Weeding at 3, 6, 9, 12 WAP; Weeding at 4, 8, 12, 16 WAP; Weed free and Weedy check as control. Results showed that application of 3.6 t ha^{-1} organo-mineral fertilizer gave the highest rhizome yield and return on investment in both years. Although plot kept weed free throughout crop life cycle produced the highest rhizome yield, plot weeded at 4, 8, 12 and 20 WAP gave the highest return on investment in both years. This study reveals that application of 3.6 t ha^{-1} of organo-mineral fertilizer and weeding at 4, 8, 12, 16 and 20 WAP resulted in optimum yield with highest return on investment.

Keywords: *Curcuma amada*, fertilizers, hoe-weeding, weed-free, yield

1 Introduction

Mango-ginger (*Curcuma amada* Roxb) belongs to Zingiberaceae family, a perennial herb cultivated as annual crop. Mango ginger is a unique spice having morphological resemblance with ginger but imparts a raw mango flavour (Policegoudra et al., 2011). Estimated world production of ginger in 2009 was 1.6 million tonnes (Abubacker, 2009). However in 2013, the production increased to 2.1 million tonnes. India is the largest producer of ginger with 0.683 million tonnes, followed by China and Nepal with 0.390 and 0.235 million tonnes, respectively. The three countries accounted for more than 60% of total world ginger production. Nigeria produced 0.160 million tonnes of ginger as the largest producer in Africa and fifth in the world (FAO, 2013). *Curcuma amada* is reportedly used invarious herbal preparations, including anti allergy formulations (Pushpangadan et al., 2006). Ginger crop is highly susceptible to weed competition especially at the initial stages of crop growth.

In most cases weed management accounts for the major share of the total cost of cultivation (KAU 2006). Despite all the potentials and opportunities of having such a long history with a diversified conducive agro- ecology base, potential of mango ginger remained unexploited. The productivity of mango ginger is still low due to several factors which include: poor soil fertility, shortage of improved varieties, and poor agronomic practices (Hailemichael and Tesfaye, 2008; MoARD, 2007).

Ginger is a nutrient exhaustive crop and application of organic manures and fertilizers are absolutely essential. Ginger rhizomes are mainly N and K exhausting, intermediary in P and Mg removal and the least in Ca removal (Nagarajan and Pillai, 1979). Ginger performs

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well with good supply of humus and organic matter, which had positive correlation with yield (Cho et al., 1987). Gradual availability of nutrients through decomposition of organics throughout the growth phase cause better growth and development of plant and ultimate yield when inorganics were substituted with organics at different levels (Roy and Hore, 2007).

The initial slow growth of mango ginger makes them highly vulnerable to weed interference with high yield losses. Like any other crop, mango ginger requires the right kind of nutrients to sustain its growth and maximize yield. Roy and Hore 2007 stated that fertilizer enhances the growth and development of ginger. The present study hypothesized that organo-mineral fertilizer with frequent weeding will enhance the initial slow growth and rhizome yield of mango ginger. Therefore, the objectives of the study are to evaluate different rates of organo-mineral fertilizer and weeding frequency on weed density, growth and yield of mango ginger.

2 Material and methods

The experiments were conducted in the early wet seasons of 2016 and 2017 at the Teaching and Research farms of the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria (70, 20′ N and 30, 23′ E) altitude 140 m above seas level. The experimental site was located in the forest-savanna transition zone of south-western Nigeria. The site received a total rain fall of 669.6 mm and 560.7 mm from June to December in 2016 and 2017, respectively (Figure 1).

The experiments in both years were laid in a split-plot arrangement in a randomized complete block design in three replicates. Main plot treatments were three levels of organo-mineral fertilizer at 0, 2.4 and 3.6 t ha^{-1}. The sub plots treatments were five weeding frequency viz: weeding at 3, 6, 9, 12, 15 WAP; Weeding at 4, 8, 12, 16, 20 WAP; Weeding at 3, 6, 9, 12 WAP; Weeding at 4, 8, 12, 16 WAP; Weed free (was weeded as soon as there was weed emergence) and Weedy check were included as control. In each year, field was ploughed and harrowed at two-week intervals to ensure a tilth weed-free soil. After the removal of weed stumps and debris, field layout was done and beds of 3 × 3 m were made manually with hoe. Mango ginger rhizomes were planted per hill at 0.20 × 0.20 m to give total plant population of 250,000 plants ha^{-1}. Organo-mineral fertilizer (Aleshinloye grade B) which is a combination of organic and inorganic fertilizer was applied at planting at 0 t ha^{-1}, 2.4 t ha^{-1} and 3.6 t ha^{-1}. Proximate analysis of organo-mineral fertilizer Grade B used is shown in Table 1. The total N in Aleshinloye Grade B is 10.2 g kg^{-1}, P in Aleshinloye Grade B is 7.6 g kg^{-1} while K in Aleshinloye Grade B is 20.9 g kg^{-1}.

Table 1 Proximate analysis of organomineral fertilizer Grade B

Nutrient element	Concentration Grade B
N (g kg^{-1})	10.2
P (g kg^{-1})	7.6
K (g kg^{-1})	20.9
C (g kg^{-1})	319.4
Mg (g kg^{-1})	2.4
Ca (g kg^{-1})	23.4
Na (g kg^{-1})	2.9
Fe (mg kg^{-1})	8,915.40
Zn (mg kg^{-1})	1.9
Mn (mg kg^{-1})	106.7
Cu (mg kg^{-1})	16.9

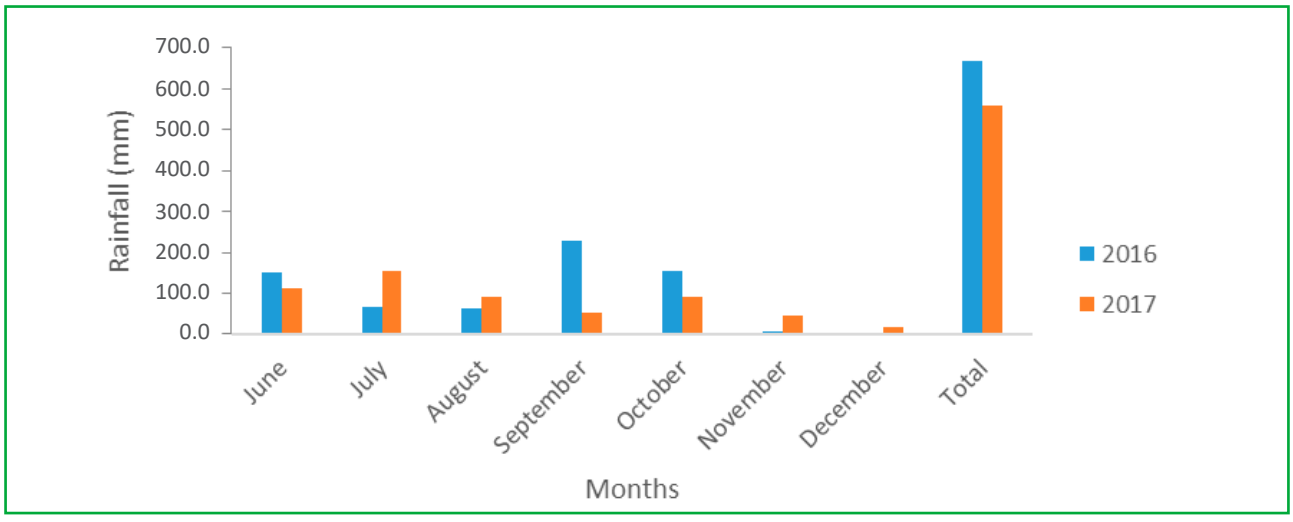

Figure 1 Monthly weather data during the experiment

Hoe weeding was carried out according to the treatment requirement using West African hand hoe. The weeding operation on each plot was preceded by collection of weed samples using systematic random sampling on the plots. Weed samples were collected from quadrat size of 0.5 × 0.5 m before every weeding according to the treatments. The weed samples collected were separated into grasses, broadleaves and sedges and counted. The samples taken from each plot were cumulatively added to determine total weed count at harvest per treatment. Data on mango ginger stands and rhizome yield at harvest were also taken. Data collected were subjected to Analysis of Variance (ANOVA) according to the procedures of GENSTAT. Significant means were separated using Duncan's Multiple Rage Test at 5% level probability. Cost benefit ratio was done to determine the profitability of the alternatives.

3 Results and discussion

Total weed count was significantly affected by organo-mineral fertilizer rates in both years (Table 2). Higher total weed count was obtained from the plots without organo-minral fertlizer (0 t ha^{-1}) compared to the other tested organo-mineral fertilizer rates (2.4 and 3.6 t ha^{-1}). Application of organo-mineral fertilizer reduced total weed count in this study. This implies that the organo-mineral fertilizer enhanced crop growth to aid its competition with weeds and also facilitate quick crop canopy closure which helps in smothering the weeds. This corroborates the findings of Rahnavard et al., 2009 who reported reduced weed dry matter production as a result of fertilizer application using NPK fertilizer. Conversely, mango ginger stand count was significantly higher with the application of 2.4 and 3.6 t ha^{-1} organo-mineral fertilizer in both years than 0 t ha^{-1} (Table 2). This is probably due to adequate and timely release of essential plant nutrients to the crop for good growth and also helps in stand establishment. Similar finding was observed by Banafar and Tiwari (1995) when effect of potassium was investigated. They observed increase in growth parameters with increase in rate of potassium fertilizer.

Total weed count was significantly affected by weeding frequency (Table 2). Keeping plot weed infested throughout crop life cycle resulted in the highest weed count which was significantly higher than various weeding frequencies including weed free. Lowest total weed count was recorded from weed – free plots. Weed count on plots weeded up to 12 WAP was significantly higher than those plots weeded up to 15 WAP and more in both years. Generally, there was reduction in weed count with increase in weeding frequency. This is because constant removal of weed on the plots did not give room for serious weed competition with the crop. This agrees with earlier results obtained by Channappagoudar et al. (2013) when he reported significant decrease in weed

Table 2 Effect of organo-mineral fertilizer and weeding frequency on weed count and mango ginger stand count at harvest

	Weed count count at harvest (× 000 ha^{-1})		Mango ginger stand count at harvest (× 000 ha^{-1})	
Treatments	2016	2017	2016	2017
Organo mineral fertilizer (O)				
0 t ha^{-1}	496a	492a	195.9b	209.3b
2.4 t ha^{-1}	455b	470b	200.9a	216.2a
3.6 t ha^{-1}	469b	447c	202.0a	214.6a
SE	6.33	1.70	0.99	0.98
Weeding frequency (W)				
Weeding at 3, 6, 9, 12 and 15 WAP	504c	497c	232.0a	243.1a
Weeding at 4, 8, 12, 16 and 20 WAP	198e	209e	234.8a	245.9a
Weeding at 3, 6, 9 and 12 WAP	709b	700b	234.7a	245.8a
Weeding at 4, 8, 12 and 16 WAP	413d	400d	233.1a	244.2a
Weed free	71f	80f	233.3a	244.4a
Weedy check	944a	931a	29.8b	56.5b
SE	18.32	21.81	2.01	2.31
Interaction				
O × W	ns	ns	3.33	ns

Table 3 Effect of organo-mineral fertilizer and weeding frequency on fresh rhizome yield and count of mango ginger at harvest

	Rhizome fresh yield (t ha^{-1})		Number of rhizome (× 000 ha^{-1})	
Treatments	2016	2017	2016	2017
Organo Mineral Fertilizer (O)				
0 t ha^{-1}	21.5b	19.1b	745.4b	757.4b
2.4 t ha^{-1}	28.1ab	22.5b	749.1b	935.1ab
3.6 t ha^{-1}	32.1a	28.8a	1,002.4a	1,083a
SE	2.38	1.65	58.4	95.1
Weeding frequency (W)				
Weeding at 3, 6, 9, 12 and 15 WAP	28.6bc	25.4b	927.5b	950.6a
Weeding at 4, 8, 12, 16 and 20 WAP	32.1bc	34.4a	1,007.7b	1,251.3a
Weeding at 3, 6, 9 and 12 WAP	23.5c	18.2b	812.2b	941.2a
Weeding at 4, 8, 12 and 16 WAP	34.1ab	22.6b	806.5b	935.7a
Weed free	41.8a	37.3a	1,339.1a	1,367.9a
Weedy check	3.28d	2.9c	100.6c	102.5b
SE	4.23	2.7	93.2	151.6
Interaction				
O × W	ns	ns	ns	ns

biomass with increase in weeding time. Application of 3.6 t ha^{-1} organo-mineral fertilizer resulted in significantly higher rhizome fresh yield and number of rhizomes than the unfertilized plots (0 t ha^{-1}) in both years (Table 3). Organo-mineral fertilizer showed a marked influence on yield and yield components in this study. This is probably due to adequate and timely release of essential plant nutrients to the crop for good productivity, efficient water use and translocation of assimilates. Bahadur et al. (2000) also reported increase in almost all the characters of turmeric with increased level of potassium fertlizer.

Keeping plots weed free throughout crop life cycle resulted in highest fresh rhizome yield in both years and significantly higher than various weeding frequencies including weedy check except weeding at 4, 8, 12 and 16 WAP in 2016 and weeding up to 20 WAP in 2017 (Table 3). There is a marked increase in rhizome yield and count when weeding was done up to 20 WAP compared to

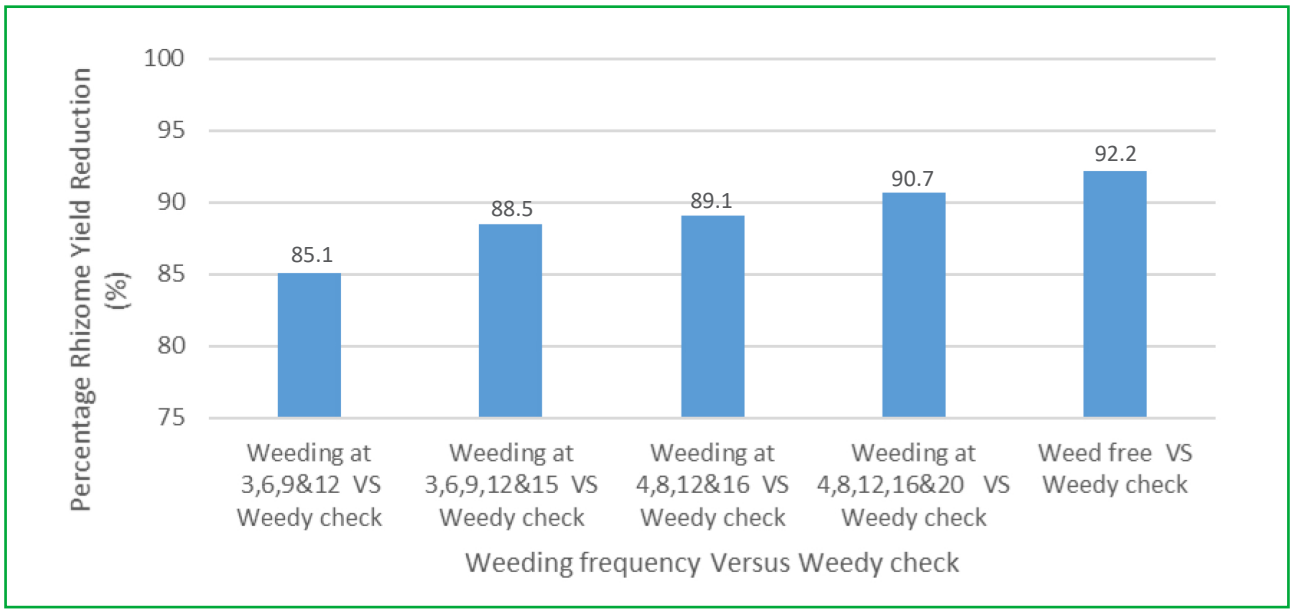

Figure 2 Percentage rhizome yield reduction of mango ginger in the weedy check relative to other weeding frequencies

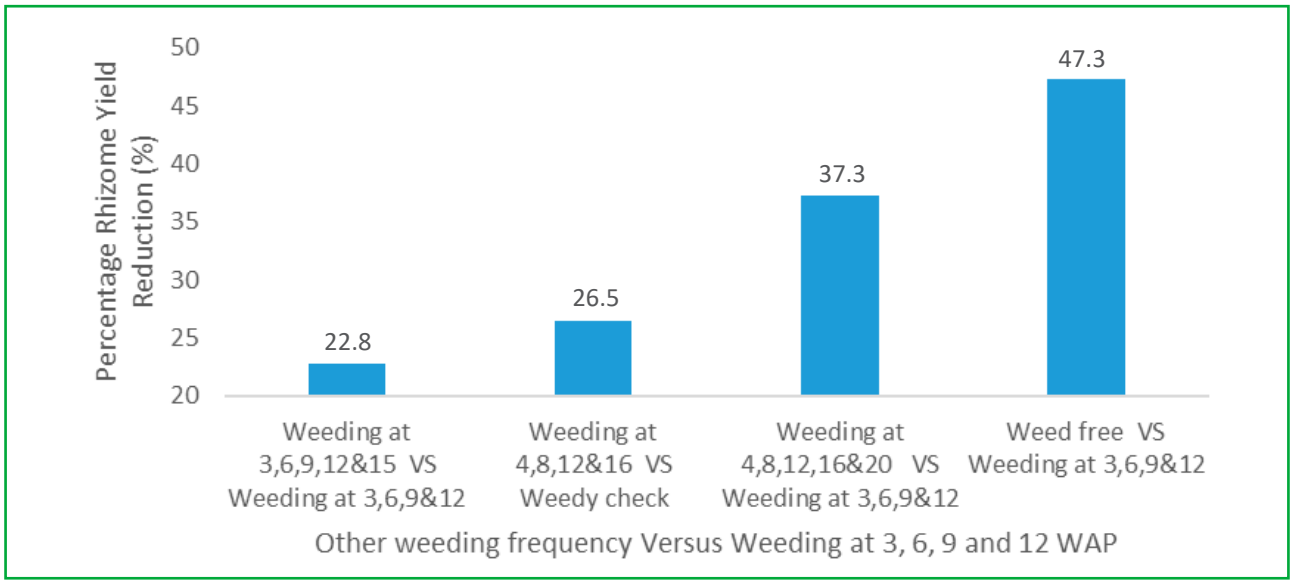

Figure 3 Percentage rhizome yield reduction of mango ginger on plots weeded at 3, 6, 9 and 12 WAP relative to other weeding frequencies

when weeding stopped earlier. Weed competition were found to significantly affect vegetative, yield and yield components of mango ginger in this study. Furthermore, keeping plots weed infested throughout crop life cycle resulted in 85.1 to 92.2% rhizome yield reduction across the years (Figure 2). This could be as a result of the slow growing attribute of mango ginger which could have probably made it prone to weed infestation at the early growth stage. The crop suffered competition with weeds uninterruptedly throughout its life cycle for nutrients and water in the soil, air, light among other things. This result is also similar to those of Habetewold et al. (2015) who reported yield loss of 93.2% in ginger. There was 22.8 to 47.3% rhizome yield reduction when weeding was done four times at 3, 6, 9 and 12 WAP (Figure 3). This shows that weed infestation after 12 WAP affected yield of mango ginger adversely. This result is similar to those reported earlier by Habetewold et al. (2015) where 33.8% yield reduction was obtained in ginger when weeded four times.

Cost-benefit ratio analysis indicated that highest amount of money was spent on plots with the application of 3.6 t ha^{-1} organo-minerals fertilizer followed by application at 2.4 t ha^{-1} while the least was recorded on the control plots where no organo-mineral was applied, hence higher revenue and return on investment (Table 4). This is because plots where organo-mineral fertilizer was applied had more rhizome yield than where no organo-mineral fertilizer was applied and this translated to more money. This result is also similar to that of

Table 4 Effect of organo-mineral fertilizer rate and weeding frequency on cost of production, revenue and return on investment in mango ginger

Treatments	Cost of	Revenue	Return on
Organo Mineral Fertilizer (O)	production (N million)	(N million)	investment (N million)
0 t ha^{-1}	3.2	5.1	1.9
2.4 t ha^{-1}	3.7	6.3	2.6
3.6 t ha^{-1}	3.8	7.6	3.8
Weeding frequency (W)			
Weeding at 3, 6, 9, 12 and 15 WAP	2.8	6.8	4.0
Weeding at 4, 8, 12, 16 and 20 WAP	2.8	8.3	5.6
Weeding at 3, 6, 9 and 12 WAP	2.5	5.2	2.7
Weeding at 4, 8, 12 and 16 WAP	2.5	7.1	4.6
Weed free	9.5	9.9	0.4
Weedy check	1.5	0.8	-0.7

Shadap et al. (2018) who reported higher cost benefit on plots with fertilizer application than the control in ginger. Highest cost of production and revenue was recorded on plots kept weed free throughout (Table 4). The highest cost of production on plots kept weed free throughout could be as a result of constant weeding of the plots which attraccted more cost. Also the highest revenue on the plots is as a result of the highest yield recorded from the plots which directly translated to highest revenue. This result is similar to that of Dan et al. (2016) who also observed highest cost of production on weed free plots in cassava. Despite the highest revenue on the weed free plot, the highest return on investment was recorded on plots weeded at 4, 8, 12, 16 and 20 WAP. This is because the cost of production resulting from keeping plots weed free throughout crop life cycle was so high and almost equal to the revenue generated on the plot.

4 Conclusions

This study showed that application of 3.6 t ha^{-1} of organo-mineral fertilizer resulted in better stand establishment of mango ginger and enhances the initial slow growth of the crop. Also, application of 3.6 t ha^{-1} of organo-mineral fertilizer resulted in 49.3 and 50.7% increase in rhizome yield in 2016 and 2017, respectively compared to 0 t ha^{-1} organo-mineral fertilizer. Thus, application of 3.6 t ha^{-1} of organo-mineral is recommended as it gives the highest yield and return on investment. In addition, keeping plots weed infested throughout crop life cycle resulted in 85.1 to 92.2% rhizome yield reduction compared to other weeding frequencies. While the weed free plots produced the highest rhizome yield and revenue, but did not resulted in the highest return on investment. However, weeding at 4, 8, 12, 16 and 20 WAP resulted in comparable rhizome yield to the maximum of those weed free throughout in 2017 and resulted in the highest return on investment in both years. Therefore mango ginger should be weeded regularly as this resulted in optimum yield with highest return on investment.

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