ISSN 2049-7318

International Journal of Science and Technology Volume 5 No. 12, December, 2016

Evaluation of Root Yield and Quality Factors and the Economic Benefits of Fertilizer Application in the Cassava Production in Semi-Deciduous Region of Ghana

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ABSTRACT

A field study was conducted at the CSIR- Crops Research Institute (CRI) at Fumesua, Kumasi, Ghana from 2014 to 2015 to evaluate root yield, post-harvest physiological deterioration (PPD), dry matter content and economic benefit of fertilizer application of cassava. A 4 x 3 factorial experiment with treatments laid in Randomized Complete Block Design (RCBD) with 3 replications using 4 levels of NPK (15-15-15) fertilizer 0, 200, 400 and 800kg/ha applied at 3 different times 8, 16 and 24 WAP was employed for the studies. The variety used was 'Ampong', and improved cassava variety from the Crops Research Institute. Data was taken on fresh root yield, post-harvest physiological deterioration, dry matter content and economic analysis of the various fertilizer treatments. All the fertilizer treatment resulted in greater number of roots/plant ranging from 4.33 to 6.50 with the 400kg/ha causing the greatest effect. Similarly, fertilizer application improved root yield ranging from 23.0 to 36.0t/ha, the greatest yield was obtained from the 400kh/ha treatment. However, there was a reduction in yield with the application of 800kg/ha. Post-harvest physiological deterioration was not affected by fertilizer application but dry matter content was enhanced. Time of fertilizer application did not affect yield and other parameters studied. Among the fertilizer rates, the 400kg/ha gave the best root yield and proved to be the most economically profitable as it produced the highest extra benefit of GH¢ 8792.00. Cassava farmers have an option to apply fertilizer to the crop to increase their yield and income without sacrificing quality.

Key words: *Ampong, Cassava, Fertilizer, Yield, PPD, Dry Matter Content, Economic Benefit*

1. INTRODUCTION

Cassava (*Manihot esculenta Crantz)* was introduced from Brazil, its country of origin to the tropical areas of Africa, the Far East and the Caribbean Island by the Portuguese during the 16th and 17th centuries (Jones, 1959). Cassava became widely cultivated and used crop among the people of the coastal plains, but now cassava is grown in all the ecological zones of Ghana (MOFA, 2003). Cassava is mostly cultivated as a sole crop or intercropped with other food crops. In Ghana, cassava is the number one root crop with respect to production levels followed by yam and cocoyam and ranked second to maize in terms of area planted (MOFA, 2009).

Cassava is an important starchy staple crop in Ghana with per capita consumption of 152.9kg per year (MOFA, 2009) and serves as a major source of income to rural farmers particularly women. Cassava serves as food for over 200 million people in Africa and also provides enough calories as compared to other crops (Hahn, 1984). Ghana remained the world 6th ranked producer of cassava between 2005 and 2010 and contributes 22% to Ghana's Agricultural Gross Domestic Product (AGDP) with annual production in the last ten years reaching more than 10 million metric tonnes (Angelucci, 2013).

Despite the various importance and benefits that cassava provides to Africa and Ghana, its yields are very low and as a result, farmers are unable to achieve the maximum economic benefit from the crop. The average farmers' yield is between 5.0 – 11.8t/ha but has an achievable yield of 48.7t/ha (MOFA, 2010). The low yield of the crop is as a result of several factors including low soil fertility status, none usage of fertilizers, diseases and pests. In spite of its low yields, farmers are uncertain about fertilizer application and its effect on root yield and shelf life of roots (Tettey and Frimpong, 1991). Therefore, farmers are reluctant to apply fertilizer on cassava cultivation. The objective of the study was to evaluate the effect of fertilizer application on yield, post-harvest physiological deterioration (PPD), dry matter content and economic returns on cassava.

2. MATERIALS AND METHODS

2.1. Experimental site

The experiment was conducted from 2014 to 2015 at the research field of Crops Research Institute at Fumesua (latitude 6º, 41 North and 1º, 28 West), Kumasi. The area has bimodal rainfall pattern with the major season rains around April to June and minor season rains from August to November with annual rainfall of 1,345mm per annum. The temperature is usually high throughout the year with annual mean temperature between 22ºC to 31ºC. The vegetation is that of humid forest type. According to Adu and Asiamah (1992) the soil is that of Ferric Acrisol Asuansi Series type.

2.2. Experimental design, Treatments and Planting

The experimental design was a 4 x 3 factorial experiment. The two factors studied were rate of fertilizer (NPK 15-15-15) application and levels employed were 0, 200, 400 and 800kg/ha. The second factor was time of application which was 8, 16 and 24 weeks after planting (WAP). Treatments were arranged in the Randomized Complete Block Design (RCBD) with 3 replications. Each replication had 12 plots which were separated from one another by a distance of 2m.

The cassava variety 'Ampong' was used for the experiment. It is a new and early maturing variety released by the Crops Research Institute, Fumesua-Kumasi and can be harvested within 12 months. Stem cuttings were cut at 25cm long with at least 5 nodes and planted at a space of 1m x 1m making a total plant population of 10,000 plants/ha. Each plot had 4 rows with a total of 20 plants/plot. The stakes were planted at 45^o with 2/3 buried in the soil on 30th May, 2014. Refilling was done two weeks after planting to maintain the plant population.

2.3. Fertilizer Application

Fertilizer was applied to the plants on 8 WAP, 16 WAP and 24 WAP according to the treatments. The fertilizer treatments applied were 0kh, 200kg, 400kg and 800kg NPK/ha and each plot/plant receiving 0g/plant, 20g/plant, 40g/plant and 80g/plant respectively. All the fertilizer treatments were applied to the plants in a half moon shaped furrow of about 3-5cm deep and 20cm from the base of the plant and covered.

3. DATA COLLECTION

3.1. Fresh Root Yield (t/ha)

An area covering 4m^2 were harvested per treatment and the fresh root weight measured. It was then converted to kilogram (kg) per hectare and in tones per hectare as;

$$Fresh\ root\ yield\ (^{t}/_{ha})\ \frac{10000m^2\ x\ Weight\ of\ root\ harvested\ in\ kg}{Area\ harvested\ in\ m^2}$$

3.2. Post-harvest Physiological Deterioration (PPD)

Twenty one roots selected randomly from each treatment were kept at ambient temperature for a maximum of 7 days. The process involved the use of the entire root as described by Morante *et al.* (2010) and cutting seven 2cm thick in transverse slice along the root, starting from the proximal end (Wheatley *et at., 1985*).

A scoring scheme of 1-10 was assigned to each slice, corresponding to the percentage of the cut surface showing discoloration (1 = 10%, 2 = 20%, etc). The mean post-harvest physiological deterioration scored for each root was calculated by averaging the score for the seven transversal sections.

3.3. Dry Matter Content (DMC)

A mechanical cassava grater was used to grate roots from all the test treatment and the control into chips after washing. 100g of the chips were sampled in two replicates. They were oven dried at 72^{o}C for 72 hours, weighed and dry matter content determined by the relation;

$$DMC = \frac{Dry\ Weight}{Wet\ Weight}\ x\ 100$$

3.4. Economic returns

The economic analysis was done using a partial budget for the production for one hectare. The yields obtained were reduced by 10% as suggested by CIAT (1988). A price per kilogram of cassava was used for the calculation of the gross benefit (GB) as per the adjustable yield obtained. The total variable cost (TVC) comprises the cost of land preparation, cost of ploughing and harrowing, cost of planting materials, cost of planting, cost of fertilizers, cost of transporting fertilizers, cost of fertilizer application, cost of weeding and cost of harvesting. Cost of hiring of land was excluded as lands are mostly own by families members.

The net benefit (NB) was calculated as $NB = GB - TVC$

The extra benefit (EB) was calculated as the differences between the net benefit of the treatments (NBT) and that of the net benefit of controls (NBC)

$$EB = NBT - NBC$$

The marginal return (MR) was estimated using the relation;

$$MR = \frac{E\ B}{TVC - CVC}$$

4. RESULTS

4.1. Fresh root yield

The yield of cassava was significantly influenced by fertilizer application. The root yield obtained per the treatments ranged between 23.0 to 36.0t/ha and the greatest yield was produced by the 400kg fertilizer treatment (Table 1.)

4.2. Post-harvest physiological deterioration

The rate and time of fertilizer application produced no significant change in post-harvest physiological deterioration (PPD) at 3, 5 and 7 days after harvesting (DAH) (Table 2).

4.3. Dry matter content

Dry matter content was affected by amount of fertilizer applied as the difference between the 200kg treatment, which was the greatest and that of 800kg treatment, the lowest, was significant (P<0.05). Other fertilizer applied treatment effects were similar. Time of fertilizer application did not affect dry matter content (Table 3).

4.4. Economic analysis of the NPK fertilizer use

The result of the economic analysis for the various treatments (Table 4) shows that fertilizer application resulted in an extra benefit over the control with the 400kg treatment producing the highest extra benefit of GH¢ 8,792.00. The 200kg treatment recorded negative extra benefit of GH¢ -1,998.00 and GH¢ -154.00 when applied at 16 WAP and 24 WAP. The fertilizer treatment produced marginal benefit ranging from -0.26 to 10.38.

Table 1. Effect of fertilizer application on fresh root yield of cassava

Treatment	Fresh root yield (t/ha)
Fertilizer Rates (kg NPK/ha)	
Control	23.0
200	26.2
400	36.0
800	30.8
LSD (0.05)	10.1
Time of Application (WAP)	
8	27.3
16	29.3
24	31.9
LSD (0.05)	NS
CV (%)	36.0

Table 2. Effect of fertilizer application on post-harvest physiological deterioration on cassava

Treatment	Post-harvest Physiological Deterioration (%)		
	3DAH	5DAH	7DAH
Fertilizer Rates (kg NPK/ha)			
Control	1.36	2.01	1.94
200	1.51	2.18	1.94
400	1.45	1.92	2.05
800	1.55	1.86	1.73
LSD (0.05)	NS	NS	NS
Time of Application (WAP)			
8	1.42	1.76	1.95
16	1.55	2.37	1.99
24	1.44	1.85	1.80
LSD (0.05)	NS	NS	NS
CV (%)	38.6	33.2	28.0

Table 3. Effect of fertilizer application on dry matter content of cassava

Treatment
Dry matter content (%)

Time of Appl.	8 WAP				16 WAP				24 WAP			
Fert. Rates	Control	200kg/ha	400kg/ha	800kg/ha	Control	200kg/ha	400kg/ha	800kg/ha	Control	200kg/ha	400kg/ha	800kg/ha
Average yield (t/ha)	20.2	31.3	33.1	24.8	26.3	24.0	35.9	30.9	22.5	23.3	38.9	36.7
Adjusted yield (t/ha)	18.2	28.2	29.8	22.3	23.7	21.6	32.3	27.8	20.3	21.0	35.0	33.0
Gross benefit (GH₵/ha)	12194.00	18894.00	19966.00	14941.00	15879.00	14472.00	21641.00	18626.00	13601.00	14040.00	23450.00	22110.00
Total variable cost (GH₵/ha)	1225.00	1814.00	2278.00	3206.00	1225.00	1816.00	2280.00	3208.00	1225.00	1818.00	2282.00	3210.00
Net benefit (GH₵/ha)	10969.00	17080.00	17688.00	11735.00	14654.00	12656.00	19361.00	15418.00	12376.00	12222.00	21168.00	18900.00
Extra benefit	-	6111.00	6719.00	765.00	-	-1998.00	4707.00	764.00	-	-154.00	8792.00	6524.00
Marginal analysis	-	10.38	6.38	0.39	-	-3.38	4.46	0.39	-	-0.26	8.32	3.29
Percentage	-	1038%	638%	39%	-	-338%	446%	39%	-	-26%	832%	329%

Table 4. Economic Analysis for the different fertilizer treatment rates and time of application

Fertilizer Rates (kg NPK/ha)	
Control	31.87
200	33.38
400	32.70
800	30.02
LSD (0.05)	2.9
Time of Application (WAP)	
8	30.59
16	33.16
24	32.22
LSD (0.05)	NS
CV (%)	9.4

5. DISCUSSION

5.1. Fresh root yield of cassava as affected by fertilizer application

The results of fresh root yield indicated that fresh root yield was significantly affected by rate of fertilizer application. The greatest fresh root yield 36.0t/ha was recorded for 400kg treatment with control treatment recording the least fresh root yield of 23.0t/ha (Table 1). The fertilizer made available more P and K necessary for root formation and inducing net photosynthetic ability of a leaf area which helps in translocation of photosynthate to the roots respectively were made available to the plant. As reported by Lahai *et al.* (2011), the high yield of 400kg treatment could be a factor of higher light interception due to its higher canopy spread. The results support the findings of FAO (1999) that fertilizer application can increase crop yield up to 49% in West Africa. Paula *et al.* (1983) reported that, cassava yield can be increased by 30% when fertilized. A report by Vanlauwe (2012) indicated that yield of cassava increased from 12 to 25t/ha when moderate level of NPK was applied and when higher rates were applied yield increased more than 40t/ha.

5.2. Post-harvest physiological deterioration (PPD)

No significant differences were observed in the PPD of all treatments after 7 days after harvesting. The findings contradict earlier report by Ekanayake and Lyasse (2003) who stated significant differences in the development and PPD severity in cassava varieties. The findings also confirm report made by Jennings and Iglesias (2002) who found strong correlation between PPD and dry matter content, which means that when dry matter is low PPD will also be low and vice versa. The low PPD level could also be attributed to the method employed in the studies which involved the use of the entire roots (Morante *et al.,* 2010) without cutting the proximal and the distal ends described by Wheatley *et al.* (1985) which accelerate PPD.

Breeding programmes could also be the results of the low PPD as more work is being geared towards reducing high rates of PPD among cassava varieties which makes the root unacceptable by consumers. The findings did not support the perception of Ghanaian farmers that fertilizer application leads to rotting of cassava roots after harvesting as reported by Tettey and Frimpong (1991). Agbaje and Akinlosotu (2004) reported that incidence of rot is not a factor of fertilizer application rather varietal differences.

5.3. Dry matter content

The dry matter yields obtained in this study were significantly affected by fertilizer application contrary to a report by Adjei-Nsiah and Issaka (2013) who reported no significant effect. The low dry matter content is characteristics of the ‘Ampong’ variety because of the high water content of about 60%. The high water content possibly led to the dilutions of assimilates stored in the roots.

5.4. Economic analysis of cassava fertilization

Based on a partial budget used for the economic analysis, all the yields obtained were reduced by 10% as suggested by CIMMYT (1988) and the adjustable yield was then used for the analysis as per cost of production (total variable cost). The result showed that, with exception of the 200kg/ha treatment at 16 and 24 WAP all other treatments recorded profitable given marginal benefit of 0.39 to 10.38 indicating that any GH¢ 1.00 spent on fertilizer will lead to corresponding increase in benefit. The most economical and profitable treatment for all the treatment was the 400kg treatment, as it recorded the greatest extra benefit of GH¢ 8,792.00 at 24 WAP which confirm what was reported by Adjei-Nsiah and Sakyi-Danso (2012) that fertilization results in higher revenue (extra benefit).

In addition, the non-profitable among the treatments was the 200kg/ha treatment which recorded negative extra benefit which may be as a result of insufficient nutrient supplied to the crop by applying fertilizer at the rate of 200kg at 16 and 24 WAP which was not enough to enhanced root bulkiness. It again produced negative marginal benefit in the range of -0.26 to -3.38 which indicates that any extra cost incurred on fertilization at that rate and time will lead to corresponding lost in investment. This finding indicates that when fertilizer is applied at the required quantities and time, it will lead to higher profit for farmers and that smallholder farmers in Africa should be encouraged to use fertilizer to increase cassava production and maximized profit (Anneke *et al.* 2009).

6. CONCLUSION

The following conclusions could be made from the results obtained. Cassava responded positively to fertilizer application. The 400kg treatment was the optimum rate of the fertilizer and can be applied at any time for the variety used. Additionally, fertilizer application did not induce post-harvest physiological deterioration after 7 days after harvesting but rather improved the dry matter content of the variety studied.

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