academicJournals

Vol. 9(5), pp. 228-234, May 2015
DOI: 10.5897/AJPS2014.1237
Article Number: 55B5C1C53409
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Potential to increase cassava yields through cattle manure and fertilizer application: Results from Bunda College, Central Malawi

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Received 7 October, 2014; Accepted 23 April, 2015

In Malawi, increasing human population and low productivity of cassava (*Manihot esculenta* [Crantz]), the second most important food crop after maize, necessitate the intensification of agronomic options for cassava production. A study was therefore conducted in 2012-2013 season on a chromic Luvisol at Bunda College (14° 35 S'; 33° 50 E'), Central Malawi, to evaluate the effects of inorganic fertilizer (kg ha^{-1} N : P_2O_5 : K_2O : S at 0 and 46:42:0:8) and cattle manure (0, 5 and 10 t ha^{-1}) on cassava growth and yield in a 3 x 2 factorial randomized complete block design replicated four times. The sweet variety Mbundumali with 9-15 months maturity and potential yield of 25 t/ha was used. The study site's inherent soil chemical characteristics in the 15-30 cm depth were: P = 102 ppm, K = 3.87 meq 100g^{-1}, N = 0.16%, pH = 5.4, organic matter = 1.79 and N = 0.064. From the results, tuber fresh yield was significantly increased by application of both cattle manure (P = 0.043) and inorganic fertilizer (P = 0.001) while there was no significant manure x inorganic fertilizer interaction. Tuber fresh yield was maximum at 27.6 t/ha with application of cattle manure at 5 t ha^{-1}, however increasing the rate of cattle manure to 10 tha^{-1} did not increase the tuber yield further. Fresh tuber yield increased from 22.8 to 29.2 t ha^{-1} with inorganic fertilizer application. Yield without fertility amendments was 21 t ha^{-1}, suggesting that appropriate amendments may raise yields above potential. There were also significant effects of inorganic fertilizer on branches per plant, tubers per plant and tuber length, while manure had no effect on these variables.

Key words: Cassava, cattle dung, integrated soil fertility management, cassava growth.

INTRODUCTION

Cassava is the most important food crop in Malawi after maize. In 2011-12, cassava was grown on an area of 207,008 ha with an average yield of 22 t ha^{-1} (MoAFS, 2012). Cassava is also an important cash crop when sold to urban dwellers that use it for domestic consumption. The crop is also an important cash crop for starch production and confectionery. The crop is tolerant to low soil fertility and drought tolerant (Janssens, 2001). Janssens (2001) indicated that cassava requires a minimum of 500 mm rainfall spread over six months.

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Table 1. Chemical and physical property of the soil at the site of experiment.

Soil property	Top soil (0-15 cm)	Subsoil (15-30) cm
Nitrogen (%)	0.16	0.064
Phosphorus (ppm)	105.67	12.34
Potassium (me/100 g)	10.83	3.87
Soil pH	5.8	5.4
Organic matter (%)	1.66	1.79
Sand (%)	43	34
Clay (%)	36	35
Silt (%)	22	25

Malawi has unimodal rainfall pattern with 5-6 months of rainfall season spanning from November to April/May. Annual rainfall ranges from 600 to 2000 mm depending on agroecological zones (Mviha et al., 2011). Yield potential of cassava ranges from 15-25 t ha^{-1} for sweet varieties and 25-40 for bitter varieties (Mviha et al., 2011; MoAFS, 2012). There are number of constraints to cassava production, including diseases, insect pests, unavailability of quality planting material, and short rainfall periods (MoAFS, 2012). Cassava is well adapted to poor or degraded soils due tolerance to low pH, high exchangeable Al and low concentration of P in the soil solution (CIAT, 1978; Howeler, 1991; Janssens, 2001; Howeler, 2002). When planted in natural soils, cassava's fibrous roots become infected with native soil mycorrhiza. The resulting hyphae grow into the surrounding soil and help in the uptake and transport of P to the cassava roots. Although, cassava tolerates drought and low soil fertility, maximum yields are only possible with adequate amount and duration and soil fertility. In Malawi, there are no recommendations for inorganic fertilizer applications for cassava production (MoAFS, 2005). However, poor soil fertility is a growing constraint in crop production in Malawi (Kumwenda et al., 1997; Snapp, 1998; ICRISAT/MAI, 2000; Kanyama-Phiri et al., 2000; Ngwira et al., 2013). The continued cropping of cassava without fertilizer application can result in soil nutrient depletion. Howeler et al. (1990) reported that 4.5, 0.83 and 6.6 kg mineral N P and K are removed per tonne of dry tuber yield. Howeler (2002) recommended that 60 kg N, 10-20 kg P_2O_5, and 50 kg K_2O ha^{-1} should be applied to the soil for an expected yield of 15 t/ha where all stems and leaves are returned to the soil. Also, Asare et al. (2009) noted that cassava is known to respond to application of organic and inorganic fertilizers. Several other reports indicate that the crop is responsive to fertilizer use (FAO, 1994; Kamaraj et al, 2008; Adjei-Nsiah and Issaka, 2013). Over-application of N fertilizer may, however lead to unusually luxuriant vegetative growth at the expense of roots and tubers (Vijayan et al., 1969).

One possible reason for lack of response to fertilizer application in Malawi are the relatively short rains of 4-5 months as compared to 9-12 months maturity period, which result in fertilizer not being available to the plants due to dry soil conditions. Application of organic source of nutrients was considered one way to enhance crop response to nutrient applications. Organic matter improves soil tilth, increases water holding capacity, lessens erosion, improves soil aeration and has a beneficial effect on soil microorganisms (Howeler, 1986, 2008). The objective of this study was therefore to explore yield and growth response of mbundumali cassava variety to cattle manure and inorganic fertilizer application.

MATERIALS AND METHODS

Site description, experimental design and treatments

An experiment to explore the role of inorganic fertilizer and cattle manure was conducted on a chromic Luvisol at Bunda Campus of the Lilongwe University of Agriculture and Natural Resources Lilongwe, Malawi in the 2012/13 growing season. The site is 1158 m above sea level, latitude 14° 35 S' and longitude 33° 50 E'. Soil type varies from clay loam to sandy loam textural classes with medium fertility. Mean annual rainfall is approximately 1031 mm with coefficient of variation (cv %) of 16.6% indicating adequate reliability of total rainfall (Jones and Kanyama, 1975). A composite soil sample was taken from the experimental site and analyzed for selected physical texture and chemical characteristics. The results are shown in Table 1. According to Howeler (2002), the following levels are considered as medium for cassava classification: Phosphorus 4-15 ppm, K 0.15 - 0.25 meq/100 g and organic matter (OM) 2-4%. The test site was therefore low in OM for cassava production.

The study was a 3 x 2 factorial field experiment in a randomized complete block design with four replications. The first factor was cattle manure applied at 0, 5 and 10 tonne ha^{-1} and the second was inorganic fertilizer at 0 and 200 $kgha^{-1}$ of the fertilizer compound 23:21:0:4S giving total of 46:42:8 kg ha^{-1} of N, P_2O_5 and S, respectively. The manure sample was analyzed for N, P, K and % organic matter. The results and amounts of N, P and K applied at 5 and 10 t/ha are shown in Table 2.

Plot sizes and field operations

The gross plots comprised of 5 ridges, 7.2 m long spaced at 0.90

Table 2. Chemical composition of the cattle manure and quantities applied.

Parameter	Analytical composition (%)	Quantity of CM applied (5 t/ha)	Quantity of CM applied (10 t/ ha)
Nitrogen (N)	0.99	49.5	99
Phosphorus (P)	0.33	16.3	33
Potassium (K)	1.45	72.5	145
Organic matter	4.741	237.5	474.1

m. Each net plot comprised of 3 middle ridges of 5.7 m long. Cassava cuttings of 20-30 cm length, with 6-8 nodes per cutting were planted at 0.9 m x 1 plant. The land preparation was done using hoes in November, 2012 while planting was done on 28 December 2012 following adequate rains. Planting materials were obtained from Bunda College Crop and Soil Sciences Students Farm and were 13 months old. The cuttings were disease free from predominantly bacterial bright and cassava mosaic diseases. Cuttings were taken from middle part of the cassava, and were planted on the day of preparation according to recommendations (MoAFS, 2005). The variety used was Mbundumali, an early maturing sweet cassava which matures in 9-15 months and is tolerant to cassava green mite (CGM) and cassava brown streak disease (CBSD) though susceptible to cassava mosaic disease (CMD). It has a yield potential of 15-25 t ha^{-1}.

Inorganic fertilizer (NPK) and cattle manure were applied during planting on December 28, 2012 according to earlier treatment descriptions. Banding method was used in application of the cattle manure and inorganic fertilizer, whereby drills were made on the ridges and the manure and/or inorganic fertilizer were applied and covered with soil immediately. Howeler (2002) reported that optimal yields of cassava were recorded when all fertilizers are either applied at time of planting or at once. Plants were drenched with Dursban on 27 January 2013 for termite control. The plots were hoe-weeded up to 14^{th} week after planting to keep weed competition negligible. Later hand weeding was done due to canopy closure. Harvesting of the cassava was done at 11 months after planting using hoes and shovels to avoid damaging the cassava tubers.

Data collection and analysis

Data was collected on daily rainfall, sprouting rate at 15 days after planting while stand count was taken at harvest. Plant height (base to the tallest apical leaf) was recorded at 6, 16 and 40 weeks after planting (WAP) as a means of monitoring treatments effects on early and final growth. Five plants were randomly selected from the net plot for plant height for measurements using a ruler (100 cm). Canopy diameter was measured from the same plants at 6 and 16 WAP. At harvest, number of branches and number of stems were determined by counting branches and the stems of the same 5 plants from each net plot. Tuber diameter and tuber length were taken by measuring the cross section of cassava tubers of 5 randomly selected of the representative plants immediately after harvesting. Yield of the cassava was determined by fresh weight, which was done by weighing all the tubers from the net plot and expressed as kg/ha. Harvest index was determined by dividing economic yield (cassava tubers) by total biological yield comprising of both the above ground parts and cassava tubers.

After determining yield data, a random sample of tubers were taken from the 5 plants from the net plot and chopped into smaller pieces. These pieces were mixed and 400 g taken and oven dried at 72°C for 72 h (Koide et al., 2000). The weight after constant value was recorded and dry matter content calculated as percentage. All data were subjected to the analysis of variance procedure using Genstat Release 16. Regression analysis yield and yield components and plant height were also done.

RESULTS AND DISCUSSION

Daily rainfall, sprouting rate (15 days after planting) and final stand count per plot at harvest.

The cumulative daily rainfall for the site is shown in Figure 1. The rainfall total and distribution were considered normal for the area. There were no significant differences on sprouting rate at 15 DAP (mean 94.5%) and establishment at harvest (mean 23.0%), such that further differences could be attributed to treatment effects. This early sprouting concurs with good early rainfall recorded (Figure 1). Lebot (2009) indicated that sprouting in cassava occurs in first 5-15 days after planting.

Manure and inorganic fertilizer effects on tuber fresh yield and yield components

Analysis of variance results showed significant ($P < 0.05$) inorganic manure effects on fresh tuber yield, branches per plant, tubers per plant, tuber diameter, and length (Table 3), but not tuber dry matter % (mean 42%) and harvest index (mean 0.77). Cattle manure application, on the other hand, significantly affected tuber fresh yield only (Table 4). There was no significant manure x inorganic fertilizer effects detected on all these variables.

Inorganic fertilizer increased the cassava fresh yield from 21.89 to 29.16 kg ha^{-1} (Table 3). Results are in agreement with the finding of other researchers (Theodor, 1965; Iman et al. (2013). Zhang et al. (1998) reported that combination of manure and inorganic fertilizers, or of inorganic fertilizers alone, generally resulted in yields of 20-40 t ha^{-1} yield than the application of only organic manures.

Application of 5 tha^{-1} cattle manure significantly increased tuber fresh yield from 21.90 to 27.61 $kgha^{-1}$ and there was no further increase with 10 t/ha of cattle manure (Table 4). Results are in agreement with Rammachat et al. (2001) who reported that application of animal manure only increased the root fresh yield of

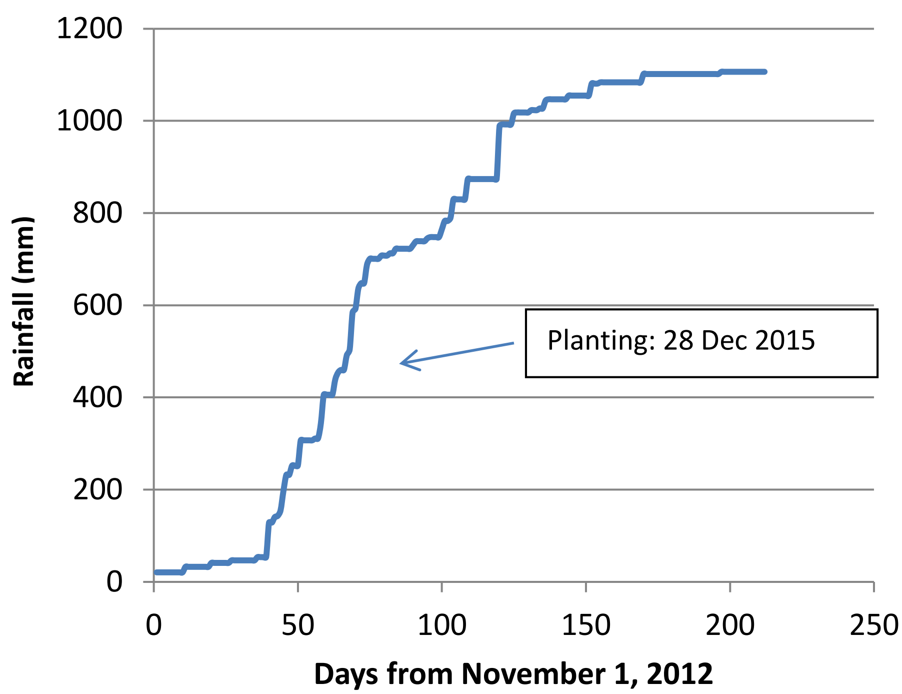

Figure 1. Cumulative daily rainfall, Bunda College 2012-13 season.

Table 3. Effects of inorganic fertilizer application on cassava fresh tuber yield, number of tubers per plant, stem weight, tuber diameter (TD), tuber length (TL) and branches/plant.

Fertilizer (kg/ha) $N:P_2O_5:K_20:S$	Fresh yield (t ha^{-1})	No of tubers/plant	Stem wt (t ha^{-1})	TD (cm)	TL (cm)	No. of branches/plant
0	21.89	10.0	9.96	3.601	32.82	6.27
46:41:8	29.16	12.5	12.45	3.987	38.89	8.26
LSD (0.05)	3.94	2.2	2.35	0.35	3.9	1.5

Table 4. Effects of cattle manure application on cassava tuber yield (t ha^{-1}).

Manure rate (t ha^{-1})	Fresh tuber yield (kgha^{-1})*
0	21.90^{a}
5	27.61^{b}
10	27.08^{b}
LSD(0.05)	4.83

*Means in column with the same letter are not significantly different at P=0.05%.

cassava. Similar responses to inorganic fertilizer application have been reported widely (FAO, 1994; Kamaraj et al., 2008; Asare et al., 2009; Adjei-Nsiah and Issaka, 2013). The manure analysis showed that cattle manure had high organic matter content (4.7%) and also supplied 49 and 99 kgha^{-1} N at the 5 and 10 t/ha. Thus, the response to manure is expected particularly noting that the organic matter and N content of the site was low (Table 2).

Asare et al. (2009) reported a response of cassava to N fertilizer only. Kamaraj et al. (2008) reported positive response to fertilizer with rates of 60 – 90 kg/ha for N, 30-90 kg/ha for P, and 80-160 kg/ha for K, with yields of up to 52 t/ha. Organic matter works as slow release source of nutrients and prevents leaching losses. The fresh tuber yield produced by both manure and inorganic fertilizer only are greater than the estimated fresh yield under smallholder farmers in Malawi which falls within the ranges of 8,000 to 20,000 kg/ha (MoAFS, 2012). The manure rate of 5 t/ha was relatively low as compared to recommended rate of 12.5 t/ha in maize (MoAFS, 2012), and perhaps has fair chance for adoption if widely verified. The cassava fresh yields produced by application of cattle manure only were higher than the potential yield of 15-25 t/ha for the Mbundumali variety (MoAFS, 2012) which was used in the study. Adjei-Nsiah and Issaka (2013) reported average fresh tuber yield increase from 13.7 tha^{-1} without amendment to 23.7 tha^{-1}

Table 5. Effect of inorganic fertilizer application on base stem diameter, canopy width and plant height at different sampling times.

Inorganic fertilizer rate $kgha^{-1}$	Growth parameter, and time of recording , weeks after planting (WAP)				
	Canopy width, cm		Plant height, cm		
Fertilizer kg/ha $N:P_2O_5:K_20:S$	6 WAP	16 WAP	6 WAP	16 WAP	40 WAP
0	30.4	88.1	15.3	94.1	153
46:41:8	39.1	98.2	20.1	109.2	173
F prob	0.002	<0.01	<0.001	0.047	0.009

Table 6. Effect of inorganic fertilizer application on base stem diameter, canopy width and plant height at different sampling times, weeks after planting, WAP.

Cattle manure rate	Growth parameter and time of recording, weeks after planting				
	Canopy width, cm		Plant height, cm		
	6 WAP*	16 WAP	6 WAP	16 WAP	40 WAP
0	45.3a	87.8a	15.3a	80.4	153
5 t/h	55.7b	94.8b	18.9b	94.8	167
10	55.4b	96.8b	19.6b	93.1	170
LSD (0.05)	9.4	6.5	3.2	Ns	Ns

*Means in column with the same letter are not significantly different at P=0.05%.

with application of 4 t ha^{-1} poultry manure. Cassava response to manure was also reported by Odedina et al. (2011) and Ojeniyi et al. (2012).

The significant increase in tubers/plant, stem weight tuber diameter and length supports the yield increased observed. An increase in number of branches per plant is important to expose the cassava leaves to sunlight for photosynthesis and increased translocation for higher photosynthate accumulation (Okogun et al., 1999). Increased branching may also suppress weeds. Increased tuber diameter and length and is important for marketing purposes. IITA/SARRNET (2007) reported that the fresh cassava market is the largest marketing cannel in Malawi. Medium to large tuber sizes are preferred for buyers who eat it raw or boiled at home because the tubers are easier to peel and can be chopped into desired sizes. Traders avoid unattractive small tubers to optimize transport.

Manure and inorganic fertilizer effects on cassava growth

Inorganic fertilizer and manure main effects on growth parameters of stem diameter, canopy width and plant height are shown in Tables 5 and 6. Canopy diameter of 90 cm reflects full canopy closure, as plants were planted in rows 90 cm apart and between plants. It is interesting to note that significant differences were observed at 6 WAP for both sources, suggesting importance of both fertility amendments in improving crop growth. Canopy diameter in cassava ensures large surface solar interception and photosynthesis (Lebot, 2009). Plants are thus more likely to suppress weeds. However, excessive foliate may lead to shedding and other leaves serving as net users of photosynthates. Tolessa (2001) reported that after 120 DAP, the leaves are able to intercept most of the radiation falling on the canopy and it is the time when the maximum size of the canopy with the maximum dry matter partition of the leaves and stems are obtained. Howeler (1990) further stated that large bulk of foliage are created by the action of nitrogen and consequently an extensive assimilating area, a prerequisite for the good development of the tubers. Plant height affects cassava growth yield similarly.

Regression relationship between growth variables, yield components versus tube fresh yield

Regression analysis was conducted on growth parameters, yield components versus yield. Significant positive regression was found between plant height at 8, 16 and 40 WAP, stem weight, tubers per plant and yield (Table 7), but not with stems per plant. The results suggest that the growth responses recorded accounted for yield differences detected. It is of interest to note significant relationship for plant height vs. yield at an 8 weeks after planting, as this indicates that good early growth is important for yield, confirming the role of fertilizer in increasing yield. The importance of the other parameters to yield has been discussed earlier.

Table 7. Regression relationship between plant height (PHT, cm) stem weight (STMWT, t ha^{-1}), stems per plant (STEMPLT) and tubers per plant (TUBPLANT) fresh tuber yield (Y = tones ha^{-1}, TUBERHA).

Pair of variables	Equation	Significance for intercept	Significance for regression
PHT at 40 WAP vs. TUBERHA	Y = -6.57 + 0.197X	t pr = 0.43	F Pr <0.001
PHT at 16 WAP vs. TUBERHA	Y = 6.77 + 0.21X	t pr = 0.29	F Pr =0.001
PHT at 8 WAP vs TUBERHA	Y = 15.6 + 0.22X	t pr = 0.001	F Pr 0.024
STMWT vs. tuberha	Y=16.3 + 0.823X	t pr = <001	F pr 0.036
STMPLT vs. tuberha	Y = 18.8 + 2.23	t pr = 0.002	F Pr =0.208
TUBPLANT vs. tuberha	Y = 13.5 +1.06	t pr = 0.007	F Pr 0.012

DISCUSSION

The observed cassava yield and growth responses to organic and inorganic are interesting considering the fairly high fertility status of the soil. The soil P and K were high while N was low according to Howeler (2002). Once complete ground cover is reached, cassava shades out weeds (Pellet et al., 1997). The crop was observed for diseases incidence and there was none observed, such that the responses to fertilizer are not confounded disease stress. Anneke et al. (2010) reported that with fertilizer use, the canopy closes within approximately 3 MAP giving potential for weed suppression. Canopy closure also helps to reduce water runoff, consequently reducing soil erosion (Zhang et al., 1998). Increase in growth traits by either the inorganic fertilizer or manure are likely to have contributed to the increased tuber fresh yield in the inorganic fertilizer and manure treatments. Considering that the status of P and K for the soils was high, the responses are likely due to N application. Inorganic fertilizer, although applied at the rate of only 23 kg/ha gave significant increase on cassava tuber yield, suggesting importance of nitrogen. Organic fertilizer has many benefits over inorganic fertilizer. Manure can be locally available for some farmers and it helps to improve the soil structure for easy penetration of shoots and development of the roots. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Tisdale et al., 1985). The yields of 27 tha^{-1} for treatments with fertility amendments were above the potential yield for the variety, indicative of potential to raise the yield potential for cassava. The positive regression relationships between growth parameters and yield components (except stems per plant) (Table 6) suggest that yield responses are a result of better growth and possible photosynthetic capture. Many reports show that fertility status of smallholder farmers in Malawi is much poorer than the study site (Snapp, 1988; Kabambe et al., 2012; Ngwira et al., 2012), thus suggesting that similar responses would be obtained on farmers' fields. These results therefore justify extensive studies to develop fertilizer responsive guides for different soil types and agro-ecological zones.

Conflict of interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Lilongwe University of Agriculture and Natural Resources for the financial support to this work, and all staff of Crop and Soil Sciences of LUANAR who assisted in this work.

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