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Prospects for Intensifying Soil Fertility Management on the Growth and Yield of Cassava in Ghana

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Conflict of Interest

The authors declare that there is no conflict of interest.

Abstract

Crop-specific fertilizer recommendations are necessary to improve yield and enhance food security in Ghana. This approach would help in improving crop productivity while maintaining a good soil health status. A new NPK fertilizer has been recently developed by the private sector with Nitrogen (N), Phosphorus (P), and Potassium (K) proportions of 11:22:21 respectively for improved cassava root yield. This study evaluated the right and economic rate of this fertilizer to apply for improved cassava productivity and farmer livelihoods. Rates of 0, 300, 400, 600, and 800 kg/ha of newly developed fertilizer were applied at Fumesua and Akumadan located in the forest agro-ecological zone, and at Ejura and Techiman located in the transitional agro-ecological zone of Ghana. The experiments were conducted in two growing seasons (May 2019 to April 2020 and May 2020 to April 2021). Increases in cassava growth were observed with the increasing levels of fertilizer at all locations and in the two growing seasons. Cassava yield was in the linear phase of the fertilizer response curve. It ranged from 28 to 52 tons/ha with the increasing fertilizer levels. Cassava in the forest agro-ecology had better growth and 25% more yield than other locations. Fertilizer rates between 0 and 400 were found to have the best yield returns and sufficient profit opportunities to sensitize adoption by financially constrained farmers. The results indicate that the newly developed fertilizer (11:22:21 N:P_2O_5:K_2O) can improve cassava productivity in the inherently poor soils of Ghana.

Keywords: fertilizer recommendation; plant nutrients; rainfall; agronomic practices; cassava productivity; root yield
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Introduction

Cassava is an important food security crop in Africa due to its potential to produce high yields under marginal soil conditions, tolerate drought, pests and diseases, and relative ease of cultivation (Kolawole et al., 2010). In Ghana, it is the most important root crop followed by yam and cocoyam (Adjei-Nsiah and Sakyi-Dawson, 2012). Sub-Saharan Africa produces about 12,260,000 Mt of cassava annually (Adjei-Nsiah and Sakyi-Dawson, 2012) at an average yield of 6-8 t/ha (on farmer fields) which is far below the 36 t/ha world average (Omondi and Yermiyahu, 2021). This yield could be largely improved if soil fertility is effectively managed. For a very long time, soil fertility decline has been described as one of the most important constraints to crop productivity in Africa (Wawire et al., 2021; Raimi et al., 2017; Vanlauwe et al., 2015). Compared to the global averages, Sub-Saharan Africa uses 87% less fertilizer (AGRA, 2018). Continuous cropping and intense crop nutrient mining inputs have resulted in poor soil fertility in Ghana (Bua et al., 2020). In cassava production, the lack of external inputs occurs because many farmers are unable to purchase fertilizer and there is an anecdotal belief that fertilizer application reduces the poundability of cassava. Traditional methods of maintaining soil fertility which included shifting cultivation and bush fallows were used in the past, but they are currently not feasible due to rapid population growth and pressure on land (Fermont et al., 2009). Hence improving cassava yield could only be achieved by improving the soil fertility of already existing lands, through sustainable intensification.

Since the year 2000, projects such as the Root and Tuber Improvement and Marketing Program (RTIMP), West Africa Agricultural Productivity Program (WAAPP), and the Presidential Special Initiative (PSI) aimed at supplying cassava to an established starch processing plant were initiated in Ghana to develop improved technologies for roots and tubers in collaboration with the CSIR-Crops Research Institute. Twenty-five cassava varieties have been developed from these programs. However, these varieties will only reach their yield potential in fertile soils.

Poor soil fertility and nutrient imbalances can be quickly remedied through rational fertilizer application (Vanlauwe et al., 2015) as many experiments have shown improvements in cassava yield with fertilizer application in areas of low soil fertility (Sungthongwises et al., 2020; Omondi and Yermiyahu, 2020; Wilson and Ovid, 2008). In Ghana, a blanket fertilizer application rate of 200 kg/ha of N-P_2O_5-K_2O 15-15-15 is recommended for root crops (Acheampong et al., 2021; Berchie et al., 2018). However such blanket applications may lead to unbalanced plant nutrition, wider yield gaps and economic loss, because cassava is cultivated on diverse soils and agro-ecologies (Ezui et al., 2016). For a root crop, equal proportions of nitrogen (N) to potassium (K) and phosphorus (P) may favour vegetative growth over root development; increase shoot to root ratio and the level of hydro cyanogenic glucoside (HCN) in many varieties (Anikwe and Ikeenganiya, 2017). Much as fertilizer application is important, the right nutrient balance and timing of application are even more important for cassava root yield. Balanced nutrition means supplying each nutrient according to the plant's needs for productivity. For cassava, the availability of more K and P is essential for the translocation of photosynthates from the leaves to the tuberous roots (Sustr et al., 2019; Luar et al., 2018). The availability of more P also improves normal root formation and synthesis of starch (Luar et al., 2018). The application of 70 kg/ha P, increased cassava root yield by 22% (Rosa et al., 2021). Research has demonstrated that applying additional 50 kg/ha muriate of potash (KCl) after 100 kg/ha NPK 15:15:15 fertilizer, resulted in 47 to 84% more cassava root yield than the 100 kg/ha NPK 15:15:15 alone (Sok et al., 2018). At the application rate of 200 kg/ha K_2O alone, cassava root yield increased three-fold above the control (Wilson and Ovid, 2008). These findings call for more specific N:P:K fertilizer recommendations for improved cassava productivity in the various agro-ecologies in Ghana.

Potassium is often highly deficient in soils that have been continuously cropped with cassava without external nutrient inputs or with unsuitable balance in the nutrient application (Sok et al., 2018). Adequate levels of K and P in properly balanced fertilizers, specifically suited for cassava root yield is needed.

As previously stated, the varied soils of Ghana`s diverse agro-ecological zones respond differently to fertilizer application; thus, the goal of this study was to develop data that could be scaled across two agro-ecologies in Ghana. The experiments were conducted in different locations in the two agro-ecologies and in two separate years to validate the results.

Material and Methods

Description of study locations

The studies were conducted in Ejura and Techiman in the forest-savannah transition agro-ecology, and Fumesua and Akumadan in the forest agro-ecology. The selected locations are specifically characterized by a decline in crop productivity, low/no nutrients input, deteriorating soil health, and rapid land use and land cover changes. Based on recommendations by the Ministry of Food and Agriculture (MoFA, Ghana), these areas were selected because of ease of cassava cultivation and the potential to become major cassava production areas for national development. The primary reason for using MoFA recommendations was to advocate for the proper use of fertilizer blends for cassava production among local farmers. Apart from Fumesua, which was an on-station research trial, the other three trials were on farmer fields.

Experimental design and treatments

The trials were established in randomized complete block design with three replications in each study site. A plot size of 10 m x 10 m with an alley of 2 m between and within plots was used.

Five fertilizer treatments (OCP formulated N:P_2O_5:K_2O 11:22:21) applied are as shown below:

1. Control (No fertilizer)
2. 800 kg/ha (N:P_2O_5:K_2O 11:22:21)
3. 600 kg/ha (N:P_2O_5:K_2O 11:22:21)
4. 400 kg/ha (N:P_2O_5:K_2O 11:22:21)
5. 300 kg/ha (N:P_2O_5:K_2O 11:22:21)

Initial soil sampling and analysis

At each site, the initial soil samples were taken at 0-30 cm depth. The samples were air-dried, ground, and passed through a 2 mm sieve to remove stones before analysis for soil chemical and physical characterization at the CSIR-Soil Research Institute at Kwadaso, Kumasi. Characteristics of the soils of the sites are described in Table 1 below.

Table 1: Initial physico-chemical characteristics of the soils at the study sites

	Locations			
Properties	Fumesua	Techiman	Ejura	Akumadan
pH	6.69	6.88	6.72	6.80
%N	0.11	0.08	0.12	0.12
P (mgkg^{-1})	11.6	9.30	8.05	9.05
K (mgkg^{-1})	0.25	0.35	1.02	0.40
Mg (mgkg^{-1})	2.13	1.70	1.80	2.02
Ca (mgkg^{-1})	3.26	3.90	3.41	4.15
%OC	0.89	0.62	0.75	0.86
%OM	2.08	1.75	1.86	2.02
%Sand	86	84	84	86
%Clay	6	3	5	5
%Silt	8	13	11	9
Texture	Loamy sand	Loamy sand	Loamy sand	Loamy sand

Land preparation and field establishment

Fields were ploughed and harrowed with a tractor. The field at Fumesua was researcher-managed while the other three were on-farm (farmer/ extension officer managed). The trials were planted between 20th May – 16th June in 2019 and 2020. Cuttings of the CRI Bankye, an improved and poundable cassava variety released by CSIR-Crops Research Institute were used. The recommended planting distance of 1m x 1m was used at each site.

Fertilizer application

The split application approach was used for fertilizer application. Fifty percent of the fertilizer rate was applied 6 weeks after planting (WAP). The second fifty percent was applied at 16 WAP. Fertilizer was applied 5cm away from the stem at 5cm depth (a common practice for high rainfall areas).

Data collection

Data on growth and yield parameters were recorded in all locations. Six plant samples were randomly selected and tagged to record the data of crop growth parameters (plant height and biomass). Plant height was determined at 9 months after planting (MAP) by measuring the distance from the soil surface to the tip of the plant. Yield parameters (number of roots per plant; root length per plant (cm); root yield per plot (kg); were recorded at the time of harvest (12 MAP). Root length was measured from the sampled plants for each treatment. Four inner representative rows were harvested from each net plot to determine the yield and biomass.

Statistical and economic analyses

Data were subjected to the Analysis of Variance (ANOVA) test using GenStat Statistical Software (GenStat, 2007). Critical differences were compared at $p \leq 0.05$ wherever the F value was significant (Panse and Sukhatme, 1985). Differences between the means were determined using the Least Significant Difference (LSD). Correlation tests were done to determine the relationship between cassava yield and other measured parameters.
Value/cost ratios (VCR) were used to calculate the economic benefit of the fertilizer rates as follows:

$$\text{VCR} = \frac{\text{marginal revenue of extra cassava yield over control (GH cedis)}}{\text{marginal cost of OCP fertilizer (GH cedis)}} \text{..........................Equation (1)}$$

The price of the NPK fertilizer was obtained from OCP fertilizers, Ghana. Farm gate price of cassava was obtained from selinawamucii.com/insights/prices/ghana/cassava/.
NB: A VCR of 2 or more indicates that the new production technology creates sufficient economic incentives to sensitize farmers to adopt it.

Results

Rainfall patterns of study locations

On average, the amount of rainfall received (Figure 1) in the first growing season (May 2019 to April 2020) was 33% higher than that received in the second growing season (May 2020 to April 2021). However, rainfall in the first growing season was more erratic than in the second. In the first growing season, total amounts of rainfall received at the locations followed the order Akumadan (2539 mm) > Fumesua (2446 mm) > Ejura (2366 mm) > Techiman (1999 mm). Whereas in the second growing season, the total amounts of rainfall received at the locations followed the order Ejura (2052 mm) > Fumesua (1884 mm) > Akumadan (1621 mm) > Techiman (1480 mm). Compared to 30-year annual averages (www.meteo.gov.gh/gmet/), none of the locations experienced drought during the two growing seasons.

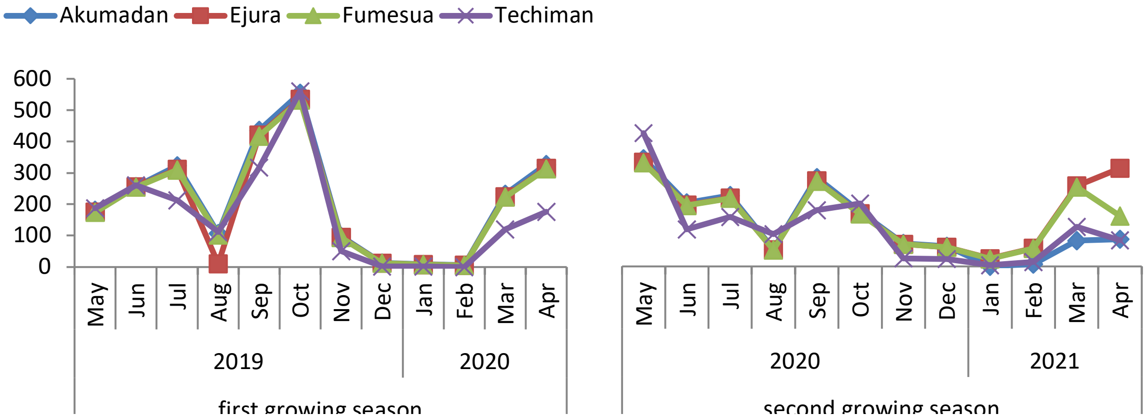

Figure 1. Rainfall patterns (mm) of Akumadan, Ejura, Fumesua and Techiman (Ghana) in two cassava growing seasons from May, 2019 to April, 2021.

Cassava growth parameters

Plant height

There were significant interactions between the fertilizer rates and location; fertilizer rates and year of cultivation and location and year of cultivation on the height of cassava plants (Figure 2). At all four locations, the 800 kg/ha of the new fertilizer resulted in 20 to 22% taller plants ($p<0.05$) compared with lower fertilizer rates and the control. Plants on the researcher-managed field at Fumesua were 2.7 to 4.3% taller than the three farmer-managed fields at Ejura, Akumadan and Techiman. In the two years of cultivation, the 800 kg/ha fertilizer still affected plants than other rates and the control; and the plants were about 34% taller in the year 2020 than 2021. On average, Akumadan plants were 3% taller than plants at Fumesua in the year 2020 but a turn of events caused Fumesua to have plants about 12% taller than plants in Akumadan in 2021.

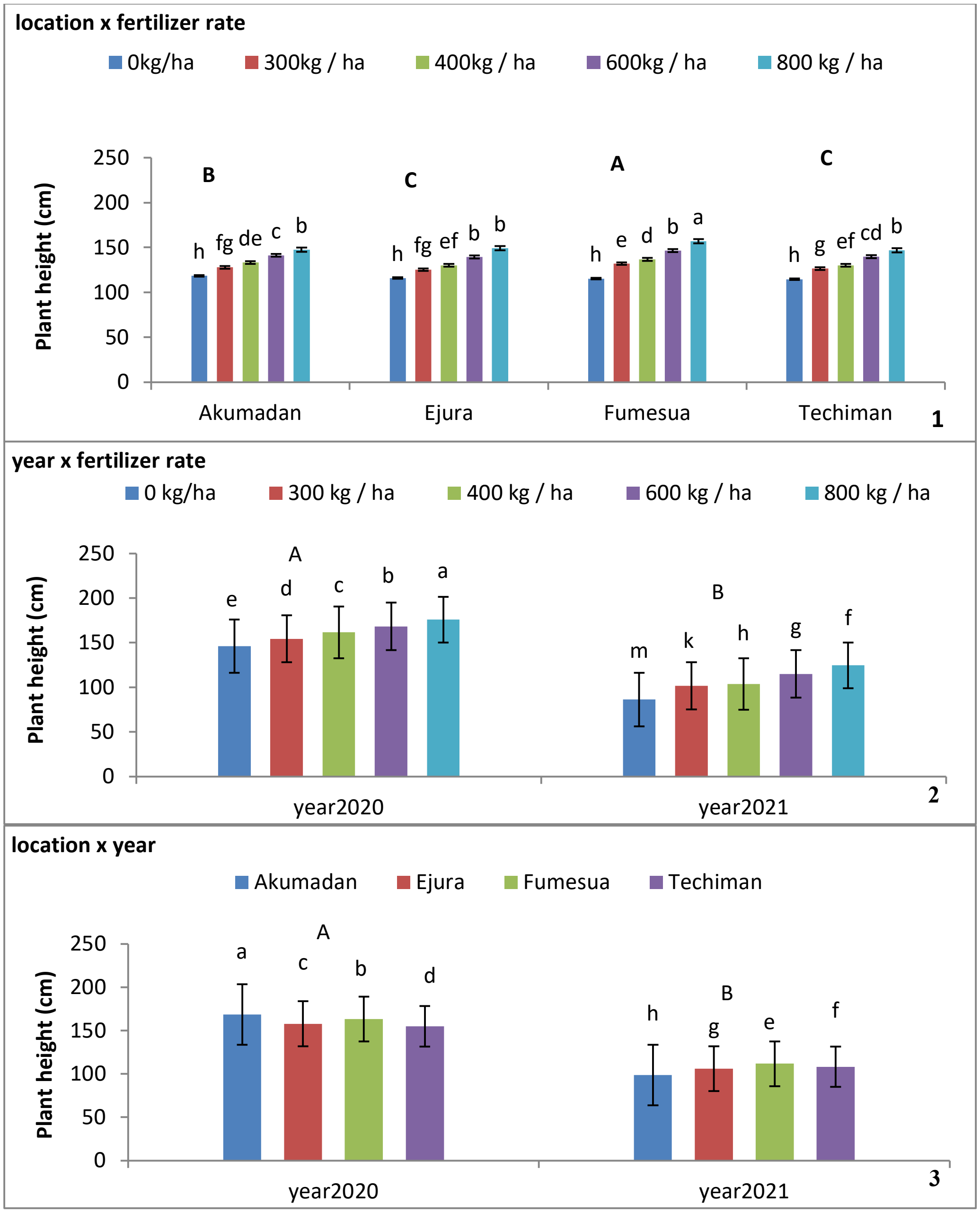

Figure 2. Interactive effects of location and fertilizer rate (1), year and fertilizer rate (2); year and location (3) on plant height (cm). Error bars represent standard errors of the means. Different lower-case letters on bars show statistical differences between the means at p <0.05. Different upper-case letters show statistical differences between the variables on the x-axis.

Biomass

Except location and year interaction, the fertilizer rates did not interact with any of the other variables to influence cassava biomass; instead, it affected biomass alone. The 800 kg/ha fertilizer produced the highest biomass between 8 to 35% more, relative to the lower rates and the control (Table 2). The interactive effect ($p<0.05$) between year and location on cassava biomass is shown by Figure 3. Akumadan had the highest cassava biomass between 25 to 32% more, compared to the other three locations in 2020. However, in 2021, Fumesua, had between 23 to 35% more cassava biomass compared to the other three locations. Altogether, cassava biomass in 2020 was about 8% more than the one observed in 2021.

Table 2. Effect of the new NPK 11:22:21fertilizer rates on cassava biomass.

11:22:21fertilizer rates	Biomass
	kg/ha
0	23900.00^{e}
300	27121.00^{d}
400	29575.00^{c}
600	33925.00^{b}
800	36786.00^{a}

Different lower case letters represent differences in the biomass means affected by the fertilizer rates.

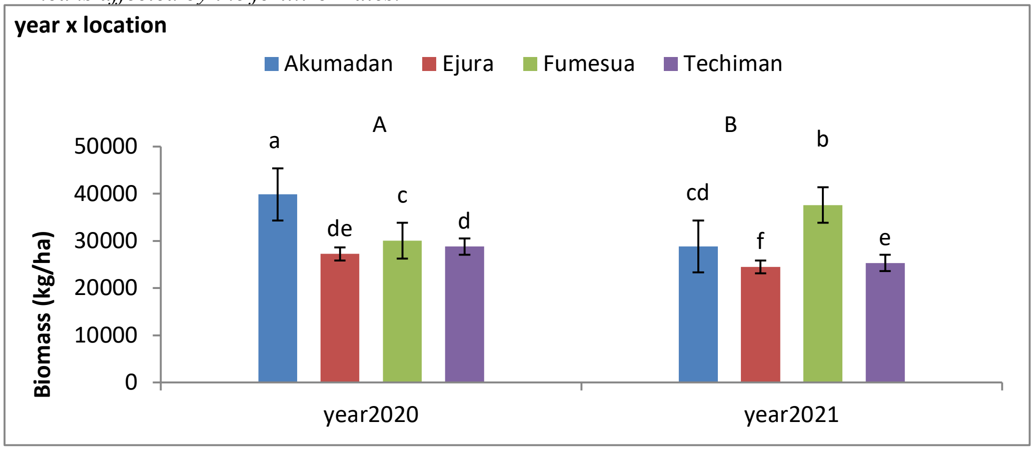

Figure 3. Interactive effect of year and location on cassava biomass (kg/ha). Error bars represent standard errors of the means. Different lower-case letters on bars show statistical differences between the means at p<0.05. Different upper-case letters show statistical differences between the variables on the x-axis.

Number of roots

There was no interactive effect of fertilizer rates, year, and/or location on the number of cassava roots per plant. The number of cassava tubers increased with increasing rates of fertilizer ($p<0.05$) such that the 800 kg/ha had the highest number of tubers (14 to 45% more) compared to the other rates and the control (Table 3). On average, Akumadan and Techiman had the highest number of cassava tubers (3-13% more) compared to the other locations (Table 3). There were 15% more cassava tubers in 2020 than in 2021 (Table 3).

Table 3. Effects of new NPK 11:22:21 fertilizer rates, location and the year of trial on the number of cassava roots.

NPK 11:22:21 rates (kg/ha)	Number of roots/plant
0	4.70^{e}
300	5.73^{d}
400	6.13^{c}
600	7.38^{b}
800	8.61^{a}
Location	
Akumadan	7.01^{a}
Ejura	6.11^{b}
Fumesua	6.13^{b}
Techiman	6.78^{a}
Year	
2020	7.02^{a}
2021	6.00^{b}

Different letters represent differences in the biomass means affected by the fertilizer rates.

Root length

There was a significant ($p<0.05$) interaction effect between location and fertilizer rate; year and fertilizer rate; year and location on cassava root length (Figures 5.1; 5.2; 5.3). The 800 kg/ha fertilizer influenced the longest cassava tubers in all four locations (Figure 4). Root length at various locations followed the order Fumesua > Ejura > Akumadan > Techiman. The 800 kg/ha fertilizer affects between 7 to 29% longer tubers than other rates and control at all locations. On average, cassava roots were 2% longer in 2020 than in 2021 (Figure 4). In these years, the 800 kg/ha fertilizer produced 7 to 31% longer cassava roots than the other fertilizer rates and the control. In these years, cassava tubers were between 20 to 40% longer in Fumesua than in other locations (Figure 4).

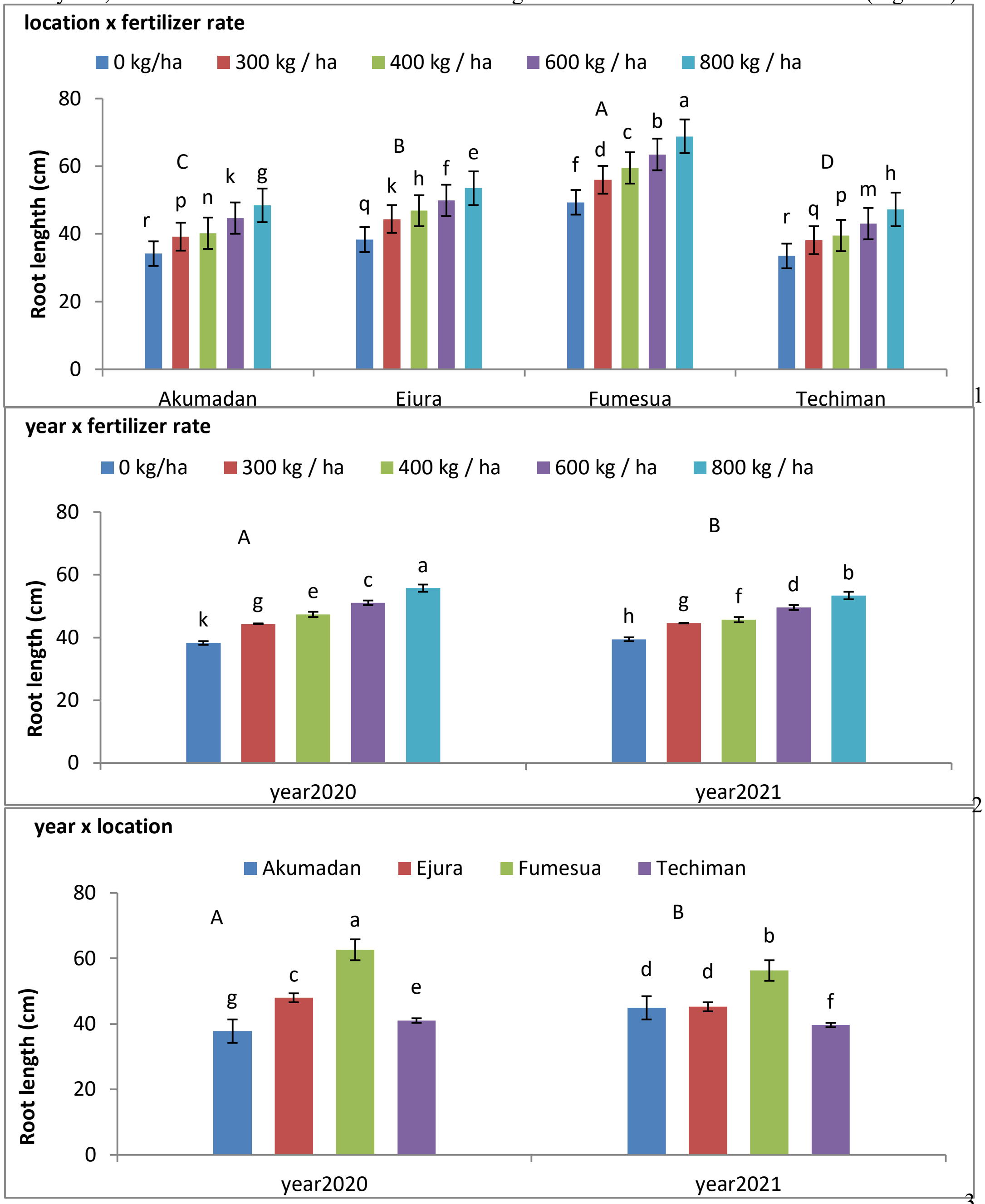

Figure 4. *Interactive effects of location and fertilizer rate (1), year and fertilizer rate (2); year and location (3) on cassava root length (cm). Error bars represent standard errors of the means. Different lower-case letters on bars show statistical differences between the means at p<0.05. Different upper-case letters show statistical differences between the variables on the x-axis.*

Yield

There was a significant ($p<0.05$) interaction effect between location and fertilizer rate; year and fertilizer rate; year and location on cassava yield (Figures 5). Cassava yield in the locations followed the order Fumesua>Akumadan=Ejura=Techiman. The yield in Fumesua was about 25% higher than in other locations. In these four locations, the 800 kg/ha fertilizer resulted in the highest yields (between 12 to 46% higher) compared to lower fertilizer rates and control. The yield of 800 kg/ha fertilizer in 2020 was 5% lower than the yield in 2021. In both years, the 800 kg/ha fertilizer affected between 11 to 47% higher yield compared to lower fertilizer rates and control. Also, Fumesua had the highest yields (between 16 to 34% more) in both years.

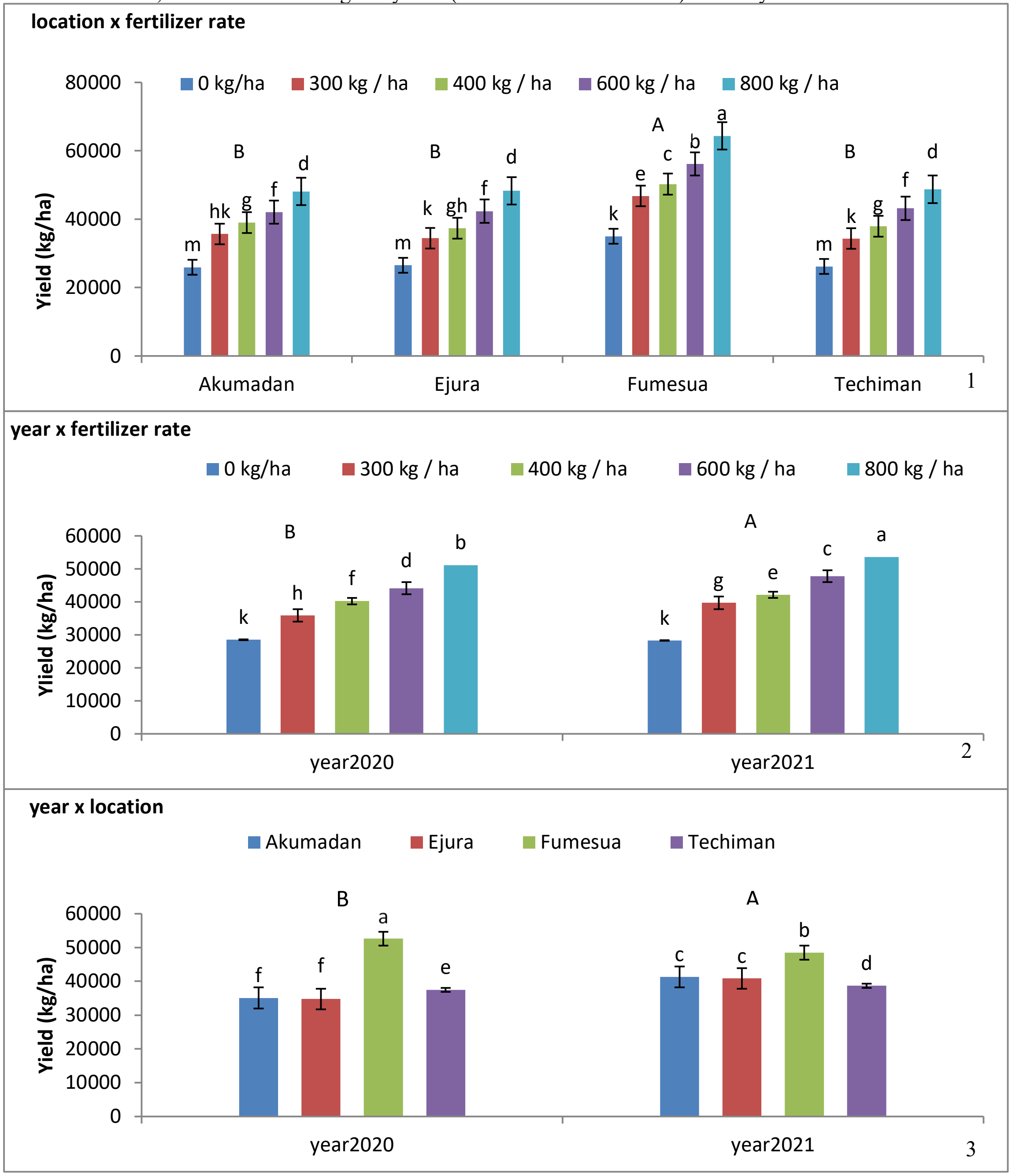

Figure 5. Interactive effects of location and fertilizer rate (1), year and fertilizer rate (2); year and location (3) on cassava yield (kg/ha). Error bars represent standard errors of the means.
Different lower-case letters on bars show statistical differences between the means at $p<0.05$.
Different upper-case letters show statistical differences between the variables on the x-axis.

There were strong positive correlations between plant height, root length, number of roots, biomass, and yield (Table 4). Thus increase in yield was associated with increases in plant height, root length, biomass and number of roots. The yield response curve in figure 6 showed that a kg increase in the new NPK 11-22-21 fertilizer application results in 5610 times increase in cassava yield. Application of 300 kg/ha fertilizer for a start resulted in a 25% increase in cassava yield compared to no input. An addition of 100 kg/ha fertilizer to the 300 kg (to make 400 kg) resulted in an 8% increase in yield. Addition of 200 kg to the 400kg (to make 600 kg) resulted in a 10% increase in yield whereas an increase from 600 kg to 800kg resulted in a 13% increase in yield (Figure 6). On average, every 100 kg/ha increase in OCP fertilizer rate from the control realized about 8% increment in yield up to 400kg/ha fertilizer, after which the rate of yield increase declined with increases in fertilizer rates (Figure 6). All fertilizer rate increased rate of yield except 400kg/ha to 600 kg/ha had VCR, greater than 2 (Figure 6).

Table 4. Relationship between the measured parameters and cassava yield when OCP fertilizer rates alone is under consideration. R is the coefficient of correlation. R^2 is the coefficient of determination

	Correlation coefficients	Plant height (cm)	Root length (cm)	Biomass (kg/ha)	Number of roots
Yield (kg/ha)	R	0.997	0.999	0.984	0.981
	R^2	0.994	0.997	0.968	0.962
	p-value	0.000197	0.000038	0.00252	0.00314

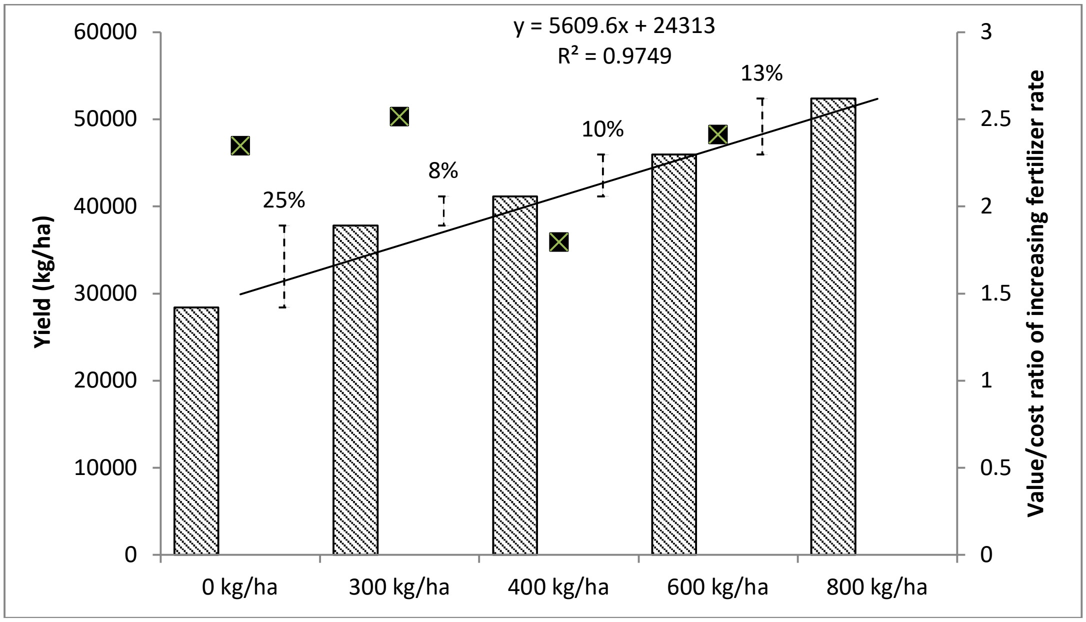

Figure 6. An illustration of cassava yield response curve to increasing rates of OCP fertilizer; yield percentage increment from one fertilizer rate to another and value/cost ratio from extra cassava yield.

Discussion

Increases in cassava height and biomass (Figures 2 and 3; Table 2) with increasing rates of the new NPK (11-22-21) fertilizer were the result of higher nutrient supply from the increasing rates. These increases were a reflection of the positive effect of nutrient supply on photosynthate accumulation during growth (Pan et al., 2020). There was a corresponding effect on yield and yield components (root number, root length; Figures 3, 4 and 5), as observed in the strong positive relationships between cassava root yield and other parameters (Table 4) when only the new NPK 11-22-21 fertilizer rates are under consideration. The results agree with the findings of Sok et al. (2018) and Senkoro et al. (2018), who observed similar improvements in cassava growth and yield with the supply of increasing levels of NPK than no inputs. Macalou et al. (2018) also identified strong positive correlations between plant height, cassava root numbers, and yield in Mali, following the application of 0, 100, 200, and 300 kg/ha NPK fertilizers. Application of the split fertilizer rates within the first four months after planting was effective timing for improved fertilizer use efficiency, as Adiele et al. (2021) have shown that cassava nutrient uptake concentrates within the first four months. The cassava yield response curve in the linear response phase (Figure 6), without a saturation or lag phase, is an indication that further increment in fertilizer rates was still practical (IPI, 2016). A positive yield response at 800 kg/ha fertilizer and the initial soil characterization (Table 1) confirm the extremely poor chemical fertility status of the soils in this study areas. The declining rate of yield increase after 400 kg/ha of OCP fertilizer follows Mitscherlich's law of diminishing returns (Gomes, 1953). The law implies that there is decreasing marginal productivity as levels of the limiting factor (nutrients in this case) increase. Mulualem et al. (2021) also reported a decline in the rate of cassava yield increase as N fertilizer rates increased from 80 to 120 kg/ha in an experiment where 0, 40, 80 and 120 kg/ha N fertilizers were applied. The highest VCRs (>2) obtained from applying up to 400 kg/ha OCP fertilizer in this study, confirm that fertilizer application between 0-400 kg/ha was the most economical (Figure 6). The higher gross profit margins in this range are great economic benefit that may sensitize resource-poor farmers to adopt fertilizer application over no input, which is in agreement with the findings of Kwadzo and Quayson (2021) and Senkoro et al. (2018).

Higher rainfall amounts received in the canopy establishment stage (May to August) (Figure 1) may have contributed to the taller plants and higher biomass in the first growing season (May 2019 to April 2020) than in the second growing season (May 2020 to April 2021). This is because nutrient uptake by cassava peaks in the first four months after planting and the availability of moisture during this phase enhances the nutrient uptake process; assimilate partitioning to the shoot and growth (Adiele et al., 2021). Moreover, maximum shoot (leaves and stem) growth is attained within this 4-month period (Anikwe and Ikenganyia, 2017), hence the availability of nutrients coupled with higher moisture availability resulted in the higher biomass in 2020 than in 2021. During the intensive vegetative growth stage, the fibrous roots that later become the number of tubers are simultaneously formed (Adiele et al., 2020). Adequate soil moisture during this stage influenced the increase in root numbers in 2020. However, corrobotating many reports (Mulualem et al., 2021; Macalou et al., 2018; Uwah et al., 2013), relatively higher plant growth and yield components (number of tubers and root length) in 2020 did correspond with relatively higher cassava root yield in 2020 when considering year of planting alone (Figure 5). In cassava physiology, a shift in more dry matter partitioning to the roots to form the tubers (bulking) strongly increases after canopy establishment (Adiele et al., 2020). Water and nutrients (especially K) availability have important controls on cassava root yield during this bulking stage (Chua et al., 2020; Anikwe and Ikenganyia, 2017). Cassava requires an annual rainfall of 1000 to 2000 mm for adequate growth and yield (Anikwe and Ikenganyia, 2017). In this study, the average annual rainfall received in the first growing season exceeded this range by over 300 mm while that received in the second growing season was within the range. Rainfall in the first growing season was also relatively erratic with peak amounts right after the canopy establishment phase (after August, 2019). These intense rainfall peaks may have led to excessive leaching of potassium (K) beyond the root zone, which resulted in low yields in 2020. Potassium is known to be the most easily leached cation, especially in soils with high sand percentage (Mendes et al., 2016; Rosolem et al., 2006), such as our experimental sites (Table 1). This is because K is highly soluble and bound to colloidal particles of clay and organic materials that are easily leached or eroded in runoff water (Goulding et al., 2020). Reduced cassava yield associated with above-average annual rainfall amounts has been reported by Dwamena et al. (2022) in the Ashanti region of Ghana and Emaziye (2015) in Nigeria, in their assessments of the effects of climatic variables on various crop yields. Agbaje and Akinlosotu (2004) reported a reduction in cassava yield following 400 and 800 kg/ha NPK fertilizer, due to excess rains following fertilizer application in Nigeria. This is one of the reasons why a high proportion of K in NPK fertilizer for cassava is important. It may be critical to apply the split part of K during the intense bulking stage of cassava to make optimum yields, especially in high rainfall areas.

Fumesua (in the forest agro-ecology) recorded the highest growth and yield parameters among all four locations because the trial there was researcher-managed compared to the farmer/extensionist-managed trials in the other three locations. This is a common occurrence often associated with timely interventions of agronomic practices such as weeding, crop protection measures, harvesting, planting dates etc in researcher-managed fields than farmer-managed fields. Many researchers (Silva and Ramisch, 2018; Kravchenko et al., 2017; Sadras et al., 2015; Odedina et al., 2009) have reported that the relatively ideal situations are different from farmer conventional, unrealistic extrapolation of yield ceilings, erasure of social or logistical factors that may affect the timing of proper agronomic practices among others, as reasons for yield gaps between researcher and farmer managed trials. On the other hand, higher soil organic carbon (SOC) content (Table 1) may also have contributed to improved growth parameters in Akumadan (2020) and Fumesua (2021) (Figures 2 and 3) and yield parameters in Fumesua, compared to other locations. SOC is associated with increased nutrient and water use efficiencies, improved soil microbial quality, and formation of chelate compounds that increase the availability of essential micronutrients to crops (Lanigan and Hackett, 2017; Delgado and Follett, 2002).

Conclusions and recommendations

In this study, the application of increasing levels of the new fertilizer (11:22:2 N-P-K) at 0, 300, 400, 600 and 800 kg/ha continued to increase cassava growth and yield. Corresponding yields ranged from 28000 kg/ha to 52000 kg/ha, however, the most economical range of application was 0 kg/ha < fertilizer rate ≤ 400 kg/ha. In high rainfall areas like the experimental sites, split application of the fertilizer should be done during the root bulking stage to ensure K supply to maximize yield. Higher soil organic matter (SOM) contents are important to improving the use efficiency of applied nutrients; hence SOM should be improved in cassava growing areas. Moreover, timely interventions of agronomic practices like weed control and fertilizer application should be ensured to bridge the yield gaps between researcher-managed and farmer-managed fields. The OCP fertilizer performs better in the forest agro-ecological zone than in the transitional zone, but yields can be maximized in both zones if applied.

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