#7513 PRECISION NUTRIENT MANAGEMENT FOR CASSAVA PRODUCTION

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ABSTRACT

Matching nutrient supplies with plant nutrient requirements is key to sustaining crop production while preserving the environment. However, in cassava production systems in sub-Saharan Africa, fertilizer recommendations are either inexistent or provided as blanket rates. We studied the effects on cassava yield and profitability of site-specific fertilizer rates against farmer's practices within the framework of the African Cassava Agronomy Initiative (ACAI) project in Nigeria and Tanzania.

A fertilizer recommendation framework combining crop modelling, geospatial analysis, machine learning techniques and price optimization was designed to estimate site-specifc fertilizer rates. This framework uses data on temporal and spatial variabilities of soil and weather, fertilizer and cassava root prices, and farmer's budget to generate fertilizer recommendations optimized to maximum return for investment. The resulting decision support tool for agronomy advice delivery was used to estimate site-specific fertilizer rates per planting and harvest dates for more than 800 farms in Nigeria and Tanzania in 2018 and 2019. The fertilizer recommendations considered the types of fertilizer available in the regional market, and accompanied with advices on split dressings and timing of fertilizer applications following 4R nutrient stewardship.

Results revealed that large variation in yield response was associated with variation in locations. Recommended fertilizer nutrient rates ranged from 0-120 kg N, 0-23 kg P and 0-115 kg K ha^{-1} in Nigeria against 0-129 kg N, 0-30 kg P and 0-46 kg K ha^{-1} in Tanzania for a maximum fertilizer budget of 200 USD ha^{-1}. Application of recommended fertilizer rates generated yield increases in 91% of cases, and 9% negative responses compared with the control without fertilizer. Average yield increase was about 7 t ha^{-1} in Nigeria and 5 t ha^{-1} in Tanzania. Revenue generated through these site-specific recommendations were profitable for 72% of the farmers.

Applying site-specific fertilizer rates was beneficial for most farmers. However, the recommendations were highly susceptible to market price fluctuations of cassava roots. Developing affordable fertilizer blends for cassava and linking farmers to markets with more consistent prices may sustain positive returns on investments for cassava producers.

Keywords: African Cassava Agronomy Initiative, decision support tool, 4R nutrient stewardship, site-specific fertilizer.

INTRODUCTION

The sustainable intensification of agricultural production is a key requirement for meeting the predicted surge in food demand due to the expected increase of the global population amounting 9.7 billion by 2050 (Worldometers, 2020). Within this context, cassava, *Manihot esculenta* Crantz, appears to be a crop of hope in sub-Saharan Africa (SSA), given that it is not only a source of energy with about 16.5 MJ kg^{-1} DM (Montagnac et al., 2009), but is also a robust crop that can survive harsh growing conditions such as drought and low soil fertility. Cassava can also perform well under optimal conditions by responding to fertilizer application (Howeler, 2002; Byju et al., 2012, Ezui et al., 2016, Adiele et al., 2020). However, high and profitable responses to fertilizer application can be achieved only when nutrients are provided at adequate rates and composition and are matching the supply with the crop's nutrient demands, in order to minimize losses to the environment as recommended by the 4R nutrient stewardship principles.

Applying 4R nutrient stewardship principles in SSA comes along with the challenge of deploying appropriate decision support tools. Unlike classical long term field experiments that are cost intensive and time consuming, computer models can effectively predict location-specific nutrient requirements and the best time for applying them to achieve high and profitable yields. Recent efforts have been reported on computer models adjusted for cassava production in West Africa with QUEFTS (Ezui et al., 2016) and LINTUL models (Ezui et al., 2018, Adiele, 2020). While the QUEFTS model covers soil spatial variabilities, LINTUL captures both spatial and temporal dimensions of weather and soil in addition to cultivar characteristics. Thus, a fertilizer recommendation system involving these models would be suitable to address both the issues of right place, right time, right rate and the right source through location-specific advices. Another decision support systems (DSS) has also been reported for cassava in SSA such as fertilizer optimization tool (Senkoro et al., 2018) based on nutrient response curve optimization with financial constraints to provide fertilizer recommendations. Other DSS for cassava exist globally but are yet to be adjusted for SSA growing conditions.

The current paper evaluates the effects on cassava root yield and profitability of site-specific fertilizer rates developed based on a LINTUL-QUEFTS fertilizer recommendation system compared with farmer's practices within the framework of the African Cassava Agronomy Initiative (ACAI) project in Nigeria and Tanzania.

MATERIALS AND METHODS

The study covered 805 cassava fields across the cassava belts in Nigeria and Tanzania. Cassava was planted from May to August in Nigeria in 2018 and 2019, and October to January in 2018 and 2019 in Tanzania, and were harvested after 12 months after planting (MAP). In each field, two 7×8m plots were delimitated, with one receiving the site-specific fertilizer rate (SSR) and the other one not receiving any fertilizer application (CON). Apart from fertilizer application, other crop management operations were the same for CON and SSR plots. For pratical reasons, fertilizer applications were made as one dressing at 2 to 6 weeks after planting (WAP) if the recommended rate is below 50 kg ha^{-1}, and otherwise in two equal dressings at 2 to 6 WAP and at 8 to 12 WAP, however with regards to sufficient rain fall around the application dates.

The fertilizer rate was obtained using a decision support tool in the form of an app named 'AKILIMO' meaning 'Smart Agriculture' inferred from the fusion of two Swahili words 'akili' and 'kilimo' (www.akilimo.org). AKILIMO calculates fertilizer recommendations based on a modular modelling framework involving Light Interception and

Utilization (LINTUL) and Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS), and machine learning techniques. This framework was improved from season to seasons based on field data. The input were daily weather data from NASA POWER (1° resolution) for solar radiation, temperature (minimum and maximum) and wind speed, from CHRIPS (0.05° resolution) for rainfall data, and from ISRIC (250m resolution) for soil grid data. Farmers provided information on their desired planting and harvest dates and estimate of current yield achieved in their farm by selecting one out of five pictures of cassava root stocks corresponding to different yield classes. The calculated SSR was also tailored to farmers investment capacity and market prices of fertilizers and produce (fresh storage roots) using an optimization procedure to generate fertilizer rates optimized to maximum return for investment.

The profitability of investments in fertilizers was evaluated using benefit-cost ratio (BCR), estimated as the ratio of the difference in gross revenues between SSR and CON plots over the cost of fertilizers used in the SSR. Gross revenue was obtained by multiplying storage root yield by its unit price. The price range per Megagram (Mg) of storage roots was 13.9-97.2 USD in Nigeria and 20.9-159.1 USD in Tanzania. For simplicity of this analysis, we calculated BCR using average values of 55.6 USD and 90.0 USD Mg^{-1} in Nigeria and Tanzania, respectively.

RESULTS AND DISCUSSION

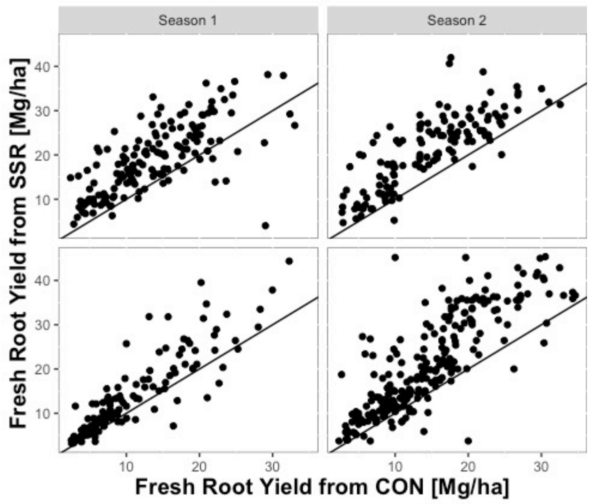
Performance of the Recommendations

The results show wide yield ranges across country and season indicating a large variability across locations and time (Fig.1A). This highlights the varying response of cassava to soil fertility management decisions. Thus, time and location-specific recommendations are indispensable. Recommended fertilizer nutrient rates ranged from 0-120 kg N, 0-23 kg P and 0-115 kg K ha^{-1} in Nigeria against 0-129 kg N, 0-30 kg P and 0-46 kg K ha^{-1} in Tanzania. Predictions improved from season 1 to 2. In about 88 and 96% of the fields in seasons 1 and 2 in Nigeria, respectively, and 88 and 92% in Tanzania (Fig. 1A), cassava root yields were higher in the SSR plots (i.e. are above the 1:1 line), indicating better performance of the recommended fertilizer rates (SSR) compared with the control plots without fertilizer (CON). This means that AKILIMO provided good advice to farmers in 91% of the cases by recommending the application of the site-specific fertilizer rate and predicting a root yield increase. However, this advice was not correct for about 9% of the fields. In these cases, the DST provided sub-optimal estimates of the attainable yield and or the initial soil supply of nutrients. The latter was obtained from soil grid data corrected with farmers estimates of their current yields during the preceeding cropping season. Picking wrong yield classes led to imcomparable values of initial soil supply of nutrients. Sub-optimal results were as well caused by the scale of predictions with differences in micro-climate conditions between farms, because weather and soil conditions were obtained at a much larger scale, thus not being able to consider small scale differences.

Profitability of the Recommendations

Financial returns of fertilizer use have also improved from season 1 to 2. Values of BCR>1, indicating that the net revenue generated from the use of fertilizer was larger than the investment, were achieved in 69 and 74% of the fields, in season 1 and 2, respectively (Fig. 1B).

A



B

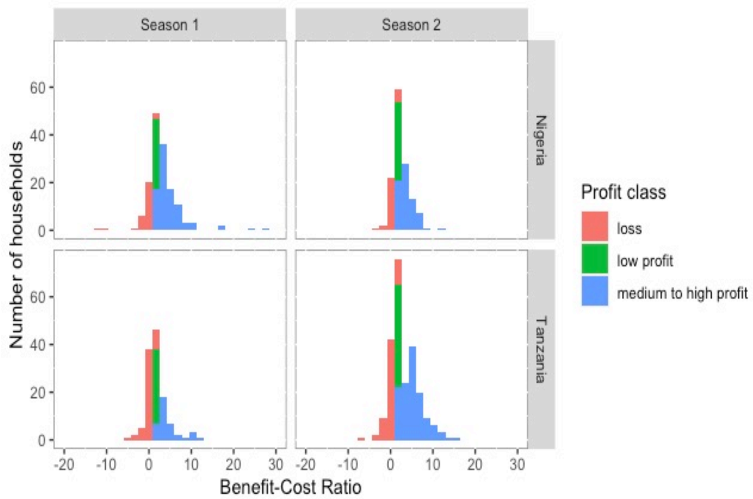


Figure 1. Fresh storage root yields achieved in the control (CON) and with recommended site-specific fertilizer rates (SSR) in Nigeria and Tanzania in two seasons (A) and the related distribution of Benefit-Cost Ratio and profit class (B). Seasons 1 and 2 are 2018 to 2019 and 2019 to 2020 growing periods, respectively. The plain line across the dots corresponds to 1:1 line (A). The profit class comprises 'loss' for BCR < 1, 'low profit' for 1 ≥ BCR < 2, and 'medium to high profit' for BCR ≥ 2 (B).

This implies that although on average 91% of the fields had yield increase due to fertilizer application, this was profitable only for 72% of them. Financial considerations are important for fertilizer recommendations. However, BCR < 2 may be risky due to price fluctuations at harvest. A safer BCR ≥ 2 is strongly recommended. The improvement of predictions from season 1 to 2 helped achieve larger number of cases with BCR ≥ 2 in season 2 compared to season 1 (53 *vs* 47%). Larger profits can be attained with higher root price while lower price can also increase the profit gap. Thus, ensuring reliable and stable root prices at harvest is of a paramount importance for producers to sustainably intensify cassava production through the use of fertilizer. This can be implemented through diverse strategies such as: i) scheduled planting and harvesting at periods with favourable root prices, ii) policies enabling a reduction in root price fluctuations or iii) linking producers with processing companies offering pre-negotiated convenable prices. The negative BCR are associated with underestimation of the current and attainable yields.

CONCLUSIONS

Increased root yields and profits can be achieved through the use of site-specific fertilizer recommendations. While efforts should be intensified to better capture the diversity of cassava farming systems for enhanced production, mechanisms should also be in place to guarantee relatively stable produce prices to ensure that profits are achieved from the use of decision support tools.

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