Chapter

Improvement in Cassava Yield per Area by Fertilizer Application

John Okoth Omondi and Uri Yermiyahu

Abstract

Cassava is a source of carbohydrates to more than 200 million people in Sub-Saharan Africa, even though its production is 6–8 t ha^{-1}, which is below the highest world production of 36.4 t ha^{-1} in India. To address this yield gap and increase cassava's availability, affordability, and adequacy, intensive but sustainable production is important. Additionally, being an emerging raw material in the animal feeds, pharmaceutical, beer industries etc., only increases its demand, however the current production levels cannot effectively sustain this. Therefore, this paper reviews: improvement in cassava yields per area under fertigation and banding of fertilizers, a common practice among many farmers; the advantage of fertilizer application on starch of the storage roots, which is the fundamental ingredient in most industries using cassava as a raw material; and the climate smart technologies for intensive sustainable cassava production. In the end, this review enhances knowledge about fertilizer application to cassava, both banding and fertigation, and expounds on effective intensive sustainable climate-smart production strategies.

Keywords: storage roots, irrigation, fertilizer, sustainability, climate smart, macro-nutrients

1. Introduction

Cassava is a root crop which provides starch to over 500 million people in the tropics and is the sixth most important crop in the world [1]. Its importance is gradually increasing in the beer and pharmaceutical industries due to demand for its starch [2]. Yet, its world production is only 262.6 million tonnes [3], in which the highest yield per hectare was achieved in India (36.4 t ha^{-1}), while Sub-Saharan Africa (SSA) produced 6–8 t ha^{-1} [3]. Also, increase in population is not parallel to food production in sub-Saharan Africa leading to deficits that can only be filled by imports. This lack of synchrony between population growth and food output is attributed to an inability of crops to achieve their potential – the yield gap. Hillocks [4] cautiously reported that there was a 46% yield gap for cassava in Africa, while globally it was 36%. He linked such to a myriad of factors: from unpredictable rainfall distribution to poor adoption of technologies, scarcity of inputs, minimum usage of inorganic fertilizers and poor agronomic practices etc. Even though these factors contribute to the yield gap, poor soil quality or lack of fertilizer application [5] are key and hence require urgent solution [6]. In order to address this, Giller et al. [7] suggested that best-fit technologies that are compatible with farm practices are essential. Such technologies include integrated soil fertility management (ISFM) and conservation agriculture (CA).

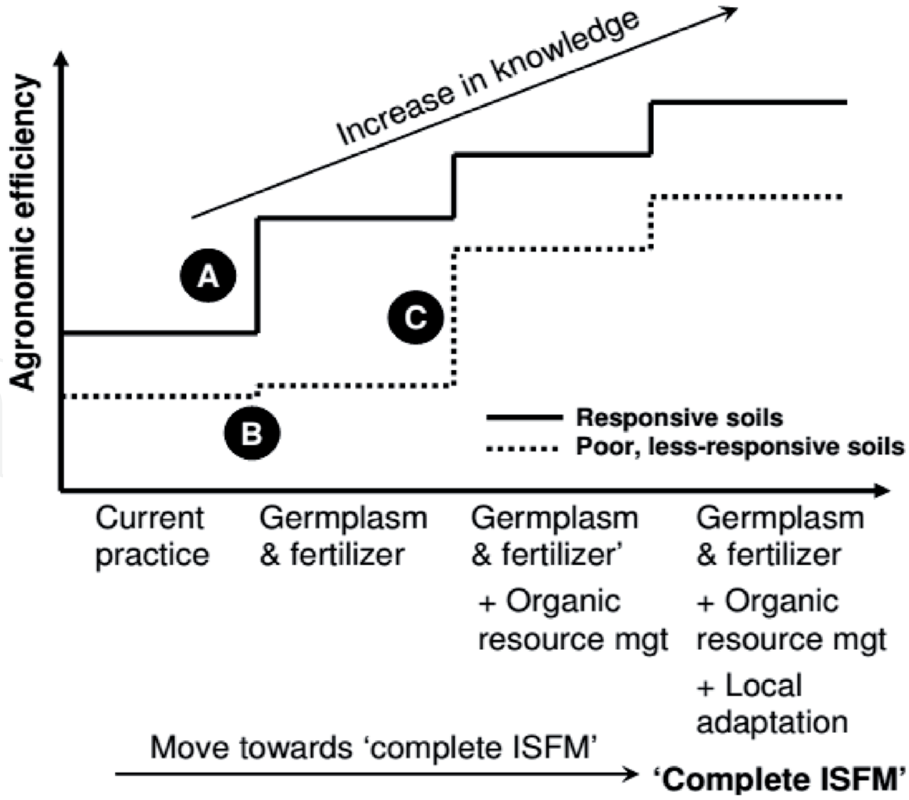

Figure 1.
Relationship between the agronomic efficiency (AE) and various components of ISFM. Source: [8].

After developing integrated soil fertility management (ISFM) concept [8], Vanlauwe et al. [9] further proposed the inclusion of appropriate fertilizer application as a principle of conservation agriculture (CA), to which Sommer et al. [10] offered a rebuttal stating that it should just be a practice rather than a pillar of CA since in Sub-Saharan Africa (SSA) low fertilizer application is a common problem not only linked to CA. Despite their divergent views, they however agreed that fertilizer usage is fundamental in SSA agricultural systems to close the yield gaps. Interestingly, it has been observed that cassava root yield increase with fertilizer application even in Sub-Saharan Africa [11–13]. Recent studies on the effects of fertigation on growth and root yield of cassava, Omondi et al. [14] established fertigation concentrations at which maximum storage root yields were achieved in the field for three cassava varieties (Mweru, Nalumino and Kampolombo).

Looking at Vanlauwe et al.'s [10] **Figure 1** on ISFM, the jump in agronomic efficiency from the current practice to germplasm and fertilizer is greater than all the other ISFM practices. However, while reinforcing the importance of appropriate fertilizer application for intensive sustainable production of cassava to close the yield gap, this review does not negate the need for improved varieties, better agronomic practices/management, adaptation to local environment and usage organic fertilizers. Thus, this paper aims to evaluate and reinforce the clarion call that appropriate application of fertilizers through the 4R-Nutrient-Stewardship (right fertilizer source, right rate, right time, right placement) [15] through fertigation or banding, proper agronomic management and right management of the ISFM traits improve cassavas' yields.

2. Cassava root yield under fertigation and banding

Table 1 shows that irrespective of the amount of fertilizer applied, there is an advantage of storage root yield against non-application. Of course, there

Site	N-P-K (kg ha^{-1})	% Fertilizer advantage on root yield against 0–0-0 NPK (kg ha^{-1})	Source
Banding			
Kabangwe (Zambia)	100–22-83	31.0	[16]
Mansa (Zambia)	100–22-83	32.9	[16]
Akure (Nigeria)	60–60-60	37.0	[17]
Kwang'amor (Kenya)	100–22-83	60.5***	[18]
Mungatsi (Kenya)	100–22-83	68.3***	[18]
Ugunja (Kenya)	100–22-83	68.3***	[18]
Kisiro (Uganda)	100–22-83	64.2***	[18]
Kerala (India)	100–300-100	56.2	[19]
Lopburi (Thailand)	250–62.5-125	23.4	[20]
Supanburi (Thailand)	250–62.5-125	19.6	[20]
Chonburi (Thailand)	250–62.5-125	23.3	[20]
Thai Nguyen (Vietnam)	160–80-160	88.7**	[21]
Fertigation			
Lusaka (Zambia)	155–23-155	24.6* (Mweru variety)	[14]
Lusaka (Zambia)	76–8-76	37.7* (Kampolombo variety)	[14]

**These varieties were harvested at eight months after planting.*
***Data used are a mean of nine years.*
****NPK application compared with the average farmer practice.*

Table 1.
Fertilizer application advantage on storage root yield of cassava.

are variations in the levels of advantage due to different factors such as variety response, agro-ecological zones characteristics, agronomic and crop management practices etc. For example, under fertigation (application of fertilizers or other soil amendments intended to improve soil fertility through an irrigation system) in [14] study, all the cassava varieties receive similar treatments yet the fertilizer advantage is different – Kamplombo variety responding better to fertilizer application.

The highest fertilizer advantage is obtained under continuous cassava cultivation (**Table 1**), for example, [21]'s long term trials indicated decline in root yield under both non – and - fertilizer applications (**Table 1**). Although, under no fertilizer application, the decline was huge perhaps due high nutrient depletion without replenishment. This is an indication that continuous cassava cultivation requires continuous application of NPK including the other elements. Here [21], the fertilizer was banded, a placement of fertilizers in bands/rings/strips near the roots, often 5 cm to the side of the plant and 5 cm deep.

Also, in their long-term nine-years study of fertilization of cassava, [21] observed a decline in storage root yield regardless of fertilizer rate or individual nutrient rates, however, they concluded that highest cassava root yield were obtained at N-P-K of 160–80-160 kg ha^{-1} (**Table 1**). Such decline in cassava's response to continuous nutrient application, especially K, on the same piece of land for five years was also observed by [22] in fourteen varieties. In both instances, [22] and [21] attributed the decline over the years to depletion of other elements such as Ca and Mg, which were not applied in their experiments. This indicates the importance of other nutrients to cassava even as many studies are focused on

NPK– adhering to Justus von Liebig Law of the Minimum - a limit in one nutrient limits the uptake of the others and hence decline in growth and yield [23].

3. Fertilizer influence on starch qualities

The importance of cassava storage roots as food and animal feed cannot be understated, especially among smallholder farmers. To enhance cassava's ability as an industrial cash crop, focus needs to shift to starch in its storage roots. However, there are many starch characteristics that are considered by various industries such as particle size, solubility, gelatinisation, purity etc. These require extensive study.

Cassava starch is being used in beer making, ethanol production [24, 25], pharmaceuticals, paper manufacturing, textile etc. [26]. In addition, it has been tested as a substitute for agar material in micropropagation in tissue culture studies with minimum success [27]. Therefore, as the usage of starch from cassava storage roots expands, factors that influence the starch suitability for various industries are of importance. Factors that influence crop growth and development like climate, soil fertility, abiotic and biotic incidences and the variety [28] are vital. Those that impact postharvest and processing are important too [29]. **Table 2** illustrates the effect of fertilizers and soil amendments on the characteristics of starch of cassava storage roots.

The response of cassava storage-root-starch varies under fertilizer application (**Table 2**). Some varieties increase storage root starch content while others decline, for example, four of the varieties tested by [32] had a decline in starch content within the storage roots. Despite these observations from [32], other studies have indicated an increase of 9–14% starch content in the storage roots on fertilizer application to cassava (**Table 2**). Remarkably, fertigating medium (Kampolombo) and long duration (Nalumino) cassava varieties improved starch content of storage

Variety	N-P-K (kg ha^{-1})	%Fertilizer advantage on starch content against 0–0-0 NPK (kg ha^{-1})	Source
Banding			
TMS 30572	22.5–22.5-22.5	10.7	[30]
TMS 419	22.5–22.5-22.5	10.2	[30]
—	60–60-150	5.6	[31]
M98/0040	24–24-24	9.6	[32]
98/0002	24–24-24	−1.3	[32]
99/6012	24–24-24	−1.7	[32]
92b/0061	24–24-24	−6.8	[32]
82/00058	24–24-24	−7.5	[32]
Fertigation			
Mweru	155–23-155	9.7	[14]
Kampolombo	76–8-76	14.0	[14]
Nalumino	54–5-54	12.5	[14]

- Variety not indicated from the source.
A negative in the % fertilizer advantage indicates that starch content under no fertilizer application was higher than under application.

Table 2.
The advantage of applying fertilizers on the starch content of storage roots of cassava.

roots than banding in other varieties (**Table 2**). It is important to note that these varieties were not tested under banding, neither were the other varieties tested under fertigation. Therefore, a direct comparison of the two fertilizer application methods (fertigation and banding) is weak, even though the observations on response of each variety are insightful.

4. Future of intensive sustainable climate-smart production of cassava

Climate is changing, and human population is growing. Cassava is one of the crops that have been observed to be tolerant to the vagaries of climate, such as increase in atmospheric temperature, CO_2 [33] and drought [34]. Furthermore, as stated in the introduction, its demand both as food and raw material for industries is increasing, to reduce the yield gap and meet the growing demand, its yield per area must improve. However, that intensive production must be sustainable and climate smart. To make it a climate-smart and a cash crop for smallholder farmers, intensive sustainable production approaches are required. Tweaking the [8]'s ISFM **Figure 1** with best of the 4R-Nutrient-Stewardship [15] of fertilizer application and other agronomic practices such as right planting time, population, pattern and proper management biotic and abiotic stresses would optimize intensive sustainable climate-smart production (**Figure 2**). Such modifications to the ISFM concept will encourage increased sustainable production not only of cassava, but other crops too and consequently feed the bulging world's population effectively.

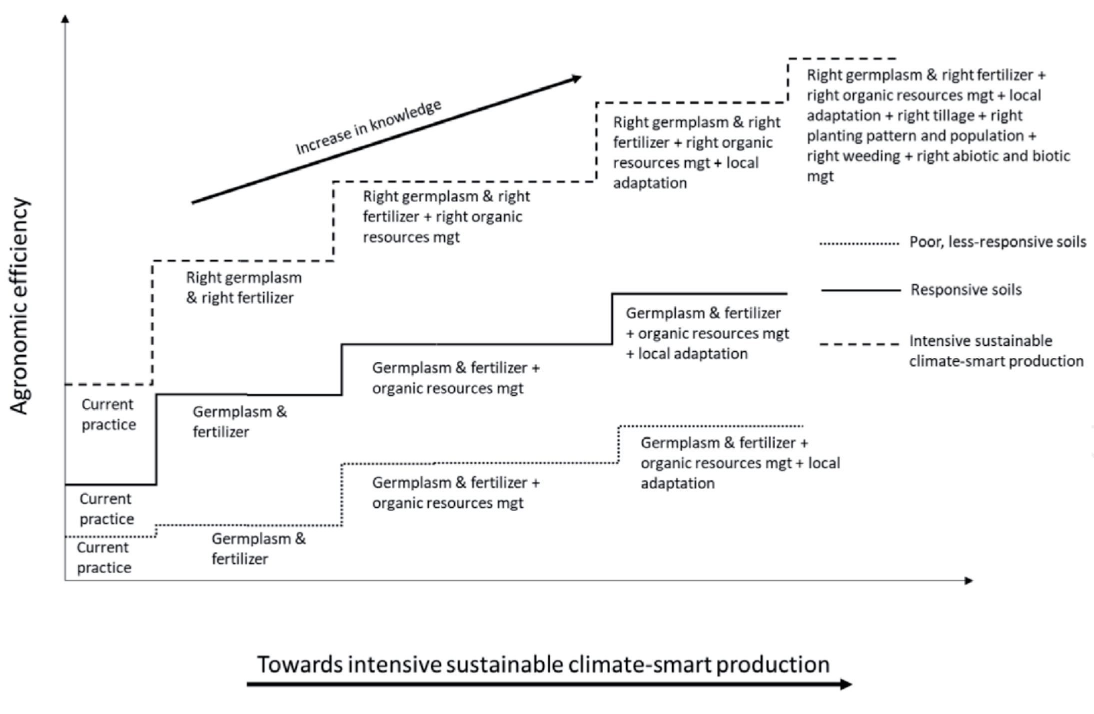

Figure 2.
The components leading to intensive sustainable climate-smart production of cassava. Mgt – Management. A modified ISFM concept from [8] to achieve intensive sustainable climate-smart production.

5. Conclusion

This review has elucidated the advantage of fertilizers to cassava storage root yield and starch content. However, this advantage is only valuable to most smallholder farmers if markets are available to absorb their produce. To improve cassava's status as a cash crop through starch production: extensive evaluations of fertilizers effect on the characteristics of starch of storage roots of best performing improved varieties is required. There should be a concerted effort to match the high root yields obtained from fertilized cassava fields with the starch requirements of industries. This should be the next major frontier of research if cassava-producing-smallholder farmers' financial earnings is to increase exponentially.

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