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# Responses of cassava growth and yield to leaf harvesting frequency and NPK fertilizer in South Kivu, Democratic Republic of Congo

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ABSTRACT

Harvesting young cassava leaves as a vegetable is a common practice in the Democratic Republic of Congo (DR Congo). However, information on its effects on growth and yield of cassava is scarce. Multi-locational trials were conducted on farmers' fields in the province of South Kivu, DR Congo, during two consecutive years to investigate the effects of harvesting frequency of 3 young leaves (no leaf harvesting (NoH); leaf harvesting at 4 week intervals (4-WI) or 2 week intervals (2-WI), starting 4 months after planting) and fertilizer (with or without NPK application) on the growth and yields of cassava, comparable to common practice by farmers in the area, based on a preceding household survey. Overall, harvesting of leaves did not result in significant effects on both height and stem diameter compared with the unharvested treatment. However, collection of leaves at 2-WI significantly ($P < 0.05$) decreased both height and stem diameter, and resulted in significant ($P < 0.1$) reduction of stem yields of 20.9% (4.0 t $ha^{-1}$) relative to leaf harvesting at 4-WI but only in the second year. Average total biomass and storage root yields in the control treatment were 35.8 and 23.5 t $ha^{-1}$, respectively and were not significantly affected by leaf harvesting. Application of NPK fertilizer resulted in significant ($P < 0.05$) increases of both height and stem diameter over time, independent of the frequency of leaf harvesting. Mineral fertilizer significantly ($P < 0.05$) increased the overall total, storage root and stem yields by 28.3% (9.5 t $ha^{-1}$), 19.9% (4.5 t $ha^{-1}$) and 45.1% (5.0 t $ha^{-1}$), respectively regardless of the frequency of leaf harvesting. This study indicates that harvesting of young leaves results in small or negligible effects on cassava growth and yields compared to the mineral fertilizers which increase both cassava growth and yields in the conditions of our study.

## 1. Introduction

Cassava (*Manihot esculenta Crantz*) is a major staple food for over 70% of the population in DR Congo and an important source of income (Lema et al., 2004). The tuberous roots of cassava (El-Sharkawy, 2006) have a high starch content (up to 90% of the dry matter) (Abdullahi et al., 2014; Silvester, 1989) and is a source of calories for millions of Africans (Achidi et al., 2005). Because of its inherent tolerance to various edapho-climatic stresses (El-Sharkawy, 2006), cassava is usually grown on severely depleted soils, often with little or no inputs of fertilizers and pesticides (Howeler, 2002) and hence with very low yields. The average storage root yield in DR Congo, between 2000 and 2014, is 8.9 t $ha^{-1}$ (FAOSTAT, 2016), which is bleak compared to its yield potential of 75–90 t $ha^{-1}$ (Cock et al., 1979; Fermont et al., 2009).

In South Kivu (DR Congo), cassava is generally grown continuously on small plots due to the high population density coupled with land scarcity. This leads to fast depletion of nutrients especially nitrogen (N) and potassium (K) (Agbaje and Akinlosotu, 2004) which are the major nutrients required for optimum growth and storage root yields (Agbaje and Akinlosotu, 2004; Howeler, 1991; Obigbesan and Fayemi, 1976). Furthermore, in many areas farmers harvest all plant parts (roots, stems and leaves) resulting in serious nutrient mining and chemical and physical soil deterioration (Howeler et al., 2000). Therefore, mineral fertilizers, especially N and K may be required in South Kivu to meet the nutrient requirements of cassava. Farmers in this region, however, only

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apply limited amounts of manure or composted crop residues to this crop (Pypers et al., 2011) while mineral fertilizers have never been used for its production in South Kivu (CIALCA, 2010).

While in some cassava-producing countries leaves are not consumed at all, or only eaten during food shortage (Latif and Müller, 2015), in DR Congo, cassava leaves are widely consumed and since they are available throughout the year (Latif and Müller, 2015; Moyo et al., 1998) constitute a major component of the diet. Bokanga (1994) reported that DR Congo may have the highest level of cassava leaf consumption in the world. According to Mahungu et al. (1992) quoted in Achidi et al. (2005), cassava leaves have a share of more than 60% of all vegetables consumed in DR Congo and are an important source of revenue. Several studies (Adewusi and Bradbury, 1993; Bokanga, 1994; Dada and Oworu, 2010; Eggum, 1970; Lancaster and Brooks, 1983; Terra, 1964) have reported the nutritional value of cassava leaves which are a major source of proteins (14–40% on a dry weight basis), vitamins (vitamin B1, B2, B6, C), carotenes and minerals (potassium, iron, calcium, sodium).

Leaf harvesting throughout the growing cycle of cassava is a common practice in South Kivu. Farmers often harvest leaves as needed without accounting for possible adverse effects on storage roots. Surveys conducted in South Kivu, indicated that for home consumption, most farmers (76%) commonly harvest the youngest leaves without petioles when cassava is still young, while later on when the crop is more mature, most farmers (80%) harvest the tender apical leaves and shoots (entire tops). They further reported that they generally cut branches with both edible and nonedible leaves (young and old leaves, respectively) for commercial purposes. The first harvesting of leaves starts as early as 3 months after planting (MAP) and continues then at 2–4 weeks intervals depending on the needs and revenue of the household. Moreover, neighbors within villages are also allowed to collect leaves from the closest fields as long as it is for family consumption. The amount of leaves harvested at each collection depends on the size of the household but also on the season (more leaves in rainy season), but in general, 63% of households reported to collect leaves from 50 to 75% of the plants at each collection event (13% reported a higher proportion), and predominantly (63%) from a single branch per plant.

Several studies have investigated the impact of leaf harvesting on storage root production, but no consistent conclusions can be drawn due to differences in the intensity and frequency of leaf harvesting. However, Dahniya et al. (1981), Lockard et al. (1985) and Phengvichith et al. (2006) tested the effects of leaf harvesting at different frequencies on storage root yields and reported a decrease in storage root yields as the harvesting frequency increases regardless of the variety used (local and/or improved variety). They recommend leaf harvesting at intervals of minimally 2 or 3-months to ensure reasonable yields. Lutaladio and Ezumah (1980), on the contrary recommended a monthly harvesting of leaves as it resulted in large leaf production with little losses in root yields in a study conducted in lowland conditions in DR Congo (Zaire). According to Salisbury and Ross (2004) cited by Dada and Oworu (2010), the effects of defoliation on plants depend on the intensity, frequency and timing of foliage removal.

The typical DR Congo practice of frequent, small amount harvesting of leaves, when only used for household consumption implies that only edible leaves per plant and from random plants within the field (not all plants) are harvested. It is not known whether such a regime (high frequency but low intensity) has a negative impact on yield, and whether there is interaction with the nutritional status of the crop. Nutrient supply by fertilizer is postulated to result in larger leaves, and faster leaf initiation, and may compensate the losses by harvesting of a few leaves. Therefore, the objective of this study was to investigate the effects of the frequency of household harvesting of a small amount of leaves and NPK fertilizer application on the growth and yields of cassava in the South Kivu, DR Congo given the absence of data on these important effects in the highlands of Central Africa.

## 2. Materials and methods

### 2.1. Study area

The study was conducted in Kalehe (2.070° – 2.162° S, 28.853° – 28.921° E, 1526–1690 m a.s.l.), a territory of the province of South Kivu in the Eastern part of the Democratic Republic of Congo. Rainfall pattern in Kalehe is bimodal and allows crop cultivation during two seasons. The “A” season lasts from mid-September to mid-January while the “B” season starts in mid-February and ends mid-June, followed by a short dry season referred to as the “C” season. Rainfall averages 1500–1800 mm per year, and the growing period extends to over 325 days per year (Hijmans et al., 2005). Daily rainfall data during the experimental period were obtained from the research center of Lwiro, the closest (distance of 30 km) meteorological station to the field trials. The variability of the rainfall during the two growing cycles was determined using the Shannon index (Bronikowski and Webb, 1996). Soils in Kalehe are classified as Plinthic Ferralsols (Jones et al., 2013) and are of a silty clay texture. Cassava is the main staple crop and an important cash crop grown by all farmers in Kalehe.

### 2.2. Trial establishment and management

Field experiments were conducted during two consecutive growing cycles of one year each (season 2014 A and 2015 A). In September of each year, seven trials were planted across five sites (a site equals a “locality” or “groupement”) with at least one trial per site. Trials were established in fields presented by participating farmers and repeated in the second year in other fields. Both degraded (unused) land and land on steep slopes were avoided. Prior to trial installation, a composite soil sample from at least 10 random sampling spots per field was collected with an Edelman auger at 0–30 cm topsoil, air-dried, passed through a 2 mm sieve and analyzed for standard physico-chemical properties. Soil texture analysis was done using the LS 13 320 Laser diffraction method, total N and organic carbon using the Dumas combustion method (Dumas, 1931), Available P using the Olsen method (Olsen et al., 1954) while the cobalt-hexamine extraction method (Ciesielski et al., 1997) was used for cation exchange capacity. All analyses were conducted in the laboratories of the Department of Earth and Environmental Sciences at KU Leuven, Belgium.

The experiment was set up following a multi-locational design with two factors. The frequency of harvesting cassava leaves was the main factor with three levels; no harvesting of leaves (NoH), harvesting at 4-week intervals (4-WI) and harvesting at 2-week intervals (2-WI) and fertilizer addition (with or without NPK application) as the other factor. Treatments were not replicated within each field, instead, farmer fields per site and year were considered as replicates. The leaf harvesting regimes were set up to closely reflect the local practice for home consumption. The harvesting of leaves started from 3 to 4 months after planting (MAP) and continued up to 10 MAP. Three youngest fully expanded leaf blades without petioles (4th, 5th and 6th leaf from the top where the 1st opened leaf from the crown was considered as leaf number 1 and the 4th leaf from the top was generally the 1st fully expanded leaf) were collected from a random branch per plant, from 10 randomly selected plants within the effective plot of 16 plants without the border rows. We used ‘Sawasawa’, an improved cassava variety resistant to cassava mosaic disease, which was introduced in DR Congo in 2003 by IITA (INERA, 2008). This variety has on average 2 main stems with 2 primary branches and 3 secondary branches each. This leaf harvesting regime is comparable to the practice used by farmers in the area when the objective of the harvesting is household consumption (not for sale). Collected leaves were mixed, air-dried, and subsequently oven-dried at 60 °C for 72 h for dry matter (DM) determination, and calculation of the harvest index (HI). Fertilizer rates were 100-22–83 kg N-P-K $ha^{-1}$. N fertilizer was split-applied as urea, half at planting (in the planting hole) and half at 3 MAP, localized around the plant. All P