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Yield of Cassava Leaves (*Manihot Esculenta* Crantz Var Obama II) in Relation to Some Harvesting Modalities during the Crop Cycle in the Hinterland of Kisangani (Tshopo Province, R.D. Congo)

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Abstract: *The study examined the impact of three cassava leaf harvesting methods on the growth and leaf yield of the Obama II variety in Kisangani. The three methods were light picking (CL), moderate picking (CM) and coarse picking (CG). Results showed that plant diameter was not affected by harvesting method, but plant height and number of tender shoots were. Rough harvesting produced the tallest plants with the most tender shoots. Yields of fresh cassava leaves varied according to harvesting method, ranging from 5.36 to 12.27 t/ha, with rough picking giving the highest yield. However, light picking had the highest rates of leaf removal (63.8%) and wilting (55.4%), followed by moderate picking (CM: 49.6% rate of leaf removal and 39.0% of wilting), while coarse picking had the lowest rates of leaf removal (21.6%) and wilting (18.6%).*
Keywords: *modality, leaf picking, leaf yield, cassava*

I. Introduction

The characteristics of cassava (Manihot esculenta Crantz) make it very attractive and interesting to farmers. More than half of the sub crop area in the Democratic Republic of Congo is covered by cassava, whose harvested products are consumed on a permanent basis by the population at rates of 70% for tuberous roots and 80%tuberous roots, and 80% for leaves (Mahungu et al., 2015). Some African countries, such as the Republic of Congo and the Central African Republic, grow cassava to produce these two useful products. However, leaf harvesting is a common practice among Congolese farmers (FAO, 2013).

Based on the literature, it appears that leaf harvesting modalities are highly variable according to the different studies conducted by Dahniya (1980); Lutaladio and Ezumah (1980); Sandifolo et al. (2010); Litucha (2011) and Mahungu et al. (2015), in the absence of a conventional and standard leaf harvesting modality during the crop cycle.
Dahniya (1980) described leaf harvesting as effeuillage, and in this trial harvested 13.6t/ha of fresh leaves at a monthly frequency for cultivar TMS 3021.

A comparative study of different cassava leaf-picking modalities defined in terms of monthly, fortnightly and frequent frequency between the varieties Kangu (local variety) and 02864 (sweet variety) was carried out by Lutaladio et al. (1980) in the province of Kongo Central in the Democratic Republic of Congo. The yields obtained per modality applied in this study were of the order of 5.7 t/ha, 16.3 t/ha and 22.7 t/ha for the Kangu variety and 6.9 t/ha, 17.6 t/ha and 24.5 t/ha for the sweet variety 02864, respectively for frequent, fortnightly and monthly picking.

Sandifolo et al (2010) compared two cassava leaf-picking processes, one of which they described as topping and the other as receiving. By subjecting local varieties (Mbundumali) and improved varieties (TMS 60142 or Silvia) to these processes, they harvested an average of 22.45t/ha of leaves for both varieties by pollarding and 25.74t/ha by receiving.

For Litucha (2011), leaf harvesting concerns the apical part of stems and shoots, and consists in removing around 20 cm from the ends of stems or shoots of plants bearing terminal buds and young leaves that are more or less fully developed and tender enough to be eaten as vegetables. Harvesting on a monthly basis, he has obtained a total of 2.46 to 4.94 t/ha of leaves for Mbongo after five passes.

A recent study by Moita-Nassy et al. (2020) on the leaf and root yields of three improved cassava varieties (Manihot esculenta Crantz) under organo-mineral fertilizers and at leaf harvest in south-western Nigeria, yielded 3.6 to 4.1t/ha with harvesting carried out 3 to 5 months and stopped 12 months after planting, with an average of 3.8t/ha. The average dry leaf yield obtained with the same trial was 1.45t/ha at the control level.
The studies mentioned above show that leaf yields vary according to cultivar, growing conditions, soil fertility, rainfall, frequency or number of harvesting passes and target, making it difficult to compare leaf yields between trials and fields.

A recent survey of the five main roads supplying the city of Kisangani with cassava leaves, as well as the rural market in the Isangi area, revealed that the number of unfolded leaves on harvested portions of stems or shoots varies on average between 5 and 9, depending on the technique used by the farmer (Molongo et al. (2023). Based on these intervals recorded in farming environments, we tested a number of leaf-picking methods in a trial, in order to identify their effect on cassava leaf yield.

This work was initiated and carried out with a view to developing a leaf-picking method based on the number of fully opened leaves on the apical, tender part of the stem or shoot, which takes into account the quality requirements of housewives (tenderness), the yield of useful or edible parts during different stages of conditioning before cooking, and provides a conventional basis for comparing leaf yields between different cultivars, trials and fields.

II. Materials and Method

2.1 Study Environment

The experiment was carried out in the concession of the Institut Facultaire des Sciences Agronomiques de Yangambi located in the village of BAKILO at kilometre point 41 of the town of Kisangani on Route Nationale 4. The geographical coordinates of the experimental field are 00°28.583' longitude North; 025°31.634' latitude East at 482m altitude. The climate of the experimental site is that of the city of Kisangani, which is equatorial continental hot and humid type Af according to Köppen's classification of Thornwaite's class B (Alongo et al., 2013). Its average temperature hovers around 25°C according to Van Wambeke and Liben (1957), and rainfall is abundant (1800 mm on average) and distributed throughout the year according to two more or less rainy seasons, one very rainy running from September to November, the other less humid, relatively short, running from March to May. Our test period ran from May 15, 2022 to April 15, 2023. Table n°01 below shows the climatic data corresponding to our test period, according to the Kisangani weather station.

Table 1. Climatic data during the trial period.

Mounths & Years	Precipitation (mm)	Temperature (°C)		
		Max	Min	Average
May 2022	2	33	20,5	26,75

June 2022	0	32,5	18,6	25,55
July 2022	95	30,1	19	25,05
August 2022	0	32,8	19	25,9
September 2022	0,4	33	19,5	26,25
October 2022	99	33,5	19,5	26,5
November 2022	10	31,5	20	25,75
December 2022	0	34,5	17	25,75
January 2023	0	33,5	19	26,25
February 2023	0	34,5	19	26,75
March 2023	0	34,5	19	26,75
April 2023	10	28	11,5	19,75
TOTAL	**216,4**	**391,4**	**221,6**	251
Average	**18,03**	**32,6**	**18,47**	25,55

Source: Kisangani weather station, call sign 64040 (https://www.infoclimat.fr/climatologie/annee/2022/kisangani/valeurs/64040.html)
Legend: P=precipitation, max=maximum and min = minimum

The soil at the experimental site belongs to the ferralitic soil family, corresponding to the oxysol order according to the soil taxonomy and to the Ferralsols group according to the FAO-UNESCO classification (Kombele, 2004). The experimental site was an old fallow colonized by various plant species, the most abundant of which were: *Musanga cecropioides, Pueraria javanica, Urena lobata, Megaphrynium macrostachyum et Bacteria nigritana*

2.2 Material

The biological material used in our experimental field was cuttings of Manihot esculenta Crantz, variety Obama 2. This variety is of Nigerian geographical origin, and its genetic origin is IITA in 2015, of which INERA M'VUAZI is the breeder and responsible for its maintenance (SENASEM RDC, 2019). The stems from which the cuttings were taken came from a woodlot adjacent to the experimental site in the village of BAKILO itself. This woodlot was visited at the outset, and healthy cuttings were selected on the spot. Once the stems had been harvested, we stored them under shade for two weeks, then cut them into standard cuttings, each 20 to 25 centimetres long and bearing an average of 4 to 6 nodes.

2.3 Methods

The trial site was selected on the basis of safety and socio-economic factors, including availability of labor, planting materials and accessibility. Site selection was based on the following factors: previous crops, relief and location. The preparatory work involved the following operations in succession: site demarcation, clearing, cleaning and stump removal. The study aimed to evaluate tuberous leaf and root yields in the same experimental field, so we adopted a Latin square layout with 4 replicates, each comprising 4 treatments. The total surface area of the experimental field was 47.5m x 47.5 m, i.e. 2256.25 m², and that of the plots 1 are, i.e. 10m x 10m. Blocks and plots were separated by 1.5m aisles. We adopted the 1m x 1m spacing for cuttings.

For the leaf production aspect, we used the same field, assimilating the experimental set-up to that of complete randomized blocks with 4 repetitions of three treatments each. The treatments considered were as follows: T1: Light leaf plucking, i.e. plucking the apical parts of stems or shoots with 3 to 5 fully expanded leaves; T2: Moderate leaf plucking, i.e.

plucking the apical parts of stems or shoots with 6 to 9 fully expanded leaves; T3: Coarse leaf plucking, i.e. plucking the apical parts of stems or shoots with more than 9 fully expanded leaves. The layout of treatments relating to the leaf yield objective on the initial set-up of the overall study is shown in Figure 1.

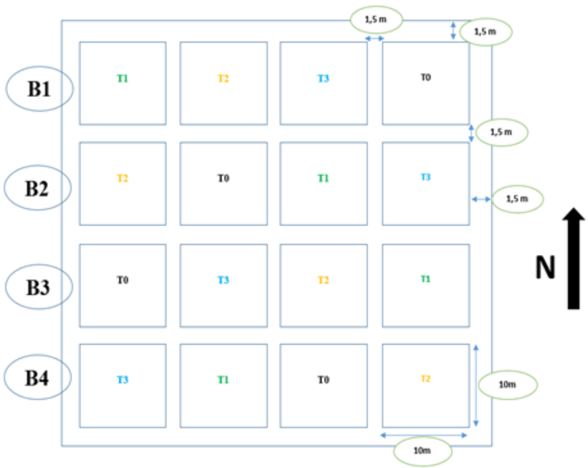

Figure 1. *Experimental set-up of the trial*

Legend: T1: Light leaf plucking, T2: Moderate leaf plucking, T3: Coarse leaf plucking, T0:

Control or no leaf plucking (treatment not taken into account for leaf yield aspect).

During the experimental period, cultivation consisted of the following operations: replanting of voids: this consisted of filling in the voids observed in the field following the failure of cuttings to take up again three weeks after planting; elimination of off-types: this phase consisted of eliminating all the cassava plants of different Obama varieties in the experimental field; removal of stems or plants: this consisted of manually eliminating extra stems and/or plants, leaving only one stem per location. This operation took place 1 month after planting; Weeding: this operation consisted in eliminating weeds in the experimental field; it was carried out on three occasions, i.e. 45, 90 and 150 days after planting; Ridging: this operation was carried out by building up the soil around the cassava stems. This was to prevent the tuberous roots from being exposed to the elements (sunlight).

Leaf harvesting began at 3 months and ended at 6 months after planting. Harvesting was carried out on a monthly basis, allowing a total of four passes. Starting harvesting at 3 months and stopping at 6 months after planting is justified by cassava physiology (Silvestre P. et al.,1983 and Philippe V. et al. 2018).

Observations focused on plant recovery and vegetative growth, as well as yields of tender shoots and edible leaves at leaf-thinning and wilting.

a. Recovery rate: this was calculated using the following formula:

$$TR\ (\%) = \frac{NBR}{NTBP} \times 100$$

Legend: TR: Trade-in rate, NBR: number of cuttings that have recovered, NTBP: total number of cuttings planted.

b. Diameter at collar: determined using a caliper every month from the third to the sixth month after planting.
c. Plant height: taken monthly using a tape measure from the third to the sixth month after planting.

d. Number of leaves produced per plant: assessed by counting leaves on each plant.
e. Number of shoots formed after each harvest: determined by counting the shoots the day before each harvest.
f. Tender shoot yield: For tender shoot yield, leaves were harvested from each plot according to its treatment, i.e. coarse, moderate or light picking. The yield of tender shoots was assessed by weighing the leaves picked in each plot during the different passages, using a precision balance. Cumulative plot production recorded during the crop was extrapolated to the hectare.

§ Leaf-thinning rate: To obtain the yield of edible parts of the leaves at leaf-thinning and wilting, we proceeded as follows: We considered a quantity of 5 kg of unleafed cassava leaves per treatment. During leaf stripping, tender cassava leaves (very young leaves that have opened out and/or not yet fully unfolded) are stripped of their petioles and separated from those deemed non-tender or very hard, as well as from the stem tips or branches carrying them. Retained tender shoots and leaves are washed with water before wilting. During this operation, the hard leaves and the portions of stems or branches bearing them are considered as rejects, while the tender ones constitute the edible or useful parts. Their weights are determined separately using a balance. The yield of edible or useful parts of leaves (leaf removal rate) and tender shoots was determined according to the following relationship:

$$\textbf{Leaf removal rate (\%)} = \frac{Pfpt(Kg)}{Pt(5Kg)} \times 100$$

Legend: Tef = leaf-thinning rate, Pfpt = weight of tender leaves and shoots and Pt=total weight.

g. The wilting rate of edible or useful leaves: Wilting can be carried out either wet or dry. In the case of our study, we opted for the dry process. The tender shoots and leaves obtained during leaf removal were wilted by slightly moistening them while stirring them in a pan set on fire for a few minutes. This operation softens the tender shoots and leaves and helps eliminate the cyanide. The following relationship has been used to calculate the yield of this leaf conditioning operation.

$$\textbf{Tf (\%)} = \frac{Pfptf(Kg)}{Pt(5Kg)} \times 100$$

Legend: Tf = wilting rate; Pfptf = weight of tender leaves and shoots after wilting and Pt = total weight.

The data processed and presented were obtained by averaging across the three blocks. Microsoft Excel 2007 was used to enter and perform a descriptive statistical data analysis. The mean values obtained were compared after analysis of variance (ANOVA) using CoSTAT software, followed by a Tukey test to identify differences in the performance of the varieties studied at the 5% threshold.

III. Results and Discussion

3.1 Results

a. Recovery Rate of Cassava Cuttings

The recovery rate of cuttings (figure 2) assessed one month after planting varied from 96.00% to 99.25% for all treatments. On average, this rate was 97.19%, reflecting the good quality of the propagation material used. However, T2 gave the highest recovery rate at 98.00%.

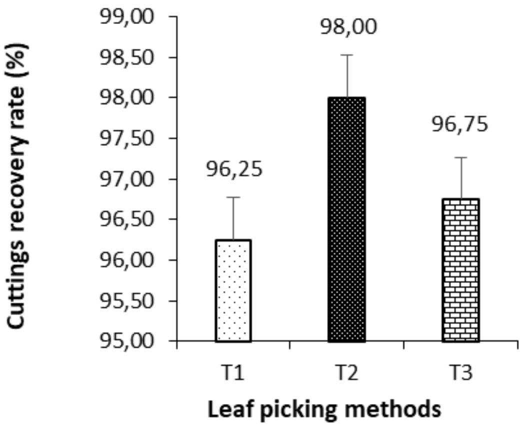

Figure 2. *Average recovery rate of cassava cuttings (in %)*
With T1: light picking, T2: moderate picking,
T3: coarse picking.

b. Average Diameter at Plant Collar

The evolution of the diameter at the collar of cassava plants (figure 3) recorded during the crop cycle under different treatments from 3 to 6 months after cassava planting is shown below. The figure above shows that, in general, the average diameter at the stem collar increases with age and varied from 2.12 to 2.80 cm between the 3 rd and 6 th months after planting. Neck diameter values recorded during the observation period were as follows: 2.12 to 2.17 cm after 3 months; 2.48 to 2.55 cm after 4 months; 2.37 to 2.42 cm after 5 months and 2.70 to 2.80 cm after 6 months. Furthermore, in the 6th month after planting, we observed that average stem sizes varied in a decreasing manner as follows: T2 (2.80 cm) > T1 (2.75 cm) > T3 (2.70 cm).

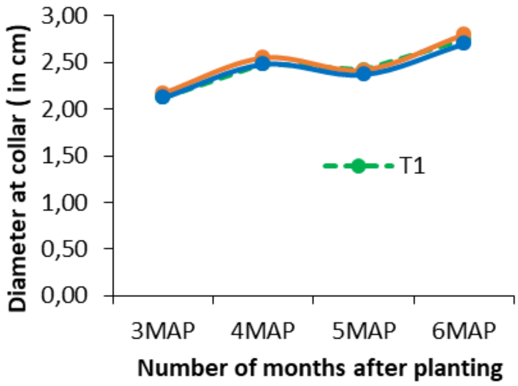

Figure 3. *Changes in average collar diameter of cassava plants from 3 to 6 months after planting during the crop cycle (Cm). With MAP: months after planting*

c. Plant Height

The evolution of plant height (figure 4) during the first 6 months of the crop cycle shows that, overall, the average height of cassava plants during the crop cycle varied from 161 cm to 287 cm. In the 6th month after planting, it appears that the average plant height varied in a decreasing manner according to the picking height, as follows: T1 (209.91 cm) > T2 (205.42 cm) > T3 (205.22 cm).

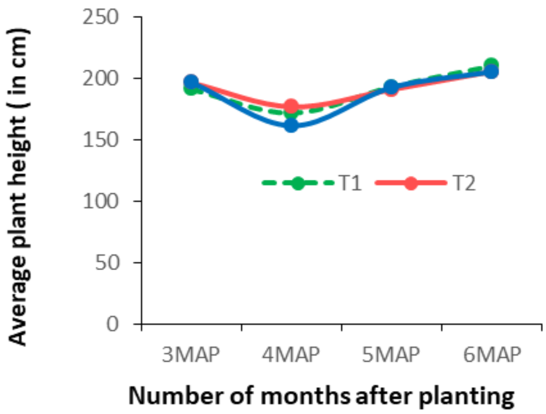

Figure 4. *Evolution of the average height of cassava plants from 3 to 6 months after planting during the crop cycle (Cm). With MAP: months after planting*

d. Average Number of Leaves on Cassava Plants

The evolution of the number of leaves per plant (figure 5) during the observation period (3 - 6 months) reveals an increasing evolution of the number of leaves on the plants from the 3rd month to the 5th month, after which it began to decrease. Leaf-picking modalities had the greatest influence on the number of leaves per plant in the 4th and 6th months, and during this period, T2 followed by T1 yielded more leaves per plant than T3.

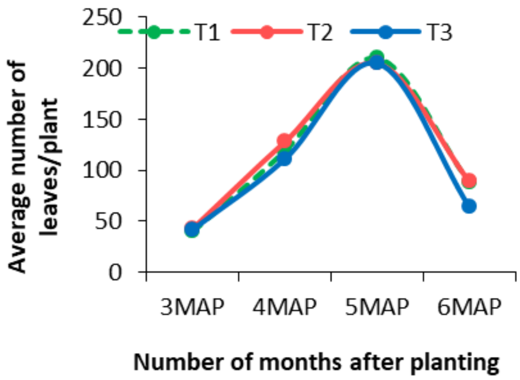

Figure 5. *Evolution of the average number of leaves on a cassava plant between 3 and 6 months after planting during the crop cycle. With MAP: months after planting*

e. Average Number of Shoots

The evolution of the average number of shoots (figure 6) developed by each plant from the 3rd to the 6th month after planting shows that shoot development varied from 1 to 9. After the first harvest three months after planting, the number of shoots per plant continued to increase until the 6th month after planting. The different harvesting methods tested were ranked in ascending order according to the number of shoots formed by the 6th month, as follows: T3 (6 shoots per plant) < T1 (8 shoots per plant) < T2 (9 shoots per plant).

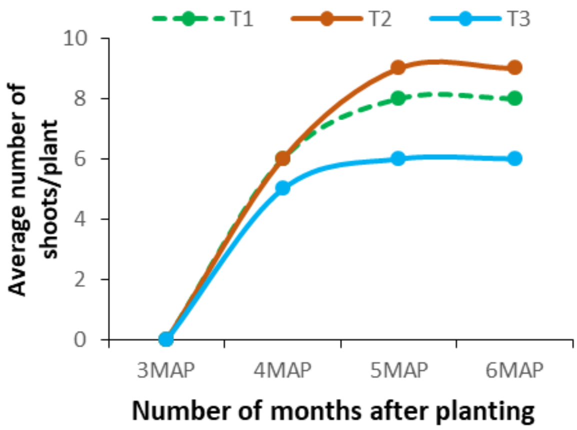

Figure 6. *Change in average number of shoots on cassava plants between 3 and 6 months after planting (cm). With MAP: months after planting*

f. Tender Shoot Yield

The average yield of tender shoots (figure 7) provided by each harvesting modality after four harvesting passes generally indicates that the average yield of cassava leaves was influenced by the harvesting modalities and varied from 5.16 to 10.82 t/ha. The different harvesting methods tested and compared in terms of fresh leaf yield are ranked in ascending order as follows: T1 (5.16 t/ha) < T2 (9.06 t/ha) < T3 (10.82 t/ha).

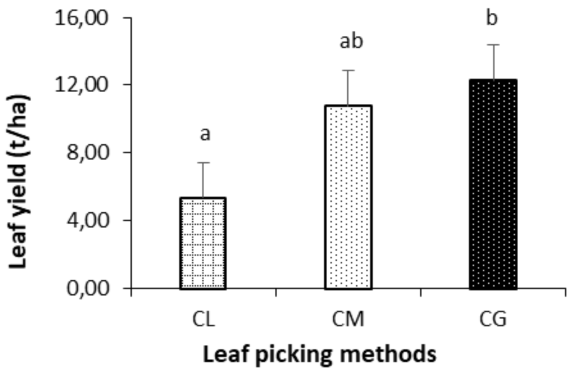

Figure 7. *Cumulative average leaf yield (t/ha). With CL: light picking, CM: moderate picking, CG: coarse picking. Treatments with the same letters do not differ significantly from each other*

The different leaf-picking modalities differ significantly from each other. However, a comparison of yield averages shows that light and moderate picking do not differ significantly from each other, nor do moderate and coarse picking. On the other hand, the latter differs significantly from light picking. The result of the comparison of average cassava leaf yields shows significant differences between T1 and T3, while between T1 and T2, and T2 and T3, there are no significant differences.

g. Relationship between Leaf-Picking Methods and Leaf Yield

The leaf-picking modality is strongly correlated with leaf yield (r= 0.96) (figure 8). Figure 8, which compares the leaf-picking modality with leaf yield, shows that considering a starting leaf yield of around 3.2t/ha per leaf-picking modality is associated with a yield increase of around 0.6175t. The numerical data recorded and the results of statistical analyses (correlation and regression) show that leaf yield evolves in the same direction as the increase in the number of leaves on the harvested portions of the stem or tender shoots.

In other words, the more leaves on the portion of stem or shoot to be harvested, the higher the yield.

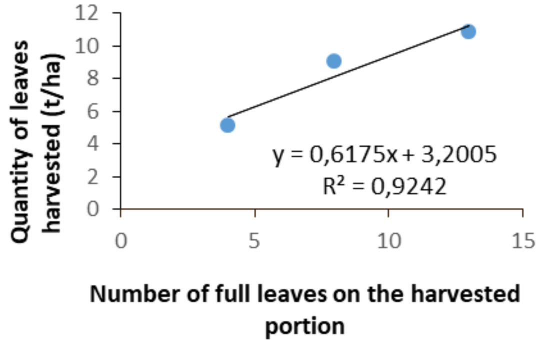

Figure 8. *Regression line between leaf-picking modality and cassava leaf yield*

h. Yield of Useful Products before Crushing

The average weight of edible leaves during leaf-thinning and wilting, as shown in Figure 9, indicates that for an initial quantity of 5 kg of raw leaves harvested for preparation, the yield at leaf-thinning and wilting varies according to the harvesting modality, without following the trend in leaf production from the leaf-picking modalities in the field. In terms of leaf-thinning rate, the harvesting methods tested ranked in descending order as follows: light harvesting or CL (63.8%) > moderate harvesting or CM (49.6%) > coarse harvesting or CG (21.6%). The same trend is observed for wilting rate or yield: light picking or CL (55.4%) > moderate picking or CM (39.0%) > coarse picking or CG (18.6%). These results show that the refusal rate is higher in the case of coarsely harvested leaves, compared with light and moderate harvesting.

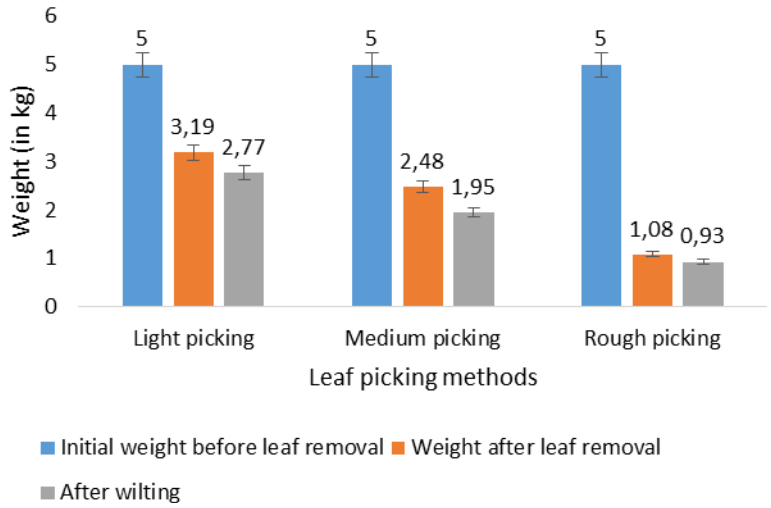

Figure 9. *Yield of useful products (edible leaves) during different leaf conditioning phases prior to crushing. With CL: light harvesting, CM: moderate harvesting and CG: coarse harvesting*

3.2. Discussion

The harvesting of cassava leaves is a very common practice in sub-Saharan Africa, where this leafy vegetable plays a vital role in the food security of both rural and urban populations. This study therefore examined the impact of this practice on leaf growth and yield during the plant's crop cycle. The average recovery rate of planting materials used, recorded one month after planting, ranged from 96.00% to 99.25% for all treatments. This indicates the good quality of the planting material used, linked to the good storage conditions (short time, dry, airy place) of the stems from which the cuttings were taken. According to Sylvestre et al (1983), as far as the recovery of cuttings and the emergence of new cassava plants are concerned, a good choice of cuttings will generally encourage recovery of over 90%. The diameter at the collar of cassava plants varied with the length of the crop cycle, but was no more influenced by leaf-picking methods. The increase in stem size with age is a natural growth process. The range of our diameters is within that of JANSENS (2001), of the order of 2 to 4 cm. Plant height increased over time from the 3rd to the 6th month after planting, in accordance with the plant growth principle. In contrast to crown diameter, plant height was slightly influenced by leaf-picking methods: at 6 months after planting, light leaf-picking produced taller plants than moderate and coarse leaf-picking.

Despite this impact on plant height, our values are included within the height range of the Obama II cultivar, which varies between 150 and 230 cm in height for a mature plant (SENASEM-RDC, 2019). The number of leaves per plant increased from month 3 to month 5, after which it began to fall. This can be explained by the drop in rainfall to 10mm, compared with 99mm in the previous month. This drop in the quantity of water had a negative impact on the vegetative growth of the plants, which reacted to the situation by failing to form new leaves and caducinating old ones. The average number of shoots formed per plant remained increasing until the 6th month after planting, and varied from 1 to 9. The monthly suppression of apical dominance at each passage would explain this growing increase in the number of shoots. In a comparison of harvesting methods, rough harvesting produced more shoots, while moderate harvesting produced fewer shoots per plant.

The average yield of fresh cassava leaves varied from one harvesting modality to another, ranging from 5.16 to 10.82 t/ha. Leaf yield increased as the number of leaves on the portion of stem or shoot to be harvested increased. Leaf yield evolved in the same direction as the increase in the number of leaves on the portion of tender stem or shoot harvested. Of the three harvesting methods compared, coarse harvesting produced a higher leaf yield than the other two.

The results show that leaf yield increases as the number of leaves on harvestable stems or shoots increases. Comparing our yields with those of our predecessors, the following emerges: ours (5.16 - 10.82 t/ha) are lower than those of the order of 13.6t/ha found by Dahniya (1980), 24.5t/ha reported by Lutaladio et al. (1980) with variety 02864, 13.08t/ha recorded by Mahungu et al. (1992) and 22.45 - 25.74 t/ha reported by Sandifolo et al. (2010). In contrast, they are higher than the yields of 2.4 - 4.96 t/ha and 3.6 - 4.1 t/ha obtained respectively by Litucha (2011) and Marielle et al. (2020). These yield differences between those of our predecessors and ours can be explained by the difference in the varieties used, the leaf-picking methods (leaf-thinning, receiving, topping, etc.) and the growing conditions (soil fertility, rainfall, crop health, etc.). Overall, by opting for one of these three harvesting methods, depending on the number of leaves on the terminal portion of the tender stem or shoot to be harvested, we can standardize harvesting and develop a conventional harvesting method applicable to different fields or trials.

Leaf-thinning and wilting yields varied according to the harvesting modality, without following the trend in leaf production from the field leaf-picking modalities. CL gave the highest leaf-thinning and flowering yields, followed by CM, while CG recorded the lowest yields for both leaf-thinning and wilting. These results show that the rejection rate is higher for coarsely harvested leaves, compared with light and moderate harvesting. If you want to combine quality (tenderness) and leaf-thinning and wilting yields, you need to buy leaves from the light harvest, since their yield during these two conditioning phases is at least 55%.

IV. Conclusion

The results of this study have demonstrated the impact of leaf harvesting methods, defined in terms of the number of fully expanded leaves on the apical and tender part of the stem, on growth and yield of tender shoots, edible leaves for leaf removal and flowering. The results show that plant collar diameter was not influenced by leaf harvesting methods. Plant height and the number of tender shoots per plant were, however, influenced by leaf harvesting methods, with coarse harvesting resulting in taller plants with more tender shoots per plant. Of the three leaf-picking methods compared, coarse picking produced the highest leaf yields. On the other hand, CL gave the highest leaf-thinning and flowering yields, followed by CM, while CG recorded the lowest yields for both leaf-thinning and wilting.

So, if we want to increase the production of cassava leaves, without worrying about quality (cattle feed), we should use coarse harvesting (CG) of the leaves during the crop cycle; whereas, for production of quality leaves, which are likely to provide a high yield of cassava leaf crush, we should use moderate harvesting (CM). In the future, we would like to experiment with the different picking frequencies (frequent, bimonthly and quarterly) in order to assess their productivity in terms of leaves and their depressive effects on tuberous root yields.

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