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# Effects of Organic Manures and Soil Preparation on Growth and Yield of Yam (*Dioscorea cayenensis* Lam, 1792) in Kisangani, Democratic Republic of Congo

Dieu merci Ambena[1], Hervé Ambakina[2], Jean Rostand Inoko[3], Jean Paul Mukandama[4] and Jean Claude Monzenga[5]

[1,2] University of Ikela, Faculty of Agronomy, Department of Plant Science, Tshuapa Province, DR Congo.

[3]University of Kisangani, Faculty of Renewable Natural Resources Management, Department of Plant Science, DR Congo.

[4]Faculty Institute of Agronomic Sciences of YangambI, (IFA/Ybi),Laboratory of Applied and Functional Entomology (LENAF), RD Congo

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**ABSTRACT**

The low soil fertility of the Kisangani region and the cost of chemical fertilisers on the market mean that farmers can only resort to palliative and sustainable fertilisation (organic manure). The objective of this study was to evaluate the effects of soil preparation and organic amendments on the growth and yield of yam (Dioscorea cayenensis). A split splot design was set up with two factors, soil preparation mode with three modalities and organic amendment as a second factor, also three modalities. The combination of these factors resulted in 9 treatments repeated three times. Vegetative parameters and yield components were measured.

The results obtained showed that:

-  Soil preparation and organic manures affected yam growth and yield;
-  Pig dung was the best organic manure for most of the parameters studied.



## Introduction

Yams (*Dioscorea spp.)* are grown by small-scale producers in the tropics of Africa, the Caribbean, Oceania and South Asia for their tubers, which are used for food security (FAOSTAT, 2017), income generation and medicine (Kangakkara., et frossard J. E. 2014). Global food yam production reached 71 million tonnes in 2017 (Hanitrinirina *et al.*, 2020).It is a major food crop in Asia, South America, Africa and especially West Africa. The yam plays an important role in rituals such as weddings and annual festivals, to the extent that Baco *et al*. (2007) state that the yam has a significance that goes far beyond that of other crops in tropical environments.

Everywhere else where yam is grown, its cultivation remains extensive and consumes few or no inputs. However, it is considered demanding in terms of soil fertility, and is the first crop in the rotation after a long fallow period, obliging the farmer to travel further to find areas suitable for its cultivation (Cornet, 2015).

Despite the importance of yam, little research has been done on this crop, which ranks among the neglected crops. Cornet (2015) pointed out that the number of publications on yam (2023 publications) corresponds to that of potato some 40 years ago (1973), and concludes by calling yam an 'orphan' crop. The few research studies on yam concern economic aspects and some aspects related to marketing, neglecting production.

Low and declining soil fertility, water stress and pests and diseases have also been identified as factors hindering increased yam production. These barriers hinder food production, the ability of farmers to generate sustainable incomes, and result in disproportionately negative consequences for rural women (FAO, 2017). However, regardless of the variety, yields on the farm remain low, at around 12 t ha in the sub-region (FAOSTAT, 2016), and less than 10t/ha in Burkina Faso (Mahrh, 2015; FAOSTAT, 2016; Pouya, 2016). Yet yam (D. alata) has an estimated yield potential of nearly 50 t ha (Diby *et al.*, 2012). In yam production areas in West Africa, a decline in soil fertility has also been observed (Dumont and Marti, 1997), and yam cultivation is thought to be a factor. This decline in soil fertility is said to be the cause of a decrease in yields observed in the farming environment.Studies around the world on organic amendment practices have obtained interesting results where soil fertility was sustainably improved and yields comparable to chemical fertilisation were achieved ( Ezzoet *al.*, 2012).

Organic matter is essential for sustainable soil fertility management. It has very beneficial effects on the physico-chemical and biological properties of the soil (Vanlauwe and Gillertnz, 2006 ; Bationo *et al.*, 2012; Maltas *et al.*,2012; Ouédrago *et al.*, 2014). Ngoyi, *et al.* (2020) who worked on the effect of organic amendments on the growth and yield of potato found that potato behaves positively under the effect of amendments compared to unamended soil.

In Kisangani, yam production is low and receives very little attention from scientific research, which has long favoured cash crops, cereals and legumes. The soil in and around Kisangani is overexploited, which makes it difficult to produce crops in general and yams in particular. Our

Tele: +243 816084780
E-mail address: ambenadieumerci60@gmail.com

study evaluated the effects of organic manures (cow dung and pig dung) on yam (*Dioscorea cayenensis* Lam) production in Kisangani.

## Materials and Methods

### Study site

The experimental field was installed in the DRC in the Kisangini region. The geographical coordinates of the experimental site taken with the GPS (Garmin map 62) are: 00° 33' 39,5" latitude north east 025° 12'43,5" longitude east: its average altitude is 393 m. The climate of our experimental site belongs to the Af type according to the KöPPEN classification. It is a humid tropical climate characterised by temperatures fluctuating around 25°C on average. According to Van wambeke and Libens (1957), rainfall is abundant (1800 mm per year on average) and is distributed throughout the year in two seasons: One very rainy long season from September to November and the other less wet, relatively short season from the end of March to June. The relative humidity varies between 80 and 90% (Borek, 1987).

The natural vegetation is rainforest, but the field on which our trial was conducted was a grassy fallow of a few months' duration dominated by the following species:*Panicum maximum, Cynodon dactylon, Pueraria javanica, Digitaria occidentalis, Commelina diffusa and Elaeis guineenesis*. The previous crop of the experimental site was cassava and maize

### Materials

The biological material used in our study was the yam species D. cayenensis, the most popular and commercialised variety in Kisangani. This species has a crop cycle of seven to twelve months. Its potential yield is around 50 t/ha (Diby *et al.*, 2012). A decameter, pen, string, machete, precision scale, empty bag, stake, spade, cow dung and pig dung were used as non-organic materials.

### Methodology

The system adopted was a split plot with two factors, namely soil preparation method with three modalities (no-till, ridge and ridge) and organic amendment as a second factor, also with three modalities (no amendment, cow dung and pig manure). The combination of these factors resulted in 9 treatments repeated three times (T1: No amendment with ridge; T2: No amendment with mound; T3: No amendment without ploughing; T4: Cow dung with ridge; T5: Cow dung with mound; T6: Cow dung without ploughing; T7: Pig manure with ridge; T8: Pig manure with mound and T9: Pig manure without ploughing).

The experimental field had a total area of 530 m2 and a total density of 576 plants. Each sub-plot was 6 m long and 1 m wide. The distance between the ridges of the same plot was 0.5 m and 1 m between the sub-plots, the ridges had the same area as the ridges, 1 fragment per ridge and were 30 cm high. The spacing applied was 1m x 1m.

### Soil preparation

The plot at our disposal had been delimited, manually cleared and finally incinerated. Ploughing took place two weeks before the trial was set up, and consisted of cutting and turning over the soil in order to maintain a better distribution of plant debris throughout the thickness of the topsoil. The aim was to maintain a better distribution of plant debris throughout the thickness of the topsoil, to promote good soil fragmentation, to control weeds and regrowth, to bury crop residues, and to ensure loosening of the surface layers (Daniel, 2008).

### Mound and ridge formation

After ploughing we proceeded to the formation of a mound. The soil was raised to a height of 30 cm and a diameter of 1 m. This technique, like the raised beds, is widespread in tropical Africa, mainly for the cultivation of root and tuber crops such as sweet potatoes, yams and cassava (Boissière, 2003). The ridges were raised to a height of about 20-30 cm and a length of 6 m, this technique was carried out after ploughing the experimental field.

### Study soil composition

Les tableaux 1 et 2 présentent les caractéristiques physico-chimiques du sol du site à une profondeur de 0-20cm et celles de la bouse de vache et déjection du porc

### Application of organic manure

For organic fertilisation, cow and pig manures were used. The quantity applied was evaluated according to the analyses carried out in the field so that it would be equivalent to the NPK exported by the tubers in order to increase the crop's production : The cow dung came from cattle aged 3 to 4 years. It was collected from the stable of the Catholic priest's scholasticate farm in Kisangani. This dung, once collected, was dried for 7 days before use; pig dung collected from the same farm was also conditioned in the same way. The organic manures were buried to a depth of 25 cm at a rate of 4 kg per square metre.

### Planting, maintenance and harvesting

Healthy tubers of the variety D. cayenensis were used for the test. These tubers were cut into seedlings (mini fragments) of about 200 g. These were treated with fungi by soaking for 10 minutes in an ash solution and left to dry for 24 hours and grown at 1x1m spacing for a total density of 576 plants. Crop maintenance consisted of staking, weeding and watering. The tubers were harvested manually, and a complete harvest of the tubers was carried out on each plot. These tubers were counted and then weighed on site using a scale, in order to evaluate the total weight of the production.

### Parameters studied

The diameter of the rod was measured with a digital caliper;

$$\textbf{Fragment recovery rate}: \frac{\textbf{Total number of fragments taken up}}{\textbf{Total number of plant fragments}} \textbf{X100}$$

**Table 1. Physico-chemical characteristics of the 0-20 cm horizon**

| Characteristics physico-chemical | N (%) | $P_2O_5$ (%) | $K_2O$ (%) | pH | MO | A g/kg | L g/kg | S g/kg |
|---|---|---|---|---|---|---|---|---|
| **Values** | 0,32 | 0,0009 | 4,07 | 4,07 | 32 | 37 | 10 | 53 |

**Legend** : N=total nitrogen; P2O5=total phosphorus; K2O=total potassium; Ph hydrogen potential; OM=organic matter; A=clay; L=silt; S=sand.

**Table 2**

| Type of organic matter | C/N | N | P | K |
|---|---|---|---|---|
| **Cow dung** | 2 | 2 | 1.5 | 2 |
| **Pig faeces** | 11.4 | 1.6 | 1.5 | 4 |

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**Average number of tubers per foot** : $\frac{Total\ number\ of\ tubers}{Total\ number\ of\ plants\ harvested}$

Tuber length: Measured with a lath ;

Tuber diameter: measured with a caliper ;

**Production in Kg**: $\frac{Total\ weight\ of\ tubers\ harvested}{Total\ number\ of\ tubers}$

Yield in t/ha:$Poids$ total of $tubercules$ x10000 / Number of harvested plants X 1000

**Statistical analysis**

State Graph software was used to perform the two-factor analysis of variance after checking for normality and the Tukey multiple test was also used to compare the means at the 5% significance level.

**Results**

Yam emergence rates varied, on average, between 77.7% for T0 and 90% for the amended plots (Table 3). The observed numerical differences were not confirmed by the analysis of variance which showed that organic matter did not influence the rate of yam mini-fragments recovery (P>0.05).

Table 4 shows the same trend as the recovery rate, not a significant difference between manure type on crown diameter. The numerically high average was obtained by the untreated plots with 1.12 cm followed by pig dung and cow dung came last.

Table 5 showed that the number of yam tubers per plant obtained by the plots amended with pig dung was slightly higher than those amended with cow dung, respectively 1.81± 2 and 1.61 tubers per plant. However, the unamended plots had an average number of tubers per plant of 1.51. The analysis of variance showed a highly significant difference between the treatments (P=0.005); Tukey's post hoc test showed a significant difference between the unamended plots and those that received pig droppings (P=0.03), but no difference between the unamended plots and those that received cow dung, and between the cow dung plots and those that received pig droppings (P>0.05).

Large tubers were obtained in T8 and T4, which recorded respective averages of 22.13 and 20.64 cm of tuber diameter. The intermediate value is noted in T7 (ridge with pig droppings), i.e. 19.82 cm. On the other hand, the smallest value is reported in the unenriched and unploughed control soil. Table 9 confirms a significant difference between treatments (P=0.01). On the other hand, with regard to tuber length, the highest average (69.21cm) was observed from the combination of ridge with pig dung (T7) followed by mound with pig dung (69.07cm), however, T 3 (no ploughing and no amendment) had the lowest value of all treatments (19.49cm). There was a significant interaction between the two factors (P=0.001).

The high tuber weight was obtained with plots T8 (pig manure) with 1.86 ± 2 kg. The intermediate value was obtained by the plots smoked with cow dung, T5 (1.45kg). The lowest value was obtained by the control plots. The two-factor analysis of variance showed a very highly significant difference between the treatments (P= 0.0000).

The yield per hectare was higher for the plots receiving the pig manure with mound, at 18 t/ha. The lowest yield was obtained by the control treatment (5.50 t/ha). Statistical analysis showed a highly significant difference between treatments (P= value 0.000).

**Table 3. Effects of organic fertiliser on mini-fragments recovery rate and crown diameter**

| Type of organic manure | Number of plants | Diameter at collar |
|---|---|---|
| Cow dung | 16,00[a] | 0,93[a] |
| Pig excrement | 16,22[a] | 1,00[a] |
| Without amendment | 14,33[b] | 1,12[a] |
| Meaning (p) | 0,4396 | 0,052 |

**Table 4. Average number of tubers per plant/organic manure**

| Organic manures | Number of tubers |
|---|---|
| Cow dung | 1,61[ab] |
| Pig excrement | 1,81[a] |
| Without amendment | 1,51[b] |
| Meaning (p) | 0,0108[*] |

**Table 5. Interaction between soil preparation method and organic manures on yield components**.

| MS x OM | Tuber diameter (cm) | Tuber length (cm) | Tuber weight (Kg) |
|---|---|---|---|
| T1 | 17,89abcd | 36,48c | 1,00bc |
| T2 | 17,23abcd | 57,52ab | 1,10bc |
| T3 | 10,44e | 19,49e | 0,78c |
| T4 | 20,64ab | 56,90b | 1,08bc |
| T5 | 17,10bcd | 60,33ab | 1,45ab |
| T6 | 15,72cd | 54,12b | 0,92c |
| T7 | 19,82abc | 69,21a | 1,20a |
| T8 : | 22,13a | 69,07a | 1,86bc |
| T9 | 15,0de | 40,82c | 1,10bc |
| Meaning (p) | 0,0177[*] | 0,0017[**] | 0,0000[***] |

Legend: Means with common letters, no significant differences for p> 0.05 according to Tukey test, P: probability: Significant differences: Highly significant differences, Very highly significant differences, OM: Organic matter and SM: Soil preparation methods.

**Table 6. Interaction between soil preparation methods and organic manures on tuber yield (t/ha).**

| Soil preparation methods x Organic manures | Yield (t/ha) |
|---|---|
| T1 : Without amendment with ridge | 6,96c |
| T2 : Without amendment with mound | 9,10bc |
| T3 : No-till no amendment | 5,50b |
| T4 : Cow dung with ridge | 12,09bc |
| T5 : Cow dung with mound | 14,54ab |
| T6 : No-till cow dung | 10,8bc |
| T7 : Pig manure with ridge | 11,68bc |
| T8 : Pig manure with mound | 18,60a |
| T9 : No-till pig manure | 10,92bc |
| Meaning (p) | 0,0000*** |

Means with common letters, no significant differences for p> 0.05 according to Tukey testP: probability ***: highly significant differences

**Discussion**

The recovery rate of mini-fragments in our trial was very good, favoured by the good rainfall observed during the period following planting. This result confirms the good quality of the tubers used and also the size of the mini-fragments which was appreciable. This corroborates the results of Onwueme and Haverkort, (1991) and Craufurd *et al*, (2000), who demonstrated that yam recovery depends more on the size, nutrient reserve, quality and physiological age of the planting material.

These results corroborate those of Dibi *et al.* (2016) who suggest that the evolution of stem diameter would be proportional to the size of the mini-fragments and the duration of yam cultivation as well as to variations. They go hand in hand with the conclusions that in yam the basal size is progressive from 1 to 6 months and decreases from 6 months onwards; because at this time the plant reaches the full period of tuber development which means that all the organic matter for the development of the plant is mobilised for tuberisation (Craufurd 2000).

Pig dung was superior to cow dung. This can be explained by a high bacterial activity, as pigs are omnivorous, and their dung makes available the nutrients phosphorus, nitrogen and especially potassium (the mobilising element for photosynthesis and responsible for the translocation of carbohydrates from leaves to tubers). This pig dung dominated in terms of number, length and size of tubers compared to cow dung and unamended plots. These results are similar to those of Pouya (2018) who worked on the combined effects of tillage type, fertilisation options and plant emergence date on yam growth and yield in Burkina Faso. Almost similar averages were obtained in Burkina by Bazie (2018) and in DRC by Molongo *et al.* (2021) ranging from 2 to 3 tubers per foot.

The yam under the application of pig manure with mound gave tubers with a larger diameter (22.13 cm) compared to the tubers of yam from the control soil (10.44 cm). These results showed that the combination of mound and even ridge with pig dung increased the size of yam tubers than cow dung and no-till soil. This is similar to Pouya (2018) who conducted similar research on yam growth and yield in Burkina Faso, he found that any fertiliser application regardless of the option significantly increases the average tuber weight compared to the control.

The average length was significantly affected by the organic amendments and soil preparation methods. The ridge and pig dung treatment produced yam tubers with a high average weight each. However, tubers from the mound and cow dung combination recorded a lower average weight and the unploughed and unamended plots yielded tubers with an average weight below 1 kg. Our results are in line with those of Agbede *et al*, (2013) and are far superior to those of Abdul (2017) in Burkina who found a lower average tuber weight (0.36 kg and 0.14 kg).

We observed that the combination of mound with pig manure gave a satisfactory result (18.6 t/ha) and mound with cow dung also (14.54 t/ha), while the unamended and unploughed plots produced only 5.50t/ha. Our results are in line with those of Agbede *et al* (2013) who showed that organic fertilisation significantly improves tuber weight. Also, Odjugo (2008) in Cameroon confirmed that mound tillage gives the highest tuber yield of yam than ridge and no-till. Similar results were reported by van Scholl (1998). The organic matter would have allowed the plants that received organic fertiliser to take better advantage of the water available in the soil. Thus, their root system could continue to draw nutrients from the soil solution in order to continue the production of above-ground biomass.

## Conclusion

The objective of this study was to evaluate the effects of soil preparation and organic amendments on the growth and yield of yam (Dioscorea cayenensis) under Kisangani conditions. A split-splot design was implemented with two factors, soil preparation mode with three modalities (no-till, ridge and ridge) and organic amendment as a second factor, three modalities (no amendment, cow dung and pig manure). Thus, the combination of these factors resulted in 9 treatments repeated three times. Vegetative parameters and yield components were measured.

The results obtained showed that :

- The highest number of tubers was obtained with pig dung followed by cow dung;
- Tuber size generally varied between treatments. The largest tubers were obtained with the combination of ridge and pig dung; mound and pig dung;
- The longest tubers were obtained with the ridged plots that received pig dung followed by ridge and cow dung.
- The mound and pig dung treatment produced yam tubers with a high average weight each;
- Pig manure increased tuber yield compared to the mound and cow dung combination.

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