# Effect of the Organic and NPK Fertilizers on the Growth and Yield of Sweet Potato (*Ipomoea batatas* (L) Lam) in the Centre of Côte d'Ivoire

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*Authors' contributions*

*This work was carried out in collaboration among all authors. Authors DKEB and KJHM designed the study, performed the statistical analysis and wrote the protocol. Author KZ wrote the first draft of the manuscript and managed the literature searches. Author BS oversaw the drafting, field work and redaction of the Manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

In Côte d'Ivoire, the sweet potato is little cultivated but stays however a culture of pension and a food mattering in certain regions. This study was conducted to assess the effect of the application of mineral (NPK 15-15-15, NPK 12-22-22) and organic (poultry manure) fertilizers on yield components of sweet potato (*Ipomoea batatas* (L) Lam). The experiment was conducted over two years (2016 to 2017) in experimental station of National Center of Agronomic Research (CNRA) of Bouaké in the centre of Côte d'Ivoire. The experiment was conducted following a split plot with 2 factors (variety and fertilizers) and 3 replicates. The main factor was variety with 2 levels (variety

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Irene and variety TIB-440060) and the subplot was fertilizers application consisted 13 levels (200, 300, 400, 500 kg ha-1 of NPK fertilizers combined 5, 10, 15 t ha-1 of organic fertilizer). Thirteen treatments based on poultry manure (T6, T7), chemical fertilizer NPK 15 15 15 (T1, T3, T4, T5) and NPK 12 22 22 (T8, T10, T11, T12) and their combination (T2 and T9) were tested. The experimental results revealed that that the effects of chemical fertilizer treatments, manure and their combination with mineral fertilizers did not influence the measured parameters. The results also showed that fertilizers improved all the agronomic parameters of sweet potato compared to the control treatment during two years of experiment. However, the Irene variety with a mean weight of 180 g tuberous roots was significantly different from the TIB variety with a mean weight of 138.73 g.

In the conditions of our study and over the two-year period, producers of sweet potatoes would benefit from using organic fertilizers with the Irene variety.

## 1. INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is a perennial herbaceous vine cultivated as an annual. It is suited to the humid tropics but can be grown in southern temperate regions. The tubers and sometimes the leaves are eaten [1]. She can grow in numerous different ecological conditions [1]. Her world production was 106 million of tons in 2016 among which more than 67% coming from Asia, particularly, China with 71 million of tons [2]. In Africa, the sweet potato is an important economic culture because of its potential of struggle against poverty and improvement of the nutritional state of the rural populations in a little expensive and long-lasting way [3]. She is widely cultivated as a basic food mattering in a number of country African and its nutritional value exceeds by far the yam, the cassava and the taro [4]. In Côte d'Ivoire, the sweet potato is little cultivated but stays however a culture of pension and a food mattering in certain regions [5]. The national production was estimated at approximately 49 357 tons in 2016 [2]. In spite of its nutritional and economic assets, her production is relatively low because confronted with enormous difficulties. Sweet potato is cultivated on poor or marginal lands. Furthermore, the majority of the cultivars receive only few or no fertilizer. In the face of these constraints, it is thus necessary to have the good cultural technique with an adapted regime of fertilization which offers better yields in the ivorian conditions. According to [6] and Palm and al. [7], it is generally admitted that organic and chemical fertilizers are necessary to increase the agricultural production in west Africa. Several hypotheses were formulated concerning a possible application or a combination of organic and chemical fertilizers [8], so improving the yields of the cultures, the fertility of grounds and production costs [7]. In spite of the numerous hypotheses which were formulated, little information is brought back on the optimal level of application of organic and chemical fertilizers for the culture of the sweet potato, in particular in Côte d'Ivoire. Consequently, it is necessary to study and to recommend the best application of organic and chemical fertilizers to the farmers committed in the production of sweet potato. Consequently, it is necessary to study and to recommend the best application of organic and chemical fertilizers to the farmers committed in the production of the sweet potato.

## 2. MATERIALS AND METHODS

### 2.1 Site Description

The present study was led to the Station of Research on Subsistence crops (SRCV) of the National Center of Agronomic Research (CNRA) of Bouaké situated in the centre of Côte d'Ivoire (7°46 'N, 5°06 'W, 376 m) [9]. Bouaké is in the zone of transition between the forest climate of the South and the climate of the savanna of the North [10]. The climate is of wet tropical type with four seasons, of which a big dry season (November in February), a big rainy season (March in June), a small dry season (July in August) and a small rainy season (September in October). These periods are less and less marked these last years [11]. The hydrography mainly consists of the river Bandama and the N'Zi and its ponds hillsides which drain Bouaké [12]. The vegetation is constituted by savanna raised with several species of Poaceae [13]. Soils are ferrallitic, averagely saturated, reshaped, shallow and stemming from a material of granitic change with a sandy-clayey texture [14]. The mean annual precipitation are 1200 mm of rains [15], with a mean annual temperature of 25.73°C [10].

## 2.2 Chemical Characteristics of the Used Fertilizer

The manure used has very high levels of carbon, nitrogen and CEC with high levels of organic matter. The chemical characteristics of the manure used are shown in Table 1.

## 2.3 Plant Material

The plant material was constituted of two (2) varieties of sweet potato with orange flesh : Irene and TIB-440060. The cuttings of these varieties were removed on plots of land of multiplication of cuttings of the Station of Research on Subsistence crops (SRCV) of the CNRA of Bouaké (Fig. 1).

## 2.4 Fertilizing Material

The fertilizing materials used for the try were constituted by two types of fertilizer organic manure and an artificial fertilizer. Chemical fertilizers consisted of the granular N-P-K 15-15-15 and the N-P-K 12-22-22 + 2SO3 + 1MgO + 5CaO. The organic fertilizer was a mixture of dung of cow and droppings of chicken.

## 2.5 Experimental Design

The try was led during two consecutive years (2016 and 2017) following to a design in Split-Splot to three repetitions. The main factor was constituted by the variety with 2 modalities (variety Irene and variety TIB-440060) and the second factor by fertilizers. So, the chemical fertilizer contained four levels : 200; 300; 400 and 500 kg.ha$^{-1}$ of N-P-K and the organic manure included three (3) levels, worth knowing, 5, 10 and 15 t.ha$^{-1}$ and their combinations distributed in a random way within the elementary plots of land. Treatments are presented in Table 2.

The total surface of the try was 702 m$^2$ with 39 elementary plots of land corresponding to treatments. Every elementary plot was constituted of sixteen (16) mounds on a surface of 3 m x 3 m with a space between the mounds of 1 m on 1 m, that is a density of 10 000 mounds in the hectare. Blocks were separated from each other by paths of 2 m and the main plots of land and main plots of land, by a spacing of 1.5 m.

## 2.6 Preparing Land

The parcel was cleaned with a machete and the crop residue was removed. These crops residues were removed from the plot and the ground was furnished, followed by the construction of humps at a height of at least 60 cm to prevent the phenomena of settlement due to rains.

**Table 1. Initial chemical characteristics of manure used**

| pH | Organic matter | | | | P | Adsorbing complex (cmol.kg$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Eau | C(%) | N(%) | C/N | MO(%) | P.ass (g.kg-$^1$) | CEC | Ca$^{2+}$ | Mg$^{2+}$ | K$^+$ | Na$^+$ |
| 7,3 | 7,05 | 0,65 | 10,84 | 12,15 | 0,056 | 11,24 | 8,77 | 2,29 | 0,90 | 0,16 |



**Fig. 1. Tunnel of multiplication of cuttings of sweet potato**

**Table 2. List of the various applied treatments**

| Identification of treatments | Composition of treatments |
|---|---|
| Te | Control without fertilizer |
| $T_1$ | 200 kg.ha$^{-1}$ NPK 15 15 15 |
| $T_2$ | 200 kg.ha$^{-1}$ NPK 15 15 15 + 5 t.ha$^{-1}$ of manure |
| $T_3$ | 300 kg.ha$^{-1}$ NPK 15 15 15 |
| $T_4$ | 400 kg.ha$^{-1}$ NPK 15 15 15 |
| $T_5$ | 500 kg.ha$^{-1}$ NPK 15 15 15 |
| $T_6$ | 10 t.ha$^{-1}$ of manure |
| $T_7$ | 15 t.ha$^{-1}$ of manure |
| $T_8$ | 200 kg.ha$^{-1}$ NPK 12 22 22 |
| $T_9$ | 200 kg.ha$^{-1}$ NPK 12 22 22 + 5 t.ha$^{-1}$ of manure |
| $T_{10}$ | 300 kg.ha$^{-1}$ NPK 12 22 22 |
| $T_{11}$ | 400 kg.ha$^{-1}$ NPK 12 22 22 |
| $T_{12}$ | 500 kg.ha$^{-1}$ NPK 12 22 22 |

## 2.7 Mound Making and Planting

The sweet potatoes were planted with stripped cuttings between 15 and 30 cm, bearing 3 to 5 knots. Three (3) cuttings were planted at equidistance (approximately 30 cm apart) at the top of each mound with a density of 30,000 plants per hectare. The height of the log at planting was at least 60 cm to prevent the phenomena of settlement due to rains (Fig. 2).

## 2.8 Application of Fertilizers

The various fertilizers were manually applied to the mounds in the planting holes before the cuttings were planted. The fertilizers were buried by mixing the fertilizers with the soil in the cuttings planting holes.

## 2.9 Maintainning of the Parcels

Dead plant replacements were performed one week after cuttings were planted. Three manual weeds (weeding) were performed during the test.

They consisted in ridding the hummocks and intermediates of the weeds. It is then advisable to trace the logs to the first weeding (between the 30th and the 40th day after planting, depending on the case). The first weeding was performed two weeks after transplanting, the second at six weeks and the third at ten weeks. The plots were irrigated regularly during the dry season. The water intake was done weekly using an irrigation system.

## 2.10 Harvesting of Tubers

The harvesting was done by hand at the ripening of the tubers using tools with great care in order to avoid the various alterations of the tuberous roots to have satisfactory yields which are kept well and long. Harvest occurred about 4 to 6 months after planting. Ripening was also appreciated by observing yellowing of the leaves, followed by thinning or by the clear colour of the latex that comes out when cutting the tubers.



**Fig. 2. Hump cuttings planting (Dibi et al. 2015)**

## 2.11 Collect of the Agronomic Parameters

### 2.11.1 Number of tuberous roots of large and small size

The average number of tuberous roots of large and small size was determined at harvest, classifying tuberous roots according to their marketable or non-marketable size.

### 2.11.2 Number of tuberous roots per plant and weight of tuberous roots

The number of tuberous roots for each parcel was determined by counting. Next, the total number of tuberous roots was divided by the number of productive plants. The number of tuberous roots per plant is given by the following formula:

$$Ntub = \frac{Nttub}{Npp}$$

(Ntub): Number of tuberous roots for each parcel;
(Nttub): Total number of tuberous roots;
(Npp): Number of productive plants.

For the mean weight (*Ptub*), the tuberous roots of each treatment were weighed and the mean was determined for two test years. It is given by the formula below:

$$Ptub \; (g) = \frac{Pttub}{Npp}$$

### 2.11.3 Yield in fresh tubers

The yield (*t.ha$^{-1}$*) of fresh tubers was determined by the ratio of the total weight in tuberose roots (*Pttub*) to the area (*Sup*) of the parcel. It is determined at harvest and is given by the following formula

$$Rendement \; (t/ha) = \frac{Pttub}{Sup}$$

### 2.11.4 Crop index

The crop index (*Ir*) which represents the efficiency of the production of tuberous roots was determined by the ratio between the total weight of the tuberose roots (*Ptub*) and the total weight of the plant (*Pttub + Ptig*).

$$IR = \frac{Pttub}{Pttub + Ptig}$$

### 2.11.5 Dry matter levels

Dry matter levels were determined by selecting tubers at random by repetition and treatment for laboratory analysis. Samples were taken at three different levels: In the middle and close to the two ends of each selected tuberose root. All of these samples were then merged to have a representative sample per treatment. The resulting pieces were peeled and a fraction of 200 g was collected to give the fresh weight (*PF*) per sample. These 200 g fractions were then cut into small strips and then put into aluminum paper depending on the treatment. Aluminum paper containing these sweet potato slats was put in the oven at 100°C for 24 hours. Dry and cooled samples were weighed to determine dry weight (*PS*). This allowed the following formula to determine the dry matter level (*TMS*):

$$TMS \; (\%) = \frac{PS}{PF} \times 100$$

### 2.11.6 Increase level

The increase level or increase in yield (incerase level) relative to the control, which shows the effect of fertilizers on yields, was calculated according to the following formula :

$$Taux \; accr. \; (\%) = \frac{Rend \; (F) - Rend \; (T)}{Rend \; T} \times 100$$

Rend (T) = yield of the control parcel ;
Rend (F) = yield of the fertilized parcel.

### 2.11.7 Coefficient of efficiency of fertilizers

The efficiency of the fertiliser which is determined by the increase in yield due to the intake of 1 kg of fertiliser has been given by the relationship :

$$Ce = \frac{Rend \; (F) - Rend \; (T)}{Dose \; engrais}$$

Ce: Efficiency coefficient; Rend (T) = control plot yield; Rend (F) = fertilized plot yield.

## 2.12 Statistical Analysis

At the end of the experiment, the data collected were subjected to data analysis (ANOVA) using the software Statistica version 7.1. This analysis was used to assess the effect of fertilizers on yield and its components on both sweet potato

varieties and significant difference was determined. The Fisher 5% test was used to classify averages into homogeneous groups. A Mann Whitney test compared mean two to two.

## 3. RESULTS

### 3.1 Effect of Treatments on Number of Marketable and Non-Marketable Tuberous Roots

For the number of non-marketable tuberous roots, the results showed a significant difference ($P = .05$) between the two varieties (Table III). Irene (234 roots) recorded the highest number of non-marketable tuberous roots compared to TIB-440060 (151 roots).

For treatments, T1 (NPK 15-15-15) with a number of 168 tuberous roots was not not signifiant from T11 (NPK 12-22-22) which obtained the highest number of non-marketable tuberous roots with an average of 215.

The effect of the control treatment was not significantly different from that of T1 (200 kg.ha$^{-1}$ NPK 15 15 15). Other treatments had mean numbers that ranged from 183 to 209 non-marketable tuberous roots. The interaction between the variety and the fertilizer, was not significant ($P = .05$).

As regards the average numbers of marketable tuberous roots, they oscillated between 82 and 123 for all treatments applied. T12 (500 kg.ha$^{-1}$ NPK 12 22 22) and T8 (200 kg.ha$^{-1}$ NPK 12 22 22) obtained the highest mean numbers of tuberous roots, with 123 and 114 marketable roots respectively, an increase of 19% and 10% compared to the witch with an average of 103 marketable roots (Table 3). Chemical fertilizer treatments were not significantly different from the control and manure treatments. At variety level, Irene recorded the highest mean number (108 marketable roots), while TIB recorded 98 marketable roots. However, the variance analysis of the mean number of marketable tuberous roots did not show a significant difference for varieties and their interaction with varieties (Table 3).

### 3.2 Effects of Varieties and Fertilizers on Average Number of Tuberous Roots Per Plant

The results showed that the varieties had highly significant effects on the mean number of tuberous roots per plant ($P < .001$). Indeed, the TIB variety obtained the highest mean number with 3 roots per plant. The Irene variety recorded the low mean number, with 2 roots per plant (Table 4).

**Table 3. Effect of fertilizers on average number of marketable and non-marketable tuberous roots**

| Variables | Levels | Number of small tuberous roots | increase level (%) | Number of big tuberous roots | increase level (%) |
|---|---|---|---|---|---|
| Variety | Irene | 234[a] | | 108[a] | |
| | TIB | 151[b] | | 90[a] | |
| *P* | | 0.001 | | 0.313 | |
| | $T_e$ | 201 | 0 | 103 | 0 |
| | $T_1$ | 168 | -17 | 84 | -19 |
| | $T_2$ | 194 | -3 | 95 | -8 |
| | $T_3$ | 198 | -2 | 94 | -9 |
| | $T_4$ | 185 | -8 | 113 | 9 |
| | $T_5$ | 188 | -7 | 102 | -2 |
| Treatments | $T_6$ | 192 | -5 | 91 | -12 |
| | $T_7$ | 183 | -9 | 97 | -7 |
| | $T_8$ | 202 | 0 | 114 | 10 |
| | $T_9$ | 183 | -9 | 82 | -20 |
| | $T_{10}$ | 185 | -8 | 88 | -15 |
| | $T_{11}$ | 215 | 7 | 99 | -4 |
| | $T_{12}$ | 209 | 4 | 123 | 19 |
| *p* | | 1.00 | | 1.00 | |
| *p*(interaction) | | 1.00 | | 1.00 | |

*\*Assigned column averages of the same letter do not differ from the 5% threshold (Fisher test)*

As regards the effect of fertilizers, the mean numbers of tuberous roots varied between 2 and 3 tuberous roots per plant for all treatments applied. The mean numbers of tuberous roots obtained from treatments involving chemical fertilizers and treatments consisting of the combination of chemical fertilizers and organic fertilizers were not statistically different from the control. The same was true for the variety fertilizer interaction (Table 4).

## 3.3 Effects of Fertilizers on the Average Weight of Tuberous Roots

Analysis of the results showed that the variety factor had a highly significant effect ($P < .001$) on the mean weight of the tuberous roots (Table 5). Irene obtained the highest mean number of tuberous roots (0.18 kg) and TIB-440060 with the lowest mean number (0.13 kg).

For the fertilizer factor, the T8 treatment (200 kg.ha$^{-1}$ NPK 12 22 22) obtained the highest average number of tuberose roots (0.19 kg) or an increase of 31%, followed by treatment T10 (300 kg.ha$^{-1}$ NPK 12 22 22) with a mean number of 0.17 kg. The smallest mean number of tuberous roots (0.12 kg) was obtained with the T7 treatment (15 t.ha$^{-1}$ of manure). Compared to the witness, the increases recorded were in the range of 7 to 31%. However, the variance analysis of the mean tuberous root weights did not show significant differences between fertilizers and their interaction with varieties.

## 3.4 Effect of Fertilizers on crop index

Results for the evolution of the crop index are presented in Table 6. Results obtained indicated that the variety TIB-440060 had the best crop index with an average number of 0.60, significantly different from the Irene variety, which recorded a mean harvest index of 0.50 ($P = .05$).

Concerning the fertilisers, the results obtained did not show a significant difference between crop indices in the different treatments. Harvest index values ranged from 0.53 to 0.58 for all applied fertilizers.

## 3.5 Effect of Fertilizers on Yield in Fresh Tuberous Roots

The highest mean yield in fresh tuberose roots (9.4 t.ha$^{-1}$) was obtained with the T8 treatment (200 kg.ha$^{-1}$ NPK 12-22-22) with a 40% growth

rate compared to the untreated control which recorded a mean yield of 6.8 t.ha$^{-1}$ and a zero increase rate (Table 6). This mean yield was significantly different from the effect of manure treatment ($P = 1.00$). On the other hand, the lowest mean yield (5.7 t.ha$^{-1}$) was recorded with the T6 treatment (10 t.ha$^{-1}$ of manure. The T12 and T4 treatments also achieved high yields in fresh tubers, respectively, 8.1 t.ha$^{-1}$ and 7.7 t.ha$^{-1}$. Compared to the control, T9, T2, and T11 showed low yields with 5.9 t.ha$^{-1}$, 6.5 and 6.6 t.ha$^{-1}$, respectively. The smallest increase was achieved by T3 treatment (7.1 t.ha$^{-1}$) with at 5%.

For varieties, the results showed that there is no significant difference between yields.

## 3.6 Coefficient of Efficiency of Organic and Mineral Fertilizers

The results of the analysis showed that the T8 treatment (200 kg.ha$^{-1}$ NPK 12 22 22) with the highest efficiency also had the highest efficiency coefficient (13). It was followed by T12, T10 and T4 treatments with efficacy coefficient 3 and 2, respectively. T2, T6, T7, T9 and T11 treatments recorded a zero efficiency coefficient (Fig. 2).

## 3.7 Effect of Fertilizers on Dry Matter Content of Fresh Tuberous Roots

The mean dry matter content of fresh tuberose roots ranged from 34.12% to 36.48% for all fertilizer levels applied to the plots, compared to 35.40% for the control (Table 7). Fertilizers and varieties did not significantly affect the mean dry matter content of tuberous roots. Indeed, they showed mean rates of statistically similar dry matter, regardless of the nature of fertilisation and variety ($P = .05$).

## 4. DISCUSSION

### 4.1 Effect of Organic Fertilizers on Agronomic Parameters of Sweet Potato

Organic fertilizers did not affect the mean number of marketable tuberous roots, the number and weight of tuberous roots per plant, and yield despite organic fertilizer inputs of 10 and 15 t.ha$^{-1}$. This result could be explained by the fact that nutrients such as nitrogen and potassium from organic fertiliser are not in sufficient quantity [16] to produce large caliber

tuberous roots. Nitrogen and potassium play a well-known role in the production of large calibers [17]. In addition, [16] reported that potassium contributes to the improvement of calibers, while a deficiency in K results in a higher proportion of small calibers. In addition, work by [18] has also confirmed that the input of N and K is essential for the production of sweet potatoes.

The decline in yield from organic fertilizers could be explained by the slow process of manure decomposition. Nutrients from organic matter are progressively released through mineralization and their action is much slower [19]. The results were in full agreement with those of [20] who also found no significant differences in performance and components with the application of organic fumire.

**Table 4. Effect of fertilizers on mean number of tuberous roots and mean weight**

| Variables | Levels | Number of tuberous roots /plant | Increase level (%) | Mean weight (g) | Increase level (%) |
|---|---|---|---|---|---|
| Variety | Irene | $2^b$ | | $180.17^a$ | |
| | TIB | $3^a$ | | $138.73^b$ | |
| *P* | | 0.001 | | 0.012 | |
| | $T_e$ | 3 | 0 | 144.63 | 0 |
| | $T_1$ | 2 | -9 | 158.24 | 9 |
| | $T_2$ | 2 | -6 | 154.89 | 7 |
| | $T_3$ | 3 | -3 | 169.91 | 17 |
| | $T_4$ | 3 | 0 | 165.13 | 14 |
| | $T_5$ | 2 | -6 | 175.37 | 21 |
| Treatments | $T_6$ | 3 | -3 | 144.32 | 0 |
| | $T_7$ | 3 | -4 | 126.48 | -13 |
| | $T_8$ | 3 | -2 | 189.34 | 31 |
| | $T_9$ | 2 | -11 | 135.9 | -6 |
| | $T_{10}$ | 2 | -12 | 177.43 | 23 |
| | $T_{11}$ | 3 | 5 | 155.25 | 7 |
| | $T_{12}$ | 3 | 6 | 175.93 | 22 |
| *p* | | 0.653 | | 0.10 | |
| *p* (interaction) | | 0.657 | | 0.10 | |

*\* Assigned column averages of the same letter do not differ from the 5% threshold (Fisher test)*

**Table 5. Effect of fertilizers on crop index**

| Variables | Levels | Crop index | Increase level (%) |
|---|---|---|---|
| Variety | Irene | $0.50^b$ | |
| | TIB | $0.60^a$ | |
| *P* | | 0.032 | |
| | $T_e$ | 0.58 | 0 |
| | $T_1$ | 0.53 | -9 |
| | $T_2$ | 0.52 | -10 |
| | $T_3$ | 0.57 | -2 |
| | $T_4$ | 0.54 | -6 |
| Treatments | $T_5$ | 0.54 | -7 |
| | $T_6$ | 0.54 | -8 |
| | $T_7$ | 0.54 | -6 |
| | $T_8$ | 0.56 | -3 |
| | $T_9$ | 0.58 | -1 |
| | $T_{10}$ | 0.53 | -9 |
| | $T_{11}$ | 0.54 | -7 |
| | $T_{12}$ | 0.54 | -7 |
| *p* | | 1.00 | |
| *p*(interaction) | | 0.10 | |

*\* Assigned column averages of the same letter do not differ from the 5% threshold (Fisher test)*

**Table 6. Effect of treatments on the mean yield in fresh tubers**

| Variables | Levels | Mean yield in fresh tubers (t.ha$^{-1}$) | Increase level (%) |
|---|---|---|---|
| Variety | Irene | 7.78[a] | |
| | TIB | 6.31[a] | |
| P | | 0.339 | |
| | $T_e$ | 6.8 | 0 |
| | $T_1$ | 6.5 | -3 |
| | $T_2$ | 6.5 | -4 |
| | $T_3$ | 7.1 | 5 |
| | $T_4$ | 7.7 | 14 |
| Treatments | $T_5$ | 7.3 | 8 |
| | $T_6$ | 5.7 | -16 |
| | $T_7$ | 6.5 | -3 |
| | $T_8$ | 9.4 | 40 |
| | $T_9$ | 5.9 | -13 |
| | $T_{10}$ | 7.4 | 10 |
| | $T_{11}$ | 6.6 | -2 |
| | $T_{12}$ | 8.1 | 20 |
| p | | 0.10 | |
| p (interaction) | | 0.10 | |

*\* Assigned column averages of the same letter do not differ from the 5% threshold (Fisher test)*

**Table 7. Effect of fertilizers on the rate of fresh dry matter of tuberous roots**

| Variables | Levels | Dry matter content (%) |
|---|---|---|
| Variety | Irene | 35.19[a] |
| | TIB | 35.10[a] |
| P | | 0.10 |
| | $T_e$ | 35.40[a] |
| | $T_1$ | 36.48[a] |
| | $T_2$ | 34.12[a] |
| | $T_3$ | 35.38[a] |
| | $T_4$ | 36.20[a] |
| Treatments | $T_5$ | 35.22[a] |
| | $T_6$ | 34.75[a] |
| | $T_7$ | 34.57[a] |
| | $T_8$ | 34.05[a] |
| | $T_9$ | 35.19[a] |
| | $T_{10}$ | 34.80[a] |
| | $T_{11}$ | 35.29[a] |
| | $T_{12}$ | 35.49[a] |
| P | | 0.10 |
| p (interaction) | | 0.623 |

*\* Assigned column averages of the same letter do not differ from the 5% threshold (Fisher test)*

## 4.2 Effect of Chemical Fertilizers on Agronomic Parameters of Sweet Potato

The application of chemical fertilizers did not positively affect the numbers of marketable and plant tuberous roots. However, the application of mineral fertilizers allowed for an increase in the weight and yield of fresh tubers compared to the control without fertilizers. This would result in the direct accessibility of N, P and K nutrients brought to the soil by compound fertilizer [21]. It is therefore likely that increases of 31% and 40% between the control (Te) and T8 treatment are due to the conjugated effects of the three elements N, P and K. Similar results were obtained in Côte d'Ivoire on cassava [22] and in other countries [23,24]. These results showed

that the highest yields were recorded by fertilizer inputs with N, P and K. Our results are consistent with those of [25] who obtained the best yields and fresh tuberous root weights with the mineral formula of $N_{60}P_{30}K_{100}$ on sweet potato.

In addition, other authors had previously reported that N and K were essential to the production of sweet potatoes. Thus, the application of chemical fertilizers that provide nutrients such as potassium and nitrogen significantly increases root yield [18,26]. In addition, the yield of the tuberous roots of the sweet potato may depend on the photosynthetic capacity of the foliar cover, the ability of the crop to translocate the assimilates of the leaf to the root and their ability to assimilate them. It is therefore possible that assimilation of photosynthesis translocated to the roots may have contributed to the high yields of the mineral fertilizer treatment [3].

### 4.3 Effect of the Combination of Chemical Fertilizers and Organic Fertilizers on the Agronomic Parameters of Sweet Potato

The application of 200 kg.ha$^{-1}$ of NPK + 5 t.ha$^{-1}$ of manure did not affect the number, weight, and average yield of tuberous roots, as well as the dry matter content of tubers and the crop index. The low yields obtained with organic mineral fertilization would be related to the application dose of the fertilizer. [27] obtained the best yields

in tuberose roots with the application of 150 kg.ha$^{-1}$ NPK + 2.4 t.ha$^{-1}$ manure. Indeed, the amount of nutrients such as nitrogen and potassium contained in fertilizers would be the basis for this result. Nitrogen and potassium are essential in the production of sweet potato, but when they are brought in excess or absorbed too late, they prolong vegetation at the expense of tubers. Thus the high concentration of nitrogen in the fertilizer could have slowed the activity of potassium. [28] reported that tuberous root magnification occurs when the nitrogen/ potassium ratio is low (1:3 ratio), because a high nitrogen concentration reduces the potassium concentration, affecting the storage roots.

### 4.4 Efficiencies of Mineral and Organic Fertilizers

The low efficiency coefficient value of fertilizer elements observed for organic fertilizers would likely be due to the slow and progressive mineralization of manure to provide mineral elements to soils and crops. Similar results were obtained by [29] with household waste composts on a Kinshasa Ferralsol, on peanut, soy and sorrel crops. Organic matter plays an important role in soil, thus promoting the growth of micro-organisms that induce activation of nutrient solubilization. Nutrients made sufficiently available over time in soil are used effectively by crops [30]. In the case of our study, inputs of 10 and 15 t.ha$^{-1}$ of organic inputs yields and efficiency coefficient were the lowest, compared
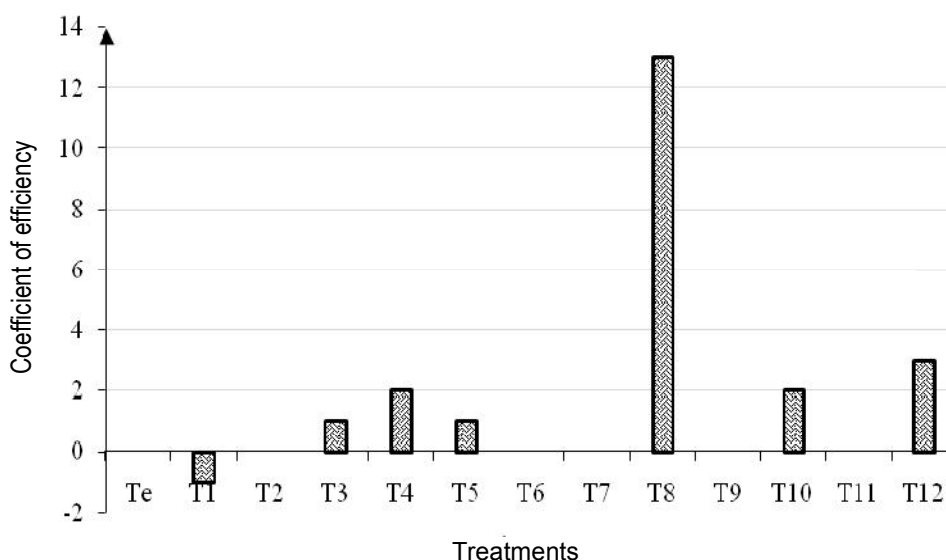


**Fig. 2. Evolution of the efficiency coefficient according to fertilizers**

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to mineral fertilizers that were more effective. This could be explained by the fact that the nutrients contained in mineral fertilizers are available and readily absorbable by crops as demonstrated by the work of [31] on the cultivation of gumbo and cabbage using mineral and organic fertilizers. For example, the 200 kg.ha^{-1} dose of NPK 12-22-22 recorded the best average weights and yields compared to NPK 300, 400 and 500 kg.ha^{-1}. In fact, for any fertiliser added, the efficiency coefficient of fertilisers for different treatments decreases with increasing doses [32]. These results show the interest and need in low availability of mineral fertilizers to use low doses. This confirms the studies of [33], which obtained similar results in yam culture.

This decline in yield, due to the combination of mineral and organic fertiliser, would also be due to rainfall, which is one of the factors determining the decline in yields of fresh tuberous roots. The effect of fertilisers could have been better if the rains had been regular throughout the cycle. Drought pockets were noted at certain periods of fertilizer intake, resulting in low solubilization and volatilization of the elements, making them less effective. Indeed, our work was conducted on horseback during the small dry season and the small rainy season during which there was not enough precipitation. Treated plants had to suffer from water stress, especially during the first two months after planting and application of fertilizers. Yields of sweet potato are reduced if severe water stress occurs during tuberization [34]. [35] reported that soil moisture status affects plant growth and yield.

## 4.5 Effect of Varieties on Agronomic Parameters of Sweet Potato

The mean number of tuberose roots varied according to varieties as was the case in the 4 sweet potato varieties Mugandé, Spk013, Kemb 10 and SPK004 grown in western Kenya, with values of 4.2, respectively; 3.1; 3.5 and 2.8 [36]. However, in the Yan Shu1 and White Delite varieties grown in eastern Congo, the number of tubers is higher at 15.5 and 14 roots/plant, respectively [37]. This large number obtained in these varieties grown in the Congo relative to the yields of our study would be related to soil type, rainfall and especially genetic variability.

Thus, the differences in the weight and yield of tuberose roots in our study compared to those reported by [38] should be within the different

varieties used in these different trials. Work by [39] reported a marketable root yield of 0.72 kg per plant, which is higher than the 0.14 kg/plant and 0.18 kg/plant found for fertilizer application in this study. This same result was observed in Nyagezi marsh conditions by [40], who found that the weight and yield of tuberose roots varied with varieties. This uniformity of the results would be due to the ecophysiology of sweet potato, which requires very sunny exposures for photo-synthesis to be done under better conditions; This would allow starch to form in large quantities and subsequently to obtain large tuberous roots. Physiologically, the conversion of $CO_2$ to carbon hydrate was well established.

The crop index showed significant differences between varieties. Current results indicate that the crop index is low. This could be due to poor separation or poor translocation of dry matter to storage roots, as claimed by [41].

Results suggest that the increase in the fresh weight of aerial biomass at harvest may have contributed to the decline in root yield and, in turn, to the decline in the crop index, as the higher fresh weight of aerial biomass could be influenced by a high translocation of vegetative biomass assimilates to the detriment of tuberous roots. Some authors, including [42], have shown a correlation between yield and dry matter in aerial biomass. These differences between varieties could be attributed to variations in the genetic composition of varieties and, therefore, to their photosynthetic sharing habits.

## 5. CONCLUSION

The results showed that the effects of chemical fertilizer treatments, manure and their combination with mineral fertilizers did not influence the measured parameters. The results also showed that fertilizers improved all the agronomic parameters of sweet potato compared to the control treatment during two years of experiment. However, the Irene variety with a mean weight of 180 g tuberous roots was significantly different from the TIB variety with a mean weight of 138.73 g.

These results are based only on a two-year study and for a single site, for a better precision of the effects of each nutrient composing fertilizers, it would be advisable for our results to extend the duration of the test to benefit from the back effects of using these organic fertilizers on soil fertility and sweet potato productivity.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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