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Response of the Yam Variety Krengle (*Dioscorea rotundata*) to Organo-mineral Fertilisation at Bouaké in Central of Côte d'Ivoire

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Abstract

The decline in yam productivity due to the lack of arable land and impoverished soils forces farmers to use fertiliser. The fertilisers used are mineral, organic or organo-mineral. A study of these fertilisers has been carried out to propose to the farmers a dose or combination that can improve their yield. Thirteen (13) fertilisers obtained from the combination of mineral fertiliser (NPK 15-15-15) and composted cow or poultry manure were tested on the yam variety Krengle in a 3 replicate randomized complete block design. The experiment was conducted over two (2) campaigns at Bouake in Central of Côte d'Ivoire. The results show that high dose mineral fertilisation (NPK 15-15-15, 300 kg/ha) negatively influenced the growth and yield parameters of the yam variety Krengle. High doses of organic fertilisers (Cow manure (CM) 20 t/ha and poultry manure (PM) 20 t/ha) have a positive effect on vegetative growth. While the medium-high doses of organic fertiliser (CM 15 t/ha and PM 15 t/ha) gave better tuber yield (13.5 t/ha) and allowed an increase in tuber yield from 17 to 18%. Organo-mineral fertilisation combining a small dose of organic fertiliser (5 t/ha) with a medium dose of mineral fertiliser (200 kg/ha) gave also fairly good yield (13.3 and 14.42 t/ha) with an increase of 15 to 25%. Thus, 200 kg/ha of NPK 15-15-15 associated with 5 t/ha of poultry or cow manure can be recommended for the cultivation of the yam variety Krengle at Bouake.

Keywords: yam variety Krengle, organo-mineral fertilisation, composted manure, growth, yield

1. Introduction

Yam (*Dioscorea* spp.) is a tuber crop grown mainly by smallholders in the tropical and subtropical regions of Africa, the Caribbean, Oceania and South Asia. It is the staple food of more than 300 million people worldwide because of its high nutritional value (Asiedu & Sartie, 2010; Cornet, 2015; Alabi et al., 2019). Yam plays a very important role in food security and livelihood systems for at least 60 million people in West Africa. It is mainly cultivated in southern Guinea's secondary savannah and savannah (FAO, 1997, 1999; Chukwu & Ikwelle, 2000). About 67.31 million tonnes of yam (92% of world production) are produced annually on 7.96 million hectares in West Africa, mainly in five countries, namely Benin, Côte d'Ivoire, Ghana, Nigeria and Togo (Faostat, 2019). Nigeria is the largest producer and alone accounts for about 66 per cent of global production, followed in third place by Côte d'Ivoire, where yam is the largest food crop by volume, with an annual production of about 7.148 million tonnes (Faostat, 2019). It is a financial source for a significant fringe of small-scale producers, especially women, mostly involved in production, processing and marketing (Asiedu, 2003). These qualities make yam a crop of the future for food security and poverty reduction in West Africa (Allogni et al., 2006).

Despite this importance, yam productivity is declining. This decrease is due, as indicated in numerous works (Carsky et al., 1998; Diby et al., 2009, 2012; Hgaza et al., 2012; Cornet et al., 2014; Cornet, 2015) to the low fertility of the soil which remains one of the main constraints encountered in traditional culture. Faced with this problem, farmers use fertilisers to increase their production. The fertilisers used are chemical, organic or organo-mineral. Therefore, it is in the interest of the scientific world to propose methods of use and adequate doses to avoid the problem of pollution of agricultural soils in yam culture.

Th is work aims to study the effect of organo-mineral fertilisation on the agronomic parameters of the yam variety Krengle (*D. rotundata*). Specifically, it involves to:

- evaluate the effect of different amounts of mineral (NPK 15-15-15), organic and organo-mineral fertilisers on the growth parameters of Krengle;
- evaluate the effect of different amounts of mineral (NPK 15-15-15), organic and organo-mineral fertilisers on the yield and dry matter content of Krengle tubers.

2. Materials and methods

2.1 Study Area

The study was conducted at the Food Crops Research Station (FCRS) of the National Centre for Agronomic Research (CNRA), located in Bouaké, Central Côte d'Ivoire. This city is located at 7°45′00″ and 7°38′00″ latitude N; 5°7′00″ and 4°58′00″ longitude W. It is in the transition zone between the forest climate of the South and the savannah climate of the North (Traoré et al., 2013).

The climate of the study zone is of the humid tropical type with four seasons, including a largely dry season (November to February), a large rainy season (March to June), a short dry season (July to August) and a short rainy season (September to October) (Yesso et al., 1991). These periods have become less and less marked in recent years (Brou et al., 2005). In addition to a high-temperature range (22 °C in the mornings to 35 °C in the afternoons), it has constant sunshine and bimodal hygrometry with an annual rainfall of 1,200 mm (Akassimadou & Yao-Kouamé, 2014).

The hydrography is mainly composed of the Bandama River and the N'Zi (sub-basin of the river) (Konan, 2017). The vegetation consists of wooded savannah with several species of *Poaceae* (Séka et al., 2009). The soils are ferrallitic gravelly, moderately saturated, reworked, and shallow and derived from granitic alteration material with a sandy-clay texture (Ettien, 2004).

2.2 Plant Material

The plant material used is the long-cycle yam variety Krengle, (*D. rotundata*). The seeds were obtained by cutting the tubers (Figure 1) into small pieces weighing between 250 and 300 grams.

Figure 1. Tubers of the yam variety Krenglè

2.3 Morpho-pedological and Physical Characteristics of the Study Site

The morphological characterisation of the soils intended for the experiment was carried out before setting up the test. The morphological parameters taken into account in this study were: coarse elements, texture, structure, porosity and consistency (Baize & Jabiol, 1995; Baize, 2004). The characteristics of the two types of soil used for the experiment are presented in Table 1.

Table 1. Morphological and physical characteristics of the soils used for the experiment

Trial years	Year 1	Year 2
Soil type	Reworked ferrallitic soil (haptic Ferralsol)	Reworked ferrallitic soil indurated at medium depth (mesoplinthic haptic Ferralsol)
Depth (cm)	150 (no mechanical stress)	64 (induration stress)
Coarse element charge (%)	1.31	19.55
Texture	Sandy-clayey	Sandy-clayey
Apparent density (Da) in (g/cm^3)	0.83	1.54

2.4 Methods

2.4.1 Experimental Design

The experimental device used is a Completely Randomised Block (BCR) with thirteen (13) treatments and three (3) (repetitions) separated from each other by 2.5 m. Each elementary plot contains 35 yam mounds. The planting density was 10,000 mounds per hectare, with a distance of 1 m between the mounds. The experiment was conducted over two (2) campaigns.

Three types of fertilisers were used for the work, namely:

- Mineral fertiliser (NPK 15-15-15) with four doses: 50, 100, 200, and 300 kg/ha;
- Composted cow manure, with four doses: 5, 10, 15, and 20 tons/ha;
- Composted poultry manure, with four doses: 5, 10, 15, and 20 tons/ha;

The thirteen (13) treatments tested were obtained from the combination of different fertilisers (mineral fertiliser, composted cow manure and composted poultry manure) (Table 2). The control(T0) did not receive any fertiliser.

Table 2. Different combination of fertilisers tested

Treatments	Fertiliser NPK 15-15-15 (kg/ha)	Composted cow manure(tons/ha)	Composted poultry manure (tons/ha)
T0 (NPK 0 + PM 0 + CM 0)	0	0	0
T1 (NPK 200 kg/ha)	200	0	0
T2 (NPK 300 kg/ha)	300	0	0
T3 (NPK 200 kg/ha + CM 5 t/ha)	200	5	0
T4 (NPK 100 kg/ha + CM 10 t/ha)	100	10	0
T5 (NPK 50 kg/ha + CM 15 t/ha)	50	15	0
T6 (NPK 200 kg/ha + PM 5 t/ha)	200	0	5
T7 (NPK 100 kg/ha + PM 10 t/ha)	100	0	10
T8 (NPK 50 kg/ha + PM 15 t/ha)	50	0	15
T9 (CM 20 t/ha)	0	20	0
T10 (CM 15 t/ha)	0	15	0
T11 (PM 20 t/ha)	0	0	20
T12 (PM 15 t/ha)	0	0	15

2.4.2 Implementation of the Experiment

(1) Establishment and Management

The yams were planted by putting a cutting (a cut piece of tuber) in each mound. The mounds were made by hand using a hoe, and about 0.5 m and 1 m in height and diameter.

The maintenance of the plot consisted of weeding and staking the yams. Weeding was done on demand (each time the plot was grassed) using a hoe. They consisted of pulling out weeds that compete with the yam plants. Staking began 2 to 3 months after planting and mounted the yam stems on previously produced stakes. One stake was provided for four mounds.

(2) Composting and Fertilisation of the Plots

Poultry and cow manure was composted in concrete bins 3 m long, 50 cm wide and 40 cm deep. A total of 4 bins were used, of which two were used for poultry litter and 2 for cow litter. The different litters were stored in the bins and then closed with palm leaves to ensure a high temperature and allow water to enter (Figure 2). To produce organic fertiliser, composting was carried out for four weeks and the turning periods were on days 2, 4, 8 and 16 after storage in the bins. Watering was done as needed.

The fertilisers were applied individually (compost or NPK) or combined (compost + NPK) depending on the treatments. A crown-shaped opening was made in the upper part of each mound to receive the fertiliser. The fertiliser was covered with soil after application on the mound (Figure 3). The application was made three (3) months after planting.

Figure 2. Different stages of composting poultry litter and cow dung

A: Mineral fertilisation B: Organic Fertilisation C: Organo-mineral fertilisation

Figure 3. Fertiliser application method

2.4.3 Data Collected

Three (3) parameters were measured during yam growth, three (3) to five (5) months after planting (during two (2) month after fertilisation). These are the stem elongation, the number of new branches and leaves emitted.

Stem's length was taken from the soil surface (mound) to the tip of the stem at three (3) and five (5) month. The difference between the two measurements gave the stem elongation. The number of branches and leaves emitted is obtained by counting each one that appears newly during the observation period.

At harvest, the tubers' weight per mound, the number of tubers per mound and the dry matter content were noted. The tubers' weight per mound was determined using a 5 Kg × 1 g precision scale. The number of tubers per mound was determined by counting the total number of tubers per mound.

Concerning the dry matter content (DMC), after the harvest, samples were taken at three different levels from randomly selected tubers: the middle, distal and apical parts of the tuber. All these samples were then merged to obtain a composite sample per treatment and year. The resulting pieces were peeled, and a 200 g fraction was taken to give the fresh weight (FW) per sample. According to the treatment and year, these 200 g fractions were then cut into small strips and placed in aluminium foil. The aluminium foil containing these yam strips was put in an oven at 100 °C for 24 hours. The dry and cooled samples were weighed to determine their dry weight (DW). The dry matter content was determined according to the following formula:

$$DMC(\%) = \frac{FW}{DW} \times 100 \quad (1)$$

2.4.5 Data Processing

The observations and measurements were analysed using SPSS version 20 software, and an analysis of variance (ANOVA) was first performed. Themeans were then separated by the Turkey test at the 5% threshold when the effects were significant. The normality of the data and the homogeneity of the variances were checked beforehand using the test of Kolmogorov-Smirnov and Shapiro-Wilk.

3. Results

3.1 Effects of Organo-mineral Fertilisation on Growth Parameters

Table 3 shows the results of the analysis of variance for mean stem length increasing, number of branches and leaves emitted for each treatment from three to five months after planting. This analysis shows a significant difference in mean stem elongation ($P \leq 0.05$). The treatments CM 20 t/ha, NPK 0 + PM 0 + CM 0 and NPK 100 kg/ha + CM 10 t/ha had the highest increasing in stem lengths (respectively 80.21, 78.68 and 76.06 cm). NPK 50 kg/ha + CM 15 t/ha (65.95 cm), NPK 50 kg/ha + PM 15 t/ha (64.93 cm) and PM 20 t/ha (59.29 cm) were ranked in second position for this parameter. Lowest increase in stem lengths were observed with NPK 200 kg/ha (40.15 cm), NPK 100 kg/ha + PM 10 t/ha (39.22 cm) and NPK 300 kg/ha (36.30 cm).

There is also a significant difference between the different treatments applied ($P = 0.00$) in terms of the number of branches produced. The highest numbers of branches (5±1) were recorded with CM 20 t/ha and NPK 100 kg/ha + CM 10 t/ha followed by PM 20 t/ha (4±1). NPK 300 kg/ha, NPK 200 kg/ha + CM 5 t/ha and NPK 200 kg/ha + PM 5 t/ha had the lowest number of branches (1±1).

The number of leaves produced also shows a significant difference ($P = 0.02$) between the different treatments used. CM 20 t/ha and NPK 0 + PM 0 + CM 0 gave the highest number of leaves produced (20 and 18). They were followed by NPK 100 kg/ha + CM 10 t/ha (16), NPK 50 kg/ha + CM 15 t/ha (16) and PM 20 t/ha (15). The smallest number of emitted leaves (11) was recorded for NPK 300 kg/ha, NPK 200 kg/ha, NPK 200 kg/ha + CM 5 t/ha and NPK 100 kg/ha + PM 10 t/ha.

High doses of organic fertiliser (CM 20 t/ha and PM 20 t/ha) had a positive impact on growth parameters. However, the inverse effect was observed with high doses of mineral fertilisers (NPK 300 kg/ha and NPK 200 kg/ha).

Organo-mineral fertilisers NPK 100 kg/ha + CM 10 t/ha, NPK 50 kg/ha + CM 15 t/ha and NPK 50 kg/ha + PM 15 t/ha allowed good vegetative growth. Combinations of organic fertiliser (CM or PM) with 200 kg/ha of NPK did not improve growth.

Table 3. Effect of treatments on stem length increasing, number of branches and leaves emitted from three to five months after planting

Treatments	Stem length increasing (cm)	Number of branches produced	Number of leaves produced
CM 15 t/ha	50.36±46.60 cd	2±1 d	13±10 c
CM 20 t/ha	80.21±75.06 a	5±1 a	18±14 a
PM 15 t/ha	50.47±52.86 cd	3±1 c	13±11 c
PM 20 t/ha	59.29±54.65 bc	4±1 b	15±12 b
NPK 0 + PM 0 + CM 0	78.68±54.60 a	2±1 d	20±14 a
NPK 50 kg/ha + CM 15 t/ha	65.95±57.23 b	3±1 c	16±12 b
NPK 50 kg/ha + PM 15 t/ha	64.93±52.44 b	2±1 d	13±10 c
NPK 100 kg/ha + CM 10 t/ha	76.06±69.92 a	5±1 a	16±13 b
NPK 100 kg/ha + PM 10 t/ha	39.22±34.44 de	2±1 d	11±9 c
NPK 200 kg/ha	40.15±44.54 de	2±1 d	11±9 c
NPK 200 kg/ha + CM 5 t/ha	48.83±33.95 d	1±1 d	11±9 c
NPK 200 kg/ha + PM 5 t/ha	55.93±44.33 c	1±1 d	13±10 c
NPK 300 kg/ha	36.30±24.03 e	1±1 d	11±8 c
Fcal	3.904 *	4.017 *	3.071 *
Pcal	0.00	0.00	0.02
Pthéor	≤ 0.05	≤ 0.05	≤ 0.05

Note. According to the Turkey test,*Averages followed by the same letter in the same column are not significantly different at the Probability threshold of 0.05.

F = Fisher's F (ANOVA), Prcal = Calculated Probability, Pthéor = Theoretical Probability, * = significant.

3.2 Effect of Organo-mineral Fertilisation on Yield Components

3.2.1 Influence of Treatments on the Weight and Number of Tubers

Table 4 shows the tuber weights per mound (TWM), the yields of fresh tubers, the gain in yield and the number of tubers per mound (NTM) for the different treatments. Analysis of this table shows that there is a significant difference in the weight of tubers compared to the treatments (P = 0.038). On the other hand, there is no significant difference in the number of tubers between treatments (P = 0.643). The treatment NPK 200 kg/ha + CM 5 t/ha results in higher tuber weights (1442.44±742.51). The lowest weight comes from the PM 20 t/ha plot (1083.58±679.03). The yield expressed in t/ha reveals that the combination of mineral and organic fertiliser at the dose of NPK 200 kg/ha + CM 5 t/ha gives the highest yield of 14.42 t/ha. It is followed respectively by the treatments CM 15 t/ha, PM 15 t/ha and NPK 200 kg/ha + PM 5 t/ha with 13.59 t/ha, 13.50 15 t/ha and 13.30 t/ha. The lowest yields were recorded by the treatments NPK 0+PM 0+CM 0 (11.56 t/ha), NPK 300 kg/ha (11.29 t/ha), NPK 100 kg/ha + CM 10 t/ha (11.25 t/ha), NPK 100 kg/ha + PM 10 t/ha (11.08 t/ha), PM 20 t/ha (10.83 t/ha).

The high dose of mineral fertiliser (NPK 300 kg/ha) gave a low yield similar to the unfertilized control (NPK 0+PM 0+CM 0). Organo-mineral fertilisation combining a small dose of organic fertiliser (5 t/ha) with a medium dose of mineral fertiliser (200 kg/ha) increased the tuber yield by 15 to 25%. A similar result is observed on yields with medium-high dose of organic fertilisers (15 t/ha) for an increase of 17 to 18%.. The high doses of organic fertiliser (CM 20 t/ha and PM 20 t/ha) did not significantly increase the tuber yield.

Table 4. Effect of treatments on the weight and number of tubers per mound

Treatments	TWM (g)	Yield (t/ha)	Gain in yield/control (%)	NTM
CM 15 t/ha	1359.09±931.95 [a]	13.59	18	2±1 [a]
CM 20 t/ha	1232.68±800.37 [ab]	12.32	7	2±1 [a]
PM 15 t/ha	1350.58±885.55 [a]	13.50	17	2±1 [a]
PM 20 t/ha	1083.58±679.03 [b]	10.83	-6	2±1 [a]
NPK 0 + PM 0 + CM 0	1156.02±879.00 [b]	11.56	0	1±1 [a]
NPK 100 kg/ha + CM 10 t/ha	1125.93±696.46 [b]	11.25	-3	2±1 [a]
NPK 100 kg/ha + PM 10 t/ha	1108.54±696.89 [b]	11.08	-4	2±1 [a]
NPK 200 kg/ha	1231.05±859.69 [ab]	12.31	6	2±1 [a]
NPK 200 kg/ha + CM 5 t/ha	1442.44±742.51 [a]	14.42	25	2±1 [a]
NPK 200 kg/ha + PM 5 t/ha	1330.72±892.88 [a]	13.30	15	2±1 [a]
NPK 300 kg/ha	1129.31±785.12 [b]	11.29	-2	2±1 [a]
NPK 50 kg/ha + CM 15 t/ha	1241.86±841.457 [ab]	12.41	7	2±1 [a]
NPK 50 kg/ha + PM 15 t/ha	1226.67±708.34 [ab]	12.26	6	2±1 [a]
Fcal	2.053 *			0.755 ns
Pcal	0.038			0.643
Pthéor	≤ 0.05			≥ 0.05

Note. According to the Turkey test, means followed by the same letter in the same column are not significantly different at the Probability threshold of 0.05.

F = File F (ANOVA), Prcal = Calculated Probability, Pthéor = Theoretical Probability, * = significant, ns = not significant.

TWM: tuber weight per mound, NTM: number of tubers per mound.

3.2.2 Effect of the Year of Cultivation on Average Weight, the Average Number of Tubers, and Dry Matter Content

The results in Table 5 show the effect of the cropping year on yield parameters. In general, the cropping year has a significant impact on the various performance components. The first season (year 1) had a better effect on these parameters than the following season, except for the number of tubers harvested. Interactions between fertilisation and crop year were only significant on the average weight of tubers harvested per mound.

Table 5. Effect of fertilisation and year of cultivation on yield parameters

Factors	TWM (g)	NTM	DMC (%)
Year 1	1531 a	1.558 a	33.71 a
Year 2	923 b	1.739 b	31.65 b
NPK 0 + PM 0 + CM 0	1151	1.5	33.79
NPK 200 kg/ha	1234	1.696	33.52
NPK 300 kg/ha	1127	1.656	33.0
NPK 200 kg/ha + CM 5 t/ha	1440	1.683	31.26
NPK 100 kg/ha + CM 10 t/ha	1129	1.695	32.66
NPK 50 kg/ha + CM 15 t/ha	1247	1.635	32.83
NPK 200 kg/ha + PM 5 t/ha	1326	1.536	33.23
NPK 100 kg/ha + PM 10 t/ha	1110	1.724	31.01
NPK 50 kg/ha + PM 15 t/ha	1235	1.594	32.58
CM 20 t/ha	1225	1.702	33.48
CM 15 t/ha	1359	1.661	33.22
PM 15 t/ha	1347	1.768	30.82
PM 20 t/ha	1090	1.537	33.44
Year	**HS**	**HS**	**HS**
Fertilisation	**S**	**NS**	**NS**
Fertilisation × Year	**S**	**NS**	**NS**

Note. HS: Highly significant; S: Significant; NS: Not significant.

3.2.3 Effect of Interaction of Fertiliser and Cropping Year on Yield Parameters

Comparing the different yield parameters according to treatments and cropping years from the analysis of variance (Table 6) shows a significant difference in tuber weight (P = 0.03). In both the first and second year, the NPK treatment of 200 kg/ha + CM 5 t/ha resulted in the largest tubers, respectively 1715.91±658.96 g and 1155.95±723 g. The combination NPK 100 kg/ha + PM 10 t/ha and the PM 20 t/ha treatment gave the lowest yields (1338.37±800.36 and 1338.57±712.87). The comparison of tuber weight in the two successive years shows that, in general, there is a reduction in tuber weight from the first year to the second year. The number of tubers (P ≥ 0.05) shows that there are no significant differences between the treatments and the two crop cycles.

Table 6. Comparison of the weight and average number of tubers according to treatments and years of cultivation

Treatments	TWM (g)		NTM	
	Year 1	Year 2	Year 1	Year 2
CM 15 t/ha	1702.27±1040.12 ᵃ	1015.91±659.08 ᵃ	1±1 ᵃ	2±1 ᵃ
CM 20 t/ha	1442.56±866.49 ᵇ	1001.28±656.39 ᵃ	2±1 ᵃ	1±1 ᵃ
PM 15 t/ha	1660.47±897.58 ᵃ	1040.70±764.71 ᵃ	3±1 ᵃ	3±1 ᵃ
PM 20 t/ha	1338.57±712.87 ᵇᶜ	808.97±522.62 ᵇ	1±1 ᵃ	1±1 ᵃ
NPK 0 + PM 0 + CM 0	1419.77±1018.00 ᵇ	872.50±591.06 ᵇ	1±1 ᵃ	1±1 ᵃ
NPK 100 kg/ha + CM10 t/ha	1374.39±746.33 ᵇᶜ	871.25±540.64 ᵇ	2±1 ᵃ	1±1 ᵃ
NPK 100 kg/ha + PM10 t/ha	1338.37±800.36 ᵇᶜ	855.13±448.94 ᵃ	1±1 ᵃ	1±1 ᵃ
NPK 200 kg/ha	1682.27±845.48 ᵃ	758.33±578.88 ᵇᶜ	1±1 ᵃ	2±1 ᵃ
NPK 200 kg/ha + CM 5 t/ha	1715.91±658.96 ᵃ	1155.95±723.32 ᵃ	1±1 ᵃ	1±1 ᵃ
NPK 200 kg/ha + PM 5 t/ha	1646.51±950.77 ᵃ	991.25±688.91 ᵃ	1±1 ᵃ	1±1 ᵃ
NPK 300 kg/ha	1478.89±764.36 ᵇ	754.76±623.01 ᵇᶜ	2±1 ᵃ	2±1 ᵃ
NPK 50 kg/ha + CM 15 t/ha	1630.23±909.81 ᵃ	853.49±544.38 ᵇ	1±1 ᵃ	1±1 ᵃ
NPK 50 kg/ha + PM 15 t/ha	1421.19±748.36 ᵇ	1032.14±614.93 ᵃ	1±1 ᵃ	1±1 ᵃ
Fcal	2.05 *		0.755 ns	
Pcal	0.03		0.643	
Ptheor	≤ 0.05		≥ 0.05	

Note. According to the Turkey test, means followed by the same letter in the same column are not significantly different at the Probability threshold of 0.05.

4. Discussion

In terms of growth parameters, a very high/mineral fertiliser (NPK 15-15-15, 300 kg/ha) dose does not promote vegetative growth. According to Kimuni et al. (2014), any fertiliser added, the coefficient of fertilisers' effectiveness for different treatments decreases with increasing doses. These results show the interest and the need to use low doses of mineral fertilisers because high doses do not give good yields. On the other hand, the growth of krenglè yam is strongly favoured by the high doses of organic fertilisers. Organic matter plays an important role in the soil, thus promoting the growth of microorganisms which induce an activation of the solubilization of nutrients. Nutrients made sufficiently available and in large quantities over time in the soil are efficiently utilized by crop plants (Ojetayo et al., 2011). Likewise, the combination of mineral fertiliser with organic fertiliser has a good effect on vegetative growth. Indeed, yams also need balanced fertilisation during the vegetative phase. Suja (2005) proved that the additional inputs of nitrogen and phosphorus increases the leaf area index, the speed of vegetative development, the rate of net assimilation, and consequently, the yields of tubers in *D. rotundata*. According to Buresh et al. (1997) and Palm et al. (1997), it is generally accepted that organic and mineral fertilisers are necessary to increase agricultural production in West Africa. The plant absorbs the two complement each other and the mineral elements.

In contrast, the organic elements constitute reserves for the plant that it can draw on as it goes. The combination of organic and mineral fertilisation would positively influence growth. It would improve the soil structure, prevent its impoverishment and maintain its fertility (Giller et al., 1998).

Regarding the effects of mineral, organic, and organo-mineral fertilisation on yam's tuber yield, organo-mineral fertilisation induced an increase in tuber yields from 15 to 25%. It is the same for organic fertilisation and mineral fertilisation at a medium-high dose (CM 15 t/ha, PM 15 t/ha and NPK 200 kg/ha) with an increase in yield of 17 to 18%. These observations suggest that the application of different manures contributed to the increase in tuber production. The quantity, the period and the technic of the fertiliser application allowed a good mineral nutrition of the plants, thus inducing their good aerial development and therefore a good photosynthetic activity. This also led to the leaves' production and the transfer to the underground parts of a greater quantity of nutrients. This could, therefore, explain the production of large tubers. The mean yields obtained vary between 10.83 t/ha and 14.42 t/ha. They are far superior to those of Ettien et al. (2003) during the evaluation of new varieties of yam and N'Goran et al. (2007) in the bibliographic review on the management of the fertility of soils cultivated with yam who noted that, in Côte d'Ivoire, the standard yield varies between 8 and 12 t/ha, even if according to FAO (1999), the yam potential is around 65 t/ha.

Several authors have observed in their work an influence of mineral fertilisation on yam yield. Godo's (1990) work has shown that the yam responds better to organo-mineral manure than to strictly mineral manure. Likewise, Diby et al. (2009), Ettien et al. (2009), Diby et al. (2011), all observed a positive effect of mineral fertilisation on yam yield. In a study of the response of local varieties (Krenglè, Djaté, Kangba and Suidié) to mineral manure in the savannah zone of Côte d'Ivoire, Ettien (2004) tested three doses of fertiliser: T0 (control), T1 (120N 38P 103K), T2 (150N 49P 130K). The highest yield was recorded with the T1 rate for each variety. Soro et al. (2003), worked on four local varieties (Bètè bètè, Gnan, Krenglè and Wacrou) with three levels of fertiliser. They showed that the doses of T1 (60 25 65 Kg/ha of NPK) and T2 (2 times T1) are the basis of an increase in yield and the leaves' nitrogen content.

The method and timing of fertiliser application could also have induced optimal fertiliser used by plants. Indeed, the yam root system develops superficially (Hgaza et al., 2011). The method consists of a localized application of the fertiliser on the mound. In addition, the application of fertilisers took place at a rather decisive period of the yam development cycle. According to Craufurd et al. (2000), particularly, the phase of maximum plant growth is.a sensitive period in the cycle of this culture. Soro et al. (2003), and Agbede et al. (2013), observed a beneficial effect of organic amendments on yam production. Organic matter acts by promoting the absorption by the plant of the mineral elements provided, in particular nitrogen, and consequently increases the efficiency of the use of these fertilisers (Vanlauwe et al., 2010). Although according to Chabalier (1982), the burying of organic matter does not affect tuber yields, Melteras et al. (2008) have shown that it intervenes by improving the soil's physical properties, which determine its capacity to retain water and mineral elements.

Yields vary from year to year. According to Maliki (2006) and Floquet et al. (2012), yam can be grown for two successive growing seasons on the same soil. However, in this case, greater difficulties of emergence can be observed. Also, this difference could be due to environmental constraints such as rainfall, humidity and temperature. Since yams are rainfed, climatic hazards, particularly the different rainfall from one year to another, can greatly reduce yields. These results are consistent with Sinsin and Kampmann (2010) work, which showed that it is the decrease in the quantity of water as the temperature increases, coupled with a decrease in the relative humidity of the water air, which affect plant growth. Ghosh et al. (1988), and Ike and Inoni (2006) similarly consider delayed rainfall as one of the main sources of decline in yam production. This work corroborates Dansi et al. (2013) and Ehounou (2014), who showed the importance of water requirements for yam cultivation, especially after germination of the crop, then between the fourteenth and twentieth week of growth.

The dry matter content varies slightly depending on the treatments. It is around 33% on average. This high dry matter rate could be explained by the fact that in practice, the harvest of the yam takes place at the complete senescence of the foliage; tuberization continues after this phenomenon and can induce an additional production of dry matter, nearly 40% of the total dry weight of the tuber harvested. Our results are similar to those of Kouame et al. (2020) when evaluating the yield and dry matter content of seven (7) varieties of sweet potato (*Ipomoea Batatas* (L.), Lam., 1793) in the region of Bouake, Côte d'Ivoire.

5. Conclusion

This work's objective was to study the effect of mineral, organic and organo-mineral fertilisation on the agronomic parameters of the yam variety Krenglè of (*D. rotundata*).

At the end of our study, it emerges that, whether it is mineral, organic or organo-mineral fertilisation, it has an effect on the agronomic parameters of Krenglè.

High dose mineral fertilisation (NPK 15-15-15, 300 kg/ha) negatively influenced the growth and yield parameters of krenglè yam.

High doses of organic fertilisers (Cow manure (CM) 20 t/ha and poultry manure (PM) 20 t/ha) have a positive effect on vegetative growth. On the other hand, it was the medium-high doses of organic fertiliser (CM 15 t/ha and PM 15 t/ha) that allowed an increase in tuber yield from 17 to 18%.

Organo-mineral fertilisation has given fairly satisfactory results on the growth of Krenglè yam. Regarding yield, organo-mineral fertilisation combining a small dose of organic fertiliser (5 t/ha) with a medium dose of mineral fertiliser (200 kg/ha) increased the tuber yield by 15 to 25%.

Finally, the combinations of doses that can be recommended for the cultivation of Krengle are as follows: 200 kg/ha of NPK 15-15-15 associated with 5 t/ha of poultry or cow manure.

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