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Improving the performance of a traditional variety of yam produced under ferralsol poor in organic matter in the forest areas of Cote d'Ivoire

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Abstract

A study on the potential of three previous cropping of ferralsol was conducted in the forest zone of Cote d'Ivoire from 1999 to 2000. These parcels were a fallow of Chromolaena odorata, a previous yam and a previous cassava. The aim of this study was to know the soil fertility and to assess the effect on the productivity of the local variety called "bete bete", a water yam very widespread. Thus, two micro doses of NPK compared to a control without fertilizer was made for an objective of 30 t/ha. This work was carried out according to the pattern blocks of Fisher with six replications. It was obtained in 1999 under fallow the highest yield (22.4 t/ha) for T1 (24N 48P 36 K) against 18.4 t/ha and 14.4 t/ha respectively, yam and cassava subplot. In 2000, it was obtained under fallow 23.1 t/ha for T1 against 22 t/ha for T2 (70N 48P 36K). The lowest yield (12 t/ha) was obtained by T0 under cassava. The difference was significant between T0 and T1 and between T2 and T0 in 1999 and 2000 under previous fallow and previous yam. But, between T1 and T2, there was no significant difference. As cons, under previous cassava, there was no significant difference between treatments. The results showed that the fertilizer had an effect on bete bete yield. The conditions of cropping yam were more suitable under fallow than land previously cultivated but need manure to increase highly the yield.

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Introduction

Yam is an important food crop for population in Sub-saharian area. Tubers of water yam (*Dioscorea alata* L.) are an important source of carbohydrates for millions of people throughout the tropics (Marcos *et al.,* 2011). In Cote d'Ivoire, yam is classified as the first food crop in terms of the tonnage. Yam is generally grown in the beginning of April in rainy season every year. With an annual production of 6,933,000 tons, Côte d'Ivoire is the world's second largest producer after Nigeria (35,017,000 t) and before Ghana (3,550,000 t) (FAO, 2010). The five major producers of yam are located in West Africa (table 1). The cropping system is still traditional and yields are very low (6-12 t / ha) depending on the species. However, the yam is consumed by over 300 million people in tropical areas with more than 100 million Saharan (FAO, 1999). It therefore constitutes a staple food for these populations and can contribute significantly to the food security in these countries. In Côte d'Ivoire, the yam is grown mainly in the north, center and east. The cultivation of yam in the western region is still low. This activity is the mainly the fact of immigrant of the Centre. Indeed, yam is a socio-cultural food of the people of Centre. Therefore, growing yam in the Western region, the study area, it is the fact of the people of Centre who emigrated there because of the economic prosperity of this region. Today, yam is an important food crop for people through the country. It allows increasing farmers' income and can constitute a fight against poverty in rural areas. The most popular yams in Côte d'Ivoire are species of *Dioscorea alata*, *D. rotundata* and *D. cayenensis*. *D. alata* is well stored and more grown in the country. The low yields are due to traditional cropping system in the absence of input. Most of the varieties used are local cultivars that are less productive (Ettien *et al.*, 2013). However, the yam is known for its requirement in organic matter, mainly N, P and K (Onwueme, 1994 O'Sullivan, 2008; Diby *et al,* 2010; Hgaza *et al*, 2010). To this is added the lack of good quality seed for planting. Therefore, the size of planting yam seeds is high a large quantity of 2.5 to 3 tons of seed to plant 1 ha (Ettien, 2004 ; Regina *et al.,* 2011). Our study was to provide answers to improve the productivity of local yams *D. alata* by supplying fertilizers. This study aimed to highlight the potential of local yam on continuous cropping system on the same land. The results could constitute also a way to restore soil fertility to increase yield of yam by using micro-doses of NPK.

Table 1. Producing countries of yam in Africa and part of the word.

Location	*Cultivated area ('000 ha)*	*Yield (t/ha)*	*Production ('000 t)*	*Percentage of world*
Word	4.928	10.5	51.778	100
Africa	4.718	10.6	49.833	96.3
West Africa	4.443	10.8	48.101	93
Nigeria	3.045	11.5	35.017	67.7
Cote d'Ivoire	820	8.5	6.933	13.4
Ghana	299	11.9	3.55	6.9
Benin	205	8.8	1.803	3.5
Togo	63	10.2	638	1.2

Source: FAO, 2010 in Regina *et al.,* 2011

Materials and methods

Site description

The current study was carried out at Walebo (05°59 N , 6°81 W, 175 m alt.) located in forest zone in the Southern Cote d'Ivoire. The study area belongs to the sector of the Guinean rainforest area characterized by a dense rainforest (Guillaumet and Adjanohoune, 1971). The type of climate is sub-equatorial South West, hot and humid (Fiege, 1996). Belonging to the rainforest area, the locality was characterized by a bimodal rainfall distribution with two dry seasons: December-February and July-August, and two rainy seasons, from March to July (great season) and

September to November (the small season). The average rainfall ranged between 2100 and 1700 mm in decreasing from west to east in this region. The humidity varied between 85% and 90% often 100 % overnight.

Materials

The plant material is mainly composed of a traditional variety: Bete bete (*Dioscorea alata*) very consumed by the majority immigrant population of this area. The immigrant population came from the Centre of Country. Bete bete is the most produced local yam in Cote d'Ivoire.

Fertilizer and application

Mineral fertilizer NPK 12-24-18 was applied at 200 kg per hectare to obtain T1 (T1 = 24N 48P 36K). Urea 46% N was brought at 100 kg/ha to complete T1 to get treatment T2 (T2 = 70N 48P 36K). The fertilizer was split and applied to the sides of hillocks. The first application of NPK was made at the tillage and the second between 80 and 100% germination of plants. The splitting of the fertilizer was due to the length of the growing cycle of the yam which is 9 months. This was to allow the efficient use of minerals and to limit losses of minerals elements. The last treatment has been T0, no fertilizer (control). These are microdoses of chemical fertilizer which have been used during both experiment years.

Soil of experimental site

The soil in the study area has been described as a ferralsol also classified as oxisol (FAO, 2002), averagely desaturated and depleted, without any chipping. Three types of fields at the same relief were used. The relief had a fertility gradient due to the low slope (2%). Fallow is at the top of the relief followed by the previous crop yam in the mid-slope. The previous crop cassava occupied the lower slope. Soil was described according to its chemical and its physical parameters.

Experiment design, land preparation and planting method

Randomized complete block (Fisher) was applied for each field. The mounds have been used as planting method without any tillage. The density of plantation was 10 000 plants / ha. It means 1 plant/m^2. The size of yam seed was 280 g. It is farmer's practice. Each trial was composed of six replications with three treat (T0, T1, T2). The size of elementary plot was 6 m x 5 m for measurements.

Statistical analysis

Analysis of variance was carried out with the General Linear Model (GLM) procedure on homogeneous data obtained using SAS version 8.2 (SAS ® Institute, Carry, NC, USA). This analysis yielded averages and significant differences or not between the means. Mean values were separated by using the method of least significant difference (LSD). Different letters indicating the values that were significantly different were used to show these differences. The probabilities were judged at the threshold of $\alpha = 0.05$. The validity of the linear model can be written as follows:

Yield = general mean + dose effect + variety effect + bloc effect + dose*variety + residual error. The equation is $Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + \delta k + \varepsilon_{ijk}$, where:

Y_{ij} : Yield
δk : bloc effect
μ : constant
γ_{ij} :: interaction dose*variety
α_i : variety effect
ε_{ijk} : residual error

Results

Soil properties

The fallow was 5 years old while the previous cassava and the previous yam were continuously used from 1997 to 1999 before the experiment. Soil properties described are mentioned in the figure 1 and in the table 2. The figure 1 described the type of soil in the area.

Table 2. Soil properties of each field.

	Depth (cm)	pH	C g/kg	N g/kg	M.O g/kg	C/N	P_2O_{5total} mg/kg	CEC cmol+/kg	Ca cmol+/kg	Mg cmol+/kg	K cmol+/kg	S	V%
Fallow	0-30	6.1	0.12	0.13	0.21	10,0	447	5.4	1.72	0.3	0.04	2.06	38
	30-60	6.8	0.24	0.04	0.41	7,0	295	2.0	0.47	0.15	0.01	0.63	31
Yam	0-30	6.2	0.92	0.10	1.60	10,0	417	4,0	1.39	0.24	0.03	1.96	41
	30-60	6.7	0.54	0.05	0.93	11,0	305	1.4	0.41	0.07	0	0.48	34
Cassava	0-30	6.0	0.77	0.06	1.32	12,0	325	3.3	1,00	0.19	0.00	1.21	37
	30-60	5.8	0.12	0.01	0.21	10,0	237	1.8	0.21	0.08	0.02	0.29	16

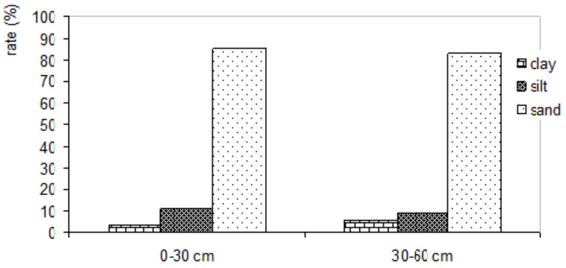

Fig. 1: Type of soil in the experiment site

Chemical analyzes were conducted on total nitrogen, the rate of organic carbon, pH, cation exchange capacity (CEC), Ca, Na, Mg, K, exchangeable bases and total phosphorus. The soil samples for analyzes were made on two levels of the soil profile: 0-30 cm and 30-60 cm. The results are shown in Table 2. The soil was loose on all three plots with a predominance of fine sand. Content of clay was low.

In the analysis of physico-chemical parameters, it was noted that base saturation percentage (BSP), the sum of exchangeable bases (S) and pH had complied with the criteria of classification: 1 meq/100 g < S < 8 meq /100 g, 20 % < BSP < 80 % and 4.5 < pH < 6.5. According to the soil value above, the three kind of soils belong to the subclass of ferralsol, moderately desaturated and depleted.

Yields of yam and fertilizers effects in 1999

Concerning only the effect of fertilizer doses on yield (Figure 2) in 1999, the treatment T2 (70N 48P 36K) yielded the highest (19.8 t/ha) and the lowest yield was recorded by the T0 control (12.4 t/ha). But it didn't exist significant differences between T1 and T2 while the difference was significant between T0 and T1 on the one hand and between T2 and T0 secondly at the 5% level. Furthermore, the fertilizer effect was significant ($p < 0.05$) from one year to another. The figure 3 shows the effects of treatments in the previous cropping in 1999. The dose T1 (24N 48P 36K) under previous fallow yielded the highest (22.4 t / ha), while T2 (70N 48P 36K) gave 21.7 t / ha and T0 control (without fertilizer) a yield of 15.6 t / ha. Statistical analyzes (Duncan test) gave a non-significant difference between T1 and T2 and a significant difference, on the one hand, between T0 and T1 ($p \leq 0.05$) and on the other hand between T0 and T2 ($p \leq 0.05$). The fallow productivity effect was very highly significant ($p \leq 0.001$). On the previous yams, average yields ranged from a dose of fertilizer to another. The results show the superiority of T1 versus T2 and T0 respectively dose. However, statistical analysis showed that there existed no significant difference between T1 and T2, while it was a significant difference on the one hand, between T0 and T1 and T2 and also between T0 ($p < 0.05$). The previous yam had a significant effect ($p < 0.05$) on the performance of yam. As in the previous cassava, the results showed that T2 had the highest (14.6 t/ha) against 14.4 and 13.4 t/ha respectively for T1 and T0. The yield difference was neither significant between T0, T1 and T2. The previous cassava had no significant effect on the performance of the water yam bete bete whatever treatment.

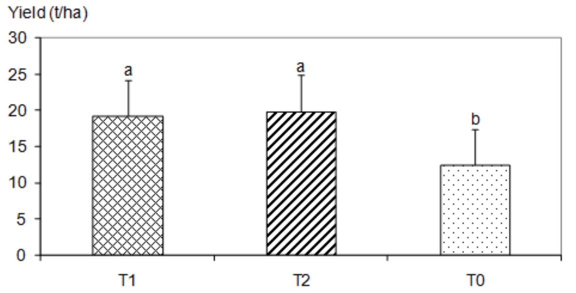

Fig. 2. Mean of yam yields per treatment under the parcels in 1999.

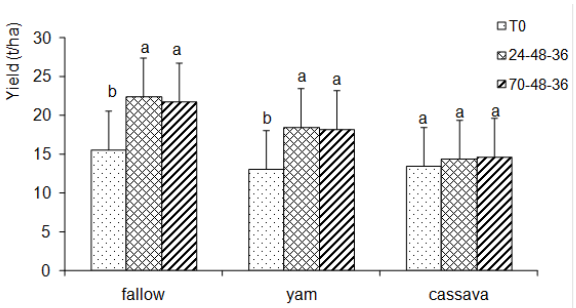

Fig. 3. Means of yam yields per treatment per previous crop in 1999.

Means with the same letters are not significantly different. α=0.05

Yields of yam and fertilizers effects in 2000

Regarding the effect of treatment under the previous cropping in 2000, it was actually noted a highly significant effect previous crop ($p \leq 0.01$) each year. This shows that the previous crop has influenced the performance of the yam. Furthermore, the fertilizer effect was significant ($p \leq 0.05$) from one year to another. By cons, there was no interaction between fertilization and previous crop, which means that the effect of fertilizers doses was the same in every plot. Concerning the effects of means of fertilizers doses on yield in 2000, the dose T1 (24N 48P 36K) yielded the highest (18.2 t/ha) while T2 recorded a yield of 17.2 t/ha. The lowest yield was obtained by T0 (13.6 t/ha). But it did not exist significant difference between T1 and T2 while the difference was significant ($p < 0.05$) between T0 and T1 on the one hand and between T2 and T0 on the other hand at the 5% (Figure 4).

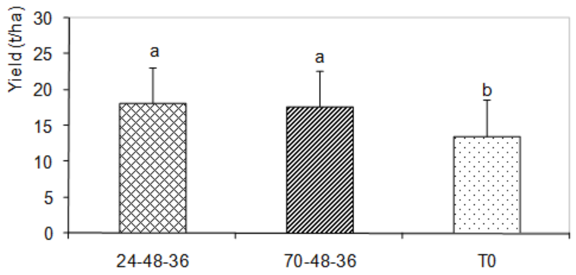

Fig. 4. Mean of yam yields per treatment under the parcels in 2000.

Means with the same letters are not significantly different. α=0.05

The figure 5 shows the yields of water yam bete bete obtained in each previous crop under treatments in 2000. It was noted that T1 under fallow obtained the highest yield (23.1 t/ha), while T2 recorded a yield of 22.0 t/ha. T0 control (without fertilizer) obtained 15.6 t/ha. Statistical analyzes (Duncan test) gave a non-significant difference between T1 and T2 and a significant difference on the one hand, between T0 and T1 ($p \leq 0.05$) and in the other hand between T0 and T2 ($p \leq 0.05$). The effect of fallow on yam productivity was very highly significant ($p \leq 0.001$). On the previous yam, the results showed the superiority of T1 versus T2 and T0 respectively. However, statistical analysis showed that there existed no significant difference between T1 and T2 while it was a significant difference between, on the one hand between T0 and T1 and between T2 and T0 in the other hand ($p < 0.05$) every year. The previous yam had a significant effect ($p < 0.05$) on the performance of yam.

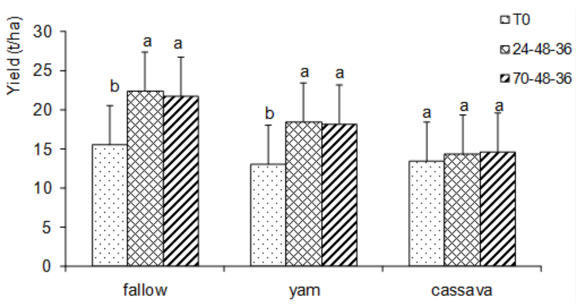

Fig. 5. Means of yam yields per treatment per previous crop in 2000.

Means with the same letters are not significantly different. α=0.05

Regarding the previous cassava, the results showed that it is T2 which recorded the highest yield (14.6 t/ha) against 14.4 t/ha and 13.4 t/ha respectively for T1 and T0. However, the difference of yield was not significant between treatments according to each year. The effect of fallow on yam productivity was very highly significant ($p \leq 0.001$) followed respectively by the previous yam and cassava. The lowest yield was obtained under previous cassava.

Figure 6 shows the average yield per year. In 1999, it was obtained under *Chromolaena odorata* fallow the highest yield whatever the level of fertilization. The highest yields were recorded in 2000 under fallow with significant differences between the three plots.

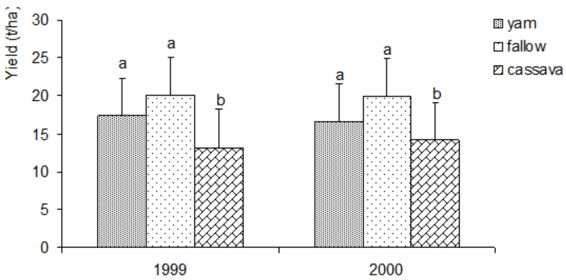

Fig. 6. Means of yam yields per previous crop in both 1999 and 2000.

Means with the same letters are not significantly different. $\alpha=0.05$ LSD0.05=3.5965

Discussion

Soil properties

The rate of organic matter (OM) ranged between 0.21% and 0.41% respectively under fallow, surface and depth while under yam, it fluctuated between 0.93 and 1.60% for the same levels. Under previous cassava, organic matter content ranged between 0.81% at the surface and 0.62% in depth. We noted that the rate of organic matter were low in all three plots. However, the need for nitrogen and potash are important for yams to obtain a good yield (Orkwor *et al.,* 1998; Vernier, 1997). For the fallow, the C/N ratio was normal at surface because ranged between 9 and 12, and low in the depth. It was normal for the previous yam and cassava in surface and in depth. This means that the land clearing followed by burning carried out by farmers, would present damage on microbial activity in the recycling of the OM. Indeed, the use of heat eliminates the soil fauna at the surface and inhibits certain microbiological activities which contribute to recycling OM and soil fertility. According to Monnier *et al.* (1986), the clearing of natural vegetation for its agricultural development is generally accompanied by a rapid decline in organic matter content. These processes of rapid mineralization of organic matter in forest areas could explain the low N content in the soil. Indeed, the soil used in the test is mostly sandy at surface and very low clay at depth. Previous agricultural holdings continuously on the same soil have certainly contributed to the degradation and depletion of these sandy soils. The pH was located above 5.5 and below 8.5. These values are normal and conducive to good biological activity. For the cation exchange capacity (CEC) and exchangeable bases, all the highest values were recorded under fallow. Despite these low chemical values, it showed that under fallow, the potentials are more favorable and acceptable. This reflects the smooth running processes of restoring soil fertility under fallow unlike the other two types of soil. This also shows that the cultivation continues such soils has resulted in the loss of their fertility Productivity of these soils requires thus an amendment to allow optimal growth of yam.

Yields and components

The results showed that it was under the previous fallow that bete bete is most productive, followed respectively by previous yam and cassava. However, the productivity difference observed between the previous yam and fallow was not significant. Doses of T1 and T2 have achieved a higher yield than the control in both 2000 and 1999. There was no significant difference between T1 and T2. Raising the dose of fertilizer 24 N to 70 N resulted in no significant increase yields regardless of the previous crop over the two years, with the exception of the previous fallow. Whatever the previous cropping, the response of the water yam bete bete to doses of mineral fertilizer was similar from one year to another. These results are in agreement with those obtained by Ettien *et al.* (2013) in the savanna, although the doses of NPK applied are different. These results showed the response of the cultivar bete bete to mineral fertilizer as showed by Hgaza *et al.* (2012). The increase in yield was due to an increase of weight unit of tubers (Vernier, 1997), which also resulted in a significant accumulation of dry matter (Onwueme and Haverkort, 1991) where the conditions for uptake of N, P and K are performed correctly (Diby *et al.,* 2011). This author has studied the factors influencing the uptake of major elements in the mineral nutrition of yams. Similar results were obtained before by Oyolu (1982). This author has referred to the irregularity of the response of varieties to major elements in yam nutrition. The contribution of fertilization can only be efficient if done when the nitrogen and potash needs are optimal for yam (Hamid, 1973; Hgaza *et al.,* 2012). These phases were targeted in studies carried out in savanna area of Cote d'Ivoire (Hgaza *et al.,* 2010). The yield obtained under each plots were important because more than the national reference (10 to 12 t/ha). But the objective of 30 t/ha was not reached. The doses of fertilizers were not appropriate. In the forest zone leaching phenomenon is important in soils (Ettien, 2004). For this, special precautions should be taken to allow proper assimilation of nutrients by the cultivars. Here, the first fertilizer application was made during critical extreme hungers of nitrogen and potash namely the 4th week after planting, when the plants were about 80% germination (Castillo *et al.,* 1989; Adeniji *et al.,* 2002; Ettien and 2004). The three types of plots had different effects on the productivity of yam. These results are consistent with those observed in Benin on tests with previous cropping legume (Carsky *et al.,* 1999). These observations were also made by Degras (1993). The best yields under fallow showed that soil properties appear to be more suitable than in other previous crops. In the absence of fertilizer, it is recommended to grow yam under fallow. This explains why african farmers have always used fallow for yam placed in head crop rotation. The additionnal microdose of urea was little benefit for yam in each plot. This shows that it is important to target specific phenological phases of yam before applying nitrogen. The other major elements (K and P) remained constant should have been completed for hope observe a significant increase yield. These results show the importance of nitrogen in yam nutrition (Obigbesan and Agboola, 1978; Lyonga, 1984). Recent studies carried out by Diby *et al.* (2011) and Hgaza *et al.* (2011) have made significant contributions to the understanding of yam nutrition using two main species D. alata and D. rotundata under West African tropical ferralsols. Soil organic matter is an important indicator of soil fertility thus soil management should be done to put available the two main different fraction (Kanokporn *et al.,* 2013) according to him, in cultivated soil, the active fraction of OM is influenced by previous management. Our study showed three practices to manage soil to grow yam. The high results of yield under fallow followed by soil under previous yam and cassava respectively were in agreement of those of Kanokporn *et al.* (2013) and Clinton *et al.* (2011). This study has highlighted the issue of management ferralsols under natural vegetation, poor in organic matter and in the absence of mineral fertilizer. Improve yield of yam and its cropping system needs the use of inputs and a good management of soil to maintain organic matter because yam's cycle is annual and is a crop demanding organic matter.

Conclusion

The West African ferralsols are poor soils with low agricultural potential, especially for yam. However, it has been noted that soil under fallow were more productive than soil under previous yam and cassava. Thus, these lastest soils need more nutrients to increase yield of yam. This reflects the good processes of restoring soil fertility under fallow. It was noted that increasing nitrogen content did not increase significantly the yield of yam. It would be useful to target the needs and apply nitrogen fertilizer at the suitable stage of development of the yam. A good management of soil is a key issue to improve yam production for food security. The application of fertilizer should consider the specific quantities, weather conditions and topography.

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