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Assessing the potential of new yam cultivars (*Dioscorea alata*) in semitraditional cropping system on low fertile ferrallitisols in the savanna zone of Cote d'Ivoire

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Abstract

To improve yam production in West Africa and stabilize its cropping system on Dystric ferrallitisols, a varietal test was conducted at Bringakro (6°401'N, 5°091'O, alt. 150 m) in the savanna zone at the Centre of Côte d'Ivoire. Five improved cultivars of *Dioscorea alata* (TDa 95-079; TDa 95-226; TDa 95-387; TDa 98-1176; TDa 98-1177) and two local checks (Florido et Bete-Bete) were used in 2000 and 2001. Yields, multiplication factor and post-harvest losses ratio were collected annually for each variety. Results of statistical analysis showed highest yields (20.31 t ha^{-1} – 15.73 t ha^{-1}) for TDa98-1176 while lowest (9.37 and 10.50 t.ha^{-1}) were obtained by local Bete-Bete. This improved variety has also the highest multiplication factor (5.62% - 7.25%) and its' post-harvest loss ratio (19.23% – 41.58%) was among the lowest. The review of these results showed that the assession TDa98-1176 can insure equivalent yield of Bete bete if soil is well managed without any fertilization under ferrallitisol.

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Introduction

Yam (Dioscorea spp.) is one of the most important food staple crop in West Africa. In addition to its nature food in this area, yam constitutes also a social, cultural and economic factor (Baco, 2007a). Unfortunately, its production is below the demand as food for West african population in spite of the great annual production of third first producers as 3 million tons in Cote d'Ivoire (3.8% of total production), 4 million tons in Ghana and 27 million tons in Nigeria. This gape is essentially the consequence of the use of low yielding (7 – 12 tha-1) traditional cultivars in low input management condition (Girardin, 1996; Asiedu, 2001; Ettien *et al.,* 2013). However, there is actually a wide genotype variability among the improve yam varieties released by research institutes as International Institute of Tropical Agriculture (IITA) (Asiedu, 2001). They have highest yield potential (more than 30 tha-1) that need to be assessed in different agro-ecologies and agro-ecosystems for accurate recommendation.

In fact, there is difference between traditional planting system (10 000 tons per hectare) and the recommended planting density with improved varieties (60 000 tons per hectare) according to Suja (1995) mainly due to lower seed weight (350 - 2500 g) in traditional agrosystems (Ettien *et al.,* 2013) depending on shifting cultivation as consequence of the depletion of soil inherent fertility which mainly concerned soil organic matter, Nitrogen, P-phosphorus and potassium-K (Rodrigez-Montero, 1997; Ettien, 2004; O'Sullivan, 2008; Asiedu, 2001; Hgaza *et al.,* 2010; Diby *et al.,* 2011). Furthermore, post-harvest threat was recorded as poor conservation potential of traditional yam varieties. All these factors are contributing for increasing food insecurity in West Africa likewise for Cote d'Ivoire where, D. alata is the preferred yam food mostly cultivated in the Guinea savanna zone.

The actual study is initiated to explore the potential of some new improved yam varieties the Guinea savanna zone of Cote d'Ivoire under low input management condition. The aim was to identify some D. alata cultivars that are friendly with farmers' practices and cropping ecological conditions including soil, rainfall and storage constraint.

Material and methods

Site description

The current study was carried out in Bringakro (6°401'N, 5°091'O, 150 m alts) in the transition zone forest-savannah of Cote d'Ivoire corresponding to a Guinea savanna ecology. The type of climate was an equatorial transition with a bimodal rainfall ranging from 900 to 1300 mm per year (Tschannen *et al.,* 2005). An average temperature of 27 ° C and a relative humidity of air around 70% characterized the landscape. The site was mainly herbaceous vegetation dominated by Imperata cylindrica. The annual rainfall of 2000 and 2001 are shown in Figure 1 respectively.

The trial was laid on a foot slope topographic position of the landscape with a gentle slope of 2 -5%. The soil was lateritic moderate leached soil as Dystric Ferrallitisol (FAO, 1998).

Sampling and analysis of soil

Before the experiment, soil samples were taken in 0 – 30 cm and 30 – 70 cm depth for composite sample of the five soil profiles done at each of the four corners and the centre of the studied area. The composite sample of each depth was dried, grounded and sieved for physical and chemical characterization: particle size analysis (Gee and Bauder, 1986), soil content of total carbon-Ct (Walkley and Black, 1934), available phosphorus (Bray I), total Nitrogen-Nt (Kjeldahl) and exchangeable cations (potassium-K, Magnesium (Mg) and Calcium (Ca)) were determined. Acetate of ammonium extraction method was used for last nutrients before spectrometry method for reading (Atomic absorption for Ca and Mg; Flame spectrometry for K). Analysis were processed as decribed by Carter and Gregorich (2006). .

Clones of yam evaluated

Five clones of D. alata (V1 = TDa 95/00079, V2 = TDa 95/00226, V3 = TDa 95/00387, V4 = TDa 98/ 01176, V5 = TDa 98/01177) were compared with two local yams used as control (V6 = Bete bete, V7 = Florido) during successive cropping seasons from 2000 to 2001 in an experimental randomized complete blocks design including four replications. The clones and local checks have the same cycle duration (8 months). The mini-sett techniques with small size of seed were used for planting on ridges.

Implementation of the trial

A plot with 650 m^2 has been cleaned and tilled using hand-hoe. Elementary plots in ridges with size 15 m over 1 m were made. Four replications consisting of seven basic plots were established at the beginning of May for eight months of vegetation. Improved varieties seeds and local checks have been planted with a size of 70 g in a planting density of 27,000 plants per hectare. The trials were repeated in 2000 and 2001.

Data collection

The daily rainfall was recorded using a rain gauge installed in the studied site. At maturity, the fresh weight (FW) of the harvested tubers per variety and per ridge was weighed before yield calculation. The multiplicative factor (MF) defined as the ratio of the fresh weight of the harvested tuber weight seed planted, was also calculated for each variety every year. After storage period (January to May), tubers were sorted by variety (one per month) in order to eliminate the wounded, rotten or infested for determination of the percentage of releases (discarded) represented by the variable-REL. They were expressed as a percentage of the total weight of each variety stored.

Statistical analysis

Analysis of variance (ANOVA) factorial type for yield, MF and REL were made year by year using SAS software version 8.2 considering the variety as the factor studied. Similarly, the combined data from two years of the experiment were used to determine the mean values of general variables. Mean values were separated by the method of least significant difference (LSD) by different letters indicating the values that were significantly different. The probabilities were judged at the threshold of $\alpha = 0.05$.

Results

Soil fertility and production

Table 1 showed soil carbon, nitrogen, potassium, calcium and magnesium contents as well as soil particle size and the acidity in 0 - 30 cm and 30 - 70 cm depths. Carbon values in top and sub soils are 5.3 g kg^{-1} and 4.5 g kg-1 respectively. Nitrogen in the same level of soil is 0.5 g kg^{-1} in the range of5.6 to 5.7 for pH. These values were low except the pH that revealed a moderate acidity. The texture was dominated by sand (873-888 g kg^{-1}) with fine particles (clay + Limon) content not exceeding 200 g kg^{-1} . Low levels of exchangeable cations (K^+, Ca^{2+} and Mg $^{2+}$) were also observed, especially for the potassium-K.

Table 1. Physico-chemical parameters of the soil.

	Soil properties	
	0 – 30 cm	30 – 70 cm
Clay (g kg^{-1})	41	47
Loam (g kg^{-1})	86	64
Sand (g kg^{-1})	873	888
pHwater	5.6	5.7
C (g kg^{-1})	5.3	4.5
N (g kg^{-1}) P_2O_5 total (mgkg-1)	0.5 227	0.5 199
K (cmol kg^{-1})	0.04	0.12
Ca (cmol kg^{-1})	0.25	0.25
Mg (cmol kg^{-1})	0.25	0.25

Yield of yam varieties, multiplicative factors and post harvest losses

The analysis of variance of the variables (yield, MF, REL) shows highly significant effects of the variety ($P < 0.01$) for all the studied parameters in 2001. There is also a significant effect of repetition on yield and MF. Table 2 shows the classification of the mean values of related parameters obtained by variety.

Excepted for REL, the general means (GM) have been decreasing from 2000 to 2001. Indeed, the yield ranged from 20.31 (V4) to 10.50 (V7) in 2000 and from 15.73 (V4) to 9.37 (V7) in 2001. The yield of V6 and V7 were respectively 17.10 t ha^{-1} and 9.90 tha^{-1} in 2000 and 2001. The yield of V6 was 10.50 t ha^{-1} and 9.90 and 9.37 t ha^{-1} respectively with no significant difference according to the LSD (3.174 t ha^{-1}) in 2000 and 2001.

Table 2. Average performance, the multiplication factor and losses for each variety in 2000 and 2001.

	Means values					
	Yield (t ha^{-1})		MF (%)		Los (%)	
	2000	2001	2000	2001	2000	2001
V1	15.15b	10.67bc	5.40b	3.81bc	19.32b	51.84c
V2	15.18b	11.07bc	5.42b	3.95bc	42.95a	44.33c
V3	17.17b	11.77bc	6.13b	4.20bc	5.81b	53.88bc
V4	20.31a	15.73a	7.25a	5.62a	19.23b	41.58c
V5	14.63b	13.12ab	5.22b	4.68ab	15.27b	45.11c
V6	17.10b	9.90c	6.10b	3,53c	14.39b	75.30ab
V7	10.50c	9.37c	3.75c	3,34c	18.82b	78.00a
Lsd.05	2.919	3.174	1.042	1,133	15.434	21.634

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

Despite of the lower yields (10 t ha^{-1}(V1) - 42% (V6)), observed for improved varieties, V6 has recorded highest yield ranking among the varieties with high potential in 2000. The MF (%), which ranged from 7.25 (V4) to 3.75 (V7) in 2000 have been similar trends in 2001 ranging from 5.62 (V4) to 3.34 (V6). But, decreasing mean values of REL (%) is observed from 2000 [5.81% (V3) – 42.95% (V2)] to 2001 [41.58 (V4) to 78 (V7)]. Between the local varieties used as control, V6 (Florido) has higher potential than V7 (Bete bete).

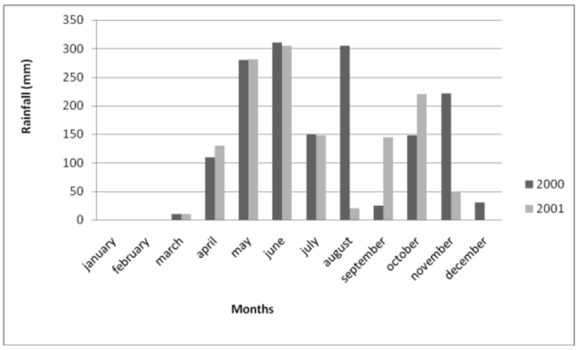

Fig. 1. Monthly rainfall recorded in 2000 and 2001.

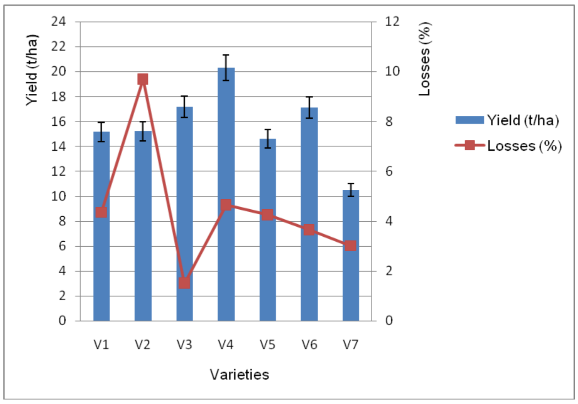

Fig. 2. General means for the yield and the losses in 2000 and 2001.

(yield; $lsd_{0.05}$ = 2.29)

(Los ; $lsd_{0.05}$ = 12.82)

Table 3. Mean of multiplying factor for variety and mean of year.

Varieties	M F (%)
V1	4.60b
V2	4.70b
V3	5.20b
V4	6.45a
V5	4.95b
V6	4.80b
V7	3.55c
2000	5.60a
2001	4.15b

Means with the same letter are not significantly, α = 0.05.

Highly significant effects (P <0.01) of year and variety on the yield, MF and REL are observed likewise for the interaction of Year x variety (P <0.01). Table 3 shows that the average value of MF was greater for V4 (6.45%) in 2000 (5.60%) than in 2001. Figure 2 confirms and the high potential of this cultivar for conservation. In contrast, greater rejection rate is noticed for V1 despite its acceptable yielding performance compared to V7. Nevertheless, V7 is preferred for its highest storage stability. The yam variety V4 appears among the best variety. The overall yield mean values is about 15.71 t ha^{-1} in 2000 and 11.65 t ha^{-1} in 2001. For a rejection rate ranging from 19.4% to 55.72% (Figure 3). These yields are low with an high rejection rate as recorded in 2001.

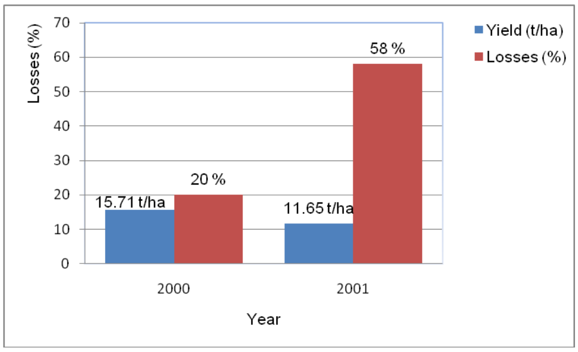

Fig. 3. General means of yield and losses in 2000 and 2001. (yield: lsd0.05 = 1.22; losses: lsd0.05 = 6.85)

Discussion

Soil properties and potential production of yams

Results on soil properties indicated that the study was conducted on a poor fertile Ferrallitisol (CPCS, 1967), with an unbalanced texture. The acidity and ionic balance Ca: Mg indicated the possibility of soil N, P, K and Ca deficiencies . However, N, P and K are required nutrients for high yielding of yam (Onwueme 1978; Hgaza et al., 2010, O'sullivan, 2010). Moreover, Calcium-Ca and Magnesium-Mg ratio of 1: 1 was at the threshold limit reducing Magnesium nutrition for chlorophyll synthesis. That physiological threat cam significantly impaired the crop quality (O'sullivan, 2010). Indeed, Mg contributes to the resistance of crops to diseases, increases protein and sugar or starch. Therefore, Mg availability should be improved in the studied soil adjusting the K / Mg ratio. However, antagonistic effect was reported between excess of Mg and K uptake and vise versa (O'Sullivan, 2010). This work didn't study especially this aspect in yam growth but it is important to explore this issue in the future. In the specific case of yam, the major nutrients are known: N, P, K and Mg and Ca values are considered moderate to obtain a high yield of yam at maturity (Diby *et al.,* 2011; O'Sullivan and Ernest, 2008).

The yields observed for the improved varieties were greater than that of the local varieties (Florido and Bete bete) as controls. The local variety named Florido has performed as much as some improved varieties of D. alata in 2000 ranging between 15 t.ha^{-1} and 20 t.ha^{-1} well above the national yam yield of 7 t.ha^{-1} (Rodriguez, 1983). Variety a98-1176 (V4) was considered as the best for its high potential production (yield and MF) without under low input management condition. Despite its performance declining about 22.5% in 2001 after a of20.31 t ha^{-1} obtained in 2000, its overall yield was higher than that of the control cultivars. Rainfall in 2000 was normal, while that of 2001 was an extreme case. It is mentioned that rain is very important for yam during its growth (Some *et al.,* 1995; Darwish *et al.,* 2006). Despite this, a98-1176 has obtained 15.73 t ha^{-1} in 2001, while local varieties yields varied between 9 and 10 t ha^{-1}. It is therefore likely that in one year normal rainfall in 2001, the rate of decrease in performance observed in V4 is smaller. However, yields (15.71 tha^{-1}) were generally low, judging by the performance of Florido an improved variety introduced in Côte d'Ivoire in 1983 which potential would be 40 t ha^{-1} (Rodriguez *et al.,* 1983). This is the consequence of low soil potential fertility l as described and yield losses caused by low rainfall in 2001. However, despite the heaviest rainfall in 2000, the overall average yield was only 15.71 t ha^{-1}. This low production can be attributed to yam genotype difference. Therefore, ecology condition, genotype difference as well as soil properties accounted for yam production. Moreover, the introduction of improved varieties alone is not sufficient to increase the yield of yam cultivation in the semi-traditional system in Côte d'Ivoire. A manuring is then necessary to achieve the high yield potential of varieties. Indeed, several studies have demonstrated the usefulness of N, P, K, Mg and Ca for yam production (Onwueme, 1994; Hgaza *et al.,* 2012).

Ability of improved yam varieties to post-harvest

A rate of postharvest loss among the lowest was recorded for the variety a98-1176 in addition to its high performance and multiplicative factor. Indeed, the ability of varieties to longer storage is an asset to the daily food availability and the availability of seed for the next season. Therefore, this parameter has been studied extensively in West Africa (Tschannen, *et al.,* 2005). These losses are due to early germination, injuries during harvest and transportation from field (Efiuvwevwer and Ejikeme, 1998) or the attack of pests such as nematodes and mealybugs. The specificity of this study has taken into account the losses due to injuries at harvest.

Because post-harvest pest treatment is rarely applied at farmers' level, it is recommended to avoid injuries during harvest. However, the production of phenol responsible for the natural protection of yam tubers against insect attacks can be recommended. It is therefore important to consider phenol production ability in breeding criteria. *D. alata* species already recognized for their good ability (Asiedu, 2001) as confirmed by a98-1176 (TDa 98/01176) in this study could be used to cross gene of yam by using molecular biology techniques as recommended by Tschannen *et al.* (2005) for improving yam productivity in West Africa.

Conclusion

This study showed that the improved yam varieties have real agronomic potential and storage suitability. The variety named TDa 98/1176 reached a yield up to 20 t / ha in the semi-traditional cropping system on relatively poor organic matter in Ferrallitisols without amendment. Its multiplication factor is high and ranked among the best. However, this variety has shown that it was less suitable for storage because it has made significant losses unlike the others. Postharvest losses of the new varieties were generally low. Local Florido showed good potential. The technique of mini fragment tested in this work is an advantage for the productivity of yams in West Africa for food security.

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