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Effect of the Soil and Sawdust Substrates on the Sprouting Rates of Yam Minissetts Varieties in the Guinea Sudan Zone of Benin

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Abstract

Yam (Dioscorea spp.) is a staple food for the Beninese population and is considered a food of great value. Despite its importance, production is limited by several factors, including the lack of planting material. In order to contribute to the sustainable production of yam plants, the technique of mini-fragmentation (minissett) was carried out as part of a land survey in the Guinea-Sudan zone in Benin. The objective of the study is to evaluate the effect of soil and sawdust substrates and interaction factors on sprouting rates of yam minissetts varieties. The experimental design consisted of a randomized complete block using a partial nested model with four factors (treatment, variety, repetition, year) conducted at the village level in the Akpéro and Gbanlin sites in central Benin. Substrate treatment varied between sites (sawdust (Sa) and sandy-clay (Scs) soil at Akpero, basket with sandy-clay soil (BScs) and basket with sawdust (BSa) at Gbanlin) according to smallholder farmers' preference. For each treatment, early yam (Gangni, yanabo) and late maturing (kokoro) varieties were used replicated four times during the 2002-2003 and 2003-2004 seasons. Substrates of the basket were tested at Gbanlin by considering 5 alternating layers of mini-strata with sandy-clay soil or sawdust for the bed of the nursery. The healthy yam plants used ranged from 500 to 800 g, cut into 25-30 g portions with early and late maturing varieties of yams. The highest sprouting rates were significantly recorded in sandy-clay soils (no-basket). Treatment, Variety, Year and Treatment × Variety interactions were significant at the site.

Keywords: Benin, Yam Seedling; Minifragmentation; On-farm research; Sustainable production

Introduction

Yam (Dioscorea spp.) is a staple food for the Beninese population and is considered a delicacy. Yams provide multiple opportunities for poverty reduction and nutrition. Despite its importance, production is limited by several factors, including the scarcity of planting material, pests and diseases (viruses, fungi, etc.) that cause considerable losses before and after harvest (Acquah & Evange, 1991; Aighewi et al., 1998; Akoroda and Okonmah, 1982). Cultivated species are preserved and propagated in the form of cuttings or vegetative propagation (Coursey, 1966, Hamon et al., 1995). About 25 to 33% of production is usually reserved for multiplication and the size of the seed beet depends on the size of the tuber to be obtained (Hahn et al., 1987, Hahn et al., 1994). Planting materials alone account for about 40 to 50% of the cost of production because of their limited availability (Dossou, 2000a and 2000b). In Benin, an average of 500,000 tons of yam seeds were buried each year (Dossou pers Comm, 2006). The lack of yam seed for crop production, the risk of spread of viruses and diseases in the traditional system of yam seed production reflected a real need for improvement of the production system, especially in of high production and yam consumption. The Umudike National Research Institute for Root and Tuber Plants (Nrcri) in Nigeria and the International Institute of Tropical Agriculture (IITA) in Ibadan in recent years have focused their research efforts on improvement of a microburst (minissetts) technique (Otoo et al., 1987; Otoo et al., 2001). Yam minisett technology has been developed to improve the insufficient supply and lack of high quality, disease-free seeds in yam production. It has been estimated that one hectare of minisett field would produce seeds capable of planting 3.7 hectares while seeds of the same hectare with the traditional practice could produce seeds to plant 1.3 hectares of land (Degras, 1978; Degras, 1982; Degras, 1989). This method produces small whole seedlings, each weighing between 200 and 800 g, from minisetts as small as around 25 g. The mini-products are generally intended to produce a large number of small tubers for planting and not to produce tubers for consumption and marketing (Okoli and Akoroda, 1995, Rochers and Evensen, 1989, Sanni et al., 2002). On the basis of these constraints, Research and Development (R & D) within the framework of on-farm research implementing in central Benin the technique of minissetts: i) selection of healthy mother seeds in the field during the growing season and the harvest by marking infected and diseased plants to avoid the spread tuber diseases and pathogens (mainly viruses and nematodes); (ii) choosing the size of the minissetts (taking into account the yam species, planting material size accepted by the farmers); iii) use of available local materials (sawdust, sandy soil, basket, etc.) for the nursery bed. The objective of the study is to evaluate the effect of soil and sawdust substrates and interaction factors on the sprouting rates of yam minissetts varieties in the Guinea Sudan zone of Benin.

Materials and Methods

Study sites:

The study was carried out in the Guinea-Sudan transition zone of Benin (centre of Benin) in two sites: Akpéro and Gbanlin (District of Ouessè) with latitudes 7 °45 ' and 8 °40' North and longitudes 2 °20 ' and 2 °35 ' East. The climate is tropical transitional Guinea-Sudan with a rainfall distribution gradient from bimodal (Southern Benin) to monomodal (Northern Benin). The average annual rainfall during the study period were 1043 mm (2002), 1455 mm (2003) and 994 mm (2004) (Fig. 1).

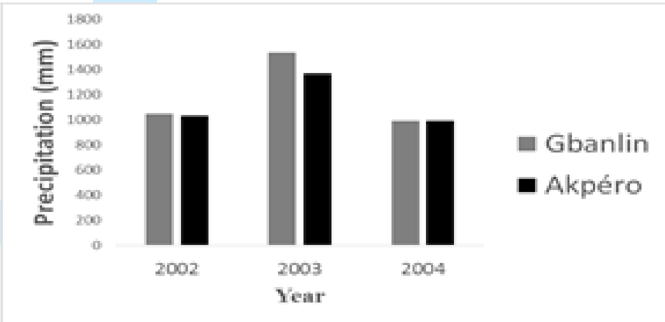

Figure: 1 Annual rainfall distribution in the two village sites (Akpéro and Gbanlin) in the 2002–2004 cropping seasons, in the Guinea-Sudan transition zone of Benin

The soils are plinthosols (Gbanlin and Akpe´ro) (Agossou & Mouïinou, 2002). Akpéro and Gbanlin are located on a plateau. Akpero with low demographic pressure on land is close to forest while Gbanlin with relatively high demographic pressure are far. The initial chemical properties of the soils are presented in Table 1 (Maliki et al., 2012).

Table 1: Initial soil characteristics at the beginning of the experiment at 0-10 and 10-20 cm layers in the two village sites (Gbanlin and Akpéro), Benin

	Akpéro		**Gbanlin**	
Depth (cm)	0-10	10-20	0-10	10-20
	"Plinthosols"		"Plinthosols"	
Clay%	6.6	7.3	5.8	5.7
Silt%	11.7	11.8	5.8	5.6
Sand%	81.7	80.9	88.4	88.7
C%	1.3	1.0	0.7	0.8
N%	0.1	0.09	0.06	0.08
C: N ratio	11.7	11.4	11.7	9.7
OM%	2.2	1.8	1.2	1.4
pH water	6.7	6.7	6.6	6.3
Bray P, ppm	20.1	14.9	7.0	4.0

Source: Maliki et al., 2012

Data are the means ± SD (Standard deviation); C%: soil carbon concentration (%); N%: soil nitrogen concentration (%); OM% (= 1.72× C%): soil organic matter content (%); C: N ratio: Index of biodegradability or ratio of soil carbon to nitrogen; Bray P, ppm: soil phosphorus (ppm). The initial soil organic matter (SOM) contents varied from one site to another, ranging from 0.93 to 2.25%, and the C: N ratio ranged from 8.7 to 11.7. Available P levels were very low and varied from 3.0 to 20.1 ppm. Soil N concentration ranged from 0.056 to 0.112%. N, P and SOM contents were significantly higher in 0-10 cm than in 10-20 cm depth, except at Gbanlin site for N and SOM. Akpéro had the highest values of carbon (C%), N%, P (ppm), and organic matter (%) for both soil depths (Maliki et al., 2012). There is a rising gradient of fertility from the continuous cropping system on degraded soils in Gbanlin towards the forests in Akpero. This degradation is related to soil organic matter decrease, which leads to nutrient depletion (nutrients removed in the crop harvest, leaching and erosion) Vegetation is a degraded woody savannah type. Maize, yam, cassava and groundnut are annual cropping systems and the cash crops are cotton and soybean.

On-farm experiment:

The concept of the experiment was to produce seed yam by minissetts technique. We carried out two-year on-farm experiment in the 2002–2003 and 2003-2004 cropping seasons with two-harvests early maturing varieties (Gangni and Yanabo) and single-harvest late maturing variety of yam ''Kokoro'' (Dioscorea rotundata). Gangni and Yanabo varieties were appreciated on different sites for their ability for pounded yam. Kokoro cultivar is one of the most cultivated species in the study area due to its good aptitude for conservation and processing into dried tubers (the so-called chips), flour, and starchy paste (locally called amala) (Vernier & Dossou, 2003). We conducted the experiment with the mixed social professional group of men and women (5 to 10) in each site (Akpéro, and Gbanlin). A healthy mother, yam tubers (Gangni, yanabo and Kokoro) weighing between 500 and 800 g, the physiological age chosen by smallholders after dormancy, was lifted at the end of March (Picture 1).

Picture 1: Selection of healthy mother seed yam (500-800g)

Picture 2: Cutting healthy mother seed yam into pieces (25-30g)

Picture 3: Planting minissetts in the planks with sand-clay soil

Picture 4: Partial view of the sawdust and sand-clay soil use for nursery bed by the group of women and men at Gbanlin site in central part of Benin

Picture 5: Partial view of the disposition of minissetts into the basket at Gbanlin site following alternated sawdust-minissetts layers

Picture 6: Partial view of nursery bed with the basket use at Gbanlin

Picture 7: Partial view of the minissetts presprouted in sand-clay soil (3-4 weeks later)

It was then cut into several cylindrical pieces about 5 cm long. Depending on the circumference of the pieces; each piece was cut longitudinally into 2, 3, 4 pieces or more, weighing 25 g, making sure that each piece carries a periderm (Picture 2).

The freshly cut minisetts were treated with an aqueous suspension, 5 handfuls of ash per 5 liters of water to protect the minisett against rotting agents.

The freshly cut minisetts were treated with an aqueous suspension, 5 handfuls of ash per 5 liters of water to protect the minisett against rotting agents.

After treatment, the minisetts were spread in the shade to let dry for 1-2 hours. Minisetts of each variety were then sprouted in a nursery bed and watered. The experimental design was a randomized complete block using a partial nested model with four factors (treatment, variety, replicate, year) conducted at village level in Akpéro and Gbanlin sites in central of Benin (Pictures 3-7). Substrate treatment varied as part of site (sawdust (Sa) and sand-clay soil (Scs) in Akpero ; basket with sand-clay soil (BScs) and basket with sawdust (BSa) in Gbanlin) according to smallholder farmers' preferences with three yam early (Gangni, yanabo) and late maturing varieties (kokoro) carried out with four replicates in the 2002-2003 and 2003-2004 cropping seasons. Substrates of the basket were tested at Gbanlin by considering 5 alternating layers of mini-strata with sandy-clay soil or sawdust for the bed of the nursery. The healthy yam seedlings used ranged from 500 to 800 g, cut into 25-30 g portions with early and late maturing varieties of yams.

Minissetts sprouting rate:

The number of minissetts during the presprouting and minissetts sprouting rate (%) were assessed in each site during the 2002-2003 and 2003-2004 cropping seasons.

Statistical analysis:

Analysis of variance (ANOVA) was applied to the minissetts sprouting rate using a randomized block design and a partial nested model with four factors: Year, Replicate, Variety and Treatment. The random factors were "Year" and "Replicate". The fixed factors were "Variety" and Treatment". The General Linear Model (GLM) procedure (SAS, 1996) was computed to assess the interactions between the factors involved. When interactions between main factors were significant, interaction diagrams were established to describe the effect of each factor. Least square means and standard error were also computed for factor levels and the Newman and Keuls test was applied for difference between treatments. Significance was regarded at $p \leq 0.05$.

Results

Effect of sand-clay soil and sawdust on the sprouting rates of yam minissetts:

During the 2002-2003 and 2003-2004 growing seasons, low sprouting rates (9% and 11%) were observed for minissetts in baskets at various sites as well as in sandy-clay soils and sawdust (Tables 3 and 5) compared to treatment without baskets (44% and 47%) during the two growing seasons (Tables 2 and 4). Yanabo sprouting rates were respectively relatively high in sawdust and sandy loam soils without the use of baskets compared to Kokoro and Gangni in the 2002-2003 and 2003-2004 seasons. Except in sawdust with basket.

Table 2: Sprouting rate of minissetts from early and late maturing varieties in nursery bed with sand-clay soil and sawdust at Akpéro site in the Guinea Sudan zone of Benin in the 2002-2003 croppings seasons

***Diosocorea rotundata* varieties**		**Substrates without basket**	**Number of minissetts in seedbed**	**Number of minissetts presprouted**	**Sprouting rate of minissetts (%)**
Early maturing varieties	*Gangni*	SCS	191	90	**47**
		Sa	401	40	**10**
	Yanabo	SCS	337	196	**58**
		Sa	340	205	**60**
Late maturing variety	*Kokoro*	SCS	99	55	**56**
		Sa	530	248	**47**
Total			**1898**	**834**	**44**

Legend: SCS: Sand-clay soil without basket, Sa: Sawdust without basket

Table 3: Sprouting rates of minissetts from early and late maturing varieties in nursery bed with the sandy soil and sawdust contents in the baskets at Gbanlin sites in the Guinea Sudan zone of Benin the 2002-2003 croppings seasons

***Diosocorea rotundata* variety**		**Substrate in the basket**	**Number of minissetts in seedbed**	**Number of minissetts presprouted**	**Sprouting rate of minissetts (%)**
Gangni	Early maturing varieties	BScs	1000	101	**10**
		BSa	250	12	**5**
Yanabo		BScs	120	14	**12**
		BSa	250	5	**2**
Kokoro	Late maturing	BScs	220	20	**9**
		BSa	1000	99	**10**
Total			**2840**	**251**	**9**

Legend: BScs: Basket with sand-clay soil, BSa : Basket with sawdust

Table 4: Sprouting rate of minissetts from early and late maturing varieties in nursery bed with sand-clay soil and sawdust at Akpéro site in the Guinea Sudan zone of Benin in the 2003-2004 croppings seasons

***Diosocorea rotundata* varieties**		**Substrates without basket**	**Number of minissetts in seedbed**	**Number of minissetts presprouted**	**Sprouting rate of minissetts (%)**
Early maturing varieties	*Gangni*	Scs	198	85	**43**
		Sa	395	55	**14**
	Yanabo	Scs	350	210	**60**
		Sa	362	220	**61**
Late maturing variety	*Kokoro*	Scs	105	51	**49**
		Sa	490	265	**54**
Total			1900	886	47

Legend: Sa: Sawdust; Scs : Sand-clay soil

Table 5: Sprouting rates of minissetts from early and late maturing varieties in nursery bed with the sand-clay soil and sawdust contents in the baskets at Gbanlin site in the Guinea Sudan zone of Benin in the 2003-2004 croppings seasons

Diosocorea rotundata variety		Substrate in the basket	Number of minissetts in seedbed	Number of minissetts presprouted	Sprouting rate of minissetts (%)
Gangni	Early maturing varieties	BScs	900	122	**14**
		BSa	300	28	**9**
Yanabo		BScs	100	15	**15**
		BSa	150	8	**5**
Kokoro	Late maturing	BScs	200	25	**13**
		BSa	800	82	**10**
Total			2450	280	11

Legend: BScs: Basket with sand-clay soil, BSa : Basket with sawdust

Effects of treatment, variety, year and factors interactions on the sprouting rates of yam minissetts:

Table 6 presents factor characteristics of the early and late variety minisetts trial at the Akpéro and Gbanlin sites during the 2002-2003 and 2003-2004 seasons. In Table 7, ANOVA partial nested model shows that sprouting rates of varieties of early and late varieties in nurseries with sandy-clay soil and sawdust at the Akpero site during the 2002-2003 and 2003-2004 growing seasons significantly differed with treatment (P <0.000), variety (P <0.001) and replicate (P <0.000) and Treatment × Variety interaction were significant (p <0.000). Table 8 shows ANOVA partial nested model of early and late nursery seedling germination rates as a basket with sandy-clay soil and sawdust at the Gbanlin site during the 2002-2003 and 2003-2004 cropping seasons. Factors Treatment (P <0.000), Year (P <0.05) and Replicate (P <0.000) and Treatment × Varietal interaction was significant (p <0.000).
[Insert Table 8 about here]

Table 6: Factor characteristics of the trial of minissetts from early and late maturing varieties at Akpéro and Gbanlin sites in the Guinea Sudan zone of Benin in the 2002-2003 and 2003-2004 croppings seasons

Site	Factor	Factor type	Factor level	Factor value
Akpéro	Replicate	Random	4	Rep1 ; Rep2 ; Rep3, Rep4
	Treatment	Fixed	2	Sa ; Scs
	Variety	Fixed	3	Gangni ; Kokoro ; Yanabo
	Year	Random	2	Year 1 (2002-2003) ; Year 2 (2003-2004)
Gbanlin	Replicate	Random	4	Rep1 ; Rep2 ; Rep3, Rep4
	Treatment	Fixed	2	BSa ; BScs
	Variety	Fixed	3	Gangni ; Kokoro ; Yanabo
	Year	Random	2	Year 1 (2002-2003) ; Year 2 (2003-2004)

Légend : Rep1 ; Rep2 ; Rep3 ; Rep4 : Replicate 1 ; Replicate 2 ; Replicate 3…Replicate 4 Sa : sawdust ; Scs : sand-clay soil ; BScs : Basket with sand-clay soil, BSa : Basket with sawdust

Table 7: ANOVA in a partial nested model of main factors effects of sprouting rate of minissetts from early and late maturing varieties in nursery bed with sand-clay soil and sawdust at Akpéro site in the Guinea Sudan zone of Benin in the 2002-2003 and 2003-2004 croppings seasons

Source	Statistic parameters				
	DF	Adj. SS.	Adj. MS.	F	P
Replicate	3	5,208	1,736	68.44	0.000
Treatment	1	1,496.3	1,496.3	58.99	0.000
Variety	2	8,392.7	4,196.3	1,398.78	0.001
Year	1	3	3	1.00	0.423
Treatment × Variety	2	2,884.7	1,442.3	56.86	0.000
Variety × Year	2	6	3	0.12	0.889
Error	36	913.2	25.4		
Adjusted R-square (%)	93.69				

Legend: DF: Degree of freedom; F: Fisher test; P: Probability; Adj SS = Ajusted squares, Adj. MS.: Adjusted Mean Square

Figures 2 to 5 show the diagrams of the main effects and interactions (average of the data) for the sprouting rates of early and late varieties of yams in the 2002-2003 and 2003-2004 growing seasons at Akpero and Gbanlin respectively. The effect of sandy-clay soil on yam seed sprouting rates of early and late maturing varieties was significantly higher (52.2%) than in sawdust (41.0%) at Akpero in the two growing seasons (P <0.000). In addition, the effect of sandy-clay soil in the basket on sprouting rates of yam varieties of early and late varieties was significantly higher (12.2%) than that of sawdust (6.8 %) in Gbanlin. In addition, the Yanabo variety expressed a high sprouting rate in the sandy-clay soil without basket in Akpero, while the sprouting rate of the Kokoro variety was relatively high in Gbanlin in the sandy-clay soil used in the basket.

Table 8: ANOVA in a partial nested model of main factors effects of sprouting rate of minissetts from early and late maturing varieties in nursery bed with sand-clay soil and sawdust at Gbanlin site in the 2002-2003 and 2003-2004 cropping seasons in the Guinea Sudan zone of Benin

Source	Statistic parameters				
	DF	Adj. SS.	Adj. MS.	F	P
Replicate	3	216.6	72.2	52.62	0.000
Treatment	1	341.33	341.33	248.74	0.000
Variety	2	32	16	4	0.200
Year	1	108	108	27	0.035
Treatment × Variety	2	162.66	81.33	59.27	0.000
Variety × Year	2	8	4	2.91	0.067
Error	36	49.4	1.372		
Adjusted R-square (%)	92.97				

Legend: DF: Degree of freedom; F: Fisher test; P: Probability; Adj SS = Ajusted squares, Adj. MS.: Adjusted Mean Square

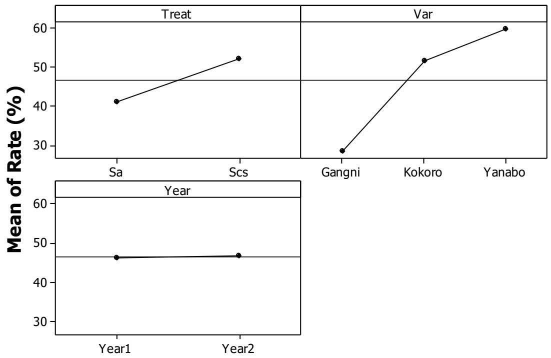

Figure 2: Main effects plot (means of data) on sprouting rates of yam minissetts from early and late maturing varieties in the 2002-2003 and 2003-2004 croppings seasons at Akpéro in the Guinea Sudan zone of Benin
Legend: Year 1: 2002-2003 cropping season; Year 2: 2003-2004 cropping season
Sa: Sawdust; Scs : Sand-clay soil ; Treat : Treatment
Var: variety; Treat: Treatment

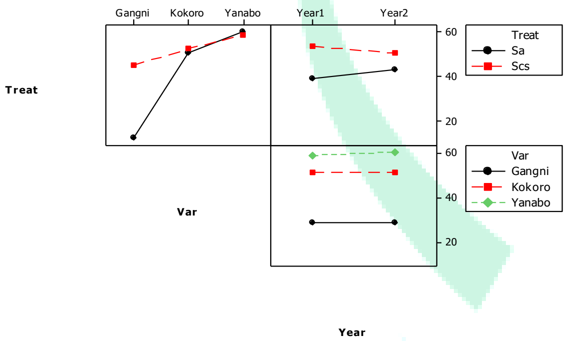

Figure 3: Interaction plot (data means) for sprouting rates of yam minissetts from early and late maturing varieties in the 2002-2003 and 2003-2004 croppings seasons at Akpéro in the Guinea Sudan zone of Benin
Legend: Sa: Sawdust; Scs: Sand-clay soil, Year 1: 2002-2003; Year 2: 2003-2004
Var: variety; Treat: Treatment

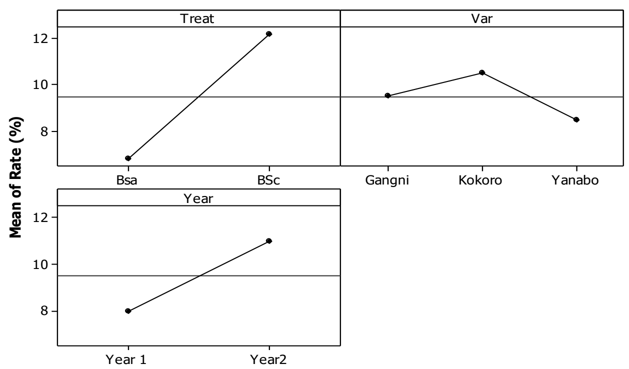

Figure 4: Main effects plot (data means) for sprouting rates of yam minissetts from early and late maturing varieties in the 2002-2003 and 2003-2004 croppings seasons at Gbanlin in the Guinea Sudan zone of Benin

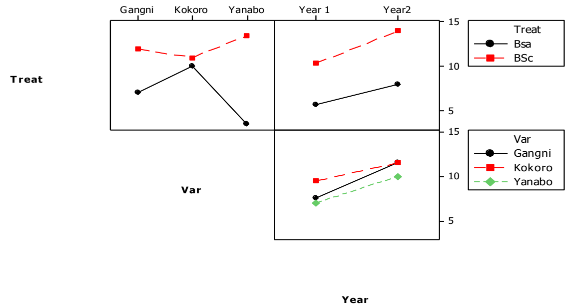

Figure 5: Interaction plot (data means) for sprouting rates of yam minissetts from early and late maturing varieties in the 2002-2003 and 2003-2004 croppings seasons at Gbanlin in the Guinea Sudan zone of Benin
Legend: BScs: Basket with sand-clay soil, BSa : Basket with sawdust

Discussions

The results showed varying responses for various varieties. The use of sandy-clay soils (without basket) appeared more appropriate in the context of the Guinea Sudan zone of Benin for the minissetts technique compared to the use of the basket. In fact, low sprouting rates during the two growing seasons were observed for minissets in baskets (Tables 3 and 5). A group of smallholder farmers in Gbanlin site made 5 layers of sawdust or sand-clay soil in each basket (Figure 4) and a large proportion of minissetts rot was observed, particularly in the layers from 3 to 5 in baskets depths with no germination due to the putrefaction losses in baskets under limited aeration conditions. In fact, yam is a relatively perishable crop, subject to high levels of losses under adverse conditions (Mignouna et al., 2016). Treatment, Variety, Year and Treatment × Variety interactions were significant at the sites. Minissetts sprouting rates were relatively improved in 2003-2004 compared to the 2002-2003 growing seasons. In fact, the 2002-03 crop year was a drought. Favorable distribution of early rains during the 2003-2004 growing season after planting yams may have had a positive impact on minissetts sprouting rates. In addition, residues recycled and accumulated over the years could have had a combined beneficial effect of using water and nutrients for the minissetts germination during the 2003-2004 growing season. The physical and chemical properties of the substrates could positively affect the responses of minissetts. Lower germination rates were observed at the Gbanlin site. In fact, parameters such as particle size, organic matter content, carbon content, C / N ratio and soil phosphorus content at depths of 0-10 cm and 10-20 cm were more favorable to Akpero than to Gbanlin (Table 1). In addition, the ability of the variety of minissetts techniques could have a positive impact on sprouting rates. As the significant responses of the early maturing variety "yanabo" compared to the other varieties (Gangni and Kokoro) at Akpero during the 2002-2003 and 2003-2004. These results are consistent with those of other authors (Dibi et al., 2016, Maroya et al., 2014a, 2014b, Ebert and van Gastel, 2008, Okoli and Akoroda, 1995, Aighewi et al., 1998, Degras, 1978; Degras, 1982, Okoli et al., 1982, Degras, 1989) and highlight that minissetts sprouting rates depended of the management practices (substrate, yam variety, nursery bed medium) and climatic factor (rainfall).

Conclusion

This paper highlights the application of the technique of minissetts for seed yam production with available local materials used in nursery beds (basket, sawdust, sand-clay soil) in the Guinea Sudan zone of Benin. The highest germination rates were significantly recorded in sandy-clay soils (no-basket). Treatment, Variety, Year and Treatment × Variety interactions were significant at the site. Therefore, minissetts sprouting rates depended of the management practices (substrate, yam variety, nursery bed medium) and climatic factor (rainfall). Further research is needed on seed yam production with minissetts under alternated dry mulch covering and sand-clay soil layers to improve microbiology activities and nutrients contribution in the nursery bed.

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