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On-Farm Evaluation of Promising *Dioscorea alata* Genotypes in the Forest – Savannah Transition Zone of Ghana

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Abstract

Dioscorea alata (L) is growing in importance in Ghana due to its long shelf life and its demonstrated potential use as a functional food to supplement the fiber and mineral needs of consumers. Research and development efforts on *D. alata* in Ghana are therefore on the ascendency. To exploit the genetic diversity of the crop, 49 genotypes of *D. alata* including 14 from IITA were evaluated on-station for three years. Using a selection pressure of 90%, the 4 best lines were evaluated on-farm under farmer-managed conditions in 12 environments in the Forest Savannah Transition agroecology of Ghana. The experimental design used was RCB with 3 replications in 3 locations for 4 years in the Forest-Savannah Transition agroecology. A local variety *D. alata* cv Matches was used as check. Highly significant ($p < 0.01$) differences were observed in pre-harvest factors such as virus and anthracnose tolerance. Postharvest factors such as yield, tuber texture, taste, aroma, and after-taste were also highly significant with texture being a very important in choice of materials by farmers. Genotypes TDa_00/0046 was the best genotype amongst the four genotypes evaluated, followed by TDa_01/0029, TDa_01/0004 and TDa_00/0003. The local check had good sensory attributes than some of the improved genotypes. Genotype TDa_00/0046, however, had sensory similar attribute to the local check. It is therefore the best candidate for release as a variety in Ghana.

Keywords: *D. alata*, Ghana, on-farm, yam

1. Introduction

Yam (*Dioscorea* spp) has great economic and social significance in sub-Saharan Africa representing greatest genetic diversity of this crop in this region (Bhattacharjee, Ntare, Otoo, & Yanda, 2011). It constitutes a cheap source of carbohydrate in the diets of millions of people worldwide and in tropical West Africa; providing some 18 metric tonnes of food for people in the yam zones. In Ghana, the most important yam species are *D. rotundata* L., *D. alata* L. and *D. cayenensis* Lam in that order of importance.

Water yam (*Dioscorea alata* L.), also known as “greater yam” is of Asiatic origin. It was never found in the wild and its hybridization with other Dioscorea species is unknown, (Siqueira, Dequigiov, Corazon-Guivin, Feltran, & Veasey, 2012) although two Asian species (*D. hamiltonii* (Hook.f) and *D. persimilis*, Prain & Burkill) could be part of its origins (Burkill, 1960). Water yam is believed to be a true cultigen derived from wild forms through human selection, although there is no concrete evidence to support this claim (Hahn, 1995). Tubers from this species are known for their high nutritional content, with crude protein content of 7.4%, starch content of 75-84%, and vitamin C content ranging from 13.0 to 24.7 mg/100 g. Due to high starch content of the tubers, *D. alata* (L) provides a good source of dietary carbohydrates in tropical and subtropical regions (Osagie, 1992).

If yams are generally a cheap source of energy then *D. alata* (L) represent even a cheaper source of energy. It also has high yield and stores longer than Dioscorea cayenensis/rotundata yam and therefore fills the hunger gap created when other yam types are not available. However, very little research has been done on it.

Very few varieties of this species however, are used for major food products in West Africa, or further processed. This is attributable to its perceived unimpressive food quality traits such as its less suitability for the preferred cohesive and elastic dough in “fufu” or pounded yam. Several cultivars are also susceptible to pests and diseases and lack aesthetic values of smooth skin and elegant tuber shape appealing to consumers in the market

(Obidiegwu, Asiedu, Ene-Obong, Muoneke, & Kolesnikova, 2009).

Under West Africa Agricultural Productivity Programme's concept of National Centre of Specialization (NCOs), Ghana is designated as the NCOs for Root and Tuber Crops making research into technology and products of regional importance, imperative. In the Cote d'ivoire *D cayenensis-rotundata* and *Dioscorea alata* (L) are consumed in approximately equal quantities (Tschannen et al., 2003). *D alata* is a classical staple food yam that is grown without difficulty and is easily stored, because of its naturally long dormancy. Its main roles, therefore, are provision for subsistence and supplying the market when there is little other yam otherwise available (Tschannen et al., 2003).

The potential health benefits from *D. alata* (L) consumption are also immense. High amylose and TDF contents have been reported for some varieties of *D. alata* (L). These varieties had Total Dietary Fibre (TDF) contents higher than that reported for brown rice while two varieties had comparable values to whole-wheat flour. Identified varieties with higher amylose and TDF contents could be of use to diabetics and other health conscious individuals due to their slower absorption rates. Moreover, the low sodium but high potassium and TDF contents indicate the possible preventive role that *D. alata* (L) could play in managing related chronic diseases (Dufie, Oduro, Ellis, Asiedu, & Mariya-Dixon, 2013). This shows the potential use of *D. alata* as a functional food to supplement the fiber and mineral needs of consumers. Thus, there is a need to exploit its use in food fortifications and formulations. *D. alata* is a polyploid, with several ploidy levels, revealing a predominance of tetraploidy (Obidiegwu et al., 2009). Effective breeding programs, genetic diversity analyses and elucidation of the phylogeny and the species origin are urgently necessary (Lebot, 2009).

The general objective of this study therefore was to develop improved *D. alata* varieties with high and stable yields, pest and disease tolerance and good culinary characteristics; and the specific objective was over 3-year period determine the performing genotype(s) on-farm under farmer-managed conditions for release as a variety.

1.1 Materials

A total of 49 *D alata* genotypes made up of 14 IITA introductions, which have been bred for anthracnose tolerance, and the rest are farmer preferred local landraces known for good culinary characteristics were studied. These materials were evaluated over 3-year period at on-station with farmer participation at CSIR-Crops Research Institute at Fumesua. Using a selection pressure of 90%, the best 4 genotypes in terms of yield potential; pest and disease tolerance and culinary characteristics were selected and further evaluated on-farm in the Forest-Transition Zone with *D. alata* cv Matches as check. The promising introductions from IITA studied were TDa_00/0003, TDa_01/0004, TDa_01/0029, and TDa_00/0046.

2. Methods

2.1 Study Area

The on-farm trials were conducted under farmer-managed conditions in 3 villages (Ejura Hiawoannwo, Nkoranza Brahoho and Kintampo Badukrom), all in the Forest Savannah Transition (FST) agroecology in Ghana from 2009-2012. The experimental design used was RCB with 3 replications. Four (4) rows of 10 plants per row constituted a plot. The FST has a bimodal rainfall pattern.

2.2 Data Collection and Analysis

Data was collected on pre-harvest characteristics such as establishment (2 weeks after 90% emergence), vigour (hedonic scale of 1-5, 1 = high vigour and 5 = weak plant), pest and disease assessment (virus and anthracnose) also on a hedonic scale of 1-5, 1 = tolerant and 5 = susceptible. Post harvest characteristics such as yield and quality of tuber were also assessed. Pre-harvest and yield data were analyzed using GENSTAT 17th Edition using factorial experiment model. Data on establishment (per cent values) were arc sine transformed before analysis. Data on postharvest assessment was analyzed by the multiplicative term of mixed model procedure (Smith, Cullis, Brockhoof, & Thompson, 2003).

2.3 Material Sampling and Preparation

Sample preparation and postharvest assessment were conducted per Adu-Kwarteng, Otoo, and Oduro (2001) and Otoo and Asiedu (2009). Twelve farmers (6 females and 6 males) were trained in each location to evaluate tuber quality of the genotypes.

The food quality assessment was therefore based on consumers' description in qualitative tests e.g. focus group discussing and in quantitative terms. A hedonic scale of 1 - 5, where 1 = like very much and 5 = dislike very much, was therefore used for descriptive purposes, to assess colour attractiveness, texture, aroma, taste description and perception, after-taste and general acceptance. The intensity of taste and after-taste, were measured on a scale of 1 - 5 where 1 = very sweet and 5 = bitter, texture was scored on a scale of 1 - 4 where 1 = very mealy and 4 = waxy; aroma on a scale of 1 - 5 where, 1 = very high and 5 = none; colour on a scale of 1 - 5 where 1 = white and 5 = purple and general acceptability on a scale of 1 - 4, where 1 = very good and 5 = very bad. Data was also collected on enzymatic oxidation (time for browning of cut surface) 1 - 3; 1 = < 1 min, 2 = 1 - 2 min and 3 > 2 min (Asiedu, Ng, Bai, Ekanayake, & Wanyera, 1998). The genotypes were ranked for individual attributes and general acceptability. The percentage of farmers giving a particular ranking to an attribute of a genotype was calculated and the mean rank for each genotype was also calculated The post harvest data was analyzed by the multiplicative term of mixed model procedure (Smith, Cullis, Brockhoof, & Thompson, 2003).

3. Results

Generally there were no significant locational differences in any of the characteristics studied (Table 1). Similarly no significant temporal differences were recorded for any of the parameters. There were also no significant interactions recorded for any of the factors. Varietal differences were however highly significant different ($p < 0.01$) for pre-harvest parameters such as anthracnose and virus tolerance and all the post-harvest parameters.

Generally, very high establishment values were recorded for all locations (above 90%) as well as variety (95.7%) (Table 2).

Similarly, *D. alata* cv Matches, had some degree of susceptibility to anthracnose (3.4) compared to the improved elite IITA introductions which were tolerant to anthracnose (2.3). The highly significant varietal differences recorded for virus and anthracnose response was expected since the varieties had varying tolerance levels to these diseases. For instance in Ejura, *D. alata* cv Matches, had some degree of susceptibility to virus (3.2) compared to the improved elite IITA introductions which were tolerant to anthracnose (Mean = 1.5).

With regard to yield, the improved elite genotypes out-yielded the check at all locations. For instance, in Ejura, genotype TDa_00/0046 was the highest yielding (48.1 t/ha) followed by TDa_00/0003 (29.1 t/ha), TDa_01/0029 (26.8 t/ha), TDa_01/0004 (25.1 t/ha) and *D. alata* cv Matches (22.1t/ha). Similar trend was observed at the other locations.

The post harvest assessment of *D. alata* genotypes revealed that the genotypes generally had very good characteristics (Table 3). Significant phenotypic variability was identified among the individual genotypes with respect to texture of tuber flesh. The textural score ranged from 2.0 (*D. alata* cv Matches) at Kintampo to 3.2 (TDa_01/0004) also at Kintampo. That is mealy (2.0) to 3.2 (soggy). The mealiness of water yam in general cannot be compared to that of *D. rotundata*. It was therefore not surprising that none of the genotypes was scored as very mealy (1.0). Generally, *D. alata* cv Matches was significantly mealier than the improved genotypes except TDa_00/0046 whose mealiness was similar to that of *D. alata* cv Matches. This has also been observed by Anokye et al. (2009). Almost all the genotypes had smooth tuber flesh when cut across, except TDa 00/0003, which had a grainy tuber flesh.

Taste, aroma and after taste, however, were all closely ranked among the genotypes. In all these instances, however, no significant differences were observed between the check and genotype TDa_00/0046. The improved genotypes were generally higher yielding than the local check. The local check had good sensory attributes than some of the improved genotypes. Genotype TDa_00/0046, however, had sensory similar attribute to the local check.

Table 1. ANOVA (Mean Square Values) of 5 *D. alata* genotypes in 12 environments (3 locations in 4 years)

		Pre-harvest				Post-harvest					
Source of Variation	d.f.	Establishment	Vigour	Anthracnose Severity	Virus severity	Yield	Taste	After Taste	Texture	Aroma	Overall Acceptability
Replication (R)	2	0.018	0.001	0.057	0.294	57.100	0.267	0.083	0.267	0.043	0.321
Location (L)	2	0.113	0.152	0.275	0.005	43.100	0.019	0.011	0.019	0.008	0.046
Variety (V)	4	0.326	0.000	10.847***	24.017***	3369.7***	0.694***	1.648***	0.694***	1.328***	20.872***
Year (Y)	3	0.005	0.362	0.185	0.107	14.400	0.000	0.048	0.000	0.000	0.000
R x L	4	0.007	0.001	0.003	0.000	12.500	0.011	0.020	0.000	0.000	0.000
R x Y	6	0.009	0.001	0.004	0.004	14.200	0.010	0.010	0.000	0.000	0.000
R x V	8	0.009	0.001	0.000	0.000	15.300	0.020	0.010	0.000	0.000	0.000
L x V	8	0.640	0.000	0.060	0.123	32.400	0.084	0.000	0.084	0.008	0.088
L x Y	6	0.013	0.082	0.006	0.001	23.200	0.000	0.020	0.000	0.000	0.000
V x Y	12	0.001	0.000	0.012	0.003	31.100	0.000	0.000	0.000	0.000	0.000
L x V x Y	24	0.000	0.000	0.006	0.003	10.800	0.000	0.000	0.000	0.000	0.000
Residual	100	0.025	0.003	0.007	0.004	42.000	0.041	0.040	0.000	0.000	0.000
Total	179	-	-	-	-	-	-	-	-	-	-

Note. *** Significant at $p < 0.001$.

Table 2. Mean Performance of promising genotypes in 12 environments (4 years in 3 locations)

Location/Variety	Mean Percent Establishment	Mean Vigour	Mean Virus Severity Score	Mean Anthracnose Score	Mean Yield (t/ha)
Ejura	94.0	1.4	1.7	2.6	30.2
TDa_00/0003	90.0	1.2	1.5	2.2	29.1
TDa_01/0004	93.8	1.5	1.3	2.3	25.1
TDa_01/0029	96.2	1.5	1.5	2.2	26.8
TDa_00/0046	100.0	1.4	1.3	2.2	48.1
D. alata cv Matches (Check)	90.1	1.4	3.2	3.3	22.1
SED (Variety)	3.0	0.1	0.1	0.2	1.7
Nkoranza	95.5	1.4	1.7	2.7	30.0
TDa_00/0003	99.8	1.4	1.6	2.2	29.2
TDa_01/0004	97.6	1.5	1.3	2.3	24.6
TDa_01/0029	99.7	1.6	1.3	2.2	30.2
TDa_00/0046	98.7	1.3	1.4	2.2	45.6
D. alata cv Matches (Check)	91.9	1.4	3.2	3.5	20.1
SED (Variety)	3.1	0.1	0.1	0.2	1.1
Kintampo	97.4	1.5	1.7	2.7	28.9
TDa_00/0003	93.8	1.3	1.3	2.2	28.3
TDa_01/0004	95.8	1.5	1.5	2.5	22.8
TDa_01/0029	93.8	1.6	1.4	2.2	27.9
TDa_00/0046	99.8	1.6	1.4	2.3	45.4
D. alata cv Matches (Check)	93.8	1.5	3.2	3.4	20.1
SED (Variety)	3.2	0.1	0.1	0.2	1.4
Mean	**95.7**	**1.4**	**1.7**	**2.7**	**29.9**
SED (Location)	3.1	0.1	0.1	0.2	1.4

Table 3. Mean quality assessment of genotypes in 12 environments (4 years in 3 locations)

Location/Variety	Mean Texture Score	Mean Taste Score	Mean Aroma Score	Mean Aftertaste	Mean General Acceptability
Ejura	2.5	1.5	1.2	1.2	1.8
TDa_00/0003	3.0	2.0	1.2	1.5	2.5
TDa_01/0004	3.0	2.0	1.4	1.3	2.6
TDa_01/0029	2.2	1.2	1.3	1.3	2.1
TDa_00/0046	2.3	1.1	1.0	1.0	1.0
D. alata cv Matches (Check)	2.1	1.0	1.0	1.0	1.0
SED(Variety)	0.06	0.05	0.05	0.04	0.09
Nkoranza	2.6	1.6	1.6	1.5	1.9
TDa_00/0003	3.1	2.3	2.2	2.2	2.6
TDa_01/0004	3.2	2.3	2.2	2.2	2.5
TDa_01/0029	2.2	1.2	1.4	1.3	2.3
TDa_00/0046	2.3	1.3	1.0	1.0	1.0
D. alata cv Matches (Check)	2.0	1.0	1.0	1.0	1.0
SED (Variety)	0.04	0.05	0.05	0.04	0.08
Kintampo	2.6	1.5	1.5	1.5	1.9
TDa_00/0003	3.0	2.0	2.0	2.0	2.5
TDa_01/0004	3.1	2.0	2.0	2.0	2.5
TDa_01/0029	2.3	1.3	1.4	1.3	2.2
TDa_00/0046	2.3	1.2	1.0	1.0	1.1
D. alata cv Matches (Check)	2.1	1.0	1.0	1.0	1.2
SED (Variety)	0.08	0.05	0.05	0.04	0.09
Mean	**2.5**	**1.5**	**1.4**	**1.4**	**1.9**
SED (Location)	0.06	0.05	0.05	0.04	0.09

4. Discussions

The non-significant locational differences recorded for all parameters could be attributed to the similarity of the locations where the trials were conducted; they are all in the FST zone of Ghana where climatic and edaphic conditions are not that different.

The highly significant variety differences ($p < 0.01$) for pre-harvest parameters such as anthracnose and virus tolerance and all the post-harvest parameters observed, could be attributed to the fact that all the IITA materials are elite collection of improved genotypes, which reflected, in the high vigour recorded for such genotypes. The check *D. alata* cv Matches characteristically has high vigour and hence its name. Due to its high proficiency, when it was introduced into the country, a match box was used as standard sett size and this was good enough to establish and produce high yields of over 2 kg tubers.

The good tolerance of the improved varieties to anthracnose and viral severity observed could be attributed to the fact that the IITA genotypes were specifically bred for anthracnose tolerance.

The observed trend could be attributed to better tolerance to both virus and anthracnose infection by the improved elite genotypes. Similar results were obtained by Osei et al. (2013).

In varietal development especially yams, sensory evaluation is critical since gastronomic preferences often differ from individuals as well as group of individuals. In Ghana, the range of utilization of yams is low especially for water yam. It is often boil-and-eat making parameters such as texture, aroma, taste and after-taste very important. Again, textural classes such as mealiness, waxiness, sogginess, stickiness and hardness are very important textural classes (Otegbayo, Aina, Asiedu, & Bokanga, 2005). Texture is therefore an important index of quality in many food products (Wilkinson et al., 2001). It is a multidimensional attribute and a collective attribute that encompasses the structural and mechanical properties of a food and its sensory perception in the hand and in the mouth (Bourne, 2002). Mealiness is thus the ease of disintegration of the boiled yam while waxiness is the extent to which the yam remains intact and does not disintegrate easily when pressed with fingers or in the mouth, (Otegbayo et al., 2005). The texture of foods is the combination of the perception of vision, hearing, somesthesis and kinesthesis (Wilkinson, Diljksterhuis, & Minekus, 2000). Differences in texture result in different chewing time, moistening and sizes of particle after mastication (Hoebler, Devaux, Karinthi, Belleville, & Barry, 2000). Texture is also important for flavour release and perception (FAO, 2000). Solid foods that are chewed need longer time than drinks that are consumed almost immediately and spend only seconds in the mouth. The forming of a thin film in the oral cavity is important for perception of flavour (Harrison, 1998; Klahorst, 1997). Mealiness therefore is an important textural characteristic influencing many food forms of yams especially in a boil-and-eat yam food culture. This might have influenced consumer preferences accounting for some of the predominance of certain cultivars in some region, in addition to agro-climatological impacts on the growing attributes of the species (Opara, 1999).

General acceptability, however, had greater dispersion in scores, and this could be attributed to the combination of all parameters assessed, which factored in the yield and other pre-harvest parameters showed.

5. Conclusion

All in all, genotype TDa_00/0046 was the best genotypes amongst the four genotypes evaluated, followed by TDa_01/0029, TDa_01/0004 and TDa_00/0003 and are potential candidates for release as varieties. Pre-harvest parameters such as tolerance to virus and anthracnose and postharvest parameters yield and texture were the distinguishing criteria for selecting *D. alata* genotypes.

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