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Yam (*Dioscorea* spp.) responses to the environmental variability in the Guinea Sudan zone of Benin

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This study analyzed the morphological characteristics and agronomic potentials of yam varieties (*Dioscorea* spp.) collected across the Guinea Sudan transition zone of Benin. *Dioscorea cayenensis - D. rotundata* varieties were characterized as wingless; some varieties were spineless, others had few or dense, robust or thin, and short or prickled spines. There was variation in leaf shape, stem and leaf colour, tuber shapes and forking tendencies. The tuber flesh presented different colours, texture, oxidation colour, oxidation time, and ability to irritate. *Dioscorea alata* varieties were all spineless and showed winged stems, pentagonal or quadrangular. Various leaf and petiole colours, and tuber shapes were observed. On average, the mean Shannon-Weaver index was 0.86 for the external morphology of the tuber, 0.55 for tuber flesh characteristics, and 1.13 for stem and leaf morphology. The pooled mean yield varied between 0.89 and 3.30 kg/heap for the early maturing varieties of the *D. cayenensis - D. rotundata*, between 0.94 and 3.03 kg/heap for the late varieties, and ranged from 1.45 to 4.17 kg/heap for the *D. alata* varieties. The year effect was highly significant for variety-type group and species, and was larger than the genotypic effect. The genotype by year interaction effects were highly significant.

Doing research with farmers and working on the agronomical and physiological constraints to develop adaptive technology emphasised the need to really understand the genetic diversity of crop traits (Zannou et al. 2004). Recent studies have also shown the necessity to put more emphasis on farm management of genetic resources (Zoundjihékpon et al., 1997; Pardey et al., 1999; Jarvis et al., 2000). Phenotypic performance reflects the joint influence of non-genetic and genetic factors (Brennan and Byth, 1979). The genotype by environment interaction is a phenomenon in which the relative performance of genotypes varies with environmental conditions and is attributed to the dependence of expression of underlying genes or quantitative trait loci on environments (Yin et al., 2004). As working and doing research with farmers for better technology development is a core principle of the Convergence of Sciences approach (Zannou et al., 2004), this paper aimed at characterizing the different varieties of yam in Benin using different morphological and agronomic techniques.

MATERIALS AND METHODS

Plant material

Tubers of 70 cultivars of the *Dioscorea cayenensis - D. rotundata* and 20 cultivars of *D. alata* were collected from farmers across the transitional Guinea-Sudan zone of Benin and were subsequently planted to analyze their morphological characteristics (Table 1). Over 2 years, the agronomic potential and seed tuber behaviour of 27 of the *D. cayenensis - D. rotundata* and 17 of the *D. alata* varieties were assessed.

Morphological analysis: Qualitative plant and tuber characteristics

Data were collected and analyzed on three different groups of variables. These groups comprised eight tuber flesh characteristics; ten characteristics relating to the external morphology of the tubers, and eight leaf or stem characteristics. The eight variables of tuber flesh characteristics were hardness, skin colour, flesh colour, uniformity of the colour at the central section of the tuber, oxidation time, oxidation colour, flesh texture, and skin thickness (Table 2a).

Morphological and agronomic data analysis

Qualitative tuber, leaf and stem morphology characteristics

The variables of the qualitative tuber, leaf and stem characteristics were encoded into 2 to 7 classes. Frequency distributions were performed for these qualitative tuber, leaf and stem morphology variables. The frequency distributions were used to calculate the Shannon-Weaver diversity index (*H'*) for each character (Grenier et al., 2004) according to the formula:

$$H' = -\sum_{i=1}^{n} p_i \ln(p_i)$$

where n is the number of phenotypic classes, p_i the frequency of the observation in the i^{th} classes. Due to its additive property, the indices of all characteristics were pooled over the characteristics and the global phenotypic diversity was estimated by the mean index value using SAS 8 program (SAS Institute Inc., 1999). In this paper, data were analysed on 70 *D. cayenensis - D. rotundata* and 20 *D. alata* farmer varieties, all of which were different according to morphological criteria.

Genotype by environment interaction

An integrated full interaction analysis of variance was carried out. Such analysis describes the phenotypic responses and allows for differential environmental sensitivity between genotypes based on the regression on the mean model of differences in environmental sensitivity (Finlay and Wilkinson, 1963; van Eeuwijk et al., 2005). The principle of this model is that in the absence of explicit physical or meteorological characterizations of an environment, a good approximation of the general biological quality of the environment is given by the average phenotypic performance across the genotypes (van Eeuwijk et al., 2005). The phenotypic responses of individual genotypes are then regressed on the average performance, and the genotype by environment interaction expresses itself by differences in the slopes between the genotypes. This regression on mean model can be written as follows:

$$\mu_{ij} = u + G_i + E_j + \beta_i E_j$$

where the genotype by environment interaction is modelled as differential genotypic sensitivity and represented by the parameters β_i to environmental characterization E_j, with the average sensitivity

Table 5. Genetic variability from individual and pooled year analyses.

	D. cayenensis - D. rotundata					*D. cayenensis - D. rotundata*					*D. alata*				
	Early		Early		Early	Late		Late		Late					
Genotypic variability	**2003**	**F**	**2004**	**F**	**Pooled**	**2003**	**F**	**2004**	**F**	**Pooled**	**2003**	**F**	**2004**	**F**	**Pooled**
Mean Square (genotype × year)	0		0		7.78	0		0		5.21	0		0		5.84
Mean Square (genotype)	5.83	6.88**	12.07	4.43**	8.57	1.72	4.73**	10.41	4.43**	5.94	4.87	7.10**	14.43	4.30**	9.49
Error	0.85		2.73		1.71	0.36		2.35		1.39	0.69		3.36		2.03
Mean	1.79		2.79		2.26	1.19		2.19		1.7	1.92		2.85		2.38
CV (%)	51.3		59.17		58.2	50.77		70		69.17	43.21		64.26		59.69
Genetic expression variability															
Genotype-by-Year variance	/		/		1.92	/		/		1.06	/		/		1.27
Genetic variance	1.29		2.34		0.10	0.26		2.02		0.09	1.05		2.77		0.46
Environmental (error) variance	0.69		3.36		2.03	0.69		3.36		2.03	0.69		3.36		2.03
Phenotypic variance	1.98		5.70		4.05	0.95		5.38		3.18	1.74		6.13		3.76
Genetic Coef. Variation (GCV) (%)	71.79		83.69		4.37	21.64		92.01		5.37	54.43		97.11		19.17

Level of significance: **: 0.01.

thus also of great importance for farmers. In selecting for better plant types in white and yellow yams information on the quantitative inheritance of important plant characters is needed. Tewodros and Getachew (2013) have analysed the qualitative and quantitative traits among the accessions of the aerial yam, *Dioscorea bulbifera* and revealed that the phenotypic variance was contributed from the genotypic and environmental variances. They suggested that profound descriptions of accessions based on genetic variance are to have significant impact on the genetic improvement of the crop, and that selection based on these characters are efficient to maximize the yield of the yam.

Most of the *D. alata* varieties (65%) yielded more than 2 kg/heap. The most widely cultivated *D. alata* variety Florido (Zannou et al., 2004) did not perform as well as the other *D. alata* varieties. This result suggests that the choice of this variety Florido by many farmers is not related to its high yield performance, but to the quality of the tuber, storability and perhaps other agronomic characteristics.

Conclusion

The current study suggests that the Guinea Sudan zone of Benin represents a very large gene-pool of yam varieties. Yam farmers in Benin, with their continuous commitment to domestication of material from the wild, clearly play a significant role in the enrichment and the maintenance of the genetic diversity of yam cultivars. Their participation in the research, and perception of the benefits of such participation suggest new ways of designing research project to enhance impact.

Conflict of Interest

The author(s) have not declared any conflict c interests.

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