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Variation, heritability and genetic advance of eight characters in white yam

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Summary. Phenotypic and genotypic coefficients of variation, heritability, and genetic advance were estimated for: time to vine emergence, leaf size, leaf virus infection, plant leafiness, shoot height, vine dry weight, number of tubers per hill and tuber yield per hill in white yam (*Dioscorea rotundata* Poir.) using plants recently derived from seedlings (SP) as well as those that have been clonally propagated for 3–5 years (CP). Estimates for these parameters were much lower in SP than in CP plants. Mean squares of characters in SP families were significant for leaf virus infection, plant leafiness, vine dry weight and tuber yield; and for all characters in CP except number of tubers per hill. Although in CP, heritability (%) was high for leaf size (67.8), plant leafiness (66.9) and fresh tuber yield (58.1), only tuber yield had a correspondingly high expected genetic advance (74.3%). The study indicated that rapid genetic advance can be achieved for tuber yield, under more uniform environment, by single plant selections followed by clonal propagation.

Key words: White yam – Selection parameters – Heritability – Genetic advance

Introduction

White yam (*Dioscorea rotundata* Poir.) is widely grown throughout the tropics as an important staple food crop. Its production is of special socio-cultural importance and magnitude in the West Africa forest zone, where three-quarters of the world's annual output of yams of around 20 million metric tons is produced (FAO 1975). Of the more important *Dioscorea* species cultivated for food, *D. rotundata* is the most preferred and also accounts for the greatest proportion of the total annual output of yams (Coursey 1967). Yam tuber is used as a major source of carbohydrates and contains an appreciable amount of 4.12 mg vitamin C/100 g of edible tuber portion (Coursey and Aidoo 1966) and 4–7% crude protein on a dry matter basis (FAO 1970), and is only marginally inferior to cereal foods for adults (Ayensu and Coursey 1972).

In selecting for better plant types in white yam, information on the quantitative inheritance of important plant characters is needed. Such information, in the form of estimates of heritability and genetic advance, enables a prediction of the amount of progress to be expected from selection.

Studies aimed at providing genetic estimates for characters in yams are few, such that an insight into character inheritance is lacking. Heritability of fresh tuber yield in *D. floribunda,* a non-food sapogenin yam, was 12.4% on a single plant basis and 58.6% on a six-replicate basis (Martin and Cabanillas 1967). While in *D. rotundata,* heritability for tuber yield based on plants resulting from open – pollinated seeds of variety 'Boki' was 54% but was lower (27%) from seeds of mixed cultivars (IITA 1974). The present study estimated the variation, heritability and expected genetic advance under selection of eight characters by using data from seedling-derived biparental progenies and a clonally propagated population. The work was conducted at the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria from 1977 to 1979.

Materials and methods

Seedling-derived plants (SP)

In 1977, hybrid seeds of biparental progenies from 8 female and 5 male parent clones of white yam were produced using

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separate spatially isolated blocks containing a male and several female clones. During 1978, seeds of the 8 families were sown in soaked peat pots and the resulting seedlings later transplanted at the 2- to 3-leaf stage to a nursery. Seedlings were staked, trained and kept weed-free during the growth period. Seedling tubers were finally harvested in October, cured and stored.

In March, 1979, whole tubers of the 1978 seedlings were weighed and planted in three blocks in a randomised complete block layout. Each block contained equal allocations of big and small tubers from each of the 8 families. Due to grossly unequal numbers among families and for ease of analysis, 15 plants were selected by stratified random sampling in each family with 5 plants per family in each block.

Clonally-derived plants (CP)

During 1979, single tubers of 20 clones of white yam were randomly selected from among tubers which originated from seedling tubers, but which had been vegetatively propagated for 3 to 5 years. From each single tuber, small slices were removed from the head and tail portions and the remaining portion out into approximately 200 g sett pieces. Tuber setts were planted in ridges at 1 × 1 m spacing with a single plant replication in each of the five blocks of a randomised complete block layout.

Character observation

During 1979, SP and CP populations were observed for the following eight plant characters: (1) time of vine emergence in weeks from planting; (2) leaf size, scored 1 = small, 2 = medium and 3 = big, on the 19th week; (3) plant leafiness, scored 1 = few leaves up to 5 = dense foliage on the 25th week; (4) leaf virus infection, scored 0 = no symptoms up to 4 = much viral chlorosis with leaf distortion; (5) shoot height, scored 1 = below one-third, 2 = between one- and two-thirds and 3 = above two-thirds of 2.4 m stakes; (6) vine dry weight (g) after harvest. The sun – dried weights used correlated with oven-dried samples, $r = 0.999$**, $n = 51$. (7) number of tubers per hill at harvest. Tubers less than 5 cm long were disregarded. (8) fresh tuber yield (kg/hill) after 30 weeks of crop growth and after curing tubers for 3 days at 30–35 °C and 85–90% relative humidity.

Statistical analyses

Mean, phenotypic and genotypic coefficients of variation (CVs), heritability and expected genetic advance (as a percentage of the population mean) were estimated for the observed characters.

In SP, phenotypic and genotypic CVs were based on the respective variances which were estimated from the expectation of the mean squares according to Mather and Jinks (1974) for biparental progeny analysis; and estimated in CP by following the procedures used Burton and De Vane (1953). Heritability (%) was estimated according to Hanson (1963); while the expected genetic advance under selection (Gs) was estimated after Allard (1960) as: $Gs = H\,\sigma_A\,K$, where H = heritability, σ_A = phenotypic standard deviation and K = selection intensity. In this study, the top 5% of the population was saved, so that K = 2.06.

Results

The analyses of variance for SP and CP for the eight characters studied are presented in Tables 1 and 2 respectively. Generally, estimates were much lower in SP than in CP plants. Significant differences among SP families were observed for leaf virus infection, plant leafiness, vine dry weight and tuber yield per hill. In CP, however, mean squares were significant for all characters except for number of tubers per hill.

Table 1. Analysis of variance showing mean squares of eight characters in SP families of white yam

Sources of variation	df	Time to vine emergence	Leaf size	Leaf virus infection	Plant leafiness	Shoot height	Vine dry weight	No. of tubers/hill	Tuber yield/hill
Between families	7	1.77	0.279	0.989*	1.167**	0.376	12,289.4**	0.504	5.661**
Error	96	2.11	0.191	0.350	0.344	0.133	2,494.5	0.495	0.945

*'** Significant at 5% and 1%, respectively

Table 2. Analysis of variance showing mean squares of eight characters in CP clones of white yam

Sources of variation	df	Time to vine emergence	Leaf size	Leaf virus infection	Plant leafiness	Shoot height	Vine dry weight	No. of tubers/hill	Tuber yield/hill
Between clones	19	9.71**	0.929**	1.379**	1.318**	1.023**	5225.8**	0.328	5.796**
Error	76	2.39	0.081	0.286	0.345	0.200	950.3	0.243	0.730

** Significant at 1% level

Table 3. Mean, phenotypic and genotypic co-efficients of variation (*CV*), heritability and expected genetic advance of eight characters in SP families of white yam

Character	Mean	Phenotypic CV (%)	Genotypic CV (%)	Heritability (%)	Expected genetic advance (% of mean)
Time to vine emergence (WK)	4.55	16.3	6.5	31.8	10.6
Leaf size (scale 1 – 3)	1.97	23.0	3.7	5.0	2.4
Leaf virus infection (scale 1 – 4)	1.69	35.0	0.0[a]	0.0	0.0
Plant leafiness (scale 1 – 5)	3.05	20.3	6.6	21.2	8.8
Shoot height (scale 1 – 3)	2.79	12.8	0.0[a]	0.0	0.0
Vine dry weight (g)	83.76	62.8	19.7	19.8	25.4
No. of tubers/hill	1.46	46.6	0.0[a]	0.0	0.0
Tuber yield/hill (kg)	2.18	47.3	15.5	21.6	21.0

[a] Negative genotypic variances

Table 4. Mean, phenotypic and genotypic co-efficients of variation (*CV*), heritability and expected genetic advance of eight characters in CP clones of white yam

Character	Mean	Phenotypic CV (%)	Genotypic CV (%)	Heritability (%)	Expected genetic advance (% of mean)
Time to vine emergence (WK)	6.94	22.3	17.4	38.0	22.0
Leaf size (scale 1 – 3)	2.30	12.4	18.0	67.8	30.5
Leaf virus infection (scale 1 – 4)	1.66	32.2	28.2	43.4	38.2
Plant leafiness (scale 1 – 5)	2.86	20.6	15.5	66.8	26.0
Shoot height (scale 1 – 3)	2.59	17.3	15.7	45.1	21.7
Vine dry weight (g)	74.65	41.3	39.2	47.4	55.5
No. of tubers/hill	1.24	39.8	10.6	6.6	5.6
Tuber yield/hill (kg)	2.13	40.1	47.3	58.1	74.3

The mean, phenotypic and genotypic CVs, heritability and expected advance for the observed characters in SP and CP populations of white yam are presented in Tables 3 and 4 respectively. Although phenotypic CVs were generally higher than genotypic CVs for most characters in CP, the reverse was the case for leaf size and tuber yield per hill. Heritability was high for most characters in CP, but was very low for number of tubers per hill. Consequently, the estimates of expected genetic advance were considerably high for most characters (Table 4). The phenotypic CV for time to vine emergence was higher in CP than in SP which was established from whole tuber sett of various weights.

Discussion

The lower estimates for characters in SP relative to those in CP may be due to: (i) differences in the mode of estimation in that seedling-derived plants were employed in SP and clones in CP, (ii) differences in the genetical variation of the individuals sampled: while the SP families originated from 13 parental clones, CP comprised 20 clones, and (iii) more uniform environment for CP which was raised on smaller and presumably more homogenous soil coupled with the use of setts of uniform weight.

The parent clones of SP did not differ appreciably in genetic constitution despite distinct morphotype differences. Thus, the number of morphotypes per se is not necessarily an index of inherent genetic diversity in a population (Dudley and Davis 1966; Fatokun 1976). For yam breeding, as well as for other crops, a preliminary evaluation of genotypes in the base population in several locations and seasons is needed for assessing available variation in desirable traits prior to selection. Where evaluations indicate insufficient diversity, the additional variation needed can be acquired by introductions or produced through hybridization.

The higher heritability and expected genetic advance in CP relative to SP suggest that more progress could be made through the assemblage of diverse cultivars followed by clonal selection since the production of suitable hybrids cannot be assured solely be crossing morphologically distinct cultivars, unless multi-locational trials for several seasons show phenotypic stability of the observed parental differences.

The more uniform emergence of vines in SP relative to CP, despite the use of setts with various weights, can largely be attributed to the greater tolerance exhibited by whole tuber setts to environmental stress factors which include microbial attack and dehydration (Onwueme 1978), in comparison with cut tuber setts of CP. The low heritability for time to vine emergence in SP and CP further indicates large environmental influences on this character, suggesting the need for using sound whole tubers setts in order to achieve more uniform vine emergence.

The high heritability of plant leafiness in CP together with its high correlation with tuber yield (IITA 1976) implies that leafiness is a good field criterion in selecting for higher yields. Shoot height is under large environmental influence and seems to be determined to a large extent by the stake height and branching pattern and can as such not be selected as indicated by estimates in this study.

The similarity in number of tubers per hill among families in SP and its low heritability and expected genetic advance in CP suggest that selection for higher yield in white yam through more tubers per hill would not be successful, because the character is largely controlled by environmental factors. Instead, selection for bigger tubers should be made because white yam commonly produces only one tuber, moreso as the number of tubers per hill is inversely related to individual tuber size (IITA 1971).

The heritability for tuber yield in CP appear rather high for a complex metrical character such as yield, which is invariably under strong environmental influence. The use of setts of uniform weight in CP as well as the relative homogeneity of the soil could reduce the environmental variance resulting in heigher heritability. Under uniform environment, single plant selections followed by vegetative propagation should improve selection progress for higher yields.

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