Theor Appl Genet (1984) 69: 217–221

Variability, repeatability, character correlation and path coefficient analyses in yellow yam

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Received April 12, 1984; Accepted May 1, 1984
Communicated by G. S. Khush

Summary. Phenotypic variances, genetic coefficients of variation, repeatability, expected genetic advance, correlation coefficients and path coefficients were estimated for seven agronomic traits in yellow yam. Plant leafiness, leaf virus infection, number of tubers per hill and tuber yield showed higher expected genetic advances associated with higher repeatability. Positive and highly significant correlations of tuber yield with plant leafiness, shoot height and vine dry weight were observed. Correlations of time to vine emergence and leaf virus infection with yield were negative. Path analysis showed that leaf virus infection had a large negative direct as well as indirect effect on yield. Based on these studies, it is suggested that resistance to leaf virus infection, as expressed by foliage vigour, is the chief criterion for selecting high yielding plant types in yellow yam.

Key words: Yellow yam – Genetic variation – Genotypic correlation – Path coefficient analysis

Introduction

Yellow yam (*Dioscorea cayenensis* Lam.) is an important carbohydrate staple in the forest regions of West Africa where about 75% of the World's annual yam crop is produced (FAO 1975). Although important, only tenuous systematic efforts towards a genetic improvement of yellow yams have been undertaken due to predominant male flowering, the rare occurrence of female plants, and a host of other factors (Waitt 1961; Chinwuba 1971).

Whereas morphotypes of yellow yam are believed to abound across the yam zone, a great deal of effort is still required to assemble, evaluate and select them. Waitt (1965) described 13 cultivars of yellow yam in his key to Nigerian yams, while Martin (1973) collected 56 cultivars from across the West African yam zone. Of the 97 cultivars of *D. cayenensis* and *D. rotundata* studied by Martin and Rhodes (1978), 25 had tubers with cream or yellow flesh but only 17 could really be grouped as yellow yams. Recently, through more extensive explorations, female plants of yellow yam have been collected (Okoli 1980). A new approach to yellow yam improvement through sexual hybridization can therefore be envisaged. Although yam tuber yield components are tuber number and weight of individual tuber (IITA 1971), both compensatory traits (Gurnah 1974), a knowledge of the direct and indirect influence of agronomic traits on yield is required for formulating an effective selection programme for both clonal and future seedling populations. Such an insight could be gained through the correlation and path analyses employed for crested wheat grass (Dewey and Lu 1959) and sweet potato (Kamalam et al. 1977). Path analysis quantifies the direct and indirect effects of characters, and thus allows relative weights of emphasis to be placed on characters to be selected or manipulated. Character associations in non-segregating populations (clones) are rather stable, and once understood, the necessary cultural practices can be developed to favour higher yields.

Whereas information on genetic variation and relationships of different agronomic traits with yield and its components are basic needs for executing any crop improvement programme, such information is not available for yellow yam. This paper reports investigations conducted to gather information on genetic variation, expected genetic advance under selection, and correlation of various agronomic traits with tuber yield in yellow yam.

Materials and methods

Twenty cultivars of yellow yam (*Dioscorea cayenensis* Lam.) collected from Eastern Nigeria and obtained from the germplasm collection at IITA, Ibadan, were used in this study.

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In 1977, single row plots of these varieties were planted at IITA, Ibadan, in one replication, due to insufficient propagules. In 1978, however, the study used data for eleven cultivars which represented the major groupings of the available yellow yam germplasm collection planted in two blocks with three plants per cultivar in each block of a randomised complete block layout. Based on 49 characters, four numerical taxonomic techniques were used to show that yellow yam collections could be represented by a smaller number of accessions without appreciable reduction in diversity (Akoroda 1982, 1983a). This was due to the elimination of duplicate entries and differences in ethnic names for similar morphotypes. The three plants of each cultivar were established from setts obtained from head, middle and tail portions of the tubers. To remove the effects of sett type, sett was considered a source of variation in the ANOVA. Consequently, degrees of freedom were (b-1), (c-1), (s-1), (c-1) (s-1), and (cs-1) (b-1) for block, clones, sett, clone X sett interaction and error, respectively. During the 1977 and 1978 seasons, the plants were scored for the following seven agronomic traits: time to vine emergence (weeks from planting); plant leafiness on a scale of 1 for least leafy to 5; intensity of leaf virus infection (scale of 0=no symptoms, up to 4=much viral chlorosis with occasional leaf distortion); shoot height on stakes (scale 1-3); vine dry weight (g/hill); number of tubers per hill; and fresh tuber yield (kg/hill) after curing for three days at 30–35 °C and 75–100% relative humidity.

The 1978 data was subjected to the analysis of variance. For each trait, phenotypic and genotypic variances and genetic coefficients of variation (CV) were estimated as suggested by Burton (1952) and clonal repeatability (broadsense heritability) was determined as suggested by Falconer (1960) and Simmonds (1979). Also, expected genetic advances as percentage of means were calculated as outlined by Allard (1960). Phenotypic and genotypic correlations were obtained by the formulae given by Falconer (1960). Path coefficient analysis was done according to Dewey and Lu (1959).

Results and discussion

The range, mean and mean squares of the seven traits studied are presented in Table 1. Significant differences between cultivars indicate considerable variation, particularly for plant leafiness, leaf virus infection, number of tubers and tuber yield per hill. Phenotypic and genotypic variances, genetic coefficients of variation, repeatability, and expected genetic advance are presented in Table 2.

Annual mean yields of all the 20 clones were studied for three seasons (1977–1979) and ranked. The significance of computed Spearman's coefficients of rank correlation after Steel and Torrie (1960), tested with df= 18, resulted in *t* values of 1.66, 1.41 and 2.00, respectively for comparisons between 1977/1978, 1978/1979 and 1977/1979. This shows that the ranking of

Table 1. Variabiility of plant traits in yellow yam clones

Trait	Range	Mean	Mean squares	
			Between clones df=10	Error df=32
Time to vine emergence (wk)	2.3 – 17.4	7.78	9.02*	3.15
Plant leafiness (1 – 5)	1 – 5	2.30	3.24**	0.29
Leaf virus infection (1 – 4)	1 – 3	1.12	4.58**	0.38
Shoot height (1 – 3)	1 – 3	2.28	0.96*	0.35
Vine dry wt (g/hill)	1 – 163	51.12	1655.90*	503.98
No. of tubers/hill	1 – 10	2.13	11.27**	1.19
Tuber yield (kg/hill)	0.045 – 5.740	2.360	7.80**	0.96

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

Table 2. Phenotypic and genotypic variances, genetic coefficients of variation, repeatability and expected genetic advance for traits in yellow yam

Trait	Phenotypic variance	Genotypic variance	Genetic CV	Repeat-ability (%)	Expected genetic advance (% of mean)
Time to vine emergence	4.13	0.98	12.7	23.7	12.8
Plant leafiness (1 – 5)	0.78	0.49	30.4	62.8	44.0
Leaf virus infection (1 – 4)	1.08	0.70	74.7	64.8	226.8
Shoot height (1 – 3)	0.45	0.10	13.9	22.2	13.9
Vine dry wt (g/hill)	695.97	191.98	27.1	27.6	29.3
No. of tubers/hill	2.87	1.68	60.8	58.5	95.9
Tuber yield yield (kg/hill)	2.10	1.14	45.2	54.3	68.8

cultivar yields (i.e. their performances) was not significantly different through the years. Throughout the tropics, methods of yam cultivation are similar (Waitt 1963). The crop duration varies little, usually 9–11 months for yellow yam and production is restricted to areas where the rain lasts for 9 months. In Nigeria, such areas occupy a rather compact rain forest zone.

Waitt (1965) reported similar or comparable yields for the same cultivars of white yam and yellow yam grown at the northern fringe of the rain forest belt (Ibadan) and at the southern part (Umuahia). This is strongly suggestive of low genotype X environment interactions in yams. The expected upward bias in the σ^2_G estimate for computing repeatability should therefore be inappreciable. Thus, the estimates of genetic parameters presented in this paper sufficiently reflect the true situation. This view is supported by the similar broadsense heritability estimates obtained for clones of two species of yam: 58.6% for *D. floribunda* (Martin and Cabanillas 1967), and 58.1% for *D. rotundata* (Akoroda 1983), despite the differences in years and locations.

Although a wide range in time to vine emergence was observed, this was largely environmental in nature as reflected by a low genetic CV while the low repeatability and genetic advance further imply a large influence from non-genetic effects. For effective field assessment of this trait, factors such as soil, sett tubers and cultural management must be sufficiently uniform to minimise environmental influence. A similar consideration holds for shoot height and vine dry weight.

Leaf virus infection had the highest genotypic CV, repeatability, and expected genetic advance (226.8%). The results suggest that single plant selection for tolerance to leaf virus infection would result in greater genetic advance. While high repeatability indicates effective selection for phenotypic performance, it may not always be associated with a large genetic advance. It is therefore more useful to consider the repeatability together with the corresponding expected genetic advance (Johnson et al. 1955). In this study moderate repeatability was also associated with fairly high expected genetic advance for number of tubers and tuber yield per hill. Thus, selection progress will be higher with greater diversity for these traits in collected yellow yam accessions, assessed through yield trials under uniform environment at several locations of different ecology.

The broadsense heritability (repeatability) of tuber yield was estimated in *D. floribunda* to be 12.4% and 58.6% based on a single plant and six replications, respectively (Martin and Cabanillas 1967). In *D. rotundata*, however, it was 54% for a single variety and 27% for mixed cultivars (IITA 1974). These reports indicate the repeatability of tuber yield to be less than moderate under usual field conditions. When a sufficient number of yellow yam female plants are assembled, hybridizational breeding can begin – but for now, improvement of yellow yam will concentrate on the evaluation of, and selections from, landraces.

Correlation coefficients among different traits are listed in Table 3. The observation of a genotypic correlation coefficient greater than unity, is attributable to rounding up errors as well as through the large sampling errors usually encountered when estimating genotypic correlations (Falconer 1960). Tuber yield/hill was significantly and positively correlated with plant leafiness, shoot height and vine dry weight as also reported in *D. rotundata* (IITA 1976) and sweet potato (Kamalam et al. 1977). Time to vine emergence and leaf virus infection showed a significant negative correlation with yield, thus, agreeing with IITA (1974) and IITA (1976) respectively. The correlation of time to vine emergence with yield is essentially similar to that

Table 3. Phenotypic (P) and genotypic (G) correlation coefficients among traits in yellow yam

Trait		Plant leafiness	Leaf virus infection	Shoot height	Vine dry wt/hill	No. of tubers/hill	Tuber yield/hill
Time to vine emergence	P	−0.641**	−0.078	−0.277*	−0.354**	−0.143	−0.535**
	G	−1.063**	−0.295*	−0.109	−0.513**	−0.523**	−0.828**
Plant leafiness	P		−0.209	0.443**	0.578**	0.018	0.752**
	G		−0.192	0.539**	0.636**	0.056	0.959**
Leaf virus infection	P			−0.445**	−0.222	0.484**	−0.290*
	G			−0.716**	−0.298*	0.760**	−0.278*
Shoot height	P				0.513**	−0.265*	0.602**
	G				0.854**	−0.254*	0.745**
Vine dry wt/hill	P					−0.111	0.607**
	G					−0.199	0.696**
No. of tubers/hill	P						−0.004
	G						0.093

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

Table 4. Path coefficient analysis showing direct and indirect effects of six traits on tuber yield in yellow yam

Trait	Direct effect	Indirect effect via						Genotypic correlation with tuber yield
		Time to emergence	Plant leafiness	Leaf virus infection	Shoot height	Vine dry wt/hill	No. of tubers/hill	
Time to vine emergence	–0.583	–	0.093	0.365	0.068	–0.390	–0.380	–0.828**
Plant leafiness	–0.087	0.620	–	0.238	–0.336	0.484	0.041	0.959**
Leaf virus infection	–1.237	0.172	0.017	–	0.446	–0.227	0.552	–0.278*
Shoot height	–0.622	0.064	–0.047	0.886	–	0.650	–0.184	0.745**
Vine dry wt/hill	0.760	0.299	–0.056	0.369	–0.532	–	–0.145	0.696**
No. of tubers/hill	0.726	0.305	–0.005	–0.940	0.158	–0.151	–	0.093
Residual factors	0.353							

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

observed between diameter of tuber zone in soil and lateness to sprout in *D. alata* (Martin and Rhodes 1973). This is because late sprouting of sett results in delayed tuber initiation (Ferguson 1973), late tuber bulking (Sobulo 1972) and consequently produces smaller tubers which occupy a smaller diameter of the tuber zone in soil.

The direct and indirect effects of different traits on yield are shown in Table 4. Although number of tubers and size of individual tubers are the direct components of tuber yield per hill (IITA 1971), the highest direct effect (–1.237) was exerted by leaf virus infection. This effect was further intensified by marginal indirect effect through number of tubers, shoot height and vine dry weight. The direct effect of number of tubers on yield was high (0.726) despite a very low and non-significant correlation with yield. Number of tubers/hill did not affect yield in *D. rotundata* (IITA 1971) and this is supported by the results of this study. It seems that tuber proliferation without a corresponding increase in yield could be virus-induced since virus infection latent in tuber (Terry 1976) can alter the hormonal system of the plant (Posthumus 1973). It is also interesting to note that leaf virus infection, when compared with other traits, showed the maximum direct as well as indirect effects on yield. It could therefore be concluded that tolerance to leaf virus infection as expressed by plant vegetative vigour should be the main criterion for selecting high yielding cultivars in yellow yam. Thus, the compromise strategy is to select for high plant leafiness with low leaf virus infection. The findings of the path analysis were supported by the correlation studies in that traits like plant leafiness, vine dry weight and shoot height, which together constitute plant vegetative vigour, showed the highest positive correlation with yield.

Acknowledgements. The author acknowledges with gratitude the varied advice and assistance rendered him by Professor H.R. Chheda as well as the helpful suggestions of Drs. Jill E. Wilson, M. E. Aken'Ova and C. A. Fatokun. The study was funded by a Research Fellowship of IITA by courtesy of Dr. Wade H. Reeves.

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