Analysis of Phenotypic Stability in Ten Cassava Genotypes in Three West African Countries

I. K. Asante [1] and A. G. O. Dixon [2]

1. *Department of Botany, University of Ghana, P. O. Box 55, Legon, Ghana*
2. *International Institute of Tropical Agriculture, Ibadan, Nigeria*

Abstract

Ten cassava (*Manihot esculenta*, Crantz) genotypes were assessed for phenotypic fresh tuber yield stability for 2 years in nine locations in three West African countries (Nigeria, Ghana and Benin). From a combined analysis of variance for fresh yield, all main effects were significant. First order interaction genotype × year was not significant, while genotype and location interaction was significant. By Finlay and Wilkinson's b-value of stability statistic genotype 82/00058 was considered high yielding with average stability and may perform well in any of the three agroecologies. Genotypes 4(2)1425 and 50395 would be adapted to any favourable agroecology by Finlay and Wilkinson's stability statistic. By Shukula's stability statistic, genotype 30572 ranked the most highly stable. The three stability statistics, Finlay and Wilkinson's, Shukula's and the rank sum method agreed in classifying genotypes 82/00661, 30572, 82/00942 and 82/00058 as high yielding and stable. A plot of environmental mean yields against coefficient of variation (CV) per cent judged genotype 82/00942 as having phenotypic yield stability for the environments considered, while genotype 50395 was judged less stable but high yielding, and, therefore, can be targeted to a specific agroecology.

Introduction

Crop varieties may not produce uniform yields across different environment as a result of the existence of Genotype-Environment (G × E) interactions. Stability to resistance of any sort is one of the most complex problems in the field of resistance breeding. For instance, yield of a crop variety with vertical resistance, i.e. complete resistance, to a particular pest/disease may be stable over time, but generally not sustainable although vertical resistance is dependent on the genetic potential of the crop variety. Sometimes, there is partial or horizontal resistance which is of polygenic, additive nature. Though this type of resistance is likely to be durable, it cannot be sustainable. Generally, these two types of resistance are not sustainable due to fluctuation and continual changes in the population of pest and pathogen. This complicates the selection of lines for release as commercial varieties and recommendations of cultivars for particular environments. It has, therefore, been imperative for the breeder to incorporate stability analyses in the selection of crop varieties that are under the influence of a reasonable level of G × E interaction.

Three concepts of stability are widely recognized (Lin *et al.*, 1985). Type A stability purports that a genotype is considered to be stable if its among-environment variance is small (Finlay & Wilkinson, 1963; Francis & Kannenberg, 1978). For type B stability, a genotype is considered stable if its response to environments is parallel to the mean response of the genotypes in the trial (Plasteid & Peterson, 1959; Plasteid, 1960; Shukula, 1972), while type C stability states that a genotype is stable if the residual mean square from the regression model on the environmental index is small (Eberhart & Russel, 1966; Lin & Binns, 1988; Kang & Gorman, 1989; Crossa *et al.*, 1991). However, the method commonly used by plant breeders is the rank sum method which integrates yield with stability (Kang, 1988). The Francis and Kannenberg's coefficient of variation (CV) (Francis & Kannenberg, 1978) is an easy statistic to compute manually. It is a measure of biological stability. By the method, genotypes that show low CV across a wide range of environment are said to be well buffered since they display a great deal of inertia as they are tested across diverse agroecologies. Varieties that combine high and stable yield are the most desirable for the resource cassava farmer.

Cassava is a drought resistant crop, which performs well even in marginal soil conditions. It is cultivated mostly under rainfed conditions without the application of fertilizer or other agrochemicals. This lack of manipulation of the environment by the farmer leads to a high degree of variability in soil texture, moisture content, nutrient status of the soil from location to location and from year to year. This paper aims at showing the existence of G × E interaction effects in cassava varietal trials and proposing an efficient, quick way of identifying high yielding and stable cassava genotypes.

Materials and methods

Yield trials were conducted for 2 years (1991 and 1992) with 10 cassava genotypes developed by the International Institute of Tropical Agriculture (IITA) at nine locations in three West African countries; seven locations in Nigeria, one location each in Ghana and Benin. In Nigeria, the locations were Abuja, Agbarho, Calabar, Ibadan, Ilorin, Onne and Ubiaja; in Benin and Ghana, the locations were Seko and Fumesua, respectively. Agbarho, Calabar, Ibadan, Onne and Ubiaja are located in humid forest; Abuja, Ilorin and Seko are located in forest savanna transition, while Fumesua is located in semi-deciduous forest.

Trials were sited on cropped lands in all locations. The cassava genotypes were 30555, 30572, 4(2)1425, 50395, 81\00110, 81\01635, 82\00058, 82\00661, 82\00942 and 90059. Genotypes were grown under rainfed conditions in a randomized complete block design. Four-row plots were used with rows 1 m apart. Each row was 10 m long, giving a total of 40 plants per plot. On the average, trials were weeded seven times in a year; first weeding was done about 2 weeks after trials were established, while the last weeding was done about 1 week before harvesting. On the average, harvesting was done at 12 months after planting. All genotypes were harvested at the same time and data collected on 20 plants from the two inner rows from each genotype were used for data analysis.

Analysis of variance was conducted for fresh yield (SAS, 1989). F-test and significance of main effects and interactions were determined by using the appropriate error terms and degrees of freedom (McIntosh, 1983).

Results and discussion

Fresh tuber yields (FYLD) averaged over replications for the two years in the nine locations are summarized in Tables 1 and 2. Mean fresh tuber yield ranged between 22.17 to 30.60 t/ha. Genotype 50395 registered the highest mean value, while genotype 30555 gave the lowest mean FYLD value.

Combined analysis of variance is presented in Table 3. All main effects of year and location were significant and contributed 2.71% and 29.86% to the total

TABLE 1

Fresh tuber yields for the individual locations averaged for the two years

	Location*									
Clone	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Mean*
30555	18.24	20.57	34.54	13.35	13.62	20.86	18.45	36.96	22.92	22.17
30572	22.87	23.99	37.24	18.37	23.12	26.04	24.34	35.53	22.32	25.98
4(2)1425	18.36	16.98	38.94	24.74	22.15	23.27	23.11	43.17	19.88	25.62
50395	21.25	24.66	39.12	22.38	27.93	28.04	28.64	57.05	26.33	30.60
81\00110	17.69	19.61	34.78	23.62	25.86	25.53	26.00	39.23	25.59	26.43
81\01635	20.12	19.32	40.36	19.41	22.38	22.99	25.72	38.01	22.86	25.69
82\00058	25.71	23.50	45.12	25.95	22.50	35.89	32.19	38.62	23.67	30.35
82\00661	22.58	24.66	38.95	24.39	24.59	27.03	30.72	45.63	24.95	29.28
82\00942	22.77	22.18	35.42	22.09	23.27	29.07	28.77	35.97	24.70	27.14
90059	20.19	17.10	28.16	19.96	22.37	28.12	18.16	38.02	20.91	23.67

* 1=Abuja; 2=Agbarho; 3=Calabar; 4=Ibadan; 5=Ilorin; 6=Onne; 7=Ubiaja; 8=Seko; 9=Fumesua.

TABLE 2

Fresh tuber yield of 10 cassava genotypes in nine locations for two years

Genotypes	*Fresh tuber yield (t/ha)*
30555	22.17
30572	25.62
4(2)1425	25.62
50395	30.60
81\00110	26.43
81\01635	25.69
82\00058	30.35
82\00661	29.28
82\00942	27.14
90059	23.67
CV%	30.78
LSD	2.99

sum of squares, respectively. The genotype and year interaction was not significant and this reflected in the low contribution to the total sums of squares. Genotype × location interaction was significant and contributed 4.83% to the total sums of squares. This is an indication that both favourable and unfavourable environments occurred during the experiment, the unfavourable condition could be due to a change in rainfall pattern or variation in agronomy practices. Yield response of the genotypes to environment was differential, thus genotypes can be targeted to specific environments.

Yield stability results are shown in Table 4 based on rank sum methods. The stability statistic used were those of Finlay and Wilkinson's b-value and Shukla's stability variance. Finlay & Wilkinson (1963) reported that cultivars with b>1, b=1 and b<1 have below-average, average, and above-average stability, respectively. By the regression method, genotype 82/00058 with a b-value less different from unity was considered as having average stability and high yielding. This genotype may, therefore, perform well in any of the agroecologies under study. Genotypes 4(2)1425 and 50395 had b-values higher than unity and, therefore, considered as having below-average stability. However, the mean yield for genotype 50395 was 30.60 t/ha which was above the grand mean yield of 26.69 t/ha. Mean yield for 4(2)1425 was 25.62 t/ha which fell below the grand mean. These genotypes would,

TABLE 3

Combined analysis of variance of 10 cassava genotypes in nine locations for 2 years

Source	*Degrees of freedom*	*Mean squares*
Year	1	3543.61**(2.71)
Location	8	4878.94**(29.86)
Year × Location(Environment)	8	3055.00**(18.69)
Replicate(location × Year)	54	256.62**(10.60)
Genotype	9	519.06**(3.57)
Genotype × year	9	37.03(0.255)
Genotype × location	72	87.62**(4.83)
Genotype × location × Year	72	82.40**(4.54)
Pooled error	48	67.11(24.95)
Total	719	

Figures in brackets refer to percentage contribution to sum of squares.

TABLE 4

Mean yield, stability parameters and rank sums yield and stability of 10 cassava cultivars in nine locations in diverse agroecological zones

Clones	*Mean yield(ton\ha)*	*Finlay & Wilkinson's b-value*	*Shukula*	*Rank sum*
30555	22.17	1.08	95.77	18
30572	25.98	0.91	31.70	8
4(2)1425	25.62	1.21	97.70	20
50395	0.60	1.21	89.78	11
81\00110	26.43	0.89	81.17	12
81\01635	25.69	1.11	68.88	13
82\00058	30.35	1.02	123.93	12
82\00661	29.28	1.07	32.32	6
82\00942	27.14	0.77	50.44	11
90059	23.67	0.74	150.19	23
Mean	26,69			

therefore, be adapted to only favourable agroecologies by Finlay and Wilkinson's stability statistic. Shukla (1972) defined a stability variance value, which considered a genotype with a relatively large variance to have low stability. By Shukla's definition, genotype 30572 ranked the most highly stable. By the rank sum method of yield performance, Finlay and Wilkinson's b-values and Shukla's variance stability, genotypes 82/00661, 30572, 82/00942 and 82/00058 satisfied the criterion for high yielding stability. In the study of G × E interaction with cassava genotypes by Otoo *et al.* (1991), genotypes 30572 and 50395 among other genotypes were found to be high yielding and stable. Their result is, therefore, in agreement with the rankings of the genotypes in the present work.

Yield stability differences among the

genotypes were further investigated by plotting individual genotype mean yields (Y-axis) against the coefficient of variation (CV) per cent for each genotype (X-axis) (Fig.1). By drawing a horizontal line through the genotype mean yield of 26.69 t/ha and a

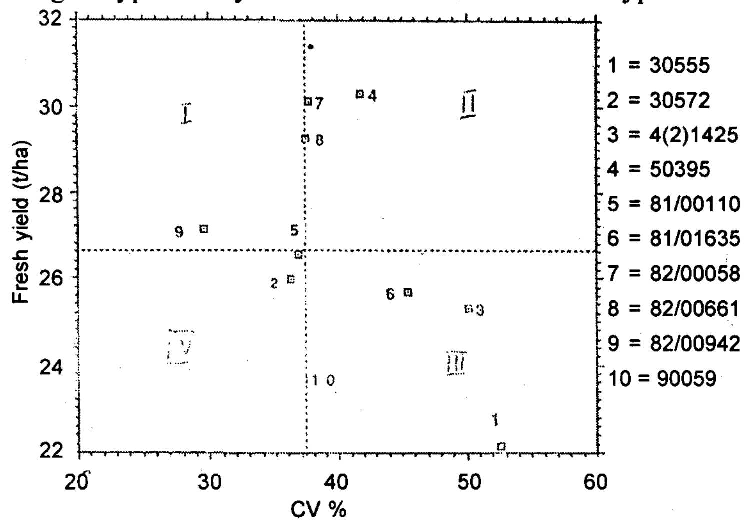

Fig. 1. Fresh tuber yield *vs* CV per cent of 10 cassava genotypes in nine locations for 2 years.

vertical line through the CV per cent grand mean, four quadrants were formed. Genotypes with CV mean and mean yield above grand mean were judged high-yielding with low stability, while genotypes with low CV per cent (i e. with CV per cent below the grand mean for the CV per cent) and mean yield below the grand mean were judged as low-yielding with high stability. In Fig. 1, genotype 82/00942 in quadrant I was considered as stable and high-yielding. This suggests that this genotype might perform well in all the agroecologies under study. Genotypes 82/00661 and 82/00058 were border-line cases of high-yielding stability. Genotypes 50395 fell within quadrant II, it was considered less stable but high-yielding and, therefore, may be targeted to a specific agroecology where it may perform well. In quadrant III, genotypes 30555, 4(2)1425, 81/01635 and 90059 had CV per cent values higher than the grand mean and their means were lower than the grand mean, thus they were considered unstable and low-yielding. Genotypes 81/00110 and 30572 fell within quadrant IV. They had CV per cent values below the CV per cent grand mean and a mean yield below the grand yield. They were thus judged as having high stability but low-yielding. As far as stability is concerned, the rank sum and the plot methods agreed in judging genotypes 30572, 82/00942 and 81/00110 as stable. However, so far as phenotypic stability is concerned genotype 82/00942 was phenotypically stable.

By this study it is possible that cassava phenotypic stability could be achieved for West African agroecologies without reduction in yields. Evaluation of phenotypic yield stability should be a necessity in cassava breeding programmes in West Africa due to erratic changes in environmental conditions.

Conclusion

Locations for fresh tuber yield trials of IITA cassava breeding clones in the three West African countries showed clearly marked differences in response of the genotypes to the environments of the locations. Stability statistics showed some yield stability in some of the genotypes, suggesting that breeding cassava for improved stability across environments is feasible.

References

Crossa, J. P., Fox, N., Pfeiffer, W. H., Rajaram, S. & Gauch, G. Jr (1991) AMMI adjustment for statistical analysis of an international wheat yield trial. *Theoretical and Applied Genetics* **81**, 27-37.

Eberhart, S. A. & Russell, W. A. (1966) Stability parameter for comparing varieties. *Crop Sci.* **6**, 36-40.

Finlay, K. W. & Wilkinson, G. N. (1963) The analysis of adaptation in a plant-breeding programme. *Aust. J. Agric. Res.* **14**, 742-754.

Francis, T. R. & Kannenberg, L. W. (1978) Yield stability studies in short-season maize. I. A descriptive method for grouping genotypes. *Can. J. plant Sci.* **58**, 1029-1034.

Kang, M. S. (1988) A rank-sum method for selecting high-yielding, stable corn genotypes. *Cereal Res. Commun.* **16**, 113-115.

Kang, M. S. & Gorman, D. P. (1989) Genotype × environment interaction in maize. *Agron. J.* **81**, 662-664.

Lin, C. S., Binns, M. R. & Lefkeviteh, L. P. (1986) Stability analysis. Where do we stand? *Crop Sci.* 26, 894-900.

Lin, C. S. & Binns, M. R. (1988) A method of analyzing cultivar × location × year: a new stability parameter. *Theor. Appl. Genet.* **76**, 425-430.

McIntosh, M. S. (1983) Analysis of combined experiments. *Agron. J.* **75**, 153-155.

Otoo, J. A., Dixon, A. G. O, Asiedu, R., Okele, J. E, Maroya, G. N. Tougnon, K. Okoli, O. O., Tetteh, J. P & Hann, S. K. (1991) Genotype × environment interaction studies with cassava. In *Tropical Root Crops in a Developing Economy* (ed. F. Ofori and S. K. Hann). *The International Society for Tropical Root Crops*. pp. 146-148.

Perkins, J. M. &. Jinks, J. L. (1968) Environmental and genotype-environmental components of variability. III. Multiple lines and crosses. *Heredity* **23**, 339-356.

Plasteid, R. L. (1960) A shorter method for evaluating the ability of selections to yield consistently over locations. *Am. potato J.* **37**, 166-17.

Plasteid, R. L & Peterson, L. C. (1959) A technique for evaluating the ability of selections to yield consistently in different locations or seasons. *Am. Potato J.* **36**, 381-385.

Statistical Analysis System (SAS) Institute (1989) *SAS User's guide*. Cary, N.C.U.S.A.

Shukla, G. K. (1972) Some statistical aspects of partitioning genotype-environmental components of variability. *Heredity* **29**, 237-245.

Wricke, G. (1962) Uer eine Methode Zur Erfassung der okologische Sreubreite in Feldversuchen. *Z. Pflanzenzuecht.* **47**, 92-96.