PHENOTYPIC STABILITY OF NINE MAIZE (*ZEA MAYS* L.) VARIETIES IN WEST MALAYSIA

WONG LOCK JAM

Accepted for publication on 15 December, 1977

RINGKASAN

Sembilan jenis jagung telah dinilaikan pada enam keadaan kawasan. Kebanyakannya perbezaan diantara jenis pada tiap-tiap kawasan adalah ternyata. Walaupun demikian tindakan jenis x keadaan kawasan (linear) tidak berkesan. Jenis-jenis Kisan, Bogor Comp. 2 dan Metro didapati adalah jenis-jenis yang tetap (stable) dengan b_i = 1.0 dan mempunyai purata gandadua (mean squares) minima untuk sisehan. Dari tiga jenis itu, jenis Bogor Comp. 2 memberi hasil purata yang paling tinggi, 17.6% lebih tinggi dari purata keselurohan. Kumpulan yang tidak tetap ialah Guatemala (PB5) dan Jawahar yang mempunyai b_i<1.0, dan jenis-jenis College White x Tuxpeno, UPCA Var 1, 2 and 4 yang mempunyai b_i>1.0. Pertalian yang tinggi terdapat diantara hasil purata dan 'regression coefficient' tiap jenis.

INTRODUCTION

A major concern in any varietal testing programme is the influence of genotype x environment interaction. The latter usually affects the reliability of estimates obtained. Its presence is attributed to the relative performances of different genotypes, or varieties, changing in different environments. This makes it difficult to evaluate a variety which is relatively stable in performance under different environmental conditions.

A statistical method to study phenotypic stability in barley was first introduced by FINLAY and WILKINSON (1963). EBERHART and RUSSELL (1966) modified and improved it for maize study, NARENDRA GRUPTA (1969) applied it on tobacco and JOSHI *et al.*, (1972) on groundnut. This paper presents a study on the phenotypic stability for yield in nine maize varieties.

MATERIALS AND METHODS

The nine varieties were grown in four locations with two being repeated over two years under the Inter-Asian Corn Programme (ANON 1969, ANON 1970). The locations in the first year were Federal Experiment Station at Serdang, College of Agriculture at Serdang (now the University of Agriculture, Malaysia), Peat Research Station at Tanjong Karang (Selangor) and Federal Experiment Station at Lundang (Kelantan). The latter two locations were retained in the second year. A randomised complete block design with four replications was used for each trial. Each plot was made up of four five-metre rows and the middle two being retained for grain yield determination. All the varieties except Metro were supplied under the Inter-Asian Corn Programme from Thailand.

The names and pedigrees of materials used are as listed below:

Variety	Grain colour	Pedigrees
UPCA Var 1	Yellowish Orange	Open-pollinated variety derived from Carribean Yellow Flint.
UPCA Var 2	White	Open-pollinated variety derived from Intermediate white Synthetic III.
UPCA Var 4	White	Open-pollinated variety derived from Late White Synthetic.
College White x Tuxpeno	White	Open-pollinated variety derived from an advanced generation cross of College White and Tuxpeno.
Bogor Comp. 2	Yellowish Orange	Composite variety derived from E.H. 228, 236, 421, 223 & 220, Vens. 1, Amarillo de Cuba and Caribean Flint.
Guatemala (PB 5)	Yellowish Orange	Open-pollinated variety derived from Tequisate Golden Yellow.
Kisan	Yellowish Orange	Composite variety derived from an advanced generation cross of J_1 x Coastal Tropical Flint.
Jawahar	Yellowish Orange	Composite variety derived from an advanced generation cross of A1 x Antigua Gr. 1.
Metro	Yellowish Orange	Open-pollinated variety derived from Tequisate Golden Yellow; sister population of Guatemala (PB 5).

The EBERHART-RUSSELL's model (1966) was adopted for the stability analysis here, where

$$Y_{ij} = U_i + \beta_i I_j + \delta_{ij}$$

Y_{ij} being the mean of ith variety at ith location, U_i is the mean of ith variety over all locations β_i is the regression coefficient of ith variety to varying environments. δ_{ij} is the deviation from regression of the ith variety at the jth environment, and I_j is the environmental index at jth environment expressed as a deviation from the grand mean of all varieties at all locations. Hence, $\Sigma I_j = 0$. The two stability parameters being estimated by tthis model are β_i and δ_{ij}.

Analysis of variance for yield was conducted for each environment followed by a combined analysis for all environments. The latter partitions the genotype x environment interactions variance into two components:-

(i) the predictable (β_i) – variation due to the responses of varieties under different environment indices, and

(ii) the unpredictable (δ_{ij}) unexplainable deviations from linear regressions.

According to this model a stable variety is one with $b_i = 1$ and having very small deviations from regression, ($S^2_d \rightarrow 0$); and $b_i = 1.0$ indicates unstable variety with varieties having $b_i > 1$ being adapted to high yielding environments and $b_i < 1.0$ being adapted to low yielding environments. The second parameter, S^2_d, in this paper was approximated by the F-test for individual mean squares for deviations. Varieties were considered acceptable when the corresponding F-test were not significant at 5% level of probability.

RESULTS AND DISCUSSION

The varietal yields in different environments are presented in *Table 3*, whereas the overall mean of varieties and the respective regression coefficients are presented in *Table 2*. The combined analysis of variance for stability of grain yield is presented in *Table 1*. *Figure 1* shows the distribution of varieties with reference to their means and regression coefficients. The mean regression coefficient over all environments is taken as one (b = 1.0). The performance of varieties in different environments are graphically presented in *Figure 2*.

TABLE 1. ANALYSIS OF VARIANCE FOR STABILITY OF GRAIN YIELD

Source of Variation		Degree of Freedom		Mean square
Replications	18			2,184,581.17
Varieties (Var)	8			6,231,507.49**
Environments (Env))	45			3,513,657.53**
Var x Env)				
Env. (linear)		1		106,455,739.89**
Var x Env (linear)		8		1,455,834.85
Pooled Deviations		36		1,111,449.17*
'Jawahar'			4	1,354,196.51
UPCA Var 1'			4	2,795,692.04**
'Bogor Comp. 2'			4	555,509.19
'College Wh. X Tuxpeno'			4	2,438,240.82**
'UPCA Var 2'			4	971,049.93
Kisan'			4	34,772.76
'UPCA Var 4'			4	588,151.16
'Guatemala (PB 5)'			4	856,792.95
'Metro (check)'			4	408,637.19
Pooled Error	144			631,766.03

* Significant at 5% level of probability
** Significant at 1% level of probability.

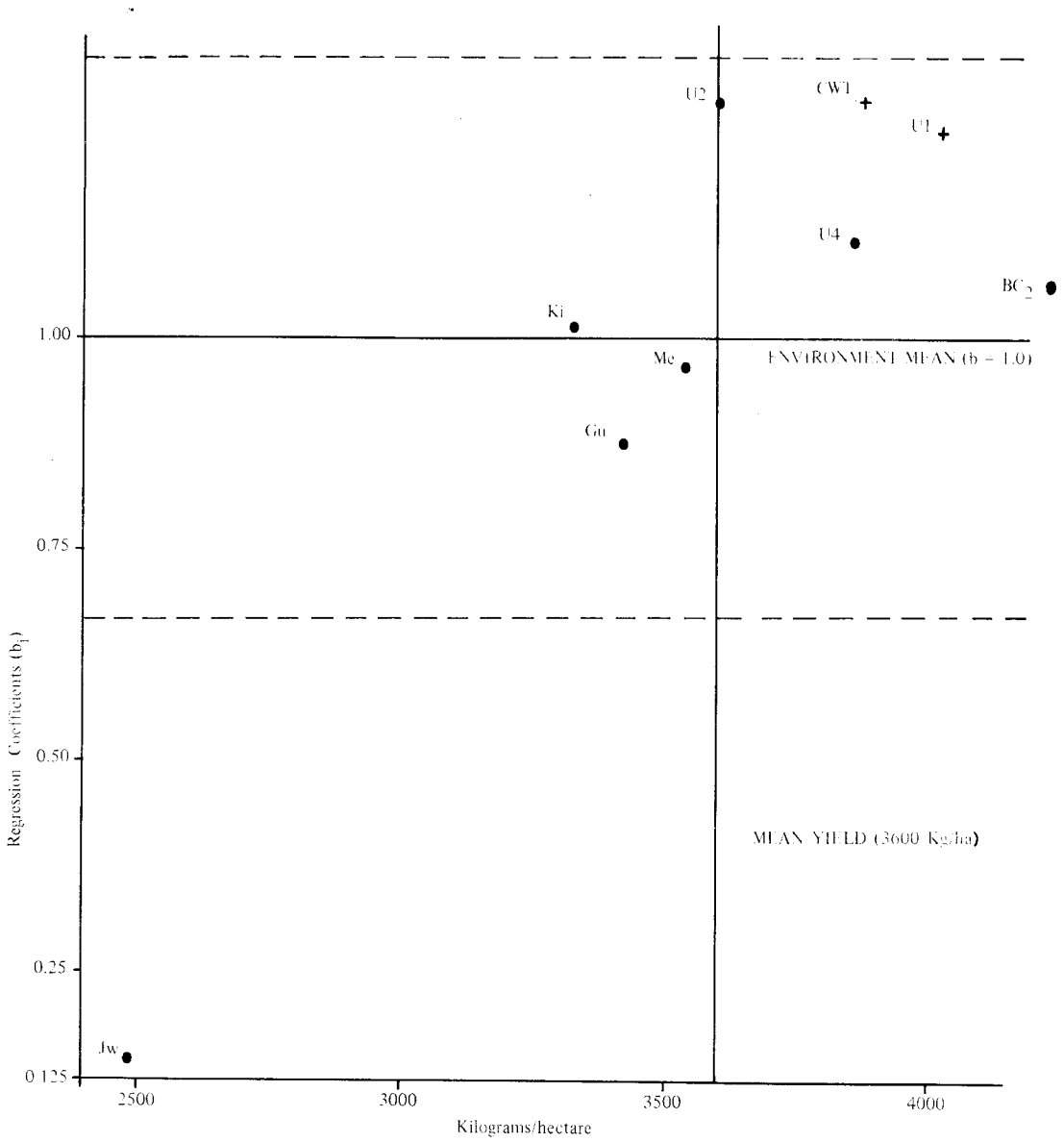

Figure 1. Regression Coefficients and Mean Yields of Varieties

*BC2 Bogor Composite 2, U1 UPCA Var 1, U2 UPCA Var 2, U4 UPCA Var 4,
CWT College White X Tuxpeno, Me Metro, Ki Kisan, Gu Guatemala,
Jw Jawahar
+ indicate estimates of deviation mean squares were significant (P = 0.01).
----- one standard deviation above and below Environment Mean.

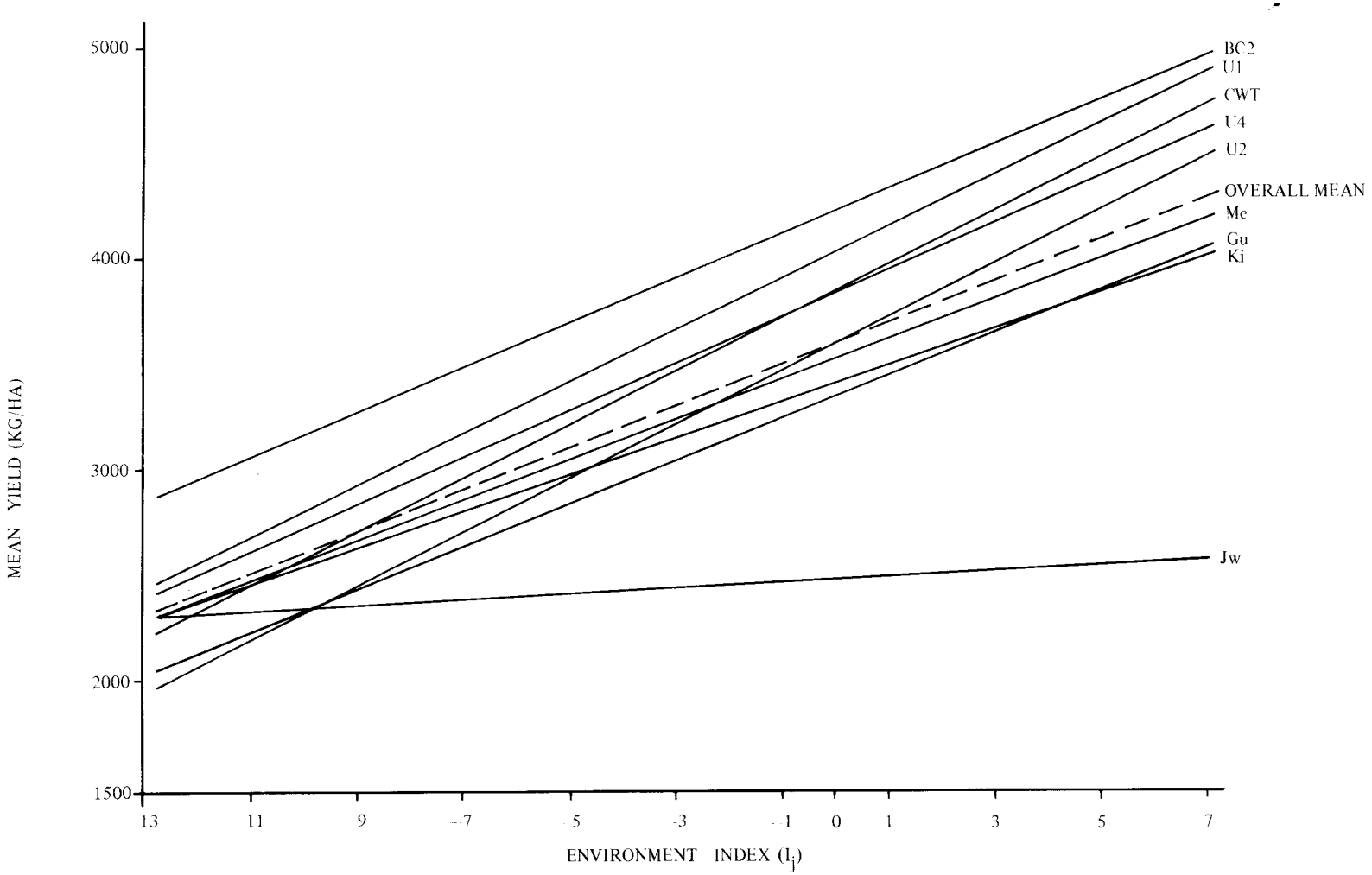

Figure 2. Relationship of Varietal Performances and Environment Indices

TABLE 2. MEAN YIELDS AND STABILITY PARAMETER OF VARIETIES

Rank	Variety	Mean Grain Yield (kg/ha)	Regression Coefficient (b_i)	F–test – Mean Squares for Deviations	Mean yield Expressed as % Overall Mean
1.	Bogor Comp. 2	4229	1.065	NS	117.6 %
2.	UPCA Var 1	4031	1.243	**	112 1
3.	College Wh. X Tuxpeno	3874	1.281	**	107.7
4.	UPCA Var 4	3861	1.136	NS	107.3
5.	UPCA Var 2	3600	1.273	NS	100.1
6.	Metro (check)	3534	0.961	NS	98.3
7.	Guatemala (PB 5)	3424	0.888	NS	95.2
8.	Kisan	3337	1.011	NS	92.8
9.	Jawahar	2483	0.143	NS	69.0
	Overall mean	3597	1.000		100.0

NS not significant. ** Significant at 1% level of probability

Separate analyses of variance for each environment were performed and the varieties compared using Duncan's Multiple Range test. In most cases the differences between varieties in each environment were marked. Bogor Comp. 2 and UPCA Var 2 were high yielding in most environments. On the other hand, Jawahar was consistently low yielding, being the lowest yielders in five of the six environments as in *Table 3.* The rest of the varieties did not give any definite trend as far as ranking of varieties were concerned.

Significant differences between varieties were also detected in the combined analysis of variance as given in *Table 1.* As normally would be expected, responses of varieties to environments were very marked. However, the mean square for variety x environments (linear) interactions was not statistically important. This indicated that the differential genetic responses of varieties to environments were absent or could not be detected. The latter could be attributed to the narrow range of environment indices used and the significant pooled deviation. Most likely this phenomenon could be due to the broad genetic bases of these composites and synthetics that aided in their adjustments to the environments, normally referred to as genetic homeostasis (EBERHART & RUSSELL 1969). JOSHI *et al.,* (1971) working with groundnut varieties also obtained non-significant interactions. Inspection of individual deviations showed that three varieties were mainly responsible for the high pooled deviation. They were UPCA Var 1. Collége White x Tuxpeno and Jawahar. Of all the other varieties showing acceptable deviations Kisan was the lowest, followed by Metro, Bogor, Comp. 2, UPCA Var 4, Guatemala (PB 5) and UPCA Var 2 in that order.

The b_i values indicated the relative behaviour of each variety in terms of mean yields with the environment mean having unit value. According to EBERHART & RUSSELL's definition (1966) the most stable varieties were Kisan, Metro and Bogor Comp. 2, having $b_i \simeq 1.0$. Of these three varieties only Bogor Comp. 2 had mean yield greater than overall environment mean.

TABLE 3. YIELD PERFORMANCE OF VARIETIES IN DIFFERENT ENVIRONMENTS

	Variety	ENVIRONMENT						Variety Mean
		FES Serdang	College Serdang	Tanjong Karang		Lundang		
		1st Year	**1st Year**	**1st Year**	**2nd Year**	**1st Year**	**2nd Year**	
1.	Jawahar	2983 c*	3110 d	2434 b	2485 b	2243 ab	1640 b	2483
2.	UPCA Var 1	3590 bc	5934 a	3683 ab	4133 a	2265 ab	4581 a	4031
3.	Bogor Comp 2	4846 a	4422 bc	4403 a	3857 ab	2671 a	5174 a	4229
4.	College Wh. X Tuxpeno	5296 a	4342 bc	4762 a	2531 b	2311 ab	4004 a	3874
5.	UPCA Var 2	4401 ab	3747 cd	4054 a	2786 ab	1873 b	4592 a	3600
6.	Kisan	3634 bc	4040 cd	3512 ab	2562 b	2117 ab	4052 a	3337
7.	UPCA Var 4	3790 bc	5133 ab	3700 ab	3368 ab	2500 ab	4676 a	3861
8.	Guatemala (PB 5)	3174 c	4022 cd	3759 ab	2669 ab	2541 ab	4488 a	3424
9.	Metro (check)	3818 bc	4077 cd	3300 ab	3012 ab	2400 ab	4606 a	3535
	Environment Mean	3965	4314	3734	3045	2325	4201	3597

*Values followed by the same letter under the same column denotes non-significance at 5% level using the new Duncan's Range test.

The other entries tended to be more adapted to specific environments. Guatemala (PB 5) and Jawahar, having b_i values of less than one, were adapted to low yielding environments. Jawahar, hhaving b_i value close to zero, appeared to give about the same yield in any location irrespective of the environment index. UPCA Var 1, UPCA Var 2 and College White x Tuxpeno, having b_i values greater than one, apparently were more adapted to high yielding environments.

Thus, it could be seen that in terms of the stability parameters of regression coefficients and deviations from regression (EBERHART–RUSSELL's model), Bogor Comp. 2, Metro and Kisan were stable varieties. However, looking at mean yield data, Bogor Comp. 2, UPCA Var 1 and College White x Tuxpeno were the highest yielders. Hence, Bogor Comp. 2 was the highest yielding and most stable variety. Based on these facts Bogor Comp. 2 should be the most acceptable variety for wide usage.

Though there are more than one models on phenotypic stability estimation (PLAISTED & PETERSON 1959, FINLAY & WILKINSON 1963, EBERHART & RUSSELL 1966, and TAI 1971), generally they could be grouped into two types – (i) a stable variety is one with b = 1, i.e. performing proportionately to the environment index, and (ii) stable variety is one with b = 0, i.e. performing consistently irrespectively of the environment index. Based on the latter, hence, Jawahar would be the most stable variety. A breeder would have to decide between breeding for a variety with high mean yield and b = 1 and another with high mean yield and having b = 0. Ideally, a variety with a mean yield of, say, 5000 kg/ha and b = 0 would be far more superior than another with mean yield of 5000 kg/ha and b = 1 as far as a developing country like ours is concerned. But is that variety realistic or easily obtainable? In other words, what is the probability of obtaining a variety with mean yield greater than the overall mean and having $b_i \doteq 0$? The data presented in *Table 1,* tend to show that varieties with $b_i<1.0$ also have mean yields below the overall mean as in the cases of Metro, Guatemala (PB 5) and Jawahar. These results added support to EBERHART & RUSSELL's (1966) finding that varieties with $b_i<1.0$ usually have mean yields below the grand mean. An analysis of regression coefficients and mean yields showed high correlation, r = + 0.864, with significance greater than 1% level of probability. Hence, the probability of obtaining a variety with mean yield in excess of overall mean and having $b_i \doteq 0$ is very low. This also explains why the lower right quadrant of *Figure 1* is empty. Thus, it is easier to obtain a high yielding variety with $b_i \doteq 1$ than another with $b_i \doteq 0$.

ACKNOWLEDGEMENT

I am greatly indebted to my colleagues for the field experimentation, data collection and analyses. In particular I would like to thank Dr. Yap Thoo Chai and Dr. Ooi Swee Chai for their helpful comments and to Encik Low Wan Loy and Encik Lee Chong Soon for their statistical assistance.

SUMMARY

Nine maize varieties were evaluated over six environments. In most cases the differences between varieties in each environments were marked. However, variety x environment (linear) interactions was not significant. Kisan, Bogor Comp. 2 and Metro were found to be stable varieties with $b_i = 1.0$ and having minimum mean squares for deviation. Of the three varieties, Bogor, Comp. 2 gave the highest mean yield, 17.6% higher than the overall mean. The unstable group comprised Guatemala (PB 5) and Jawahar, having $b_i<1.0$ and College White x Tuxpeno, UPCA Var 1, 2 & 4 having $b_i>1.0$. Mean yields and regression coefficients of varieties were found to be highly related.

REFERENCES

ANON. (1969). Summary report of the 1969 IACP Uniform Yield Trials – An activity of Inter-Asian Corn Programme.

ANON. (1970). Summary report of the 1970 IACP Uniform Yield Trials – An activity of Inter-Asian Corn Programme.

ALLARD, R.W. and BRADSHAW, A.D. (1964). Implication of genotype x environment interactions in applied breeding. Crop Sci. 4 : 503–507.

EBERHART, S.A. and RUSSELL, W.A. (1966). Stability parameters for comparing varieties. Crop Sci. 6 : 36–40.

EBERHART, S.A. and RUSSELL, W.A. (1969). Yield and stability for a 10 – line diallel of single – cross and double-cross maize hybrids. Crop Sci. 9 : 357–361.

FINLAY, K.W. and WILKINSON, G.N. (1963). The analysis of adaptation in a plant – breeding programme. Aust. J. Agr. Res. 14 : 472–754.

JOSHI, S.N., VAISHANANI, N.L. and KABARIA, M.M. (1971). Stability parameters in bunch varieties of groundnut (Arachis hypogaea L.) Ind. J. Agr. Sci. 42 : 145–7.

NARENDRA GUPTA, T.B.R. (1969). Stability parameters for comparing a few newly evolved flue-cured 'virginia' tobacco varieties. Ind. J. Agri. Sci. 39 : 1102–12.

PLAISTED, P.I. and PETERSON, L.C. (1959). A technique for evaluating the ability of selections to yield consistently in different location or sessions. AM. Potato J. 36 : 381–5.

TAI, C.C. (1971). Genotypic stability and its application to poto regional trials. Crop. Sci. 11 : 184–190.