GENOTYPE-ENVIRONMENT INTERACTIONS IN WINGED BEAN (<u>PSOPHOCARPUS</u> <u>TETRAGONOLOBUS</u> L.DC.) AND THEIR IMPLICATIONS IN SELECTION.

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SUMMARY

A series of experiments was carried out in Sri Lanka in which a set of 13 winged bean varieties (ten University of Papua New Guinea selections - UPS, One Nigerian selection - TPT-2,One Thailand selection - Thailand D and One Sri Lankan selection - SLS 47) was grown in replicated trials at two locations (University Experimental Station, Dodangolla - 367 amsl and Ratmalagara Estate Madampe - 30 amsl) over two popular cropping seasons (Yala and Maha). Dodangolla was a higher yielding environment than Ratmalagara.

The analysis of variances indicated a genotype x environment (GE) interaction for all the characters (grain yield, vegetable pod yield and number of pods per plant). The GE interaction was further partitioned into heterogeneity between regression and the residual. A significant contribution for heterogeneity between regression was shown.

Linear regression of genotype and average yield, and the average yield of all the genotypes in each environment were evaluated. This resulted in having regression coefficients (b) ranging from 0.527 to 1.664, 0.401 to 1.765 and 0.536 to 1.622 for the three yield components respectively.

Thailand, Nigerian and Sri Lankan selections showed below average phenotypic stability and above average yield response indicating that they are highly sensitive to environmental changes and are specifically adapted to high yielding environments. UPS selections showed varying stability performances. The interesting feature was that within all the 13 varieties, one set showed below average phenotypic stability while the rest showed above average stability.

The implications of GE interactions in winged bean selection are also discussed.

INTRODUCTION

The winged bean (Psophocarpus tetragonolobus (L) DC) which is popularly known as 'Dambala' in Sri Lanka has become one of the most important crops. It is generally grown under rainfed conditions during two rainy seasons, Yala and Maha. The crop is mainly used for human consumption. The mature seeds and immature pods are very rich in protein content. The immature leaves too are used for human consumption as a protein-rich vegetable.. This could be grown in widely varying altitudes ranging from about the sea level to about 1000 m above sea level. But the yield varies greatly from location to location and season to season. One major cause of this variation in yield may be due to the interaction of the varieties with the environment.

Plant breeders generally believe that screening of varieties is best done under optimum conditions of climate and management. This certainly is a misconception. What prevents high yielding selections under optimum environments showing themselves as relatively greater failures under adverse conditions? Further this tendency to screen varieties under optimum conditions will bias the selection towards the varieties specially adapted to high yielding environments and reject those with general adaptability, which the latter may be just the variety that would be needed in a given situation. These early misconceptions were the result of our failure to appreciate the all important concept of genotype-environment interactions, namely, the tendency for different genotypes to respond differently to different climatic and management conditions.

Breese (1969) emphasizes the significance of this phenomenon when he states that "The occur nce of Genotype-environment interactions has long provided a major challenge in obtaining a further understanding of the genetic control of variability.

They have posed serious problems in interpreting evolutionary trends and have hampered the rationalisation of policy and procedure in breeding for improved performance in economic crops".

Genotype-environment interactions were reviewed by Hill (1975) and have been discussed by many others for several other crops such as, wheat, barley and oats (Liang, Hapne and Walter, 1966), soybeans (Shultz and Bernard, 1967). If the genotype-environment interactions for yield in winged bean are subject to genetic control as in other crops, then the level of interaction could be used as a selection criterion. There are clear indications of the existence of such interactions with respect to yield, however no detailed work appears to have been reported. Linear regression technique could be used to assess these interactions (Finlay and Walkinson, 1963; Eberhart and Russell, 1966; Freeman and Perkins, 1971). The use of this technique and its application on many other crops have been reviewed by Hill (1975). The present paper describes the results obtained from regression analysis for yield in winged bean using data from a varietal evaluation trial conducted at two locations over two seasons.

STATISTICAL PROCEDURE

The genotype-environment interaction of each genotype could be partitioned into two components. (1) the variation due to the response of the genotype to change in environment, measured by the slope (b) of the regression line and (2) the extent of unexplained variation in this response to environment change, indicated by significant deviations from the linear regression. The usual analysis of variance will be followed by a joint regression analysis, the final format of which will be as shown in Table (1). The two locations and the two seasons will be considered as 4 environments and analysis of variance done accordingly.

The response of each genotype to the range of environments was assessed by computing a linear regression of individual yield, on the mean yield of all genotypes for each location. Statistical methods used are explained by Breese (1969), Freeman and Perkins (1971).

As described by Finlay and Wilkinson (1963), Eberhart and Russell (1966), the 'b' values thus obtained for each variety will provide a dynamic interpretation (Table 2) of varietal adaptation to natural environments.

MATERIALS & METHODS

Thirteen varieties of winged bean (Table 3) were grown in a varietal evaluation trial at two locations and over two seasons of the year.

The two locations were University Experimental Station, Dodangolla (367 amsl) and Ratmalagara Estate, Madampe (30 amsl). The average rainfall and the temperature of the two seasons for the two locations are summarized in Table 4.

Each trial was grown in a randomized block design with 3 replicates. The spacings between and within rows was 1m respectively. Nitrogen as Ammonium sulphate (20% N) at the rate of 125 kg/ha, Phosphorus as Conc. Super Phosphate (48% P_2O_5) at the rate of 50 kg/ha, and Potassium as Muriate of Potash (60% Kl.) at the rate of 100 kg/ha were applied at planting. Thereafter Urea at the rate of 50 kg/ha was applied every four weeks after one month of planting. Out of the characters (growth, vegetative and yield) recorded, only the number of pods per plant, immature vegetable pod yield and grain yield were used in the analysis.

RESULTS

The means of the three yield components, grain yield, vegetable pod yield and number of pods per plant for all the genotypes at each of the location and over the two seasons are presented in Table 5. Clear indications were that there were large differences among locations and between seasons for the three yield components. As far as the grain yield was concerned the grading of the environments, in relation to their productivity, was Dodangolla - Yala > Dodangolla - Maha > Ratmalagara - Maha > Ratmalagara - Yala. However, for the vegetable pod yield and number of pods per plant the grading was Dodangolla - Yala > Dodangolla - Maha > Ratmalagara - Yala > Ratmalagara - Maha.

The analysis of variance for the three yield components are shown in Table 6. For all the components genotypes were significantly different ($p<0.001$). Further those characters were strongly influenced by the environmental differences ($p<0.001$) associated with the locations and seasons. The large mean squares for the environmental variations compared to the error mean square indicated the wide range of environments selected. This overcomes (Hardwick and Wood, 1972) some limitations expressed by Freeman and Perkins (1971). The analysis further showed the existence of the genotype-environment interaction ($p<0.001$).

The GE interaction sums of squares were further partitioned into a part measuring differences between the slopes of the regressions and a residual part which measured the scatter of points about the regression lines. When heterogeneity of regressions and the residual variation for vegetable pod yield and number of pods per plant were tested against the error term, only heterogeneity of regressions indicated a significant variation ($p<0.001$). A similar test for grain yield indicated significance for both heterogeneity of regression and residual variation ($p<0.001$). However heterogeneity of regression indicated a significant difference ($p<0.001$) when tested against by its residual. This indicated that most of the interaction for grain yield was accounted by the heterogeneity of regressions.

Thus the linear regression model may be of considerable value in predicting, for grain yield, vegetable pod yield and number of pods per plant.

The 13 genotypes used in this study showed regression coefficients ranging from 0.527 to 1.664, 0.401 to 1.765 and 0.536 to 1.622 (Table 7) for grain yield, vegetable pod yield and number of pods per plant, respectively. The large variation in the regression coefficients indicated that the genotype had different environmental responses. The coefficients of determination ranged from 93 to 99%, 96 to 99% and 96 to 99% for grain yield, vegetable pod yield and number of pods per plant respectively. Thus the regressions gave nearly perfect fits to the actual yields of the genotypes in the different environments. Given such a high degree of linearity in the interactions of genotypes with environments the linear model would have a high predictive value. Thus it could be said that the yields and the regression coefficients could be sufficient for selection of the winged bean varieties.

DISCUSSION

The existence of genotype-environment interaction may mean that the best genotype in one environment is not the best in another environment. The difficulties of evaluating selected varieties in the presence of such an interaction could be overcome to some degree by the use of regression techniques, which help the comparison of the performance of each genotype over the range of environments.

The regression coefficient measures responses to increments in an improving environment. Genotypes with b-values greater than unity would be adapted to more favourable growing conditions; whereas those with b-values less than unity would be adapted to less favourable growing conditions. A good genotype should have a very high genotype mean yield and general adaptation.

Regression coefficients thus estimated, along with variety mean yield could be used in the evaluation of selected varieties. The evaluation may be for grain yield and/or vegetable yield where immature pods are used as a vegetation. Fig. 1, indicates the relation of average grain yield and b-values estimated for the 13 winged bean varieties.

The interesting feature was that all the varieties tried were either highly sensitive to environmental changes or resistant to these changes, with the exception of UPS 62 having an average stability (b=1.015) and an average yield, almost equal to the population average.

Thus, UPS 62 could be reasonably identified as having general adaptability to all environments, and with an average yield response. The UPS strains 31, 32, 45, 47, 66 and 102 having b-values less than unity are specifically suited for poor environments with above average phenotypic stability. However, these varieties cannot be recommended for these environments since their yielding abilities were below average.

The UPS strains 99, 121 and 122 appear to be highly sensitive to environmental changes with below average stability (b>1.000). With the exception UPS 99, the performance of UPS 121 and 122 showed an above-average yield performance. Hence these could be considered as specifically adaptable varieties to high yielding environments. The yielding performance of UPS 99 is almost near the population average. On a close study (Table 1), it would be reasonable to suggest that the yielding ability of the UPS strains under Sri Lankan conditions appear to be related to the origin of their selections. All the other foreign (introduced) strains (compared with UPS), namely the Nigerian, Thailand and Sri Lankan, show a below-average phenotypic stability (b>1.000) and above-average yielding ability. These strains are all highly sensitive to environmental changes and could be considered as specifically adaptable to high yielding environments. The best out of these three was the Sri Lankan selection SLS 47, having the highest average grain yield of 115.6 (g/plant).

The relation of average vegetable pod yield and stability is shown in Fig. 2.

Here too, as for the average grain yield, the performance of the varieties could be classified into two groups, having below-average (b>1.000) and above-average (b<1.000) phenotypic stability. Further with regard to the yield the varieties were either above or below-average with the exceptions of UPS 31 and 62, which were showing the population average. Thailand-D, showed an average stability having an above-average yield performance. The performance (in to-to) of UPS -32, 45, 47, 66, 99, 102, 122, TPT2 and SLS 47, for average vegetable pod yield showed a similar response as was shown for grain yield.

Fig 3, indicates the relation of number of pods per plant and stability of the 13 winged bean varieties. As far as the nature of the phenotypic stability was concerned the performance of the varieties could be grouped as below-average and above-average, which was similar to the performances shown for grain yield and vegetable pod yield. The Thailand-D variety showed a similar performance as was shown for vegetable pod yield. UPS 31 and 62 showed a greater deviation in performance with regard to number of pods per plant, when compared to their performances with regard to grain yield and vegetable pod yield. The Nigerian and the Sri Lankanvarieties maintained the same status for all the three characters.

The ideal genotype as mentioned elsewhere should have a very high genotypic mean yield and general adaptation having a low variability. However, none of the varieties indicated such a performance. This suggests the necessity for further research ih evolving such varieties. Perhaps a judicious crossing programme with varieties having b-values > 1.000, and that of varieties showing b-values < 1.000 and evaluating the performances of the progenies thus obtained under widely varying environmental conditions, would evolve the varieties that will be most favoured by the farmers. Herath et. al. (1981) too have suggested a plant improvement and breeding programme based on results obtained under very favourable conditions.

The necessity for such an extensive programme could be amply justified by the establishment of the International Winged Bean Research Institute in Sri Lanka.

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Table 1. Table of analysis of variance and regression analysis.

Source of Variance	d.f.	Sum of squares	Mean square	F
Genotypes (G)	v-1			
Environments (E)	p-1			
Interaction (GxE)	(v-1) (p-1)			
Heterogenity of Reg.	v-1			
Residual	(v-1) (p-2)			
Replicates wn Env.	p(r-1)			
Error	p(r-1) (v-1)			

Table 2. Interpretation of the Response

Regression Coefficient	Phenotypic stability	Sensitivity to environment	Variety yield	Response
Greater than 1.00	Below Average	High	Above Average	Highly sensitive to environment changes and specifically adapted to high yield environments.
Greater than 1.00	Below Average	High	Below Average	Highly sensitive to environment changes but a poor yielder.
Approx. 1.00	Average	Average	Above Average	General adaptability to all environments.
Approx. 1.00	Average	Average	Below Average	Poorly adapted to all environments.
Less than 1.00	Above Average	Resistant to environmental change	Above Average	Specifically suited for poor and/or fluctuating environments.
Less than 1.00	Above Average	Resistant to environmental change.	Below Average	Not recommended.

Table 3. Winged bean varieties and their description.

Variety	Description	
1. UPS - 31	Province - Western Highlands;	Collection site - Kuk
2. UPS - 32	Province - Western Highlands;	Collection site - Bans
3 BBS - 45	Province - Simbu	Collection site - Kindeng
4. UPS - 47	Province - Simbu	Collection site - Kindeng
5. UPS - 62	Province - Era	Collection site - Kindeng
6. UPS - 66	Province - Eastern Highlands;	Collection site - Aiyura
7. UPS - 99	Province - Eastern Highlands;	Collection site - Goroka
8. UPS - 102	Province - Eastern Highlands;	Collection site - Aiyura
9. UPS - 121	Province - Madeng;	Collection site - Efn
10. UPS - 122	Province - Western Highlands;	Collection site - Chimbu
11. TPT - 2	Nigerian selection	
12. Thailand-D	Thailand selection	
13. SLS - 47	Sri Lanka selection	

UPS = University of Papua New Guinea selections.

Table 4. Climatic records at the two locations and over the two seasons.

Period		Dodangolla						Ratmalagara					
		Yala			Maha			Yala			Maha		
		Rainfall (mm)	Max. Temp °C	Min. Temp °C	Rainfall (mm)	Max. Temp °C	Min. Temp °C	Rainfall (mm)	Max. Temp °C	Min. Temp °C	Rainfall (mm)	Max. Temp°C	Min. Temp °C
May	a	40.0	34.5	24.7				42.4	31.1	26.7			
	b	8.9	32.8	24.4				154.4	31.0	28.3			
June	a	20.8	29.1	24.2				101.8	29.7	26.7			
	b	34.3	30.5	27.7				89.0	29.5	27.0			
July	a	43.2	30.2	23.9				10.6	30.3	27.3			
	b	14.5	30.5	24.1				25.0	30.3	27.3			
August	a	19.1	30.9	23.7				153.4	30.3	27.3			
	b	32.3	32.3	24.2				1.8	30.3	27.1			
September	a	0.0	33.5	25.0				0.0	27.9	25.6			
	b	128.0	31.7	24.1				36.6	29.0	26.7			
October	a	135.1	31.4	23.6	135.1	31.4	23.6	135.5	30.6	27.3	135.5	30.6	27.3
	b	60.7	30.2	23.7	60.7	30.2	23.7	137.3	30.4	24.5	137.3	30.4	24.5
November	a				127.0	28.6	22.0				114.9	29.4	25.2
	b				117.6	28.8	23.0				85.9	30.2	25.7
December	a				47.0	27.1	21.3				108.3	30.5	24.9
	b				20.6	27.1	22.3				10.4	31.7	25.5
January	a				97.8	26.7	21.2				0.0	31.4	25.2
	b				0.0	27.6	21.7				0.0	33.3	24.9
February	a				15.2	29.2	21.2				0.0	33.9	24.9
	b				0.0	30.9	19.5				0.0	34.3	26.4
March	a				0.0	32.8	23.6				0.0	34.1	28.0
	b				45.2	32.9	24.9				0.0	32.2	25.0

a - 1st two weeks

b - 2nd two weeks

Table 5. Average grain yield (g/plant), vegetable pod yield (g/plant) and no. of pods per plant of different genotypes at different environments.

Genotype	Grain yield (g/plant				Vegetable pod yield (g/plant)				No. of pods per plant			
	Dodangolla		Ratmalagara		Dodangolla		Ratmalagara		Dodangolla		Ratmalagara	
	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha
UPS - 31	113.6	157.2	10.0	19.4	3501.3	442.3	431.0	208.7	444.0	43.8	65.3	32.2
UPS - 32	119.8	61.8	9.3	18.9	2439.0	522.3	232.1	138.4	123.0	30.6	21.5	12.6
UPS - 45	176.5	52.3	9.5	18.8	2837.7	499.0	295.0	240.7	184.0	32.4	24.4	16.6
UPS - 47	83.2	37.5	13.1	19.2	1418.3	347.7	224.6	373.8	125.0	26.4	24.7	12.1
UPS - 62	192.9	72.8	13.4	14.7	3554.0	510.0	337.2	178.9	345.0	46.0	42.4	18.5
UPS - 66	105.4	49.6	11.8	13.3	1595.0	420.0	294.8	194.1	158.7	34.0	35.3	23.0
UPS - 99	222.3	48.8	17.1	27.6	3672.0	638.0	574.3	316.0	197.3	36.9	48.7	22.4
UPS - 102	121.4	60.5	10.3	14.1	1401.3	531.0	252.1	105.4	178.3	61.3	46.7	19.3
UPS - 121	287.5	71.4	5.9	25.7	2169.0	958.0	453.4	354.1	135.0	51.0	28.5	21.9
UPS - 122	310.1	54.4	8.0	28.4	5149.7	948.0	540.1	240.4	188.3	97.4	28.9	13.0
TPT - 2	270.3	111.6	6.3	30.4	5593.0	861.7	668.8	252.9	330.0	40.9	39.7	18.2
Thailand - D	232.3	103.6	5.4	30.3	3374.0	986.7	416.3	357.2	224.0	56.4	37.6	24.5
SLS - 47	254.6	176.7	3.7	27.9	5576.0	1056.7	340.5	366.5	281.0	53.8	24.5	24.0
Environmental Average	191.5	81.4	9.5	22.2	3252.4	670.9	389.2	255.9	224.1	47.0	36.0	19.9
Population Average			76.2				1142.1				81.7	

Table 6, Mean squares in analysis of variance and regression analysis for 13 winged bean varieties.

Source of Variation	d.f.	Grain yield		Vegetable pod yield		No. of pods per plant	
Genotype (G)	12	8052	***	2469186	***	9661	***
Environments (E)	3	268479	***	78800998	***	356149	***
Interaction (GxE)	36	4738	***	1465383	***	6930	***
Heterogeneity of Reg.	12	11532	*** +++	4304258	***	19470	***
Residual	24	1341	***	45945	n.s.	660	n.s.
Replication wn environments	8	185		125438		1288	
Error	96	314		27476		447	

*** Significant at $p<0.001$, when tested against error.

+++ Significant at $p<0.001$, when tested against residual.

Table 7. Stability parameters for yield characters in winged been varieties.

Variety	Grain yield			Vegetable pod yield			No. of pods per plant		
	$\bar{X}$	b±se	r^2	$\bar{X}$	b±se	r^2	$\bar{X}$	b±se	r^2
UPS - 31	50.1	0.564±0.043	0.9900	1145.8	1.103±0.065	0.9930	146.3	2.070±0.155	0.9988
UPS - 32	52.5	0.603±0.056	0.9841	832.9	0.762±0.016	0.9990	46.9	0.536±0.012	0.9990
UPS - 45	64.3	0.924±0.066	0.9900	968.1	0.879±0.026	0.9982	64.4	0.837±0.023	0.9984
UPS - 47	38.3	0.381±0.005	0.9996	528.8	0.422±0.009	0.9990	47.1	0.547±0.014	0.9986
UPS - 62	73.4	1.015±0.041	0.9960	1145.1	1.133±0.036	0.9978	113.0	1.622±0.054	0.9976
UPS - 66	45.0	0.527±0.033	0.9920	625.9	0.459±0.007	0.9994	62.8	0.670±0.028	0.9964
UPS - 99	78.9	1.139±0.169	0.9565	1300.2	1.114±0.052	0.9956	76.3	0.847±0.064	0.9886
UPS - 102	51.6	0.620±0.054	0.9841	572.4	0.401±0.052	0.9671	76.4	0.727±0.070	0.9819
UPS - 121	97.6	1.548±0.144	0.9821	983.6	0.575±0.982	0.9604	59.1	0.540±0.055	0.9797
UPS - 122	100.2	1.664±0.255	0.9545	1719.5	1.622±0.012	0.9988	81.9	0.777±0.216	0.9656
TPT - 2	104.6	1.436±0.048	0.9960	1844.2	1.765±0.062	0.9974	107.2	1.555±0.063	0.9966
Thailand - D	92.9	1.223±0.073	0.9920	1283.5	0.997±0.060	0.9926	85.6	0.974±0.025	0.9986
SLS - 47	115.6	1.359±0.350	0.9390	1835.0	1.768±0.062	0.9974	95.9	1.296±0.065	0.9948

$\bar{X}$ - average over all the environments

b - regression coefficient

se - std. error of b.

r^2 - coefficient of determination

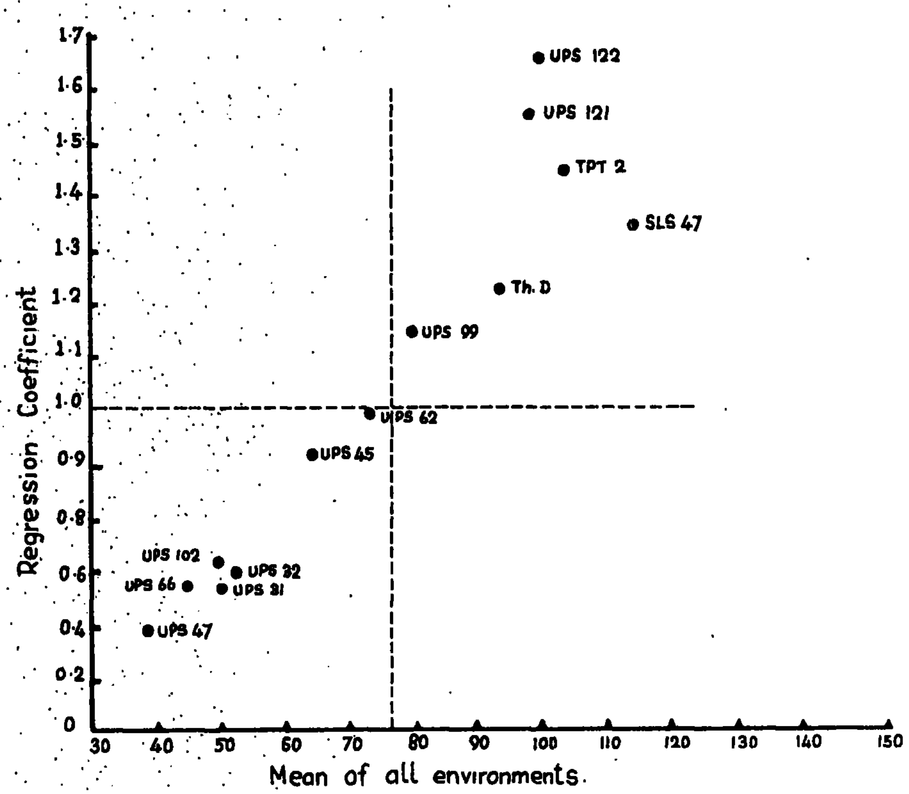

Fig. 1. The relation of Average grain yield (g/plant) and stability of 13 Winged bean varieties.

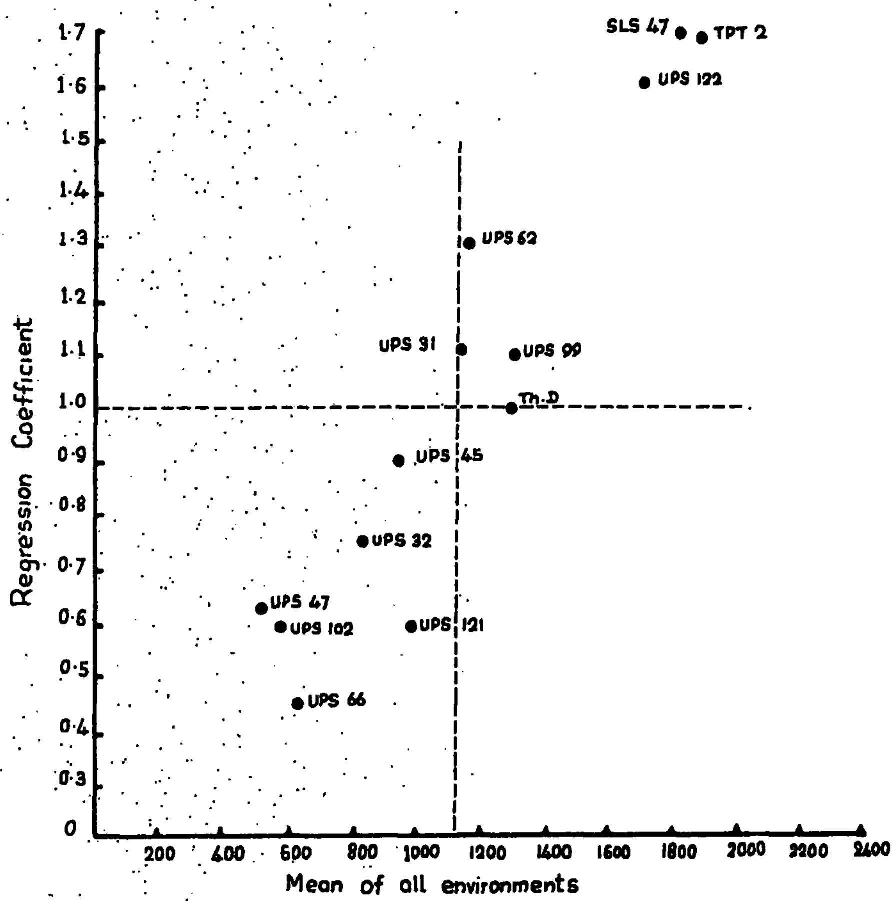

Fig. 2. The relation of Average vegetable pod yield (g./plant) and stability of 13 winged bean varieties.

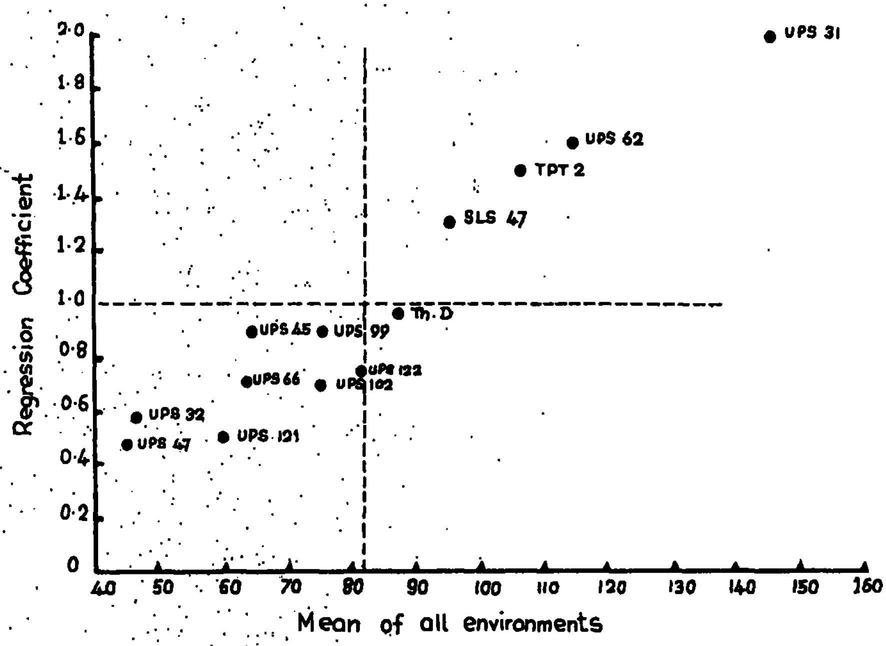

Fig. 3. The relation of no. of pods per plant and stability of 13 winged bean varieties.