834 JA 1013

Maydica 36 (1991): 83-86

YIELD STABILITY ANALYSIS OF PROMISING PEARL MILLET GENOTYPES IN SENEGAL[1]

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Received March 15, 1990

ABSTRACT - Genotype environment interaction in pearl millet (*Pennisetum glaucum* [L.] R. Br.) was studied for grain yield by growing 10 to 12 genotypes at 4 locations for 4 years in Senegal. Genotype x environment interaction was present; a large portion of the interaction was accounted for by the non-linear regression on the environmental means. Although the linear component was significant, its magnitude was considerably smaller than that of the non-linear component. All the genotypes except Souna III were stable and their responses to changes in environments could be predicted. The highest yielding entry was IBV 8001 which was significantly superior to the local checks in terms of grain yield production. IBV 8001 was the most desirable genotype as it had the highest grain yield and slope of unity, and the mean square due to deviation from regression was zero.

KEY WORDS: *Pennisetum glaucum* (L.) R. Br.; Stability; Genotype x environment interaction; Yield; Regression; Senegal.

INTRODUCTION

The importance of yield-testing of crop genotypes over a range of environments has been recognized by plant breeders (Comstock and Moll, 1963). A cultivar must not only yield well in its area of initial selection, but ideally it also must maintain a high yield level in many environments within its intended area of production.

Several approaches have been made to extract parameters of genotypic stability from genotype-environmental interactions. Finlay and Wilkinson (1963) utilized a regression technique first proposed by Yates and Cochran (1938) to measure "stability indexes" of barley varieties. They considered linear regression as a measure of stability (i.e., a genotype is more stable with a slope less than one and less stable when the slope is more than one). Eberhart and Russell (1966) defined a stable genotype as having a slope equal to one and a deviation from regression equal to zero. This approach has been extensively used by plant breeders (Reich and Atkins, 1970; Kofoid *et al.*, 1978; and Virk *et al.*, 1985). Later, Breese (1969), Samuel *et al.* (1970), Paroda *et al.* (1973), Singh and Gupta (1978), and Pethani and Kapoor (1985) emphasized that the linear regression should simply be regarded as a measure of the response of a particular genotype, whereas the deviation around the regression line should be considered as a measure of stability, genotypes with the lowest deviations being the most stable and vice versa. Eberhart and Russell (1966) reported that the deviation from regression, a second stability parameter, appears very important, as the genotype x environment (linear) sum of squares was not a very large portion of the genotype x environment interaction. Eagles *et al.* (1977), Fatunla and Frey (1974), and Gonzalez-Rosquel (1976) have found that only 5 to 20% of the genotype x environment sum of squares for random oat lines were attributable to differential regression values. Witcombe (1988) indicated the invalidity of mean squares for deviation from regression as a measure of stability in certain circumstances such as the deviations from regression caused by differences in disease resistances. A review of the

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[1] Submitted as J.A. No. 1013 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Institut Senegalais de Recherches Agricoles (ISRA), Bambey, B.P. 53, Senegal.

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methods for computing parameters of stability was made by FREEMAN (1973).

In the present paper, we have attempted to identify the high-yielding and stable genotypes of pearl millet *(Pennisetum glaucum* [L.] R. Br.) suitable for most of the pearl millet-growing areas of Senegal. The three evaluation traits used were mean grain yield, regression response to changing environments, and the stability of production estimated as deviation from regression.

MATERIALS AND METHODS

Materials

We used grain yield data from the advanced yield trials conducted at four diverse locations, representative of millet-growing regions of Senegal, for 4 years (1981 to 1983), by ICRISAT and ISRA cooperative program. The 16 environments and details of their location, latitude, total rainfall during the crop season, and environmental mean for grain yield are given in Table 1.

The number of genotype varied from 10 to 12 in different years and data analysis was only carried out on nine common genotypes. These genotypes consisted of seven open-pollinated cultivars newly developed by the authors plus two checks. One check, Souna III, was an improved cultivar. The other was the cultivar grown by the farmers in their respective regions. In each environment, the trial was planted immediately after the first good rain (20 mm) in a randomized block design. In each trial, there were six replications and the plot size was six rows of 5.2 m long and 80 cm apart. The plant-to plant spacing was 40 cm. The same dose of fertilizer (15 kg N, 33 kg P_2O_5, and 33 kg K_2O /ha) was applied as a basal dose in each environment. Forty-six kilos of nitrogen in the form of urea was top-dressed in equal two doses 20 and 40 days after planting. About 10 seeds per hill were planted and the crop was thinned to one plant per hill after 10 to 15 days of planting. The plot areas were weeded by horse-drawn implements and supplemented by hand weeding. The trials grown in all environments were rainfed. When mature, the ear heads from the central four rows, leaving the border plants, in each plot were harvested, air dried, threshed and weighed to estimate grain yield.

Statistical Procedure

Yield data from individual environments were analyzed as a randomized block. Before pooling the data, Bartlett's test for homogeneity of error variances was conducted (STEEL and TORRIE, 1980) and the data for grain yield of nine genotypes averaged over 10 environments was homogeneous. Stability parameters were estimated for grain yield by using the model described by EBERHART and RUSSELL (1966). This method utilizes the deviations from the grand mean of the yield over the various environments as production indexes of the environments. It provides regression response indexes (b values) and mean squares for deviations from regression minus pooled error (S^2d values) as indexes of production response and stability, respectively. Pooled error was obtained by averaging the error mean squares from analysis of variance of individual environments and dividing by the number of replications. The significance of mean squares were tested against pooled error. For testing significance of mean values, Least Significant Difference (LSD) was computed by using the pooled error. The t-test based on the standard error of regression value was used to test significant deviation from 1.0. To determine whether deviations from regression were significantly different from zero, the F-test was employed (i.e., comparing the mean squares due to deviations from regression with pooled error).

RESULTS

The environments used in this study covered a broad geographical area and are representative of the early-maturing pearl millet growing zones of Senegal. There was little variation in latitude and altitude, but large variation in rainfall and soil type. The mean yields at individual environments (Table 1) ranged from 0.19 t/ha at Louga in 1983 to 3.78 t/ha at Nioro in 1982. On an average over years, the highest-yielding location was Nioro and the lowest-yielding location was Louga. This is primarily because the total rainfall received at Nioro (565 mm) was much higher than at Louga (196 mm) during the cropping seasons.

The analysis of variance for grain yield was conducted only for 10 environments (Table 1) for which error variances were homogeneous. The analysis of variance (Table 2) showed significant differences in yield among the genotypes and a significant genoty-

TABLE 1 - *Description of environments with year wise, location wise, latitude, total rainfall in crop season and environmental mean for grain yield averaged over nine genotypes grown in each environment.*

Environment	Year	Location	Rainfall (mm)	Environmental mean (t/ha)
1	1981	Nioro	777	2.52*
2	1981	Darou	692	2.77*
3	1981	Bambey	504	2.26
4	1981	Louga	250	1.17*
5	1982	Nioro	542	3.78*
6	1982	Darou	745	1.51*
7	1982	Bambey	452	2.80
8	1982	Louga	215	1.03*
9	1983	Nioro	407	0.50*
10	1983	Darou	390	1.70*
11	1983	Bambey	316	1.89*
12	1983	Louga	146	0.19
13	1984	Nioro	536	1.42
14	1984	Darou	616	1.06
15	1984	Bambey	458	0.43
16	1984	Louga	173	0.44*

* Error variances are homogeneous.
Latitude: Nioro 13°8', Darou 13°9', Bambey 14°3' and Louga 15°3'.

TABLE 2 - *Pooled analysis of variance for grain yield (t/ha) based on means over six replications.*

Source	d.f.[1]	M.S.[2]
Genotype (G)	8	0.1812**
Environment (E)	9	9.9408**
G x E	72	0.0333**
E + G x E	81	1.1311
E (linear)	1	89.3670**
G x E (linear)	8	0.0496**
Pooled deviation from regressions	72	0.0278**
IBV 8001	8	0.0218
IBV 8004	8	0.0331
ICMS 7819	8	0.0272
PS 90-2	8	0.0121
H7 66	8	0.0163
H9 127	8	0.0303
H24-38	8	0.0277
Souna III	8	0.0608**
Local check	8	0.0176
Pooled Error	400	0.0174

** Significant at the 1% probability level when tested against pooled error. All other mean squares were not significant at 5% level.
[1] d.f. = Degrees of freedom.
[2] M.S. = Mean squares.

pe x environment interaction. The significant genotype x environment interaction indicated that the genotypes responded differently, relative to each other, to a change in environment. The significant genotype x environment (linear) comparison indicated that the stability parameter b, estimated by the linear response to a change in environment, was not the same for all genotypes. The mean square due to pooled deviations from regression was significant, indicating that the performance of at least some of the genotypes were not stable over environments. A large portion of sum of squares of genotype x environment interaction (83.4%) was accounted for by the deviations from regression. Only 16.6% were accounted for by the linear regression on the means in different environmental situations. These results are in agreement with EBERHART and RUSSELL (1966), EAGLES *et al.* (1977), FATUNLA and FREY (1974), GONZALEZ-ROSQUEL (1976) and WITCOMBE (1988).

The genotype, IBV 8001, produced the highest grain yield and was significantly superior to the best check. The four genotypes: IBV 8004, H7-66, Souna III and PS 90-2 were statistically at par with the local check (Table 3).

Estimates of regression coefficients (b) and the mean square due to deviation from regression (S^2d) did not show a wide range of values (Table 3). The regression coefficients were not significantly different from 1.0 for any genotype except H24-38. The regression value for H24-38 was less than 1.0 but more than zero, indicating that the genotype did not respond as much to improving environments as did other genotypes. The mean square due to deviation from regression was significantly different from zero only for Souna III, suggesting that the performance of this genotypes in different environments cannot be predicted. The farmers' cultivars (i.e., the local checks) were stable as their S^2d values and slopes not significantly different from zero and 1.0, respectively. However, they produced significantly less yield than IBV 8001.

DISCUSSION

A study of genotype x environment interactions can lead to a successful evaluation of stable genotypes which could be released to farmers and/or use in future breeding programs.

Three approaches have been used while defining a stable genotype using a regression technique.

a) A genotype is more stable when the slope is less than 1.0 and less stable when the slope is more than 1.0 (FINLAY and WILKINSON, 1963).
b) A genotype is stable when the slope is 1.0 and the S^2d is zero (EBERHART and RUSSELL, 1966).

TABLE 3 - *Mean grain yields, regression response indexes (b), and deviations from regressions (S^2d) for nine genotypes based on ten environments.*

Genotypes	Mean (t/ha)	b	SEb	S^2d
IBV 8001	1.94*	1.04	±0.05	0.0074
IBV 8004	1.87	1.05	±0.06	0.0160
ICMS 7819	1.68	1.05	±0.05	0.0098
PS 90-2	1.69	0.97	±0.03	-0.0053
H7-66	1.77	1.04	±0.04	-0.0011
H9-127	1.62	0.95	±0.06	0.0129
H24-38	1.49	0.86*	±0.05	0.0103
Souna III	1.73	0.97	±0.08	0.0434*
Local check	1.80	1.09	±0.04	0.0002
Mean	1.73			
SE ±	0.042			
LSD at 5%	0.116			
CV %	18.7			

* Yield significantly greater to superior check, and b values different from one at 5% level, and S^2d different from zero at 1% level. All other mean squares were not significant at 5% level.

c) A genotype is stable when the S^2d is zero (Breese,1969; and Pethani and Kapoor, 1985).

While using the first approach, all nine genotypes except H24-38 were average stable in performance, while H24-38 was more stable than the others. Using the second approach, all the genotypes except Souna III and H24-38 were highly stable, as they had slopes of unity and their S^2d values were zero. H24-38 did not respond as others to environmental improvement. Using the third approach, all the genotypes except Souna III are highly stable as S^2d values were zero. Using different approaches, different genotypes can be defined as stable as well as unstable.

In our view, a genotype should be designated as stable on the basis of the importance of the component(s) of variation of genotype x environment interaction found in the study. In our study, the genotype x environment variation due to linear as well as non-linear regression, were significant. However, most of the genotype x environment variation was accounted for by the non-linear regression. The genotype IBV 8001 had the highest mean value, unit slope, and the deviation from regression was not significantly different from zero. It can therefore be described as a stable genotype over environments and its yield potential can be predicted with accuracy within the limits of sampling error. The farmers' local cultivars were the most stable in their environments as the S^2d values were the lowest and the slopes were unity. Souna III, with high deviation from regression, can be defined as an unstable variety because its performance over environments cannot be predicted.

Dancette (1974) recommended the use of pearl millet cultivars of different maturity types for the different regions of Senegal. Our study indicates a single cultivar could do very well in most of the pearl millet-growing areas of Senegal.

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