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Full Length Research Paper

Yield stability analysis of pearl millet hybrids in Nigeria

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Genotype x environment interaction in pearl millet [*Pennisetum glaucum* (L.) R.Br.] was studied for grain yield by growing 90 genotypes consisting of 81 hybrids and 9 inbred parents at 5 locations for 2 years. Genotype x environment interaction was observed, a large component of which was accounted for by non-linear regression on the environment means. Although the linear portion was significant, its magnitude was smaller than that of the non-linear component indicating the significance of environmental effects on the genotypes. Six hybrids were found to be stable across the environments. They yielded above the average mean yield of all the genotypes under test, with a slope of unity and the mean square due to deviation from regression equal to zero.

Key words: Genotype x environment interaction, yield, stability, pearl millet.

INTRODUCTION

The importance of evaluating many potential genotypes in different environments (location and years) before selecting desirable ones for release and commercial cultivation has been recognized by breeders (Gupta and Ndoye, 1991). A desirable cultivar is one that does not only yield well in its area of initial selection, but also maintains the high yielding ability over a wide range of environments within its intended area of production. Many authors have used several approaches to determine the stability of genotypes over wide range of environments. Finlay and Wilkinson (1963) utilized a regression technique first proposed by Yates and Cochran (1938) to estimate stability in barley. They considered linear regression associated with high mean yield as measure of stability. Genotypes with regression coefficient of 1.0 and high mean yield indicate average stability and general adaptation. However, genotypes with low mean yield are poorly adapted to all the environments. Regression values above 1.0 describe genotypes with increasing sensitivity to environmental changes and greater specificity of adaptation to high yielding environments. Regression coefficients below 1.0 provide a measure of greater resistance to environmental changes and therefore increasing specificity of adaptability to low-yielding environments.

Eberhart and Russell (1966) considered a stable genotype to have a slope equal to unity and deviation from regression equal to zero. They reported that the deviation from regression, a second stability parameter appears very important as the genotype x environment interaction (linear) sum of squares was a small portion of the genotype x environment interaction. This approach has been extensively used by several breeders (Singh and Gupta, 1978; Pethani and Kapoor, 1985; Virk, et al., 1985) emphasizing that linear regression should be regarded as a measure of the response of a particular genotype, whereas deviation from regression should be considered as a measure of stability of genotype with the lowest deviation being the most stable. Eagles et al. (1977) observed that less than 20% of genotype x environment sum of squares for oat lines was attributed to different regression values. Witcombe (1988) indicated the invalidity of mean squares from deviation from regression as a measure of stability in certain circumstances such as the deviation from regression caused by difference in disease resistance.

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Table 1. The different environments, years, locations, total rainfall, latitudes and environmental means for grain yield average over 90 genotypes grown in each environment.

Environment	Year	Location	Rainfall (mm)	Mean grain yield
1	1999	Samaru	1050	1.5
2	1999	Bagauda	950	2.71
3	1999	Maiduguri	843	1.77
4	2000	Samaru	1000	1.84
5	2000	Bagauda	650	1.29

Latitude: Samaru, 11°11'; Bagauda, 11°05'; Maiduguri, 7°11'.
Altitude: Samaru, 686 m; Bagauda, 440 m; Maiduguri, 120 m.
Soil type: Samaru, loamy; Bagauda, luvisol; Maiduguri, sandy clay.

The objective of this study is to test the performance of millet hybrids and assess their stability in the millet growing areas of Nigeria.

MATERIALS AND METHODS

The 90 genotypes were laid in 9 x 10 rectangular triple lattice in each environment. Each plot consisted of 2 rows of 5 m long. Inter- and intra-row spacing of 75 cm and 50 cm were used, respectively. Plants were thinned to two seedlings per hill three weeks after sowing. Fertilizer applications were carried out accordingly, where 60N: $40P_2O_5$:$30K_2O$ kg/ha was applied as basal dressing and Urea (46% N) was top dressed 4 weeks after planting. All cultural practices for millet production were carried out. At maturity, harvested heads from the two row plots were dried, threshed and weighed to estimate grain yield. Data on grain yield averaged over 5 environments and details of their locations, latitude, total rainfall during the growing season and environmental mean yield are presented in Table 1.

Data on grain yield from individual environment were analysed as lattice design. Bartlett's test of homogeneity of error variance was conducted (Steel and Torrie, 1980) and the data on grain yield of the genotypes tested averaged over 5 environments were homogenous before the data was pooled. The stability model proposed by Eberhart and Russell (1966) was used to estimate stability parameters for grain yield. This model provides regression indices (b values) and mean square for deviation from regression minus pooled error (S^2d) as indices of a stable genotype. The stable hybrids will be those having mean yield higher than the average yield of all the genotypes under test, regression coefficient of unity and deviation from regression equal to zero. Pooled error was obtained by averaging the error mean squares from the analysis of variance of individual environments and dividing by the number of replications. The significance of mean squares were tested against the 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 deviation from regression were significantly different from zero, the F-test was employed i.e. comparing the mean square due to deviation from regression with pooled error.

RESULTS AND DISCUSSION

The environments used in this study represent the three agroecological zones (sahel, sudan and northern guinea savanna) where millet is grown in Nigeria. Variations were observed in latitude, altitude, rainfall and soil types in these areas.

Table 2. Pooled analysis of variance for stability of grain yield (t/ha) over five environments.

Sources of variation	df	Mean squares
Genotypes	89	0.23090**
Environments (Env.)	4	26.49875**
Genotype x Env.	356	0.15659**
Env. + (Genotype x Env.)	360	2.9933**
Environment (linear)	1	105.98**
Genotype x Env. (linear)	89	0.0173*
Pooled deviation from regression	270	0.1496**
Pooled error	900	0.101

*, **, significant at 5% and 1% probability levels, respectively.

The analysis of variance (Table 2) indicated significant differences in the yield among genotypes and a significant genotype x environment interaction. This interaction showed 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 deviation from regression was significant showing that the performances of some of the genotypes were not stable over environments. A large portion of the sum of squares of genotype x environment interaction (95.5%) was accounted for by the deviation from regression. Only small amount of this interaction (4.5%) was accounted by the linear regression on the means in different environment. Six hybrids (Table 3) were found to be stable across environments: NCd_2BC_720A-2 x DMR68G.I.446-1, NCd_2BC_721A-1 x

Table 3. Regression response indices (b), deviation from regression (S^{2}d) and mean grain yield for the various genotypes.

Genotype	**Mean**	**b**	**SE**	**S^{2}d**
NCd$_2$ BC$_7$ 6A-2 x DMR 4 AVTE - 12	1813	0.978	0.443	0.111
X DMR 12 ICMV-IS-88127	2063	0.520	0.539	0.223*
X DMR 15 ICMV-IS-94208	1966	1.166	0.228	-0.058
X DMR 22-F$_7$ IKMV-8210 x Djiguifa	2066	1.105	0.507	0.184*
X DMR 36-1 IKMP 2-1	1684	0.798	0.460	0.130
X DMR 36-2 IKMP 2-2	1448	0.874	0.120	-0.102
X DMR 43 ICMV-IS-91116	2212	0.583	0.450	0.119
X DMR 65 G.I. 381-1	1759	1.302	0.421	0.090
X DMR 68 G.I. 446-1	1668	0.842	0.131	-0.099
NCd$_2$ BC$_7$ 20A-2 x DMR 4 AVTE - 12	1183	0.869	0.230	-0.056
X DMR 12 ICMV-IS-88127	1860	1.098	0.337	0.015
X DMR 15 ICMV-IS-94208	1813	0.706	0.179	-0.081
X DMR 22-F$_7$ IKMV-8210 x Djiguifa	1697	0.801	0.157	-0.090
X DMR 36-1 IKMP 2-1	1447	0.742	0.470	0.141
X DMR 36-2 IKMP 2-2	1888	1.346	0.495	0.170*
X DMR 43 ICMV–IS-91116	1795	0.970	0.121	-0.102
X DMR 65 G.I. 381-1	1597	0.988	0.263	-0.037
X DMR 68 G.I. 446-1	1952	0.863	0.258	-0.041
NCd$_2$ BC$_7$ 21A-1 x DMR 4 AVTE-12	1597	1.015	0.639	0.363*
X DMR 12 ICMV-IS-88127	1681	0.233	0.295	-0.016
X DMR 15 ICMV-IS-94208	1712	0.387*	0.120	-0.102
X DMR 22-F$_7$ IKMV-8210 x Djiguifa	2052	1.058	0.163	-0.088
NCd$_2$ BC$_7$ 21A-1 x DMR 36-1 IKMP 2-1	1711	0.715	0.579	0.276**
X DMR 36-2 IKMP 2-2	2090	1.767*	0.243	-0.050
X DMR 43 ICMV-IS-9116	1987	0.333	0.236	-0.054
x DMR 65 G.I. 381-1	1819	1.513*	0.161	-0.088
x DMR 68 G.I. 446-1	1713	1.246	0.140	-0.106
NCd$_2$ BC$_7$ 24A-5 x DMR 4 AVTE-12	1697	1.335	0.436	0.105
X DMR 12 ICMV-IS-88127	1851	1.156	0.427	0.096
X DMR 15 ICMV-IS-94208	1837	1.073	0.141	-0.096
X DMR 22 F$_7$ IKMV-8210 x Djiguifa	1945	1.035	0.126	-0.100
X DMR 36-1 IKMP 2-1	2029	0.728	0.307	-0.088
X DMR 36-2 IKMP 2-2	1939	1.130	0.328	0.088
X DMR 43 ICMV-IS-91116	1683	0.305	0.680	0.425**
X DMR 65 G.I. 381-1	2265	0.970	0.141	-0.095
X DMR 68 G.I. 446-1	1607	1.402	0.403	0.072
NCd$_2$ BC$_7$ 25A-4 x DMR 4 AVTE - 12	1330	0.674	0.480	0.153*
X DMR 12 ICMV-IS-88127	2000	1.177	0.211	-0.067
X DMR 15 ICMV-IS-94208	1875	0.468	0.237	-0.053
X DMR 22-F$_7$ IKMV-8210 x Djiguifa	2095	0.420	0.375	0.046
X DMR 36-1 IKMP 2-1	1735	1.374	0.314	0.003
X DMR 36-2 IKMP 2-2	1756	1.081	0.345	0.021
X DMR 43 ICMV-IS-91116	2008	1.313	0.154	0.091
X DMR 65 G.I. 381-1	1335	0.428*	0.160	-0.089
X DMR 68 G.I. 446-1	1759	0.524	0.401	0.070
NCd$_2$ BC$_7$ 47A-3 x DMR 4 AVTE - 12	1678	0.566	0.830	0.692*
x DMR 12 ICMV-IS-88127	1764	0.564	0.198	-0.073
x DMR 15 ICMV-IS-94208	2167	0.936	0.395	0.065
x DMR 22-F$_7$ IKMV-8210 x Djiguifa	2292	0.657	0.192	0.076
x DMR 36-1 IKMP 2-1	1703	1.222	0.282	-0.025

Table 3. Contd.

x DMR 36-2 IKMP 2-2	1693	1693	0.215	-0.064
x DMR 43 ICMV–IS-91116	2009	0.899	0.460	0.130
x DMR 65 G.I. 381-1`	1646	1.150	0.362	0.035
x DMR 68 G.I. 446-1	1706	0.785	0.457	0.127
NCd_2 BC_7 51A-4 x DMR 4 AVTE-12	1978	0.457	0.332	0.011
x DMR 12 ICMV-IS-88127	1408	1.282	0.266	-0.036
x DMR 15 ICMV-IS-94208	1583	0.523	0.296	-0.016
x DMR 22-F_7 IKMV-8210 x Djiguifa	2108	0.313	0.525	0.206
x DMR 36-1 IKMP 2-1	1797	0.901	0.221	-0.061
x DMR 36-2 IKMP 2-2	1892	1.340	0.091	-0.109
x DMR 43 ICMV-IS-9116	1790	1.947*	0.247	-0.047
x DMR 65 G.I. 381-1	1723	1.626	0.202	-0.071
x DMR 68 G.I. 446-1	1652	0.710	0.180	-0.081
NCd_2 BC_7 60A-2 x DMR 4 AVTE-12	1594	1.075	0.245	-0.048
x DMR 12 ICMV-IS-88127	2069	1.551	0.116	-0.103
x DMR 15 ICMV-IS-94208	2094	1.549*	0.552	0.240*
x DMR 22 F_7 IKMV-8210 x Djiguifa	1665	0.753	0.219	0.063
x DMR 36-1 IKMP 2-1	1707	0.665	0.217	-0.063
x DMR 36-2 IKMP 2-2	1858	1.435	0.495	0.169
x DMR 43 ICMV-IS-91116	1772	1.463	0.336	-0.014
x DMR 65 G.I. 381-1	1729	1.318	0.274	-0.031
x DMR 68 G.I. 446-1	1867	0.890	0.117	-0.103
NCd_2 BC_7 66A-2 x DMR 4 AVTE-12	1529	1.515*	0.414	0.083
x DMR 12 ICMV-IS-88127	1979	0.996	0.530	0.212*
x DMR 15 ICMV-IS-94208	2035	0.771	0.397	0.067
x DMR 22 F_7 IKMV-8210 x Djiguifa	1908	1.361	0.258	-0.041
x DMR 36-1 IKMP 2-1	1876	1.683	0.509	0.186*
x DMR 36-2 IKMP 2-2	1602	1.388	0.266	-0.036
x DMR 43 ICMV-IS-91116	1827	1.256	0.338	0.016
x DMR 65 G.I. 381-1	2021	1.539	0.145	0.094
x DMR 68 G.I. 446-1	1416	1.011	0.115	-0.103
DMR 4 AVTE-12	1965	1.005	0.253	0.044
DMR 12 ICMV-IS-88127	2121	1.269	0.156	-0.090
DMR 15 ICMV-IS-94208	2101	0.338*	0.912	0.861**
DMR 22 F_7 IKMV-8210 x Djiguifa	2018	0.567	0.571	0.265**
DMR 36-1 IKMP 2-1	2100	1.092	0.256	0.042
DMR 36-2 IKMP 2-2	1645	1.488	0.201	-0.072
DMR 43 ICMV-IS-91116	1933	0.815	0.348	-0.024
DMR 65 G.I. 381-1	1883	1.133	0.182	-0.080
x DMR 68 G.I. 446-1	1621	1.365	0.303	-0.011
		1.421		

*, **, b values significantly different from unity at 5% and 1% probability levels, S^2d significantly different from zero at 5% and 1% probability levels, respectively.

DMR22F_7IKMV-8210 x Djiguifa, $NCd_2BC_7$24A-5 x DMR15 ICMV-IS-94208, $NCd_2BC_7$24A-5 x DMR65 G.I.381-1, $NCd_2BC_7$47A-3 x DMR15 ICMVIS-94208 and NCd_2BC_7-66A-2 x DMR65 G.I.381-1 had mean yield higher than the average yield of all the genotypes under test with a regression coefficient of unity and deviation from regression equal to zero. Therefore, these genotypes are recommended for cultivation across the test sites.

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