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STABILITY ANALYSIS OF MAIZE HYBRIDS ACROSS NORTH WEST OF PAKISTAN

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Abstract

Stability analysis was carried out to study stability in performance and genotype x environment interactions for 18 maize hybrids across three locations of NWFP i.e., Agricultural University Peshawar (AUP), Agricultural Research Station (ARS), Baffa, (Mansehra) and Cereal Crops Research Institute (CCRI), Pirsabak (Nowshera), during 2006. Data were recorded on different morphological and yield parameters. Analysis of variance indicated significant differences among the three locations for all the traits studied. Hybrids showed significant differences for all parameters except anthesis silking interval (ASI) and ear height, which were non significant across the three locations. The hybrid x location interactions also revealed significant differences for days to 50% silking, days to 50% anthesis, ASI, grain moisture at harvest and grain yield per hectare while non significant differences were observed for plant height and ear height. Based on yield performance of hybrids across the three locations, Baffa ranked first as compared to the other two locations. Hybrid DK-1 x EV-9806 was the highest yielding across the three locations followed by hybrid AGB-108, while the lowest yield was observed for hybrid CSCY. Stability in performance was evident for hybrid CS-2Y2 with regard to days required for silking and anthesis. Stability in anthesis silking interval (ASI) was manifested for hybrid CS-222. Hybrid AGB-108 was comparatively stable for grain yield across the tested locations. Remaining hybrids seemed to be considerably influenced by Genotype x environment interactions encountered at the tested locations and location specific selection has to be made while selecting a maize hybrid for a particular location.

Introduction

Crop production is the function of genotype, environment and their interaction (GEI). Significant GEI results in changing behavior of the genotypes across different environments or changes in the relative ranking of the genotypes (Crossa, 1990). A significant G x E interaction for a quantitative trait such as seed yield can seriously limit the efforts on selecting superior genotypes for improved cultivar development (Kang & Gorman, 1989). G x E interactions become important when the rank of breeding lines gets changed over environments. This change in rank is called crossover G x E interaction (Baker, 1988). Understanding the relationship among yield testing locations is important if plant breeders are to target germplasm better adapted to different production environments or regions (Trethowan *et al.,* 2001).

A genotype is considered to be stable if its among-environment variance is small. This is called stability statistic, or a biological concept of stability. A stable genotype possesses an unchanged or least changed performance regardless of any variation of the environmental conditions. This concept of stability is useful for quality traits, disease resistance and for stress characters like winter hardiness (Baker & Leon, 1988). In breeding for wide adaptation, the aim is to obtain a variety, which performs well in nearly all environments (Cooper & De-Lacy, 1994). Several stability analyses have been proposed to determine linear relationship between genotypic performance and the environment. Eberhart & Russell (1966) proposed a method in which the environmental index is the mean performance of all entries in an environment. The performance of each genotype is regressed on the environment to obtain its mean performance over all environments. A desirable genotype is one with high mean value, with regression coefficient of 1.0 and deviation from regression is 0. Such a genotype would have increased performance as the productivity of environment improves. Tollenaar & Lee (2002) reported that high-yielding maize hybrids can differ in yield stability and that yield stability and high grain yield are not mutually exclusive.

Maize hybrids are reported to give higher yields under good management than open-pollinated varieties of similar maturity (Duvick, 1984; Russel, 1984; Gul *et al*., 2009). However, these require a specific crop production package and are prone to changes in environment. This results in changes in performance of maize hybrids across environments. The present study was therefore aimed to evaluate maize hybrids for their adaptability and stability of performance for yield and yield components across different environments of NWFP.

Materials and Methods

To assess the adaptability and stability in performance of maize hybrids for yield and yield components across different environments of NWFP, the present study was conducted during summer 2006. Eighteen maize hybrids were used in the study. These included 9815, Baber, POP.9864, 9864 x 9845, CSCW, WD-3 x 6, FRW-4 x FRHW-20-4, 974, Opener, CS-201, CS-222, 3025, CSCY, DK-1 x EV-9806, C3WY, H1 corn-11, CS-2Y2 and AGB-108. These were sown at three locations of North West Frontier Province (NWFP) of Pakistan.

The experiment was laid out in randomized complete block design (RCBD) with three replications, at all locations. Sowing was done during June, 2006 at NWFP Agricultural University, Peshawar (AUP) and Agricultural Research Station (ARS) Baffa (Mansehra) and in July 2006 at Cereal Crop Research Institute (CCRI) Pirsabak (Nowshera). Each hybrid was planted in a plot of two rows having five meters length, keeping the plant to plant distance of 25 cm and row to row distance of 75 cm. A basal fertilizer dose of 50 kg urea and 200 kg SSP per acre was applied. Before sowing, seeds were treated with Confidor and Imkan fungicides, to avoid the attack of corn borer. Standard cultural practices essential for crop management were practiced at all locations through out the growing season.

Data were recorded on days to 50% silking, days to 50% anthesis, anthesis silk interval (ASI), plant height, ear height, grain moisture at harvest and grain yield per hectare.The data were statistically analyzed and mean separation tests were carried using least significance difference (LSD) test. Stability analysis of maize hybrids across the three locations was carried out, following Eberhart & Russell (1966).

Results and discussion

Mean square values for days to 50 % silking, days to 50% anthesis and anthesis-silking interval (ASI), plant height (cm), ear height (cm), grain moisture (%) at harvest and grain yield (kg ha^{-1}) are given in Table 1, showing a highly significant variation across three locations for these parameters. Similarly, highly significant differences were observed among hybrids across the three locations for days to 50% silking and days to 50% anthesis while non significant differences were obvious for anthesis silking interval (ASI), plant height, ear height, grain moisture at harvest and grain yield kg ha^{-1}. The interaction between hybrids and locations were also highly significant for days to 50% silking, days to 50% anthesis, ASI, grain moisture at harvest and grain yield kg ha^{-1}, revealing that these parameters were considerably influenced by the environmental variations encountered across the three locations. However, Hybrid x location interaction was non-significant for plant height and ear height, indicating stability of these two parameters across the tested environments, during the present study.

The mean values for days to 50% silking, days to 50% anthesis, anthesis silking interval, plant height, grain moisture at harvest and grain yield (kg ha^{-1}) of 18 maize hybrids at three locations are given in Table 2. Hybrid CS-2Y2 and DK-1 x EV-9806 had the highest mean value of days for 50% silking (58.8 and 58.4 respectively) across three locations. The shortest duration for days to 50% silking was observed for hybrid WD-3x6 with mean value of 54.4 days. Highest mean value of 57.0 for days to 50% anthesis was observed for hybrids CS-2Y2 and DK-I x EV 9806. The minimum value for days to 50% anthesis was observed for hybrid WD-3 x 6 i.e., 53 days. Non significant differences were observed among the hybrids across the three locations for anthesis silking interval (ASI) and ear height. Hybrid DK-1 x EV-9806 showed the highest mean value for plant height (205 cm) while the lowest mean value was recorded for hybrid WD-3 x 6 (174.9 cm). Remaining hybrids were having their mean values within this range. The mean values for plant height revealed that significant differences were present among the hybrids for the trait.

Significant differences were observed for grain moisture at harvest (Table 2). The maximum grain moisture at harvest was observed in hybrid CS-2Y2 with a value of 25.78 %. The minimum grain moisture was observed for hybrid 9815 (21.67 %) followed by hybrid Baber (21.89%). Similarly, hybrid DK-1 x EV-9806 had the maximum grain yield of 9541 kg ha^{-1} followed by hybrid AGB-108 and hybrid CS-2Y2 with average grain yield of 8923 kg ha^{-1} and 8729 kg ha^{-1}, respectively. The minimum grain yield was observed for hybrid CSCY with average value of 6470 kg ha^{-1}. Table 3 revealed that hybrid CS-2Y2 ranked first with average yield of 13450 kg ha^{-1} at ARS, Baffa, Mansehra followed by hybrids DK-1 x EV-9806 and AGB-10 which were second and third in rank with average yield of 12620 and 11890 kg ha^{-1}, respectively.

The overall means for grain yield per hectare given in Table 3 showed that maximum grain yield of 9851 kg ha^{-1} was produced at ARS, Baffa, Mansehra followed by 7496 kg ha^{-1} at CCRI, Pirsabak while at AUP grain yield was the least of all (5029 kg ha^{-1}). The lowest yield was 3960 kg ha^{-1} produced by hybrid WD-3 x 6 at AUP. All hybrids produced higher yield at ARS, Baffa, Mansehra as compared to the other two locations. This may be due to the favorable environment at Baffa which makes it highly conducive for increased maize production. Mean square values for grain yield per hectare also showed that all the hybrids were significantly different from each other at all the three locations. Significant differences among maize hybrids for grain yield have been also reported by Akbar *et al*., (2000).

Stability parameters: Stability of cultivar performance over a set of diverse environments is of considerable importance and is given special consideration in breeding programs. There is always a need to test newly developed cultivars across different environments (both years and locations) in order to elucidate the pattern and the magnitude of genotype x environments interactions. These genotypes x environments interactions, if present for a certain trait of breeder's interest, can reduce the correlation between phenotypic and genotypic values and will ultimately reduce progress from selection (Kang & Gorman, 1989). On the other hand, if the genotype x environment interactions is not prevailing, a single genotype can be recommended for a wider geographical area. This approach will not only lead to increased productivity, but can also considerably reduce the input cost by developing a single variety for a wider agro-ecological zone. Understanding the relationship among yield testing locations is important if plant breeders are to target germplasm better adapted to different production environments or regions (Trethowan *et al*., 2001).

A wide range of two stability parameters i.e., regression coefficient "bi" and deviation from regression "S^2d" was observed for various hybrids (Tables 4a and 4b). According to Eberhart & Russell (1966) model, a genotype with a unit value for regression coefficient and minimum deviation from regression is considered to be stable. During the study, stability parameters of 18 maize hybrids were calculated according to Eberhart & Russell (1966) model for different plant parameters. Table 4a shows the values of regression coefficient and deviation from regression for the tested maize hybrids and reveals that the hybrid CS-2Y2 gave a value of 1.16 for days to 50% silking and 50% anthesis which is closer to unity. For other hybrids, the regression coefficient varied from 0.75 to 1.36. Taking the deviation from regression into consideration, it can be observed from Table 4a, that the hybrid CS-2Y2 showed minimum deviations from regression i.e., 0.001. The highest value for deviation from regression was recorded for hybrid WD-3 x 6, which was 11.13. The mean values for days to 50% silking and days to 50% anthesis ranged between 53 and 57 days as shown in Table 2. The minimum mean value of 53 days was shown by hybrid WD-3 x 6 while maximum mean value of 57 days was shown by hybrid DK-1 x EV-9806 and CS-2Y2. Stability analysis for anthesis silking interval (Table 4a) indicated that hybrids showed the regression coefficient value in range between 0.50 to 1.44 for hybrids AGB-108 and 9815, respectively. Deviation from regression ranged from 0.003 to 3.86, obtained for hybrids CS-222 and POP.9864, respectively. Other hybrids were in between this range and varied considerably. For ASI, hybrid CS-222 gave the value of regression coefficient as 0.92, which is comparatively closer to unity and deviation from regression being 0.003, which is the minimum deviation from regression as compared to other hybrids and can therefore, be considered as a stable hybrid for this parameter. Loffler *et al*., (1986) have also reported significant G X environment interaction for maturity traits of maize.

Regression coefficient value for grain moisture at harvest ranged from -5.63 to 5.97 (Table 4b) for hybrids 3025 and 974. Hybrid CSCY also showed regression coefficient value of 5.97. None of them was having regression coefficient value closer to unity. Deviation from regression ranged from 0.002 to100.39, obtained for hybrids 9864 x 9845 and 3025, respectively. Other hybrids were in between this range and varied considerably. The regression coefficient value for 18 maize hybrids for grain yield ranged from 0.02 to 1.87, observed for hybrids DK-1 x EV-9806 and 9815, respectively. Taking the deviation from regression into consideration, it can be observed from Table 4b that hybrid CS-222 showed the least amount of deviation (0.03) followed by hybrid 9815 with value of 0.04. Other hybrids indicated a wide range of values which ranged from 0.03 to 15.63. The highest value for deviation from regression (15.63) was noted for hybrid Opener. Table 4b shows that hybrid AGB-108 has the regression coefficient value of 0.91, which is closer to unity and deviation from regression as 0.17. Considering both criteria of stability together, hybrid AGB-108 showed stability in yield across the three locations as compared to other hybrids.

Table 1. Mean squares for maturity and yield traits of 18 maize hybrids across three locations of NWFP.

Source of variance	Degree of freedom	Days to silking	Days to anthesis	Anthesis silking interval	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain yield (Kg ha^{-1})
Locations	2	556.41^{**}	954.88^{**}	83.15^{**}	22588.66^{*}	4904.7^{*}	252.17^{**}	140502139.5^{**}
Replications	6	3.1^{NS}	2.11^{NS}	0.69^{NS}	343.3^{NS}	278.1^{NS}	6.29^{NS}	4146538^{NS}
Genotypes	17	11.7^{**}	11.11^{**}	1.29^{NS}	487.46^{**}	75.5^{NS}	12.11^{**}	6680664.17^{**}
G x L	34	4.79^{**}	4.79^{**}	1.74^{**}	240.26^{NS}	77.5^{NS}	7.12^{**}	5353058.4^{**}
Error	102	2.09	1.6	0.77	177.87	61.04	3.7	804363

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 2. Mean values for maturity and yield parameters of 18 maize hybrids across three locations.

Maize hybrid	Days to Silking	Days to anthesis	Plant height (cm)	Grain moisture (%)	Grain yield (kg ha^{-1})	ASI
9815	55.6 gh	54.3 efd	179.9 ef	21.67 d	7697 b	-1.3
Baber	57.2 bcdef	55.6 bc	186.7 bcdef	21.89 d	7349 bcd	-1.6
9864	56.5 defg	55.0 edc	186.4 cdef	24.11 abc	7011 bcde	-1.5
9864 x 9845	56.5 defg	55.4 dc	183.6 def	24.67 abc	7729 b	-1.1
CSCW	56.0 gf	55.6 fg	191.0 bcde	23.22 bcd	6587 de	-0.4
WD-3 x 6	54.4 h	53.0 g	174.9 f	23.33 bcd	6909 bcde	-1.4
FRW-4xFRHW20-4	55.5 gh	53.7 fg	195.1 abcd	23.11 bcd	6553 de	-1.8
974	55.7 gh	54.1 efg	194.2 abcd	24.78 ab	7561 b	-1.6
Opener	56.8 cdefg	55.0 edc	197.6 abc	24.44 abc	6701 cde	-1.8
CS-201	56.6 defg	55.3 dc	196.0 abcd	24 abc	7608 b	-1.3
CS-222	57.3 bcdef	55.1 edc	194.2 abcd	24.7 abc	6643 de	-2.2
3025	57.6 abcde	55.2 edc	194.2 abcd	24.44 abc	7199 bcde	-2.4
CSCY	57.5 abcde	55.8 abc	196.2 abc	22.89 cd	6470 e	-1.7
DK-1xEV-9806	58.4 a	57.0 a	205.7 a	24.89 ab	9541 a	-1.4
C3WY	56.3 efg	54.7 fgdc	196.8 abc	22 d	7566 b	-1.6
H1 corn-11	57.8 abcd	55.6 bc	199.1 ab	24.11 abc	7483 bc	-2.2
CS-2Y2	58.8 a	57 a	192.6 bcd	25.78 a	8729 a	-1.8
AGB-108	58.1 abc	56.6 ab	191.9 bcde	24.78 ab	8923 a	-1.5
LSD value	1.35	1.2	12.47	1.8	838.7	Ns

Mean values in the same column followed by different letters are significantly different at $p = 0.05$.

Table 3. Grain yield (kg ha^{-1}) of 18 maize hybrids during 2006 across three locations.

Maize hybrid	NWFP AU Peshawar	ARS, Baffa Mansehra	CCRI, Pirsabak Nowshera
9815	4923	8097	10070
Baber	4784	10370	6899
9864	4588	9539	6907
9864 x 9845	5107	10190	7885
CSCW	4139	10170	5452
WD-3 x 6	3960	10730	6041
FRW-4xFRHW20-4	4414	8257	6988
974	5425	8356	8902
Opener	4609	7419	8075
CS-201	5831	11080	5915
CS-222	4892	10590	4446
3025	5382	9428	6787
CSCY	5168	7435	6808
DK-1xEV-9806	5851	12620	10150
(C3WY	4507	9385	8806
H1 corn-11	5928	8309	8211
CS-2Y2	5549	13450	7185
AGB-108	5473	11890	9406
Means	**5029**	**9851**	**7496**

Stability parameters for grain yield per hectare revealed that regression coefficient for average grain yield per hectare across locations ranged from 0.02 to 1.86. The regression coefficient value for hybrid mean on environmental index for different characters illustrated differences in hybrids with a change in environment. The differential response of hybrids used in this study to changing environmental conditions was also manifested in the significant genotype x environment interactions. Hybrid AGB-108 based on and σ value could be considered as a stable hybrid. Other hybrids gave wide range of values for β and exhibited tremendous amount of deviation from regression. For grain yield per hectare seven out of 18 maize hybrids gave regression coefficient values greater than one, indicating that these hybrids responded to favorable environment and can produce higher yields when provided with suitable environments. Tollenaar & Lee (2002) reported significant differences among high-yielding maize hybrids for their yield stability. Gama & Hallauer (1980) detected significant hybrid x environment interaction for maize hybrids, while some were reported to be stable when both stability parameters were considered. Kang & Gorman (1989) and Vulchinokova (1990) also reported significant G x E interactions for different traits of maize.

Table 4a. Regression coefficient and deviation from regression for maturity parameters of 18 maize hybrids evaluated over three locations of NWFP during 2006.

Maize hybrid	Days to silking		Days to anthesis		Anthesis-silking interval	
	Regression coefficient	Deviation from regression	Regression coefficient	Deviation from regression	Regression coefficient	Deviation from regression
9815	1.10	0.04	1.10	0.04	1.44	0.42
Baber	0.75	0.003	0.75	0.003	0.83	0.20
9864	1.04	3.52	1.04	3.52	1.06	3.86
9864 x 9845	1.36	1.76	1.36	1.76	1.26	0.27
CSCW	0.95	0.48	0.95	0.48	1.04	0.27
WD-3 x 6	1.14	11.13	1.14	11.13	1.30	19.14
FRW-4xFRHW20-4	0.85	2.62	0.85	2.62	0.86	2.87
974	1.002	0.50	1.002	0.50	0.80	0.004
Opener	0.75	0.003	0.75	0.003	0.71	0.43
CS-201	1.03	0.87	1.03	0.87	0.89	1.39
CS-222	0.79	0.18	0.79	0.18	0.92	0.003
3025	0.77	0.03	0.77	0.03	1.04	0.27
CSCY	1.33	2.46	1.33	2.46	1.36	0.43
DK-1xEV-9806	1.44	0.13	1.44	0.13	1.25	0.03
C3WY	0.87	0.07	0.87	0.07	0.84	0.07
H1 corn-11	0.82	0.55	0.82	0.55	0.76	2.47
CS-2Y2	1.16	0.001	1.16	0.001	1.03	0.03
AGB-108	0.75	0.17	0.75	0.17	0.50	0.10

Table 4b. Regression coefficient and deviation from regression for grain moisture and grain yield of 18 maize hybrids evaluated at three locations of NWFP during 2006.

Maize hybrid	Grain moisture (%)		Grain yield per hectare	
	Regression coefficient	Deviation from regression	Regression coefficient	Deviation from regression
9815	-1.90	0.78	1.87	0.04
Baber	12.71	8.81	0.56	0.42
9864	1.54	72.7	0.99	7.28
9864 x 9845	-1.83	0.002	0.66	0.60
CSCW	4.89	8.46	0.69	2.21
WD-3 x 6	3.88	92.6	1.44	5.17
FRW-4xFRHW20-4	0.31	70.9	1.30	2.29
974	5.97	90.07	0.48	0.57
Opener	-0.85	15.43	0.53	15.63
CS-201	-3.56	25.70	1.32	1.17
CS-222	-4.93	13.15	1.60	0.03
3025	-5.63	100.39	1.17	1.67
CSCY	5.97	68.9	1.13	2.35
DK-1xEV-9806	-1.97	66.22	0.02	2.73
C3WY	-1.10	2.96	1.07	0.13
H1 corn-11	0.24	30.17	1.43	0.63
CS-2Y2	-1.72	0.67	0.74	0.62
AGB-108	5.96	0.21	0.91	0.17

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