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Stability and Environmental Interaction of Some Promising Yellow Maize Genotypes

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Abstract: This study was mainly aimed to estimate stability degree of twenty four promising yellow maize single crosses. These 24 single crosses along with two commercial yellow check hybrids; SC 155 and SC 3084 were evaluated in 2005 growing season under different environmental conditions at Sakha, Gemmeiza, Sids and Mallawy Agricultural Research Stations for estimating stability parameters for grain yield, days to 50% silking and resistance to late wilt disease. These single crosses developed at Giza Research Farm and constituted in 2004 summer season. Randomized complete block design with four replications was used. Results obtained showed that two single crosses, i.e. G14 and G23 significantly outyielded the commercial check hybrid SC 155 by 5.74 and 2.06 ard/fad, respectively. Meanwhile, these two crosses were earlier than the check hybrid SC 3084 and manifested high resistance to late wilt disease. Highly significant genotype x environment interaction was detected for all studied trait. A larger portion of this interaction was accounted for the linear regression on the environmental means. The magnitude of non linear components was considerably small. Stability parameter indicated that five single crosses, i.e. G1, G2, G8, G14 and G23 possess high yielding potential and earliness, as well as manifested high resistance to late wilt disease. These hybrids were more responsive to a wide range of environments. In other words, these hybrids could be the most stable hybrids across all locations, since they had small and insignificant deviations from linearity. These five hybrids would be recommended as stable, high yielding resistant hybrids and/or incorporated as breeding stocks for further use.

Key words: Maize, hybrids, genotypes, environments, stability

INTRODUCTION

New maize hybrids to be released must show high performance for yield over a wide range of environmental conditions. In other words, the superior hybrids have to be highly stable and possess a great yield potential. The instability of genotype x productivity under different environments is due to high genotype environmental interactions. In hybrid maize breeding, the choice of a suitable hybrids is subject to two considerations, (1) high grain yield across a wide range of environments, and (2) consistency of performance over environments. Consistency of performance is dependent upon the genotype x environment interaction (GE). Hybrids, which show less GE are described as more stable or well buffered. Stability of yield is defined as the ability of genotype to avoid substantial fluctuations in yield over a range of environments[1].

Evaluation of new maize hybrids under different locations would provide maize breeders with important information about the performance of these hybrids and whether they behave similarly or differently to different environments. Plant breeders are more interested in hybrids that are not affected much by environment to environment variations, *i.e.* the stable hybrid(s). Some hybrids, however, show their best performance at certain locations. Evaluation of these hybrids on the average basis over different locations would underestimate their productivity of such hybrids were grown at their best performing environments. Although the phenotype of an individual is determined by both genotype and environment, these two effects are not always additive[2].

Stability analysis provides a general summary of the response patterns of genotypes to environmental changes. The main type of stability analysis, termed Joint regression analysis Freeman,[3] involves the regression of genotype means on an environmental index. Joint regression analysis provides a means of testing whether the genotypes have characteristic linear responses to environmental change. It has been widely used and reviewed (Finlay and Wilkinson[4], Eberhart and Russel[5], Perkins and Jinks[6], Shukla[7], Hardwick and Wood[8], Freeman[3], Lin *et al.*[9], Baker[10] and Hohls *et al.*[2]. However, Freeman and Perkins[11], Hill[12], Westcott[13], Crossa[14], Ragheb *et al.*[15,16] Abd El-Aziz[17] and Mahmoud and Atia[18]) have pointed out that stability parameters determined for a given entry will vary according to the mean performance of the genotypes with which the entry is compared. On the other hand, many investigators proved that the environ-mental variation can be classified into predictable and

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unpredictable variations[19-21]. The predictable ones caused by more permanent features, while the unpredictable variations are caused by year to year fluctuations in weather, insect infestation and disease infection. To reduce the magnitude of genotype x environment interaction within region, George *et al*.[22], Dhillon and Singh[23], Francis and Kannenberg[24], Ibrahim *et al*.[25], Ragheb *et al*.[15,16] and Abd El-Aziz[17] suggested that the environmental variations can be minimized by grouping the locations into regions of similar environmental conditions. They obtained a highly significant genotype x environment interaction, even after grouping the environments into regions of similar climatic conditions. Eberhart and Russel[5] stressed that the most important stability parameters appeared to be the deviation from linear regression mean square because all types of gene action were involved in this parameter. Lin *et al*.[9] reported that a particular genotype may be considered to be stable if (i) its deviation among environments variance is small, (ii) its response to environments is parallel to the mean response of all genotypes in the trial or (iii) the residual mean square from regression model on the environmental index is small.

The objective of this study was to estimate stability degree of some promising yellow maize single crosses for grain yield, days to 50% silking and resistance to late wilt disease at different environments.

MATERIALS AND METHODS

Twenty four promising yellow maize single crosses (G-1 through G-24) developed at Giza Research Station, ARC by crossing the highly GCA common parent inbred line Giza 639 with 24 promising yellow maize inbred lines derived from different heterotic groups, i.e. Sd 35 x Gz 632 (1), Sd 35 x Gz 632 (2), Arifay (29), Arifay (31), Arifay (32), Arifay (37), ADA (13), ETO x CB (6), 6-POP 31 DMR C_4, 19-PRO 90B, 30-Sd 7 x B 84(1), 30-Sd 7 x B 84 (2), 30-Sd 7 x B 84 (3), (Mo 17 x W 153) x Sd 7, HT1 source (1), HT1 source (2), HT1 source (3), HT1 Source (4), HT1 source (5), HT1 source (6), HT1 source (7), Sd 7 ms x YND 410 (1), Sd 7 ms x NYD 410 (2) and CML-28, respectively. These hybrids were constituted in 2004 growing season. The resultant 24 single crosses along with two commercial yellow check hybrids; SC 155 and Pioneer SC 3084 were evaluated in replicated yield trials conducted at four locations (environments), *i.e.* Sakha (Env-1), Gemmeiza (Env-2), Sids (Env-3) and Mallawy (Env-4) Agricultural Research Stations, ARC, Egypt in 2005 growing season. Randomized complete block design with four replications was the design used. Plots consisted of two rows, 6 m long and 80 cm apart. Planting was done in hills spaced 25 cm along the row. Two kernels were planted per hill and thinned to one plant/hill before the first irrigation, giving a plant density of 22000 plants per faddan (Faddan= 4200m^2). Nitrogen fertilizer, 120 kg N/fad was split into two equal doses and was applied before the first and second irrigation in urea form. Phosphorus and potassium were broadcasting at the rate of 30 kg P_2O_5 and 24 kg K_2O for all plots before planting irrigation. All other cultural practices for maize production were applied as recommended. Ears were harvested at maturity, weighed and about 5 kg/plot were taken for measuring moisture percentage. Grain yield was adjusted to 15.5% moisture content and recorded in ardab/faddan (ard/fad), where one ardab=140 kg. Data were recorded for adjusted grain yield in ard/fad, number of days to 50% silking and percentage of resistance to late wilt disease. The three studied traits were statistically analyzed for each location and combined[26]. Stability analysis for these traits across all locations was performed according to the following model of Eberhart and Russel[5]:

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

Where:

Y_{ij} = Variety mean of the i^{th} variety at the j^{th} environment (location).

U_i = Mean of the i^{th} variety over all_environments.

β-$_i$ = Regression coefficient that measures the response of the i^{th} variety to varying environments.

I_j = Environmental index obtained as the mean of all varieties at the environment j^{th} minus the grand mean.

σ_{ij} = Deviation from the regression of the i^{th} variety at the j^{th} environment.

RESULTS AND DISCUSSIONS

Test of homogeneity of the error mean squares across all locations was not significant indicating that selecting of these locations was not biased. Hence, the combined analysis was performed in this study. It is worth noting that the locations used provided a wide range of environments. Results obtained in Table (1, 2 and 3) indicate that the average grain yield (ard/fad), days to 50% silking and percentage of resistance to late wilt disease for the 24 maize hybrids and two checks differed greatly and significantly from one locations to another. Based on the combined data across all locations, it ranged from 22.10 to 32.69 ard/fad, 58.2 to 61.4 and 73.0 to 99.8% for grain yield, silking date and resistance to late wilt, respectively. Coefficient of variation (CV%) were below 15% for all experiments.

Ibrahim *et al*.[25], Ragheb *et al*.[15,16] and Abd El-Aziz[17] observed that the differences in mean performance of a particular set of genotypes (varieties and/or hybrids are considered to be mainly due to the use of those

Table 1: Average grain yield (ard/fad) for 24 promising yellow single crosses and 2 check hybrids evaluated at 4 environments, 2005 growing season.

Hybrids	ENV-1	ENV-2	ENV-3	ENV-4	Average
G-1	34.70	27.15	22.35	27.18	27.85
G-2	34.58	23.45	23.08	29.13	27.56
G-3	38.48	27.08	17.48	28.23	27.82
G-4	36.43	28.03	17.68	28.40	27.64
G-5	31.70	23.75	15.90	31.48	25.71
G-6	36.60	24.30	17.38	25.53	25.95
G-7	27.98	22.68	18.50	27.43	24.15
G-8	40.00	23.60	20.43	27.98	28.00
G-9	32.03	25.23	20.03	29.55	26.71
G-10	33.45	23.78	15.58	29.18	25.50
G-11	32.10	23.25	22.35	24.18	25.47
G-12	32.23	23.40	22.93	26.70	26.32
G-13	29.18	22.65	26.23	25.93	26.00
G-14	40.65	28.38	28.03	33.68	32.69
G-15	30.73	18.53	14.98	24.15	22.10
G-16	36.78	25.40	17.60	29.48	27.32
G-17	34.13	23.90	15.63	29.98	25.91
G-18	38.35	23.25	19.40	28.70	27.43
G-19	33.93	25.10	18.30	26.75	26.02
G-20	36.03	22.55	17.33	27.80	25.93
G-21	39.10	22.23	18.18	30.48	27.50
G-22	30.35	22.48	23.30	27.10	25.81
G-23	33.83	24.05	28.03	30.13	29.01
G-24	34.90	25.60	18.20	31.45	27.54
SC 155	32.18	23.73	22.50	29.40	26.95
SC 3084	38.13	28.03	19.80	30.83	29.20
Env. Average	34.56	24.29	20.04	28.49	26.85
LSD 0.05	4.57	2.52	3.90	3.59	1.83
CV%	9.38	7.37	13.81	8.94	9.83

Table 2: Average number of days to 50% silking for 24 promising yellow single crosses and 2 check hybrids evaluated at 4 environments, 2005 growing season.

Hybrids	ENV-1	ENV-2	ENV-3	ENV-4	Average
G-1	59.8	59.5	59.3	61.8	60.1
G-2	59.5	59.3	58.3	61.3	59.6
G-3	59.8	60.5	60.0	61.5	60.5
G-4	60.3	59.0	59.3	62.3	60.2
G-5	61.0	60.0	59.5	61.3	60.5
G-6	60.5	60.8	61.3	62.0	61.2
G-7	59.3	59.0	57.3	60.5	59.0
G-8	59.8	60.5	60.8	62.3	60.9
G-9	60.0	59.8	59.8	60.5	60.0
G-10	61.3	61.0	61.0	62.5	61.5
G-11	60.5	59.8	59.8	62.3	60.6
G-12	60.5	60.3	59.8	62.8	60.9
G-13	59.0	60.0	56.8	61.0	59.2
G-14	59.5	59.0	58.0	61.0	59.4
G-15	59.0	60.0	59.5	61.8	60.1
G-16	60.0	59.3	59.5	62.3	60.3
G-17	61.0	60.5	61.0	62.5	61.3
G-18	60.0	60.3	61.3	62.3	61.0
G-19	59.5	59.8	59.0	61.3	59.9
G-20	60.5	61.5	59.3	62.3	60.9
G-21	60.3	62.5	59.3	62.3	61.1
G-22	57.5	58.3	56.5	60.0	58.1
G-23	58.8	59.5	58.5	60.5	59.3
G-24	59.3	58.5	58.5	60.5	59.2
SC 155	57.8	59.0	57.3	58.5	58.2
SC 3084	60.3	60.0	62.3	63.0	61.4
Env. Average	59.8	59.9	59.3	61.5	60.1
LSD 0.05	1.42	1.27	1.64	1.44	0.71
CV%	1.69	1.51	1.96	1.66	1.71

Table 3: Average late wilt resistance (%) for 24 promising yellow single crosses and 2 check hybrids evaluated at 4 environments, 2005 growing season.

Hybrids	ENV-1	ENV-2	ENV-3	ENV-4	Average
G-1	99.0	97.1	83.4	100.0	94.9
G-2	99.5	97.6	91.2	99.5	97.0
G-3	92.0	96.0	64.4	100.0	88.1
G-4	77.7	91.8	28.6	100.0	74.5
G-5	62.2	85.3	44.4	100.0	73.0
G-6	97.5	100.0	65.9	100.0	90.8
G-7	99.5	96.7	64.8	100.0	90.2
G-8	99.0	95.2	76.3	100.0	92.6
G-9	99.0	97.2	74.9	100.0	92.8
G-10	94.5	93.8	36.1	99.4	80.9
G-11	100.0	99.4	91.0	100.0	97.6
G-12	99.0	100.0	94.5	100.0	98.4
G-13	100.0	100.0	99.0	100.0	99.8
G-14	100.0	98.9	94.0	100.0	98.2
G-15	98.0	84.6	33.5	100.0	79.0
G-16	100.0	96.4	35.0	100.0	82.9
G-17	98.5	94.2	50.0	100.0	85.7
G-18	92.5	92.1	51.1	100.0	83.9
G-19	91.5	100.0	53.5	100.0	86.2
G-20	98.0	96.6	30.5	99.5	81.1
G-21	98.5	96.9	29.7	100.0	81.3
G-22	81.9	87.3	80.0	99.0	87.0
G-23	97.5	100.0	97.0	100.0	98.7
G-24	93.9	94.9	21.5	98.9	77.3
SC 155	100.0	100.0	95.0	100.0	98.8
SC 3084	100.0	98.8	72.3	100.0	92.8
Env. Average	95.0	95.8	63.8	99.9	88.6
LSD 0.05	15.32	4.01	27.01	0.83	7.71
CV%	11.46	2.98	30.08	0.59	12.55

new improved varieties or hybrids and the differences among locations can be mainly attributed to the farmer factor, as well as the variation in soil fertility and varied cultural procedures. The environmental index for all traits was calculated as the difference between the location mean and the mean over all locations. For the three studied traits, the indices covered a wide range and displayed a good distribution within this range. Therefore, the assumption for stability analysis is fulfilled as suggested by Eberhart and Russell[5].

Based on the combined data, the 26 maize hybrids differed significantly with respect to all studied traits across all locations (Table 4). Considering grain yield, the obtained data in Table 1 showed that the two yellow single cross hybrids; G-14 and G-23 produced the highest grain yield and significantly outyielded the commercial yellow check hybrid SC 155 by 5.74 and 2.06 ard/fad, respectively. Furthermore, the single cross G-14 significantly outyielded the highest check hybrid SC 3084 by 3.49 ard/fad. Moreover, nine single crosses, *i.e.* G-1, G-2, G-3, G-4, G-8, G-18, G-21, G-23 and G-24 produced high grain yield and did not significantly differ from the highest check hybrid SC 3084 (Table 1). At the same time, the two top most outyielding crosses, *i.e.* G-14 and G-23 were also significantly earlier than the check hybrid SC 3084 and manifested high resistance to late wilt disease (Tables 2 and 3, respectively).

Table 4: Stability analysis of variance for grain yield, days to 50% silking and late wilt resistance of 24 promising yellow single cross hybrids and 2 check hybrids evaluated under different environmental conditions, 2005 season.

S.O.V	DF	Grain yield	Days to 50% silking	Late wilt resistance
Genotypes (G)	25	14.45**	3.53**	266.87**
Environments (E)	3	3985.72**	96.93**	28971.40**
G x E	75	27.05**	1.76**	642.83**
Env + G x E	78	44.83**	1.35**	433.04**
Env. (linear)	1	2989.41**	72.70**	21728.46**
G x E (linear)	25	11.67**	0.31	436.27**
Pooled deviation	52	4.14**	0.48**	21.95
G-1	2	3.11	0.07	1.31
G-2	2	2.85	0.10	1.10
G-3	2	6.02	0.11	3.54
G-4	2	8.42*	0.58	55.28
G-5	2	14.02**	0.44	267.91**
G-6	2	4.77	0.30	4.15
G-7	2	3.89	0.59	5.68
G-8	2	5.52	0.52	4.72
G-9	2	2.41	0.02	2.00
G-10	2	4.75	0.05	3.83
G-11	2	5.09	0.20	0.43
G-12	2	1.95	0.03	0.20
G-13	2	6.41*	1.48**	0.01
G-14	2	3.70	0.24	0.40
G-15	2	0.39	0.31	55.74
G-16	2	1.51	0.29	21.96
G-17	2	5.31	0.24	10.05
G-18	2	1.46	0.84*	1.61
G-19	2	2.18	0.01	14.61
G-20	2	0.06	0.63	18.09
G-21	2	1.54	1.95*	18.76
G-22	2	2.73	0.25	63.11
G-23	2	10.21**	0.11	1.84
G-24	2	4.82	0.20	10.29
SC 155	2	1.90	0.63	0.15
SC 3084	2	2.68	2.37**	4.01
Pooled error	312	2.14	0.29	33.41
CV %		9.83	1.71	12.55

*, ** indicate significant differences at 0.05 and 0.01 levels of probability, respectively.

Results obtained in Table 4, reveal that the interaction of genotypes x environment (G x E) for grain yield and other studied traits was highly significant.

In this regard, Eberhart and Russell[5] , Freeman and Perkins[11], El-Nagouly, *et al.*[20], Ibrahim *et al.*[25], Ragheb *et al.*[15,16] , Abd El-Aziz[17] and Mahmoud and Atia[18] stated that the basic cause of the differences among genotypes in their yield stability is the wide occurrence of genotype x environment (G x E) interaction. Such significant interactions encourage maize breeders to develop high yielding and more uniform hybrids under varied environmental conditions. High yield potentiality and average stability are due to most attributes involved in determining the wide adaptation of a new variety or hybrids[5-14] .

The significant linear effect of environments and G x E interaction (Table 4) for grain yield and resistance to late wilt disease revealed that locations (environments) differed remarkably in their effects on the performance of evaluated genotypes, and all hybrids responded differently within the specific range of varied locations. Highly significant pooled deviation, on the other hand, was obtained for grain yield and days to 50% silking. This means that the deviation of all genotypes from linearity was significant and more obvious. These results are in the same line with those obtained by Vasil and Milas[27] and Abd El-Aziz[17].

Estimates of various stability parameters for all studied genotypes (24 new single cross hybrids as well as two checks) with respect to grain yield, days to 50% silking and late wilt resistance are presented in Table 5 and Figure 1. These parameters are 1. average of different genotypes over all environments, 2. regression coefficient (b) of the average performance on environmental indices, and 3. squared deviation (S^2_d) of the average from

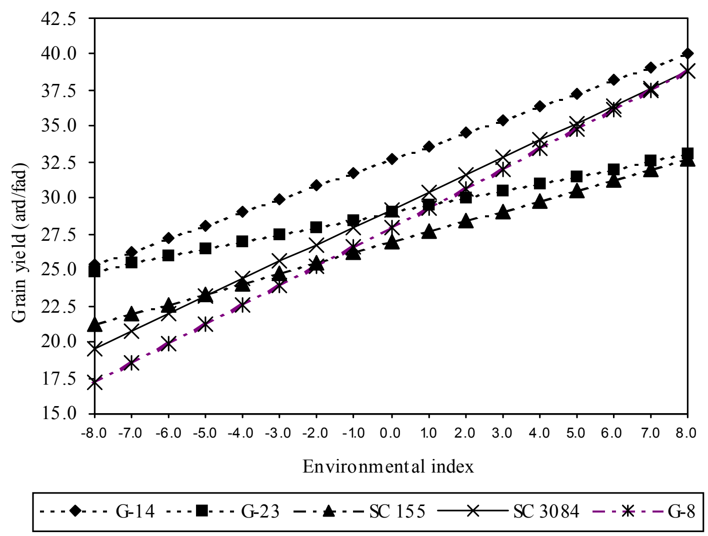

Fig. 1: Response of new maize single crosses to environmental conditions as compared to the check hybrids (SC 3084 and SC 155).

Table 5: Stability parameters for grain yield, days to 50% silking and late wilt resistance of 24 promising yellow single cross hybrids and 2 check hybrids evaluated under different environmental conditions, 2005 season

	Grain yield (ard/fad)			Days to 50 % silking			Late wilt resistance		
Genotypes	Average	b	S^2_d	Average	b	S^2_d	Average	b	S^2_d
G-1	27.85	1.205	0.965	60.1	0.489	-0.219	94.9	0.198	-32.102
G-2	27.56	1.153	0.705	59.6	0.594	-0.187	97.0	0.181	-32.313
G-3	27.82	1.676	3.876	60.5	0.625	-0.176	88.1	0.326	-29.865
G-4	27.64	1.983	6.278*	60.2	1.421	0.294	74.5	1.286	21.870
G-5	25.71	2.559	11.876**	60.5	1.233	0.150	73.0	2.832	234.501**
G-6	25.95	1.493	2.634	61.2	1.024	0.014	90.8	0.353	-29.255
G-7	24.15	1.348	1.750	59.0	1.426	0.298	90.2	0.412	-27.728
G-8	28.00	1.607	3.384	60.9	1.347	0.235	92.6	0.376	-28.689
G-9	26.71	1.061	0.270	60.0	0.233	-0.273	92.8	0.245	-31.405
G-10	25.50	1.490	2.610	61.5	0.428	-0.236	80.9	0.338	-29.582
G-11	25.47	1.542	2.948	60.6	0.822	-0.093	97.6	0.113	-32.983
G-12	26.32	0.954	-0.194	60.9	0.348	-0.254	98.4	0.078	-33.207
G-13	26.00	1.730	4.266*	59.2	2.264	1.191**	99.8	0.014	-33.403
G-14	32.69	1.316	1.564	59.4	0.907	-0.051	98.2	0.109	-33.010
G-15	22.10	0.426	-1.753	60.1	1.041	0.024	79.0	1.292	22.336
G-16	27.32	0.841	-0.627	60.3	1.001	0.001	82.9	0.811	-11.445
G-17	25.91	1.575	3.167	61.3	0.916	-0.046	85.7	0.548	-23.361
G-18	27.43	0.824	-0.686	61.0	1.711	0.556	83.9	0.220	-31.798
G-19	26.02	1.009	0.040	59.9	0.227	-0.274	86.2	0.661	-18.799
G-20	25.93	0.170	-2.079	60.9	1.481	0.345	81.1	0.736	-15.320
G-21	27.50	0.849	-0.596	61.1	2.598	1.658**	81.3	0.749	-14.648
G-22	25.81	1.128	0.585	58.1	0.939	-0.034	87.0	1.374	29.702
G-23	29.01	2.184	8.073**	59.3	0.607	-0.182	98.7	0.235	-31.571
G-24	27.54	1.501	2.683	59.2	0.843	-0.084	77.3	0.555	-23.117
SC 155	26.95	0.943	-0.237	58.2	1.479	0.342	98.8	0.068	-33.256
SC 3084	29.20	1.118	0.537	61.4	2.867	2.083**	92.8	0.346	-29.401

*, ** indicate significant differences at 0.05 and 0.01 levels of probability, respectively.

regression. According to the definition of Eberhart and Russell[5], a stable preferred hybrid would have approximately b=1, S^2_d = 0 and a high mean performance. However, Johnson, *et al*.[28], Paroda *et al*.[29] and Lin *et al*.[9] considered the squared deviation from regression as a measure of stability, while the regression was regarded as a measure of response of a particular hybrid to environmental indices.

The regression analysis (Table 5), shows that each hybrid had a (b) value equal to one indicating their linear response to environmental indices (Fig. 1). On the other hand, the highly significant pooled deviation for grain yield, days to 50% silking (Table 4), indicated that some of the studied hybrids differed significantly with regard to the deviation from their respective average linear response. According to Paroda and Hayes[30] and

Lin *et al.*[9], the hybrids G-1, G-2, G-8, G-14 and SC 155 would be considered the most stable hybrids with respect to grain yield, since the regression coefficient values of the average of these crosses on the environmental index are approximately equal one, and their deviations from linearity are small and insignificant (Table 5). For days to 50% silking, the crosses G-2, G-7, G-14, G-22, G-23 and SC 155 were considered to be the most stable hybrids (towards earliness) across all locations (Table 5), since it possessed small and insignificant deviations (-0.187, 0.298, -0.051, -0.034, -0.182 and 0.342, respectively). With respect to resistance to late wilt disease (Table 5) single crosses G-1, G-2, G-8, G-11, G-12, G-14, G-23 and SC 155 would be considered the most stable hybrids across all locations, since they had small and insignificant deviations. However, all hybrids which had significant deviations were considered to be unstable across all locations. The highest deviations were obtained for G-4, G-5, G-13 and G-23 (6.278, 11.876, 4.266 and 8.073, respectively) for grain yield, G-13, G-21 and SC 3084 (1.191, 1.658 and 2.083, respectively), for days to 50% silking and G-5 (234.501) for late wilt resistance.

Generally, five single crosses, i.e. G-1, G-2, G-8, G-14 and G-23 were good yielders, earlier in silk appearance and had higher resistance to late wilt disease as compared to the commercial check hybrid SC 155. These hybrids were more responsive to a wide range of environments. In other words, these hybrids could be the most stable hybrids, since they had small and insignificant deviations, and had the highest yielding potentiality. These five hybrids might be recommended to be released as stable high yielding resistant hybrids and/or incorporated as breeding stock for further use.

REFERENCES

1. Heinrich, G.M., C.A. Francis and J.D. Eastin, 1983. Stability of grain sorghum yield components across divers environments. Crop Sci., 23: 209-212.
2. Hohls, T., P.E. Shanahan, G.P. Clarke and H.O. Gevers, 1995. Genotype x environment interactions in a 10 x 10 diallel cross of quality protein maize (*Zea maize* L.), Euphytica, 84: 209-218.
3. Freeman, G.H., 1973, Statistical methods for the analysis of genotype-environm-ent interactions. Heredity, 31: 339-354.
4. Finlay, K.W. and G.N. Wilkinson, 1963. The analysis of adaptation in a plant breeding programme. Aust. J. Agric. Res. 14: 742-754.
5. Eberhart, S.A. and W.A. Russell, 1966 Stability parameters for comparing varieties. Crop Sci., 6: 36-40.
6. Perkins, J.M. and J.L. Jinks, 1968. Environmental and genotype-environmental components of variability III. Multiple lines and crosses. Heredity, 23: 339-356.
7. Shukla, G.K., 1972. Some statistical aspects of partitioning genotype-environm-ental components of variability. Heredity, 29: 237-247.
8. Hardwick, R.C. and J.T. Wood, 1972. Regression methods for studying genotypes-environment interactions. Heridity, 28: 209-222.
9. Lin, C.S., M.R. Binns and L.P. Lefkovitch, 1986. Stability analysis, Where do we stand ? Crop Sci. 26: 894-900.
10. Baker, R.J., 1988. Analysis of genotype-environmental interactions in crops. ISI Atlas of Animal and plant Sci., 1: 1-4.
11. Freeman, G.H. and J.M. Perkins, 1971. Environmental and genotype-environm-ental components of variability. VIII. Relation between genotypes grown in different environments and measures of these environments. Heredity, 27: 15-23.
12. Hill, J., 1976. Genotype-environment interactions - a challenge for plant breeding. J. Agric. Sci., 85: 477-493.
13. Westcott, B., 1986. Some methods of analyzing genotype-environment interaction. Heredity, 56: 243-253.
14. Crossa, J., 1988. A comparison of results obtained with two methods for assessing yield stability. Theor. Appl. Genet., 75: 460-467.
15. Ragheb, M.M.A., H.Y. Sh. El-Sherbieny, A.A. Bedeer and S.E. Sadek, 1993a. Genotype-environment interaction and stability in grain yield and other agronomic characters of yellow maize hybrids. Zagazig J. Agric. Res. 20(5): 1435-1446.
16. Ragheb, M.M.A., A.A. Bedeer, A. Sh. Gouda, Sh. F. Abo-El-Saad, and A.A. Abdel-Aziz, 1993b. Phenotypic stability parameters for grain yield and other agronomic characters of white maize hybrids under different environmental conditions. Zagazig J. Agric. Res., 20(5): 1447-1461.
17. Abd El-Aziz, A.A., 2000. Stability parameters for grain yield and other agronomic characters of yellow maize (*Zea mays* L.) hybrids. Egypt. J. Plant Breed., 4: 287-301.
18. Mahmoud, A.A. and A.A.M. Atia, 2005. Estimating stability degrees of some maize single crosses using four statistical models. Minufiya J. Agric. Res., 30:365-582.
19. Allard, R.W. and A.D. Bradshaw, 1964. The implication of genotype-environme-ntal interactions in plant breeding. Crop Sci., 4: 503-508.

20. El-Nagouly,O,O., M.A. Khalifa, E.M. Shokr and E.A. Mahmoud, 1980. Estimates of stability for yield and some yield components of maize (*Zea mays* L.) under different treatments of irrigation. Annals Agric. Sci. Moshtohor, 14: 75-85.
21. Mead, R., J. Riley, K. Dear and S.P. Singh, 1986. Stability comparison of intercropping and monocropping systems. Biometrics 42: 253-266.
22. George, H.L., L.G. Liang, E.G. Heyne and T.L. Walter, 1966. Estimates of variety x environment interaction in yield tests of three small grain crops and their significance in breeding program. Crop Sci., 6: 135-139.
23. Dhillon, B.S. and J. Singh, 1977. Estimates and inheritance of stability parameters of grain yield in maize. J. Agric. Sci., 86: 257-265.
24. Francis, T.R. and L.W. Kannenberg, 1987. Yield stability studies in short season maize 1. A descriptive method for grouping genotypes. Can. J. Plant Sci., 58: 1029-1034.
25. Ibrahim, M.S.A., O.O. El-Nagouly and M.I. Salama, 1984. On- Farm evaluation for yield stability of maize varieties in Egypt. Administrative Report. Proc. EMCIP, 1: 103-112.
26. Steel, R.G.D. and J.H. Torrie, 1980. Principles and procedures of statistics. A biometrical approach 2nd (Ed.) McGraw-Hill Book Co. Inc., N.Y., USA.
27. Vasil, J.D. and S. Milas, 1984. Relationships between yield stability parameters estimated with different methods for some maize and wheat genotypes. Vortr Pflanzenzuchtg, 7: 266-279.
28. Johnson, H.W., H.F. Robinson and R.E. Comstock, 1955. Estimates of genetic and environmental variability in soybeans. Agron. J., 47: 314-318.
29. Paroda, R.S., K.R. Salaniki and B.S. Chandhary, 1973. Phenotypic stability in oats. Indian J. Genetic and Plant Breed., 33: 92-95.
30. Paroda, R.S. and J.D. Hayes, 1971. An investigation of genotype-environment interaction for rate of ear emergence in spring barley. Heredity, 26: 157-175.