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Utilization of Parametric and Nonparametric Yield - Stability Measurements and their Relationship in Yellow Maize

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ABSTRACT

The maize hybrid possessing high grain yield and stability to various environmental is required in maize breeding. Eleven yellow hybrids beside two checks were evaluated in a randomized complete block design (RCBD) with four replications at five locations in Egypt *i.e.* Sakha, Gemmeiza, Sids, Mallawi and Nubaria in 2022 season to identify, the superior hybrids for both high grain yield and stable under multi-locations.The mean squares of locations, hybrids and their interaction were highly significant for most studied traits. The best hybrids were SC Sk166 for earliness, plant and ear heights and SC Sk157, SC Sk158, SC Sk162 and SC Sd155 for high grain yield compared to commercial hybrids, SC168 and SC162. The two hybrids SC Sk162 and SC Sd155 were more stable in most stability measures used.So,this study recommended using hybrids, SC Sk162 and SC Sd155 in Egyptian breeding program for high grain yield and stable. The correlation between two parameters (CV% and b_i), (CV% and S^2d_i), (CV% and $S_i^{(2)}$), (b_i and R^2), (W_i^2 and $S_i^{(1)}$), (W_i^2 and $S_i^{(2)}$) and ($S_i^{(1)}$ and $S_i^{(2)}$) were positive and significant, indicating that both two parameters were similar in selection stability hybrids, hence only one from the two parameters would be sufficient to select stable hybrid. Meanwhile, the correlation between two parameters; (R^2 and W_i^2) and (R^2 and P_i) were negative and significant, consequently the two parameters were differ in estimation stability of hybrids, so the two parameters should be used independently to estimate stability of hybrids.

Keywords: Zea mays, hybrids, Stability, Parametric and nonparametric measures.

INTRODUCTION

Maize (*Zea mays* L.) is a cereal crop with a remarkable potential for production and it is the third most important grain crop after wheat and rice. The production and trade of maize targeted at animal husbandry. However, maize has been a leading and integral staple food for humans. Considering the importance of maize and its cultivation potential worldwide. (Shojaei *et al.* 2021). Now a days in Egypt , production is unable to meet the demands. Many factors affected due to limit production of maize such as genotypes, environmental conditions, including cropping system, location, season, infection by pathogens and insects and interaction between genotypes and environments. One of main goals of Egypt maize breeding programs is to develop good performing hybrids which are characterized by high stability and adaptability to a variety of different environments. Environmental factors have a great influence on qualitative and quantitative traits, so performance tests of potential varieties have been conducted in multiple locations over years (Ararsa *et al.* 2016). Besides the genotype (G) and environment (E) main effects, performance of genotypes is also determined by genotype × environment interaction (GEI) which refers to the differential response of genotypes to environmental changes (Hallauer and Miranda, 1988). Quantitative characteristics that are economically and agronomical important such as grain yield is influenced by genotypes, environment and management approaches as well as their interplay (Messina *et al.* 2009). Selection under various environments is very difficult due to G x E interaction (Badu *et al.* 2003 and Mortazavian and Azizi-Nia 2014). The emergence of GEI due to unpredictable macro and micro- environmental influences as temperature, humidity and rainfall (Abo-Hegazy *et al.* 2013)

The stability of yield depends on the ability of a given variety to react to environmental changes (Frey 1983). There are many methods to estimate the GEI and to select stable genotypes including, parametric, nonparametric measures and graphical estimation. Which, the selection of stable and high-yielding genotypes based on a single stability method were less accurate and effective (Mosa *et al.* 2019, Ruswandi *et al.* 2022 and Wicaksana *et al.* 2022). Simultaneous selection for yield and stability has been studied by many investigators (Zivanovic *et al.* 2004, Changizi *et al.* 2014 and Mosa *et al.* 2021). Parametric and nonparametric statistics would be useful for simultaneous selection for high grain yield and stability (Delic *et al.* 2009, Sabaghnia 2015, Ruswandi *et al.* 2022 and Wicaksana *et al.* 2022). The purposes of this research were to identify hybrids that have high grain yield and are stable to environmental changes and study the relationship between the stability measures.

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MATERIALS AND METHODS

The experiment was made in 2022 growing summer season at five locations (Sakha, Gemmeiza, Sids, Mallawi and Nubaria). Eleven promising yellow single crosses *i.e.* SC Sk157, SC Sk158, SC Sk159, SC Sk160, SC Sk161, SC Sk162, SC Gz310, SC Gm114, SC Sd155, SCSd 157 and SC Sd166 beside two checks commercial hybrids, *i.e.* SC168 and SC162 were included in this study. These crosses were developed by maize breeding program at Sakha (Sk), Giza (Gz), Gemmeiza (Gm) and Sids (Sd) Agriculture Research Stations. In each location the experiment was laid out in a randomized complete block design (RCBD) with four replications. The experimental plot comprised four rows each 6 m in length and 80 cm apart, the seeds were planted in hills with spaced at 25 cm along the row at the rate of two kernels per hill, later thinned to one plant per hill. All the recommended agronomic practices were followed to raise a good crop. Observation on number of days to 50% silking, plant height (cm), ear height (cm) and grain yield (ard/fed) adjusted at 15.5% grains moisture (one ardab=140 kg and one feddan=4200 m^2) were recorded on each hybrid.

Combined analysis across five locations was done by (Snedecor and Cochran 1989), after the homogeneity test by (Bartlett 1937). ANOVA revealed that locations (L), hybrids (H) and (H x L interaction). Analysis of variances was carried out by using computer application of statistical analysis system (SAS, 2008). Means of hybrids were compared using least significant difference LSD at 0.05 and 0.01 level of probability. Six parametric and two nonparametric stability approaches were used as follows: Parametric methods were, regression coefficient (b_i), deviation from regression (S^2d_i) proposed by (Eberhart and Russell 1966), determination coefficient (R^2) by (Pinthus 1973), coefficient of variation (CV %) by (Francis and Kannenberg 1978), ecovalence (W_i^2) by (Wricke 1962) and superiority measure (P_i) by (Lin and Binns 1988), while nonparametric methods were, both the genotype absolute rank difference mean as tested across environments ($S_i^{(1)}$) and the variance between the ranks across environments($S_i^{(2)}$) according to (Huehn 1990).

RESULTS AND DISCUSSION

Analysis of variance for the traits under study in pooled analysis is shown in Table 1. The differences among locations (L) were highly significant for all studied traits, indicating that the locations were diverse in soil and climate conditions for all traits under study. The impacts of hybrids (H) were highly significant for all studied traits, indicating greater diversity among crosses for all traits under study.The interaction between hybrids and locations (H x L) was highly significant for traits under study except for plant height. This confirms that hybrids are affected by change locations. Similar results were obtained by Mosa *et al.* (2012), Hassan (2015), Soumya *et al.* (2018), Bachkar *et al.* (2020), Shojaei *et al.* (2021), Abd El-Latif *et al.* (2023) and Hugues *et al.* (2023).

Table 1. Mean squares due to locations, hybrids and their interaction for four studied traits.

SOV	df	Days to 50% silking	Plant height	Ear height	Grain yield
Locations (L)	4	450.94**	41650.92**	22769.64**	1221.14**
Rep/L	15	1.74	338.66	187.75	25.75
Hybrids (H)	12	61.61**	2915.80**	933.44**	30.34**
H x L	48	5.61**	604.55	244.32**	43.68**
Error	180	1.48	127.98	50.12	7.32

**** Indicate significant at 0.01 level of probability.**

Table 2, the lowest mean and environmental index obtained, for days to 50% silking at Sakha location, for plant height at Mallawi location, for ear height and grain yield at Sids location, indicating that this location was considered stress environment for these traits. On the other hand, the highest mean and environmental index were obtained for plant and ear heights and grain yield at Sakha location, meaning that this location was considered non stress environment for these traits. Frey (1964) and Frey and Maldonado (1967) found that the stress environment as the one in which mean for a certain attribute is low. Also, they reported that under optimum environment the tested genotypes were fully expressed leading to an enlargement in genetic differences, while the stress conditions curtail genetic differences among different genotypes.

Table 2. Means and environmental index for four studied traits at five locations.

Location	Days to 50% silking	Env. index	Plant Height (cm)	Env. index	Ear Height (cm)	Env. index	Grain yield (ard/fed)	Env. index
Sakha	59.38	-2.61	299.78	40.00	162.42	21.38	35.53	5.68
Gemmeiza	60.19	-1.81	270.61	10.83	160.53	19.50	31.76	1.91
Sids	66.90	4.90	233.75	-26.03	115.86	-25.17	22.47	-7.37
Mallawi	61.30	-0.69	231.55	-28.22	124.32	-16.71	31.06	1.21
Nubaria	62.23	0.22	263.21	3.42	142.03	1.00	28.41	-1.43

Mean of eleven hybrids and the two commercial hybrids for traits under study are presented in Table 3.

Number of days to 50 % silking, the hybrids ranged from 57.85 days for (SC Sd166) to 64.35 days for (SC Gz310), five hybrids were earlier than the best check SC168 (62.55 days), the best hybrids from them were SC Sd157 and SC Sd166. Plant height (cm), the hybrids ranged from 238.95cm for (SC Sd166) to 276.80 cm for (SC Sk162). Ear height (cm), the hybrids ranged from 128.4.0 cm for (SC Sd166) to 152.15cm for (SC Sk162), the hybrid SC Sd166 was significantly lower than the best check SC168 for plant and ear heights. Grain yield (ard/fed), the hybrids ranged from 28.62 ard/fed for (SC Sd166) to 32.02 ard/fed for (SC Sk158), five hybrids *i.e.* SC Sk157 (31.56 ard/fed), SC Sk158 (32.02 ard/fed), SC Sk161 (30.30 ard/fed), SC Sk162 (31.09 ard/fed) and SC Sd155 (31.24 ard /fed) had grain yield more than (30.00 ard/fed).

Percentage of superiority of eleven hybrids relative to commercial hybrids SC168 and SC162for grain yield are shown in Table 4. The results showed that four yellow promising hybrids SC Sk157 (7.60 ** and 9.10** %), SC Sk158 (9.15** and 10.68** %), SC Sk162 (5.98* and 7.46* %) and SC Sd155 (6.51* and 8.0** %) were significant or highly significant superiority for grain yield than commercial hybrids SC168 and SC162, respectively. So, these hybrids are favorite and desirable in maize breeding Program. Several researchers reported significant superiority % for grain yield of maize *i.e.* (Abdel-Azeem *et al.* 2013, Silva *et al.* 2014, Mosa *et al.* 2019 and Abdel-Latif *et al.* 2023).

Table 3. Means performance of eleven hybrids and two commercial hybrids SC168 and SC162 for traits under study across five locations.

Hybrid	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard/fed)
SC Sk157	62.95	273.70	146.10	31.56
SC Sk158	62.10	262.10	137.00	32.02
SC Sk159	61.05	250.15	130.15	29.23
SC Sk160	62.10	268.40	140.55	28.67
SC Sk161	62.65	275.50	149.65	30.30
SC Sk162	63.75	276.80	152.15	31.09
SC Gz310	64.35	253.50	142.45	28.70
SC Gm114	61.20	259.55	140.10	28.82
SC Sd155	61.00	255.30	144.30	31.24
SC Sd157	60.40	247.55	138.25	29.53
SC Sd166	57.85	238.95	128.40	28.62
Check SC168	62.55	247.95	139.20	29.33
Check SC162	64.10	267.75	145.20	28.93
LSD at 0.05	0.75	7.01	4.38	1.67
LSD at 0.01	0.98	9.22	5.76	2.19

Table 4. Superiority percentage of eleven promising hybrids relative to the two commercial hybrids SC168 and SC162 for grain yield.

Hybrid	Superiority%	
	SC168	SC162
SC Sk157	7.60**	9.10**
SC Sk158	9.15**	10.68**
SC Sk159	-0.34	1.05
SC Sk160	-2.24	-0.88
SC Sk161	3.30	4.75
SC Sk162	5.98*	7.46*
SC Gz310	-2.16	-0.79
SC Gm114	-1.75	-0.38
SC Sd155	6.51*	8.00**
SC Sd157	0.66	2.07
SC Sd166	-2.43	-1.07
LSD 0.05	1.67	
0.01	2.19	

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

Kang and phan (1991), Bachireddy *et al.* (1992), Changizi *et al.* (2014), Mosa *et al.* (2021), Shojaei *et al.* (2021), Wicaksana *et al.* (2022) and Matongera *et al.* (2023) stated that one of the main goals in the breeding program is select hybrid combines both high grain yield and stable. Hence estimates of means performance, stability parameters and against between them for thirteen hybrids for grain yield are presented in Table 5 and figures (1 to 8).

Table 5. Means performance, parametric and nonparametric stability measures for thirteen hybrids for grain yield.

Hybrid	Parametric measure							Nonparametric measure	
	Mean	b_i	S^2d_i	R^2	CV%	W_i^2	P_i	$S_i^{(1)}$	$S_i^{(2)}$
SC Sk157	31.57	1.84*	-0.01	0.96	28.78	78.92	13.92	2.10	22.5
SC Sk158	32.01	1.19	8.48**	0.77	20.47	42.05	8.48	1.90	11.5
SC Sk159	29.25	0.61*	-3.56	0.94	10.53	16.37	19.10	1.30	8.50
SC Sk160	28.68	1.15	4.65**	0.82	21.43	29.09	22.58	1.40	13.75
SC Sk161	30.31	1.61*	2.82*	0.92	26.94	57.20	16.05	1.40	20.75
SC Sk162	31.10	0.90	0.95	0.82	15.44	17.15	9.29	0.90	8.25
SC Gz310	28.70	1.03	10.98**	0.68	20.99	45.83	26.70	2.50	17.50
SC Gm114	28.83	1.22	6.98**	0.80	22.88	39.06	26.17	2.20	19.0
SC Sd155	31.24	0.43*	-4.25	0.98	6.72	31.07	10.54	1.70	11.75
SC Sd157	29.53	0.81	-4.13	0.99	13.42	3.92	16.11	1.50	6.50
SC Sd166	28.62	0.04*	-3.00	0.04	3.61	89.82	30.82	2.10	17.50
Check SC168	29.33	0.99	9.76**	0.69	19.80	42.37	23.55	1.50	19.50
Check SC162	28.93	1.17	5.00*	0.82	21.65	31.04	22.68	1.70	13.50
Mean	29.85	1.00	2.61	0.79	17.90	40.30	18.92	1.71	14.65

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

Stable genotype according to (Eberhart and Russell 1966) should have regression coefficient equal to unity (b_i=l) or b_i was not significant in addition to deviation from regression (S^2d_i) closed to zero or not significant. So, the hybrid SC Sk162 was combines both high grain yield (>grand mean or two checks) and stable for both (b_i) and (S^2d_i) (Figures 1 and 2).

The promising hybrids which stable for determination coefficient R^2 (Pinthus 1973) which had higher values (>80%) in addition it's high grain yield were SC Sk157, SC Sk161, SC Sk162 and SC Sd155 (Figure 3).

Depending on both (Francis and Kannenberg 1978) which used coefficient of variation (CV %) plus Wricke (1962) which used ecovalence (W_i^2), the hybrid with the smallest value was stable, hence the promising hybrids which smallest for CV % and W_i^2 values and high grain yield were SC Sd155 and SC Sk162 (Figures 4 and 5).

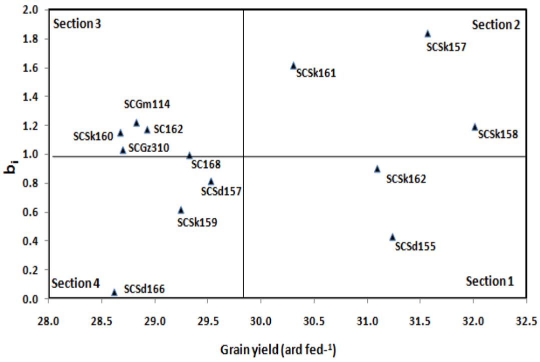

Figure 1. The regression coefficient (b_i) opposite grain yield (ard fed^{-1}) for 13 hybrids.

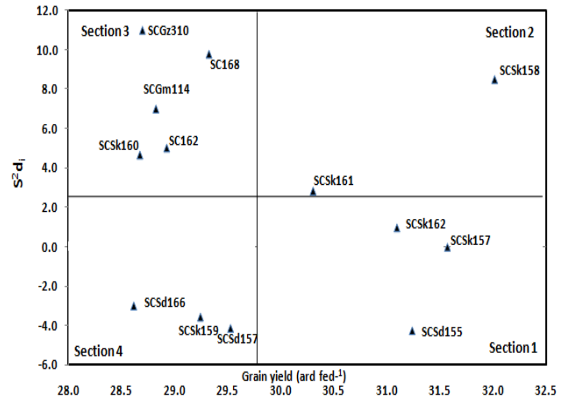

Figure 2. The deviation from regression (S^2d_i) versus grain yield (ard fed^{-1}) for 13 hybrids.

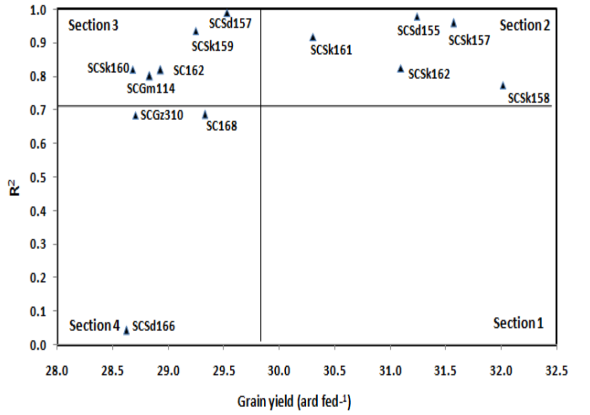

Figure 3. The determination cofficient (R^2) opposite grain yield (ard fed^{-1}) for 13 hybrids.

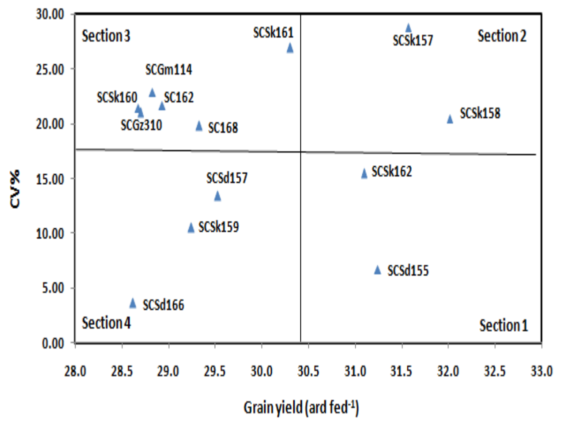

Figure 4. The Coefficient of variatiom (CV %) opposite grain yield (ard fed^{-1}) for 13 hybrids.

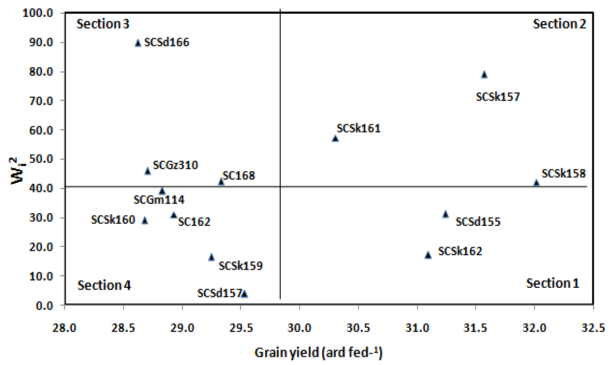

Figure 5. The ecovalence (W_i^2) opposite grain yield (ard fed^{-1}) for 13 hybrids.

The hybrid with small value of superiority index (P_i) is the most stable one (Lin and Binns 1988), hence the hybrids which had both stable based on Pi and high grain yield were SC Sk157, SC Sk158, SC Sk161, SC Sk162 and SC Sd155 (Figure 6).

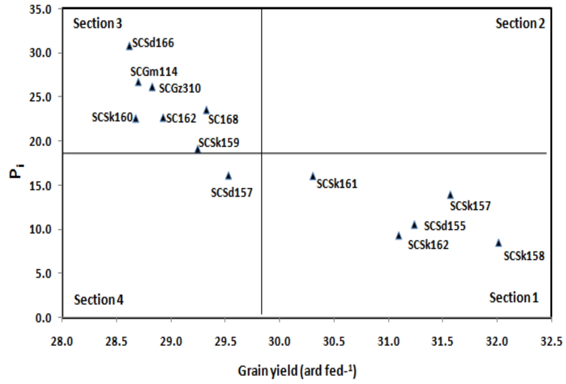

Figure 6. Superiority index (P_i) opposite grain yield (ard fed^{-1}) for 13 hybrids.

According to two non-parametric stability measures proposed by Huehn (1990) $S_i^{(1)}$ and $S_i^{(2)}$ the desirable hybrid which record the lowest value. So the promising hybrids which had smallest values for $S_i^{(1)}$ and had high grain yield were SC Sk161, SC Sk162 and SC Sd155 (Figure 7). Meanwhile, the hybrids which had smallest values for $S_i^{(2)}$ and had high grain yield were SC Sk158, SC Sk162 and SC Sd155 (Figure 8).

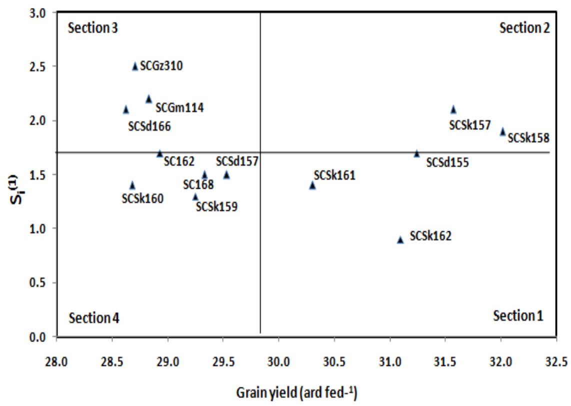

Figure 7. The mean absolute rank difference of genotype across environments $S_i^{(1)}$ opposite grain yield (ard fed^{-1}) for 13 hybrids.

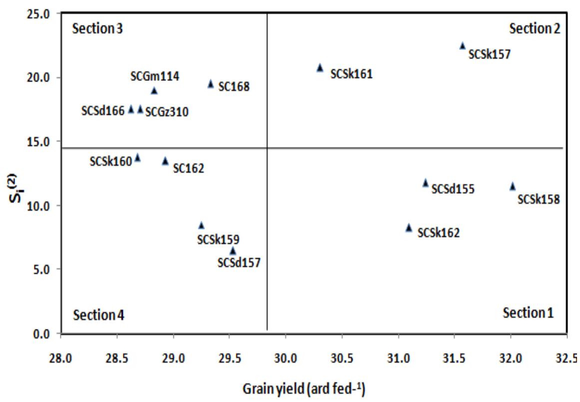

Figure 8. The variance between the ranks across environments $S_i^{(2)}$ opposite grain yield (ard fed^{-1}) for 13 hybrids.

From above results the hybrid SC Sk162 was the best hybrids for stability based on all stability parameters in this study (bi, S^2d_i, R^2, CV%, W_i^2, P_i, $S_i^{(1)}$ and $S_i^{(2)}$) followed by hybrid SC Sd155 depended on (S^2d_i, R^2, CV%, W_i^2, P_i, $S_i^{(1)}$ and $S_i^{(2)}$). Also, above two hybrids (SC Sk162 and SC Sd155) were significantly outyielded than the two checks. So, this study recommended moves these hybrids to next stage of evaluation according to the Egyptian hybrid's registration protocol.

The correlation coefficient (r) between different stability measures for grain yield is presented in Table 6.

The correlation between (CV% and b_i), (CV% and S^2d_i), (CV% and $S_i^{(2)}$), (b_i and R^2), (W_i^2 and $S_i^{(1)}$), (W_i^2 and $S_i^{(2)}$) and ($S_i^{(1)}$ and $S_i^{(2)}$) were positive and significant, indicating that both two measures move in one direction, hence the two parameters were similar in classification of the hybrids depending on their stability under different environment, so, only one from the two parameters would be sufficient to select the stable hybrid in breeding program. Meanwhile the correlation between (R^2 and W_i^2) and (R^2 and P_i) were negative and significant, indicating that two parameters were differ in estimation stability of hybrids. Consequently, two parameters should be used independently to estimate stability of hybrids. Same results obtained by Alberts (2004) and Mosa *et al.* (2019) for (r) between (CV% and b_i), Akcura *et al.* (2006)for (r) between (R^2 and W_i^2), Showenimo (2007) for (r) between (b_i and R^2), Piepho and Lotito (1992) for (r) between ($S_i^{(1)}$ and $S_i^{(2)}$), Mohebodin *et al.* (2006) for (r) between (R^2 and P_i), Fikere *et al.* (2009) for (r) between (CV% and S^2d_i) and Wicaksana *et al.* (2022) for (r) between (W_i^2 and $S_i^{(2)}$).

Table 6. Correlation coefficient between different stability measures for grain yield.

Stability measure	Stability measure							
	b_i	S^2d_i	R^2	Cv%	W_i^2	P_i	$S_i^{(1)}$	$S_i^{(2)}$
b_i	-	-	-	-	-	-	-	-
S^2d_i	0.456	-	-	-	-	-	-	-
R^2	0.530 *	-0.087	-	-	-	-	-	-
Cv%	0.976**	0.614*	0.413	-	-	-	-	-
W_i^2	0.117	0.089	-0.603*	0.142	-	-	-	-
P_i	-0.251	0.261	-0.630*	-0.081	0.335	-	-	-
$S_i^{(1)}$	0.069	0.342	-0.362	0.146	0.572*	0.465	-	-
$S_i^{(2)}$	0.474	0.420	-0.264	0.541*	0.799**	0.417	0.541*	-

****, *Indicate significant at 0.01 and 0.05 levels of probability, respectively.**
b_i = regression coefficient, S^2d_i = deviation from regression, CV% = coefficient of variation, W_i^2 = ecovalence, Pi = superiority measure, $S_i^{(1)}$ = absolute rank difference of genotypes across environments, $S_i^{(2)}$ = variance between the ranks across environments.

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إستخدام مقاييس الثبات المحصولى البارومترية وغير البارومترية والعلاقات بينها فى الذرة الشامية

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الملخص

يعتبر إنتاج الهجن التى تجمع بين المحصول العالى والثبات تحت مختلف البيئات من أهم الأهداف لبرنامج تربية الذرة الشامية فى مصر. وعليه تم تقييم أحد عشر هجيناً فردياً من الذرة الشامية الصفراء الجديدة بالإضافة إلى اثنين من الهجن التجارية للمقارنة فى تصميم القطاعات الكاملة العشوائية فى أربع مكررات فى خمسة مواقع مختلفة على مستوى الجمهورية وهى محطات البحوث الزراعية بسخا والجميزة وسدس وملوى والنوبارية فى موسم صيف ٢٠٢٢ للتعرف على الهجن المتفوقة والثابتة فى محصول الحبوب تحت البيئات المختلفة. أظهرت النتائج أن الإختلافات بين المواقع والهجن وتفاعلهما كانت عالية المعنوية لكل الصفات المدروسة ماعدا صفة إرتفاع النبات لتفاعل الهجن والمواقع. أوضحت النتائج أن هجين فردى سخا ١٦٦ كان أفضل الهجن لصفة التبكير وقصر إرتفاع النبات والكوز مقارنة بهجينى المقارنة ، كما أظهرت النتائج تفوق الهجن (هـ.ف سخا ١٥٧ ، هـ.ف سخا ١٥٨ ، هـ.ف سخا ١٦٢ ، هـ.ف سدس ١٥٥) معنوياً عن هجينى المقارنة هـ.ف ١٦٨ ، هـ.ف ١٦٢ لصفة محصول الحبوب. أظهر الهجينين (هـ.ف سخا ١٦٢ ، هـ.ف سدس ١٥٥) ثباتاً فى معظم مقاييس الثبات المستخدمة فى هذه الدراسة بالإضافة لتفوقهما معنوياً عن هجن المقارنة فى محصول الحبوب ولذلك توصى الدراسة بإستخدامهما فى البرنامج المصرى لإنتاج هجن من الذرة الشامية للمحصول العالى والثبات. كان التلازم بين كلاً من (CV% and bi) و(CV% and S2di) و (CV% and Si(2))و (bi and R2) و(Wi2 and Si(1)) و (Wi2 and Si(2)) و (Si(1) and Si(2))موجباً ومعنوياُ وهذا يشير إلى أن كلا المقياسين متماثلين فى تقدير الثبات للهجن وبالتالى يكفى مقياس واحد منهما. بينما كان التلازم بين(R2 and Wi2) و (R2 and Pi) سالباً ومعنوياً وهذا يشير إلى إختلاف المقياسين فى تقدير الثبات المحصولى للهجن ولذلك يجب إستخدام كلاهما.