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Estimation of Genetic Variability Using Line X Tester Technic in Yellow Maize and Stability Analysis for Superior Hybrids Using Different Stability Procedures

Cross Mark

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ABSTRACT

Fifteen inbred lines were crossed to three testers of maize to estimate combining ability effects for maturity and yield traits. The produce 45 crosses, S.C. 168 and T.W.C. Giza 368 were evaluated across two years at the Farm of Faculty of Agriculture, Moshtohor, Benha University in RCBD with 3 replicates. Mean squares due to year (Y) genotypes (G), crosses (C), testers (T), inbred lines (L), line x tester (LxT) and interaction variance for C, L, T and LxT with (S) were significant (P<0.05) for most studied traits. Non- additive gene action (δ^2_{SCA}) is more pervading in determining inheritance of the most traits. The non-additive type of gene action is fluctuated by year changed more than additive. The inbred lines M. 645a (L4), M. 653 (L5), and M. 674 (L11) showed desirable $\hat{g}_i$ for early maturity and grain yield plant^{-1}. The crosses M.221xM.653, M.221xM.655b, M.221xM.657, M.221xM.671, M.221xM.674 and M.221xM.677 exhibited out-yielded SC 168 reached 9.96%, 11.35%, 12.53%, 8.32%, 11.80% and 4.80%, respectively across years. TWC (SC M 200xM418)xM.653 and (SC M200xM418)xM.674 showed superiority than TWC 368 being 9.11% and 3.78%, respectively. The eight superior hybrids along with SC168, SC hytech 2066, TWC 368 and TWC 352 were evaluated in 2019 year at various environments using RCBD with 3 replicates to identify suitable adapted maize hybrids. The main effects of genotypes, environments and their GxE interaction were highly significant (P<0.01). Hybrids M. 221 x M. 674, M. 221 x M. 655b, SC hytech 2066 and SC 168 were the most crosses stable phenotypically and genetically across environments.

Keywords: Combining ability, GCA, Inbred lines, SCA, Testers and Yellow Maize.

INTRODUCTION

Successful development of improved corn hybrids is depending upon precise evaluation of genotypes under selection. Inbred lines performance *per se* does not extend an entirely suitable measure of their value in the line x tester crosses. Thus, development of simple but effective method of evaluating new inbred lines has been a major dilemma in the development of new hybrids. Line x tester analysis has become a standard procedure for evaluating both types of combining ability (GCA and SCA) of parental inbred lines to be used in cross combinations. However, there has been much controversy over the choice of appropriate tester.

The line x tester procedure with using different tester's base (narrow and broad) is the most prevalent method for the evaluating process. A wished tester described as give ultimate output on the predictable performance from the tested lines. Also, it combines the more simplicity utilization when used in other crosses or grown in various environments. No unique tester is able to completely fulfill these purposes.

There were unsolved problem that, chose the kind base of testers used in line x tester schema for assess inbred lines is still confused. Therefore, the choice of desirable tester is a serious decision. Utilization of low yielding variety carrying recessive factors for traits of economic interest should be used as a tester parent. But, the masking dominat desirable allels effect in such testers is making them ineffective. While, use of high yielding single crosses or elite inbred lines is useful for produce new three way crosses and single crosses, respectively. Also, assess of the top crosses gave a better idea SCA of the inbred lines. Matzinger (1953) reported that a narrow tester's genetic base participate more to line x tester interaction than does a large bases one. On the other hand, Grogan and Zuber (1957) illustrated that some double crosses like single crosses in effective for measuring GCA. El-Hosary (2014) estimated the relative value of various testers and found the small bases teeter like inbred line or single cross is more important in evaluating inbred line than open pollinated population. Sprague (1939) mentions that early testing for efficient test of inbred lines depend on bases of testers needed.

The essential final stage in most applied plant breeding programs is the evaluation of promising hybrids over diversified environments (years and locations). Grain yield plant^{-1} of crosses as quantitative inherited trait, often differ from environment to other one thus, a significant hybrid x environment (GxE) interaction will detected. Understanding the interaction of those factors and how they affect grain yield plant^{-1} is crucial for maintaining new high yield and stable crosses. A hybrid with high mean is considered stable if it has low fluctuations under various environments. Many investigators reported the importance of GxE interaction in stability analysis of maize *i.e.*, Sowmya *et al.* (2018), Arunkumar, *et al.* (2020) and El-Hosary (2020).

Various statistical methods (parametric and non-parametric) are proposed to measure stability by modeling the GxE interaction. However, the widely used methods are those based on regression models, variance components and multivariate analysis. The popular stability forms of regression

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statistics was proposed by Eberhart and Russell (1966) and Tai (1971). According to the regression procedure, the stability is extrapolates two parameters being slope regression line and the deviation from regression.

The ultimate goal of this study were to give an insight in the choice of desirable tester for evaluating inbred lines and determined superior inbred lines of maize, estimate GCA and SCA of the testers and inbred line and identify superior hybrid with high yield potentials and stability across various.

MATERIALS AND METHODS

The parental materials in this concern consisted of three various testers (males) *i.e.*: open-pollination population (Sakha pop.), a promising high yield single cross M 200 x M 418, and an elite of combining abilities inbred line M 221 as well as new 15 yellow inbred lines (females) in S$_7$ *i.e.* (Moshtohor) M. 601 (L1), M. 603c (L2), M. 642 (L3), M. 645a (L4), M. 653 (L5), M. 655b (L6), M. 657 (L7), M. 658A (L8), M. 671 (L9), M. 673 (L10), M. 674 (L11), M. 675a (L12), M. 677 (L13), M. 678 (L14) and M. 682r (L15). The fifteen females were crossed with the three testers in line x tester program at the 2016 summer season to produce 45 crosses combinations. Across two years of 2017 and 2018, the 45 test crosses and 2 various check hybrids single cross 168 (SC 168) and three way cross 368 (TW 368) were arranged in a randomized complete block design (RCBD) with three replications to determine the best parent and combinations.

The sowing dates were 6th June and 16th June in 2017 and 2018 seasons, respectively at farm of the Faculty of Agriculture, Moshtohor, Benha University. Each entry consisted of one 6-m long ridge with a 25 x 70 cm plant density. Agriculture practices of maize growing were followed according to the last recommendations.

Statistics were taken on a random sample of 15 guarded plants in each plot; days to maturity (day), plant height (cm), ear height (cm), number of rows ear^{-1}, number of kernels row^{-1}, 100-kernel weight (g) and grain yield plant^{-1}(g) (adjusted to 15.5% moisture content). ANOVA in each and across the two seasons was made. Further, combined analysis was not performed until after testing the homogeneity of errors in two years. Combining ability analysis was computed according the procedure developed by Kempthorne (1957). All parents except SK Pop were planted in 1st August 2018 to recombine the elite hybrids which superior relative to check hybrids in the previous experiment and to obtain a sufficient amount of grains. The elite hybrids along with four check hybrids (SC168, SC hytech 2066, TW 368 and Tw 352) were assessed in eight trials *i.e.* four governorate 1) El-Dakahlya (Mansoura) – 2) El-Menofya (Tala) – 3) Baneswif (Sids) - 4) El-Qaluobya (Moshtohor) under different planting date in each location of season 2019 (Table 1). The first planting date was 23, 22, 25 and 22 May and the second one was 13, 12, 15 and 15 Jun for the mention trails, respectively.

In each trial the eight promising crosses (6 SC and 2 TWC) along with four check hybrids were evaluated in a RCBS with three replicates. The planting dates were illustrated in each environment in table 1.

Table 1. Planting dates at each location of season 2019.

Locations	First planting date	Second plant date
El-Mansoura (El-Dakahlya)	23/5/2019	13/6/2019
Tala (El-Menofya)	22/5/2019	12/6/2019
Sids (Baneswif)	25/5/2019	15/6/2019
Moshtohor (EL-Qaluobya)	22 /5 / 2019	12/ 6/ 2019

Each plot consisted of four ridges of 4 m length and 70 cm width. Hills were spaced at 25 cm apart with two grains per hill on one side of the ridge. Dry method of planting was used in this concern. The seedlings were minimized to one seedling hill^{-1}. The cultural practices were allowed as usual for ordinary maize fields in these locations. The grain yield plant^{-1} was recorded as an average of 20 graded plants from the two middle rows of each plot. Analysis of variance of RCBD as outlined by Gomez and Gomez (1984) was conducted for each environment. Bartelett test (1937) was performed prior to the combined analysis to test the homogeneity of error terms indicating the homogeneity of variances. The regression approach comprised two stability methods that were described by Eberhart and Russell (1966) and Tai (1971)

RESULTS AND DISCUSSION

Table 2 showed that significant (P <0.01) mean squares due years (Y), genotype (G) and GxY interaction were detected for all studied traits, indicating change in years has obvious effects on the studied traits. Furthermore, genotypes performance influences significantly by change in years and the possibility of selecting genotypes that stable across years and exclude the unstable one. Also, Table (3) crosses and its partitioning of crosses mean squares into inbred lines (L), testers (T) and line x tester (LxT) were significant for all studied traits of each year and across the them except T for no of rows ear^{-1}, and LxT for 100-kernel weight in the first year, revealing a wide range of variability among parental tester (males), inbred lines (females), and that the lines performed differently according to the tester which they crossed.

Table 2. Mean squares for the studied traits at both and across years of 2017 and 2018 this analysis involved line x tester crosses and two check hybrids.

S.O.V.	df	days to maturity (day)	plant height (cm)	Ear height (cm)	No of rows ear-1	no of kernels row-1	100 kernel weight (g)	grain yield plant-1 (g)
				First year of 2017				
Rep	2	1.16	94.47*	21.24	0.009	0.49	1.97	57.89
Genotypes	46	13.38**	1161.546**	1272.52**	2.043**	24.11**	19.99**	3176.37**
Error	92	0.620	34.26	12.11	0.080	0.75	3.24	20.94
				Second year of 2018				
Rep	2	2.65	0.03	0.13	0.002	2.32	16.64**	42.15
Genotypes	46	16.50**	753.77**	1025.02**	2.01**	25.94**	19.16**	2929.50**
Error	92	0.96	28.30	22..52	0.047	0.83	2.67	15.45
				Combined across years				
year (Y)	1	59.29**	346.79*	7338.79**	0.67**	1938.54**	2005.33**	177901**
Rep/Y	4	1.90	47.25	10.68	0.005**	1.40	9.31	50.02
Genotypes	46	24.63**	1700.15**	1602.79**	2.36**	42.56**	30.22**	5158.5**
Genotype x Y	46	5.24**	215.17**	494.75**	1.69**	7.49**	8.93**	947.36**
Error	184	0.79	31.28	17.32	0.06	0.79	2.96	18.19

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

Table 3. Mean squares and combining ability analysis of line x tester for the studied traits at both and across years of 2017 and 2018.

S.O.V.	df	days to maturity (day)	plant height (cm)	Ear height (cm)	No of rows ear-1	no of kernels row-1	100 kernel weight (g)	grain yield plant-1 (g)
First year of 2017								
Rep	2	1.21	90.38	20.52	0.01	0.47	1.88	61.61
Crosses (c)	44	13.52**	1214.35**	1330.25**	2.14**	25.20**	20.90**	3300.31**
Line (L)	14	20.33*	2206.53**	1526.40**	2.18	45.10**	23.55**	3205.65**
Tester (T)	2	20.59*	8792.68**	12805.20**	1.99	184.03**	252.02**	39855.01**
L x T	28	9.61**	176.94**	412.54**	2.13**	3.90**	3.06	736.59**
Error	88	0.63	35.82	12.66	0.08	0.78	3.39	21.8
δ^2_{GCA}		0.05	13.21	11.68	0.04	0.27	0.23	32.64
δ^2_{SCA}		2.99	47.04	133.29	0.68	1.04	-0.11	238.26
Second year of 2018								
Rep	2	2.67	0.02	0.07	0.02	2.23	15.87**	67.75**
Crosses (c)	44	14.96**	787.95**	1049.46**	2.1**	27.12**	20.03**	2832.84**
Line (L)	14	27.15**	1234.91**	1161.49	1.32*	31.97**	25.54**	1058.09*
Tester (T)	2	24.90**	5903.76**	3743.18*	27.91**	233.11**	166.57**	47208.03**
L x T	28	8.16**	199.06**	801.03**	0.64**	9.98**	6.80**	550.56**
Error	88	0.99	29.59	17.66	0.05	0.86	2.79	12.66
δ2GCA		0.09	7.5	3.16	0.02	0.22	0.17	29.06
δ2SCA		2.39	56.49	261.13	0.2	3.04	1.34	179.3
Combined across years								
Year (Y)	1	71.56**	325.95**	6910.07**	0.66**	1854.26**	1923.86**	183366.69**
Rep/Y	4	1.94	45.2	10.3	0.05	1.35	8.87*	64.68**
Crosses (c)	44	23.47**	1777.36**	1683.72**	2.46**	44.49**	31.59**	5274.00**
Line (L)	14	42.69**	3030.62**	1894.49**	1.63**	67.77**	31.87**	3062.85**
Tester (T)	2	45.38**	14551.78**	13066.35**	20.57**	415.04**	393.17**	84833.17**
L x T	28	12.29**	238.26**	765.29**	1.58**	6.38**	5.63**	696.77**
CxY	44	5.01**	224.94**	695.99**	1.77**	7.82**	9.33**	859.15**
LxY	14	4.79**	410.82**	793.39**	1.87**	9.30**	17.23**	1200.89**
TxY	2	0.1	144.66*	3482.03**	9.33**	2.1	25.42**	2229.87**
LxTxY	28	5.48**	137.73**	448.29**	1.18**	7.49**	4.24	590.38**
Error	176	0.81	32.71	15.16	0.07	0.82	3.09	17.23
δ^2_{GCA}		0.64	155.8	93.07	0.09	4.39	3.51	780.12
δ^2_{SCA}		1.14	16.75	52.83	0.07	-0.18	0.23	17.73
δ^2_{GCAxY}		0.34	137.53	92.2	0.11	3.87	3.63	775.17
$\delta^2_{SCA\,xY}$		1.55	35.01	144.38	0.37	2.22	0.38	191.05

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

Significant interaction between CxY, LxY, TxY and LxTxY were obtained for all traits except for TxS for No of kernels row^{-1} and LxTxY for 100-kerenl weight, representative that testers, lines and crosses influenced from year to another. Also, these results designate significant the both types of combining ability (GCA for parent and SCA for crosses) and an indication to the predominance of dominance in controlling traits under study at both years and the weak effects of additive gene action. These results are in harmony with those obtained by EL-Hosary and EL-Gammal (2013), Bayoumi (2018), El-Hosary (2020) and Ismail *et al* (2020). However, Amer and El-Shenawy (2007) reported that significant interactions (P <0.01) between treatments, lines (L) and testers (t) for earliness and grain yield plant^{-1}. El-Morshidy *et al.* (2003) reported that lines were stable much more by change in environment than tester.

The estimates of variances due to GCA, SCA and their interactions with years (Table 3) showed that δ^2_{SCA} played the major role in determining the inheritance of all studied traits except 100-kernel weight at the first year and the combined across year, revealing that the largest part of the total genetic variability associated with these traits was a result of non- additive gene action. These results for most studied traits support the findings Ahmed *et al* (2017), who reported that δ^2_{SCA} was useful in the inheritance of grain yield plant^{-1} and other agronomic traits.

The magnitude of the interaction of δ^2_{GCA} x year was higher than that of δ^2_{SCA} x year for plant height, no of kernels row-1, 100-kerenl weight and grain yield plant^{-1}. Consequently, additive gene effects seemed greatly affected by environment. *Vice versa*, remain traits (maturity date, ear height and No of rows ear^{-1}) showed $\delta^2_{SCA\ x\ year\ (Y)}$ was generally higher than for $\delta^2_{GCA\ x\ Y}$. This finding showed that non-additive type of gene action were more changed than additive and additive x additive types of gene action by seasonal change. This is in harmony with the findings of several investigators who reported that δ^2_{SCA} is more sensitive to environmental changes than δ^2_{GCA} (El-Hosary 2020 and Ismail *et al* (2020).

General combining ability effects ($\hat{g}_i$) calculated for each tester and lines (combined over two years) are presented in Table 4. High positive values would be of interest under all traits in question except that of days to maturity where high negative values would be useful from the breeder's point of view. The effects of $\hat{g}_i$ for males (testers) showed that the inbred line M 221 behaved as a good combiner for all traits except, plant and ear heights. Earliness and high yielding if found in maize, would expand the opportunity for intensive cropping. Therefore, the male parent M 221 could be an excellent parent in breeding programs towards releasing early and high yield potentiality of hybrid maize. On the other hand, the parental tester Sakha pop. expressed a highly significant negative results for days to maturity, plant and ear heights. The male parents SC (M200xM418) had undesirable

$\hat{g}_i$ effects for all traits. Therefore, both male parents were of greatest interest and should be used as testers for evaluating the new inbred lines for these traits. The parental females (inbred lines) M. 645a (L4), M. 653 (L5), M. 658A (L8), M. 671 (L9), M. 673 (L10), M. 674 (L11) and M. 678 (L14) showed significant negative effects for $\hat{g}_i$ days to maturity; M. 603c (L2), M. 673 (L10), M. 675a (L12), M. 677 (L13) and M. 678 (L14) for plant and ear heights, M. 601 (L1), M. 645a (L4), M. 658A (L8), M. 674 (L11) for No of rows ear^{-1}, M. 653 (L5), M. 655b (L6), M. 657 (L7), M. 671 (L9), M. 674 (L11), M. 682r (L15) for No. of kernel row^{-1}, M. 642 (L3), M. 653 (L5) for 100-kernel weight, M. 645a (L4), M. 653 (L5), M. 655b (L6), M. 657 (L7), M.674 (L11) for grain yield plant^{-1} had significant positive $\hat{g}_i$ effect.

Table 4. General combining ability effects for testers and inbred lines for all studied traits in the combined analysis.

Parent	Days to maturity (days)	plant height (cm)	ear height (cm)	No of Rows ear^{-1}	No of kernel row^{-1}	100-kernel weight (g)	Grain yield plant^{-1} (g)
Tester							
M. 221 (T1)	-0.56**	12.10**	11.61**	0.49**	2.16**	2.21**	31.73**
M 200 x M 418 (T2)	-0.24**	1.14	0.84*	-0.02	-0.02	-0.26	-2.17**
Sakha pop. (T3)	0.80**	-13.25**	-12.45**	-0.47**	-2.14**	-1.95**	-29.56**
LSD (gi) 5%	0.16	1.18	0.7	0.05	0.16	0.36	0.74
1%	0.21	1.55	0.92	0.06	0.21	0.48	0.98
kLSD (gi-gj) 5%	0.26	1.67	1.14	0.08	0.27	0.51	1.21
1%	0.35	2.2	1.5	0.1	0.35	0.67	1.59
Line							
M. 601 (L1)	3.48**	-10.82**	-0.29	0.72**	-1.64**	-2.37**	-11.91**
M. 603c (L2)	2.81**	-22.09**	-12.65**	0.00	-2.41**	-0.41	-10.84**
M. 642 (L3)	0.98**	18.54**	12.41**	-0.1	-3.05**	1.57**	-9.90**
M. 645a (L4)	-1.58**	14.68**	9.05**	0.38**	-0.37	0.65	5.74**
M. 653 (L5)	-1.47**	10.77**	7.46**	-0.27**	2.04**	2.57**	19.27**
M. 655b (L6)	1.03**	4.31**	-0.14	0.01	1.26**	1.01*	11.46**
M. 657 (L7)	-0.3	13.41**	4.31**	0.03	1.33**	-0.01	7.59**
M. 658A (L8)	-1.63**	4.22**	10.61**	0.21**	-0.52*	0.58	2.52*
M. 671 (L9)	-1.13**	15.87**	19.29**	0.07	3.72**	-1.15**	11.93**
M. 673 (L10)	-0.91**	-12.95**	-9.04**	-0.34**	-0.47*	-0.21	-9.32**
M. 674 (L11)	-0.97**	0.67	-5.49**	0.17**	2.61**	0.72	20.65**
M. 675a (L12)	-0.19	-9.09**	-14.45**	-0.28**	-2.22**	-2.44**	-26.76**
M. 677 (L13)	-0.13	-13.37**	-12.01**	-0.24**	-0.82**	-0.26	-6.78**
M. 678 (L14)	-0.58**	-13.38**	-7.07**	0.09	-0.11	-0.4	-1.16
M. 682r (L15)	0.59**	-0.78	-1.98*	-0.44**	0.65**	0.16	-2.48*
LSD (gi) 5%	0.42	2.64	1.8	0.12	0.42	0.81	1.92
LSD (gi) 1%	0.55	3.47	2.36	0.16	0.55	1.07	2.52
LSD (gi-gj) 5%	0.59	3.74	2.54	0.17	0.59	1.15	2.71
LSD (gi-gj) 1%	0.77	4.91	3.34	0.22	0.78	1.51	3.56

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

Specific combining ability effects (SCA) of 45 line x tester cross are presented in Table 5. The greatest inter-and intra-allelic interaction as deduced from SCA effects were observed in crosses: M. 221 x M 671, M. 221 x M 674, M. 221 x M 678, M. 221 x M 682r , M SC x M603c, M SC x M653, M SC x M657, Sakha Pop. x 642, , Sakha Pop. x 645a and , sakha Pop. x 658A for early maturity; M 221 With each of M 645a, M671, M 677; M SC with each of M 603c and M 657 for plant and ear heights; M 221 with each of M 601, M655b, M 657, M 682r; Sakha Pop. with each of M 673, M 674 and M 675a for No of rows ear^{-1}; M 221 With each of M 642, M653, M 673; M SC with each of M 642, Sakha po. X M 675a, M 678 and M 682r for the number of kernels row^{-1}; M 221 with each of M 657, M677; Sc x M 678 for the 100-kernel weight; and M 221 with each of M 601, M 655b, M657 and M 677; SC (M 200xM418) and each of M 642, M 653, M 677, M678, M 682r; and Sakha Pop. with each of M 603c, M 645a, M 673, M 672a and M 678 for grain yield plant-^{1}. These test-crosses might be of interest in breeding programs as most of them involved at least one good combiner for the concerned traits. These test crosses could be of interest to obtain synthetic varieties or produced inbred lines.

It could be concluded that testers of broad genetic base are more efficient than those of the narrow genetic base for evaluation of GCA inbred lines of maize. Among the material evaluated, the line M 642a, 653, 658, 671 and M 674 gave the highest GCA effects for early maturity with high yielding ability, and that the top crosses M 221 x M 653, SC x M653 and Shakha with each of M645a and M 658A appeared efficient and promising in improving early maturity and grain yield. Also, these hybrids used in breeding program to produce new inbred lines.

Mean performance and relative superiority% relative to check hybrids

Table 6 showed that the mean performance of 45 test crosses and two checks (SC 168 and TWC 368) for days to maturity and grain yield plant^{-1}. Also, the percent of out-yielded of test crosses relative to mention check varieties. For days to maturity, results showed that twelve, sixteen and twenty six test crosses exhibited the lowest mean values for days to maturity and the deviation between these crosses and earlier check SC 168 were significant. However, the crosses M 221xM674, M221xM682r, MSC x M653, MSC x 657, Sakha Pop. X M645a and Sakha Pop. X M658A were earlier than the two check hybrids in both and across years. Early maturity crosses in maize is convenient for escaping destructive injuries caused by borer *like Sesamia cretica*, *Chilo simplex* and *Pyrausta nubilialis*. Similar results were reported by El-Hosary and El-Fiki (2015) and Ismail (2019 a & b).

Table 5. Specific combining ability effects for test crosses over both years for all studied traits.

test crosses	Days to maturity (days)	plant height (cm)	ear height (cm)	No of Rows ear^{-1}	No of kernel row^{-1}	100-kernel weight (g)	Grain yield plant^{-1} (g)
M. 221 x M. 601	-0.11	0.85	10.41**	0.62**	0.40	0.64	8.27**
M. 221 x M. 603c	-0.61	4.00	-5.29**	-0.01	0.68	-0.80	-0.84
M. 221 x M. 642	0.56	-3.81	7.24**	-0.60**	1.23**	-0.18	-6.68**
M. 221 x M. 645a	2.11**	-6.46**	-6.27*	-0.22*	-0.28	-0.18	-7.40**
M. 221. x M. 653	0.83*	-1.17	-13.12**	0.04	0.83*	-0.62	-0.94
M. 221 x M. 655b	-0.67	2.92	1.92	0.57**	-0.38	-0.22	9.81**
M. 221 x M. 657	0.83*	1.25	1.63	0.69**	0.14	1.64*	16.22**
M. 221. x M. 658A	1.00**	-1.06	0.45	-0.05	-1.07**	-0.56	-8.88**
M. 221 x M. 671	-0.83*	-11.77**	-7.32**	-0.04	-0.38	0.41	2.88
M. 221 x M. 673	0.28	-2.77	-3.46*	-0.36**	1.62**	-0.64	3.88*
M. 221 x M. 674	-1.00**	8.30**	7.02**	-0.36**	-0.33	0.48	1.58
M. 221 x M. 675a	0.56	4.05	-2.42	-0.10	-1.08**	-0.18	-10.20**
M. 221 x M. 677	0.17	-7.43**	-15.78**	-0.15	0.10	2.39**	14.07**
M. 221 x M. 678	-1.06**	2.91	10.44**	-0.32**	-0.10	-1.33	-14.39**
M. 221 x M. 682r	-2.06**	10.19**	14.54**	0.28**	-1.40**	-0.86	-7.38**
M. S.C. x M. 601	0.08	-2.25	-22.91**	-0.53**	0.66	-0.49	-6.05**
M. S.C. x M. 603c	-0.76*	-6.67**	-7.83**	-0.01	-0.97**	0.06	-5.49**
M. S.C. x M. 642	1.24**	-2.60	0.77	0.39**	0.96**	-0.22	9.19**
M. S.C. x M. 645a	1.13**	2.00	3.26*	-0.56**	-0.11	0.31	-6.11**
M. S.C.. x M. 653	-1.98**	0.67	11.72**	0.47**	-0.47	0.21	8.84**
M. S.C. x M. 655b	0.52	5.50*	7.76**	0.08	-0.23	0.33	1.18
M. S.C. x M. 657	-2.48**	-4.48	-5.13**	-0.21*	0.33	-0.77	-2.13
M. S.C. x M. 658A	0.52	-0.29	-6.43**	-0.15	0.51	0.03	1.02
M. S.C. x M. 671	-0.14	5.88*	6.99**	-0.04	0.46	-0.54	-1.22
M. S.C. x M. 673	-0.03	-1.74	-2.34	-0.23*	-1.36**	-0.10	-11.54**
M. S.C. x M. 674	0.19	-3.71	-5.71**	-0.23*	0.53	0.20	-2.86
M. S.C. x M. 675a	-0.42	1.53	14.63**	-0.23*	0.34	-0.81	-4.69**
M. S.C. x M. 677	-0.31	2.10	2.37	0.90**	0.62	-0.67	6.94**
M. S.C. x M. 678	0.63	3.61	2.83	0.19	-0.66	1.42*	5.46**
M. S.C. x M. 682r	1.80**	0.46	0.03	0.18	-0.60	1.04	7.44**
Sakha Pop. x M. 601	0.03	1.39	12.50	-0.09	-1.06**	-0.15	-2.22
Sakha Pop. x M. 603c	1.37**	2.67	13.11	0.03	0.29	0.75	6.33**
Sakha Pop. x M. 642	-1.80**	6.42	-8.01	0.21*	-2.19**	0.40	-2.51
Sakha Pop. x M. 645a	-3.24**	4.46	3.01	0.78**	0.39	-0.14	13.51**
Sakha Pop. x M. 653	1.14**	0.50	1.40	-0.51**	-0.37	0.41	-7.89**
Sakha Pop. x M. 655b	0.14	-8.42	-9.68	-0.66**	0.60	-0.11	-11.00**
Sakha Pop. x M. 657	1.64**	3.23	3.50	-0.49**	-0.48	-0.88	-14.09**
Sakha Pop. x M. 658A	-1.52**	1.35	5.98	0.20	0.56	0.54	7.86**
Sakha Pop.x M. 671	0.98**	5.89	0.33	0.09	-0.08	0.13	-1.65
Sakha Pop. x M. 673	-0.24	4.51	5.81	0.59**	-0.26	0.74	7.66**
Sakha Pop. x M. 674	0.81*	-4.59	-1.30	0.59**	-0.20	-0.68	1.28
Sakha Pop. x M. 675a	-0.13	-5.58	-12.21	0.33**	0.74*	0.99	14.89**
Sakha Pop. x M. 677	0.14	5.33	13.41	-0.74**	-0.72	-1.72*	-21.01**
Sakha Pop. x M. 678	0.42	-6.52	-13.26	0.13	0.76*	-0.09	8.93**
Sakha Pop.x M. 682r	0.26	-10.65	-14.57	-0.47**	2.00**	-0.18	-0.06
L.S.D. (Sij) 5%	0.72	4.58	3.12	0.21	0.73	1.41	3.32
L.S.D. (Sij) 1%	0.95	6.01	4.09	0.27	0.95	1.85	4.36
L.S.D. S(ij-ki) 5%	1.02	6.47	4.41	0.29	1.03	1.99	4.70
L.S.D. S(ij-ki) 1%	1.34	8.51	5.79	0.38	1.35	2.61	6.17

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

Concerning grain yield plant^{-1} for the studied test crosses ranged from 140.67 (Sakha Pop. x M. 677) to 278.0 (M. 221 x M. 674) in the first year, 100.44 (Sakha Pop. x M. 601) to 214.6 (M. 221. x M. 653) in the second years and 127.52 (Sakha Pop. x M. 677) to 240.41 (M. 221 x M. 657) in the combined analysis. The six SC between M L 221 and each of inbred lines M. 653, M. 655b, M. 657, M. 671, M. 674 and M. 677 showed significantly and out yielded than check hybrid SC 168 in the combined analysis. Also, most TW crosses out yielded or insignificant than check hybrid Twc 368. The fluctuation of hybrids from years to another was detected for yield plant^{-1}. Hence, it could be concluded that these crosses offer possibility for improving grain yield of maize. In the same time, for grain yield plant^{-1}, six single crosses *i.e.* M.221xM.653, M.221xM.655b, M.221xM.657, M.221xM.671, M.221xM.674 and M.221xM.677 expressed significant and positive superiority relative to SC 168 in the combined analysis reached 9.96%, 11.35%, 12.53%, 8.32%, 11.80% and 4.80%, respectively. However, the two three way crosses *i.e.* S.C. (M200xM418) x M.653 and S.C. (M200xM418) x M.674 recorded significant positive superiority effective to TWC 368 being 9.11% and 3.78%, respectively. Hence, it could be concluded that these crosses offer possibility for improving grain yield in maize. Several investigators reported high heterosis for yield of maize; *i.e.* Sadek, *et al.* (2002), Hefny, (2010) and Abd El-Aal, (2012).

Stability analysis for the eight promising hybrids and the four check hybrids.

Analysis of variance (ANOVA)

The regular combined analysis of variance for grain yield plant-1 of the 12 genotypes (G) evaluated across 8 environments (E) and their (GxE) interaction is presented in Table (7). The results indicated that the main effects of genotypes, environments and their GxE interaction were highly significant ($P < 0.01$). On the other hand, the pooled analysis showed that 28.83 % of the total sum of squares was attributed to environment while the genotype and GxE interaction effects explained 63.20 % and 7.96 %, respectively (Table 7). The large sum of squares of environment+ GxE interaction almost duplicated 5 times the corresponding percent of genotype term indicating that there were substantial differences among studied environments which advocated the adequacy of running stability analysis. It is axiomatic to say that the yield as a final outcome was the most responsible for the environmental variation. Also, the ratio of the sum of squares for genotype was nearly eight times higher than the share of interaction effect indicating wide genetic variation among tested genotypes. The significant interaction effect gives another justification to discuss the genotype stability. Sowmya *et al.* (2018), Arunkumar, *et al.* (2020) and El-Hosary (2020) found significant GxE interaction component indicating that the maize genotypes fluctuated in their rank performance for seed yield across the aimed environments.

Table 6. Test crosses mean performance and studied check varieties in both and across years for days to maturity and grain yield plant^{-1} and relative superiority % for grain yield in the combined analysis.

Test cross	days to maturity (day)			grain yield plant $^{-1}$ (g)			% superior for grain yield in Comb. (g)	
	Frist year 2017	Second year 2018	Combined	Frist year 2017	Second year 2018	Combined	H% Relative to S.C.168	H% Relative to T.w.c. 368
M. 221 x M. 601	105.67	105.00	105.33	228.26	197.67	212.96	-0.31	10.23**
M. 221 x M. 603c	106.00	102.33	104.17	225.33	184.50	204.92	-4.08**	6.06**
M. 221 x M. 642	103.67	103.33	103.50	204.70	195.33	200.02	-6.37**	3.53**
M. 221 x M. 645a	101.33	103.67	102.50	229.79	200.09	214.94	0.61	11.25**
M. 221. x M. 653	103.00	99.67	101.33	255.24	214.60	234.92	9.96**	21.60**
M. 221 x M. 655b	103.33	101.33	102.33	271.00	204.76	237.88	11.35**	23.13**
M. 221 x M. 657	102.33	102.67	102.50	275.00	205.82	240.41	12.53**	24.43**
M. 221. x M. 658A	101.33	101.33	101.33	239.13	181.36	210.25	-1.59	8.82**
M. 221 x M. 671	101.33	98.67	100.00	259.30	203.51	231.41	8.32**	19.78**
M. 221 x M. 673	101.67	101.00	101.33	230.64	191.68	211.16	-1.16	9.30**
M. 221 x M. 674	99.67	100.33	100.00	278.00	199.67	238.83	11.80**	23.62**
M. 221 x M. 675a	101.33	103.33	102.33	189.57	169.71	179.64	-15.91**	-7.02**
M. 221 x M. 677	105.33	98.67	102.00	237.33	210.44	223.89	4.80**	15.88**
M. 221 x M. 678	101.67	99.00	100.33	217.67	184.44	201.05	-5.89**	4.06**
M. 221 x M. 682r	100.00	101.00	100.50	241.26	172.23	206.74	-3.23**	7.01**
M. S.C. x M. 601	106.00	105.67	105.83	192.05	137.44	164.75	-22.88**	-14.73**
M. S.C. x M. 603c	104.00	104.67	104.33	191.10	141.66	166.38	-22.12**	-13.88**
M. S.C. x M. 642	103.67	105.33	104.50	206.10	157.89	182.00	-14.81**	-5.80**
M. S.C. x M. 645a	103.33	100.33	101.83	223.31	141.37	182.34	-14.65**	-5.62**
M. S.C.. x M. 653	98.67	99.00	98.83	248.67	172.95	210.81	-1.32	9.11**
M. S.C. x M. 655b	104.00	103.67	103.83	228.24	162.46	195.35	-8.56**	1.11
M. S.C. x M. 657	100.00	99.00	99.50	242.67	133.67	188.17	-11.92**	-2.61*
M. S.C. x M. 658A	101.67	100.67	101.17	211.66	160.82	186.24	-12.82**	-3.60**
M. S.C. x M. 671	101.33	100.67	101.00	222.17	164.67	193.42	-9.46**	0.11
M. S.C. x M. 673	101.00	101.67	101.33	180.38	143.32	161.85	-24.24**	-16.23**
M. S.C. x M. 674	101.67	101.33	101.50	243.33	157.67	200.50	-6.15**	3.78**
M. S.C. x M. 675a	104.00	99.33	101.67	183.45	119.06	151.25	-29.20**	-21.71**
M. S.C. x M. 677	103.33	100.33	101.83	217.66	148.08	182.87	-14.40**	-5.35**
M. S.C. x M. 678	103.33	101.33	102.33	209.38	164.64	187.01	-12.46**	-3.20**
M. S.C. x M. 682r	106.00	103.33	104.67	215.67	159.67	187.67	-12.16**	-2.86*
Sakha Pop. x M. 601	106.67	107.00	106.83	181.93	100.44	141.18	-33.91**	-26.92**
Sakha Pop. x M. 603c	107.33	107.67	107.50	172.20	129.40	150.80	-29.41**	-21.95**
Sakha Pop. x M. 642	102.00	103.00	102.50	181.33	104.47	142.90	-33.11**	-26.04**
Sakha Pop. x M. 645a	98.67	98.33	98.50	215.29	133.84	174.56	-18.29**	-9.65**
Sakha Pop. x M. 653	103.67	102.33	103.00	178.67	154.70	166.68	-21.98**	-13.73**
Sakha Pop. x M. 655b	105.00	104.00	104.50	176.67	134.90	155.78	-27.08**	-19.37**
Sakha Pop. x M. 657	106.00	103.33	104.67	185.99	111.62	148.80	-30.35**	-22.98**
Sakha Pop. x M. 658A	100.67	99.67	100.17	176.95	154.43	165.69	-22.44**	-14.24**
Sakha Pop.x M. 671	105.00	101.33	103.17	190.35	140.83	165.59	-22.49**	-14.29**
Sakha Pop. x M. 673	102.33	102.00	102.17	169.13	138.18	153.65	-28.08**	-20.47**
Sakha Pop. x M. 674	104.00	102.33	103.17	229.15	125.33	177.24	-17.04**	-8.26**
Sakha Pop. x M. 675a	103.33	102.67	103.00	166.40	120.47	143.43	-32.86**	-25.76**
Sakha Pop. x M. 677	103.33	103.33	103.33	140.67	114.38	127.52	-40.31**	-33.99**
Sakha Pop. x M. 678	104.67	101.67	103.17	173.33	152.83	163.08	-23.66**	-15.59**
Sakha Pop.x M. 682r	104.33	104.00	104.17	155.91	149.63	152.77	-28.49**	-20.93**
SC 168	103.33	105.30	104.32	218.80	208.47	213.64		
TWC 368	105.67	106.90	106.29	195.48	190.92	193.20		
L. S. D 5%	1.27	1.59	1.01	7.42	6.37	4.86		
L. S. D 1%	1.69	2.10	1.34	9.83	8.44	6.41		

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

Results of joint regression analysis of variance as suggested by Eberhart and Russell (1966) are also shown in Table (7). The model partitioned the environment + (genotype x environment) term into three parts; including environment (linear), genotype x environment (GxE linear) and the part of pooled deviation which expressed the unexplained deviation from linear regression. The mean squares of GxE (linear) component was highly significant indicating that at least one regression coefficient (b values) significantly differed from unity which meaning that some tested genotypes are linearly affected by the aimed environments. Also, the highly significant effect of pooled deviation component indicated that the tested genotypes differed regarding their deviations from their respective average linear response.

Table 7. Regular combined analysis of variance and partitioning the proper source of variation for grain yield plant^{-1} according to each of Eberhart and Russell model.

Source of variation	df	Grain yield plant^{-1} SS	Grain yield plant^{-1} MS
Genotype	11	15456.94 (63.20%)	1405.18**
Environment+ G*E	84	8998.603 (36.79%)	107.13**
Environment	7	7050.977 (28.83%)	1007.28**
Genotype x Env.	77	1947.626 (7.96%)	25.29**
a) Env . (linear)	1	7050.977	7050.98**
b) V x Env. (linear)	11	189.2443	17.20**
c) pooled deviations	72	1758.382	24.42**
		Genotypes	
M. 221 x M. 657 (1)	6	209.1003	34.85**
M. 221 x M. 674 (2)	6	175.7746	29.30**
M. 221 x M. 655b (3)	6	164.0391	27.34**
M. 221. x M. 653 (4)	6	151.3271	25.22**
M. 221 x M. 671 (5)	6	146.3716	24.40**
M. 221 x M. 677 (6)	6	282.7828	47.13**
M. S.C.. x M. 653 (7)	6	153.2355	25.54**
M. S.C. x M. 674 (8)	6	89.0453	14.84**
SC hytech 2066 (9)	6	81.44573	13.57**
SC 168 (10)	6	39.52813	6.59**
TWC 368 (11)	6	12.8728	17.15**
TWC 352 (12	6	162.8587	27.14**
poled error	176	10.6113	0.06

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

The previous results appeared the magnitude of both predictable (linear) and unpredictable (non-linear) interaction components in explaining the stable breeding materials. The obtained results are in agreement with those reported by Sowmya *et al.* (2018), Arunkumar, *et al.* (2020) and El-Hosary (2020).

According to Eberhart and Russell model, regression coefficients ranged from 0.67 to 1.24 indicating that genotypes already had different responses to environmental changes. The values of regression coefficient (b) did not significantly differ from unity for all tested genotypes except for TWC 368 (11). The values of deviation from regression (S^{2}d) were insignificantly different from zero for all genotypes except for M. 221 x M. 657 (1), M. 221 x M. 674 (2), M. 221 x M. 655b (3), M. 221 x M. 677 (6), SC hytech 2066 (9) and SC 168 (10).

It is evident that the values of b and S^{2}d for the aforementioned genotypes were not significantly different from unity and zero, respectively. Moreover, their mean performances exceeded or insignificant decrease the mean of all genotypes. Therefore, these genotypes were considered phenotypically stable according to Eberhart and Russell (1966) model. These results are in accordance with those obtained by Sowmya *et al.* (2018), Arunkumar, *et al.* (2020) and El-Hosary (2020).

With regard to genotypic stability as outlined by Tai (1971), the estimates of α and λ are displayed in Table (8) and graphically shown in Fig. (1). It is important to report that, the most stable genotypes resulted using Tai model exactly coincided with those obtained by Eberhart and Russell model. The stability parameters according to Tai were not significantly differed from zero for all genotypes at all the probability levels except numbers 6 and 1. The λ statistics were significantly differed from λ = 1 for all genotypes except genotypes 6 and 1. These results indicate that maize genotypes 12, 7 and 5 showed average degree of stability, while, genotype 3, 4, 9 and 10 showed below average degree of stability at 0.90 probability levels for the grain yield plant-1. On the contrary, genotype 2, 11 and 8 showed above average degree of stability at 0.90 probability levels for the mention trait.

Table 8. Estimation of stability parameters of grain yield plant-1.

Genotype	Grain yield plant^{-1}				
	Mean (g)	b$_i$	S^{2}di	α	λ
M. 221 x M. 657 (1)	220.17	0.85	3.790	-0.15	2.59
M. 221 x M. 674 (2)	214.57	0.80	2.235	-0.21	2.18
M. 221 x M. 655b (3)	205.35	1.08	2.280	0.08	2.04
M. 221. x M. 653 (4)	198.7	1.11	5.161*	0.11	1.88
M. 221 x M. 671 (5)	202.69	1.04	4.335*	0.04	1.82
M. 221 x M. 677 (6)	208.43	1.24	3.070	0.24	3.50
M. S.C.. x M. 653 (7)	191.59	1.03	5.479*	0.03	1.90
M. S.C. x M. 674 (8)	174.8	0.85	4.781*	-0.15	1.10
SC hytech 2066 (9)	195.04	1.14	3.514	0.14	1.01
SC 168 (10)	202.27	1.17	2.528	0.18	0.49
TWC 368 (11)	191.08	0.67	7.085**	-0.33	1.27
TWC 352 (12)	181.79	1.02	2.083**	0.02	2.02
Average	198.87				
LSD 5%	3.72				
LSD 5%	4.94				

Where, bi and S^{2}d refer to regression coefficient and deviation from regression, respectively; α and λ measure linear response to environmental effects and deviation from linear response in terms of the magnitude of error variance, respectively.

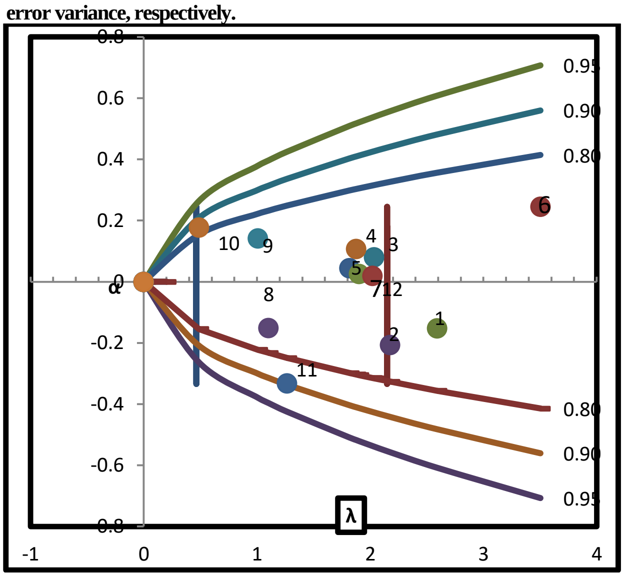

Fig. 1. Distribution of Tai's stability statistics for grain yield plant-1 of twelve genotypes across eight environments

Notes: 1- M. 221 x M. 657, 2- M. 221 x M. 674, 3- M. 221 x M. 655b, 4- M. 221. x M. 653, 5- M. 221 x M. 671, 6- M. 221 x M. 677, 7- M. S.C.. x M. 653, 8- M. S.C. x M. 674, 9- SC hytech 2066, 10- SC 168, 11- TWC 368 and 12- TWC 352.

It can be concluded that the hybrids M. 221 x M. 674 (2), M. 221 x M. 655b (3), SC hytech 2066 (9) and SC 168

(10) were the most crosses stable phenotypically and genetically in this study.

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تقدير التباين الجيني باستخدام تقنية السلالة x الكشاف في الذرة الشامية الصفراء و تحليل الثبات للهجن المتفوقة باستخدام طرق مختلفه

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أجري التهجين بين خمسة عشر سلالة مرباه داخليا و ثلاث كشافات من الذرة الشامية لتقدير القدرة على التالف للتبكير و المحصول. تم تقييم 45 هجين قمى الناتجين و هجين فردى 168 و الهجين الثلاثى 368 فى موسمي 2017 و 2018 بمزرعة البحوث و التجارب – كلية الزراعة بمشتهر – جامعة بنها فى تصميم قطاعات كاملة العشوائية بثلاث مكررات لصف. كان متوسط التباين الراجع إلى السنوات, التراكيب الوراثية, الهجن, الكشافات, السلالات, السلالة x الكشاف و التفاعل مع سنوات الزراعة معنويا لمعظم الصفات تحت الدراسة. أظهر التباين الغير مضيف دورا اكثر أهمية فى وراثة الصفات محل الدراسة. و أظهر التأثير الغير مضيف اختلافا من سنة إلى أخرى أكثر من تأثير الفعل الجينى المضيف. أظهرت السلالات (L4) M. 645a , (L5) M. 653 و M. 674 (L11) تأثيرات للقدرة العامة على التآلف لصفات التبكير فى النضج و محصول الحبوب/ النبات. و تفوقت الهجن M.221xM.653, M.221xM.655b, M.221xM.657, M.221xM.671, M.221xM.674 و M.221xM.677 على صنف المقارنة فردى 168 و بلغت الزيادة 9.96% , 11.35% , 12.53% , 8.32% و 4.80% على الترتيب فى التحليل المشترك بين السنوات. و تفوق الهجينين الثلاثين (SC M 200xM418)xM.653 و (SCM200xM418)xM.674 عن صنف المقارنة 368 و وصلت الزيادة الى 9.11% و 3.78% على الترتيب. تم زراعة الثمانية هجن المتفوقة مع هجين فردى 168 , هجين فردى هايتك 2066 , هجين ثلاثى 368 و هجين ثلاثى 352 فى موسم 2019 فى بيئات مختلفة. و أستخدم تصميم قطاعات كاملة العشوائية بثلاث مكررات بكل تجربة و ذلك لتحديد الثبات الوراثى و المظهرى لتلك الهجن. كان تباين التراكيب الوراثية و البيئات و التفاعل بينهم عالى المعنوية. و كانت اكثر الهجن ثباتا مظهريا و وراثيا هى M.221xM.674, M.221xM.655b, فردى هايتك 2066,و فردى 168 فى البيئات المختلفة.