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EVALUATION OF SOME NEW YELLOW THREE-WAY CROSSES OF MAIZE DERIVED VIA LINE × TESTER MATING METHOD UNDER CONDITIONS OF TWO LOCATIONS

R.H.A. Alsebaey, A.M. Abu Shosha, H.M. El-Shahed and M.M. B. Darwich

Maize Research Department, Field Crops Research Institute, ARC, Egypt

ABSTRACT

Two field experiments were carried out during 2019 summer season at two diverse locations of Gemmeiza and Mallawy Experimental Stations of Agricultural Research Center (ARC), Egypt, to evaluate twenty-six new yellow three-way crosses resulted from mating of 13 yellow maize inbred lines with two yellow single crosses, i.e. S.C 162 and S.C 168, as testers, using line × tester mating design. Also, to compare performance of these new three-way crosses with the best commercial three-way cross TWC 368. Results showed that location mean squares were significant or highly significant for all studied traits. Mean squares due to crosses were highly significant for all the studied traits. Mean squares due to lines and testers and their interaction were significant or highly significant for all studied traits, indicating that non-additive gene effects were more important than additive ones in the inheritance of all studied traits, except for days to 50 % silking. Two crosses (L_1 × SC 162 and L_1 × SC168) surpassed significantly in grain yield/fed the commercial hybrid TWC 368. The best in general combining ability effects were; inbred lines L_7, L_9, L_{11} and the tester SC168 for earliness, L_4, L_5, L_7, $L_{11}$and SC 168 for plant height, L_4, L_6, L_{11}, L_{12} and SC 168 for ear height and L_1 and SC 162 for grain yield. The best specific three-way combinations were; L_3 × SC 162 and L_6 × SC 168 for earliness, L_9 × SC 168, L_{10} × SC 168 and L_{11} × SC 162 for plant shortness, L_9 × SC 168 for lower ear position and L8 × SC 168 for grain yield.

Key words: ***Zea mays*, L., line × tester, general combining ability, specific combining ability, gene action.**

INTRODUCTION

Maize (*Zea mays*, L.) crop is extensively grown as grain for humans and fodder for livestock consumption. Maize is one of the most important grain crops in Egypt; area devoted to maize cultivation is about 2.7 million feddan. Maize productivity increased form 1.5 ton/fed where one feddan = 4200 m^2 in 1980 to (3.3 ton /fed) in 2020 season. Assessment of combining ability and genetic variance components are important in the breeding programs for hybridization. In any breeding program, the choice of the correct parents is the secret of the success. One of the most important criteria in breeding programs for identifying the hybrids with high yield is knowledge of parent genetic structure and information regarding their combining ability (Ceyhan *et al* 2008). For maize yield, it is known that the importance of general combining ability was relatively more important than specific combining ability for unselected inbred lines, while specific combining ability was more important than general combining ability for previously selected lines. General combining ability is a good estimate of additive gene action, whereas specific combining ability is a measure of non-additive gene action (Sharief *et al* 2009).

The study of Line × tester analysis of the genetic traits would certainly be a valuable aid in selection and breeding for better maize hybrids. Line × tester mating design was developed by Kempthorne (1957), which provides reliable information on the general and specific combining ability effects of parents and their hybrid combinations in applied breeding programs Castellanos *et al* (1998) and Sharma *et al* (2004) studied 21 maize inbred lines and seven testers (five single crosses, one synthetic and one inbred line) to identify the best tester and concluded that the single cross was the best alternative in a breeding program oriented to generate superior three- way and double crosses.

The present study aimed to evaluate general and specific combining ability effects of 13 new yellow inbred lines and type of gene action for grain yield and some related traits and to identify and select the superior hybrid combination.

MATERIALS AND METHODS

This study was carried out in 2018 and 2019 summer seasons at Gemmeiza and Mallawy Research Stations, Agricultural Research Center (ARC), Egypt. In 2018 growing season, 13 yellow inbred lines and two single crosses, i.e. SC 162 and SC 168, as testers were sown in separate plots and top crosses were made between lines and testers at Gemmeiza Research Station according to line x tester mating design suggested by Kempthorne (1957). In 2019 summer season, 26 three-way crosses resulting from first season and one check (TWC 368) were evaluated at Gemmeiza and Mallawy Research Stations. A randomized complete block design (RCBD) with four replications was used for each location. Each experimental unit consists of one row/ plot, 6-meters long and 80 cm wide (4.8 m^2). Plant to plant hill within row was 25 cm apart. All agricultural practices were applied as recommended on the proper time. The name and origin of the studied thirteen yellow maize inbred lines are presented in Table 1.

Table 1. Name and origin of the thirteen yellow maize inbred lines.

Inbred line number	Origin
L_1 to L_5	Comp# 21
L_6 to L_8	Gm Y. Pop.
L_9 to L_{11}	Nub. Y. Pop.
Gz 664	SD. 62 MS(M017cw. 153)
Gm 6065	Pool- 18-627 M

Data were collected on mean plot basis regarding to the following characters: days to 50% silking (number of days to 50% silking), plant height (cm) was measured from the soil surface to the base of the flag leaf, ear height (cm) was measured from the soil surface to ear node., grain yield, weighed in kg/plot then adjusted to ard / fed based on 15.5 % grain moisture content.

Statistical analysis

Combining ability analyses were determined by using line × tester analysis as described by Kempthrone (1957). Data were analyzed using the following statistical model for combined analyses:

$$X_{lijk} = \mu + L_1 + Rs / L_1 + g_i + g_j + S_{ij} + (Lg_i)_{li} + (Lg_j)_{lj} + (LS_{ij})_{ilj} + \lambda_{isij},$$

where

μ = over all genotype mean

L_i = locations effects.

Rs/L_i = replications within locations effects.

g_i= G.C.A. effect of the i the male parents (testers).

g_j = G.C.A. effect of the j the female parents (inbred line)

S_{ij}= S.C.A. effect of the ij the cross combinations.

$(Lg_i)_{li}$ = interaction of location x males (testers) effects.

$(Lg_j)_{lj}$ = interaction of location x female (inbred lines) effects.

$(LS_{ij})_{ilj}$= interaction of between location, males and female effects.

λ_{isij} = the error associated with each observation

Then, data were analyzed using Agrobase 21 (2001) and Microsoft excel, according to line by tester Method. The LSD test at 5% and 1% was done according to Steel *et al*. (1997) and was used for comparison of mean performances of the studied genotypes.

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance for number of days to 50% silking, plant height, ear height and grain yield across two locations is presented in Table (2). Locations mean squares for all studied traits were significant or highly significant, meaning that the environmental conditions differ from location to another.

Table 2. Combined analysis of variance for number of days to 50% silking, plant height, ear height and grain yield traits of 26 crosses across two locations.

SOV	df	Days to 50% silking	Plant height	Ear height	Grain yield
Locations (Loc.)	1	11.54**	11476.08*	28740.51**	5920.57**
Rep/Loc	6	1.31	1030.89	369.19**	15.08
Crosses (Cr)	25	8.33**	1469.74**	715.26**	40.59**
Lines(L)	12	8.67**	1524.84**	1099.36**	52.36**
Testers(T)	1	61.39**	7815.51**	1275.12**	109.14*
L x T(L x T)	12	3.58**	885.82**	284.50**	23.10**
Cr. x Loc	25	4.26 **	374.58 **	219.26 **	23.40 **
L x Loc	12	4.27 **	562.02 **	318.63 **	21.42 **
T x Loc	1	0.81	640.51 *	202.04	40.72 *
L x T x Loc	12	4.54 **	164.98	121.31	23.94 **
Error	150	1.16	138.06	112.36	7.78
C.V. %		1.76	4.72	8.19	8.97

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

These results are in agreement with Barakat and Osman (2008). Mean squares due to crosses were highly significant for all the studied traits. This indicates that there were differences among the crosses for all traits. These results are in agreement with Ibrahim *et al* (2007). Partitioning of sum squares due to crosses into its components showed that mean squares due to lines and testers were significant or highly significant for all studied traits, revealing great diversity existed among testers and lines. Mean squares due to interaction between lines x testers were highly significant differences for all the traits under study, indicating that inbreds did not express similar orders of ranking according to performance of their crosses with the two testers. Mean squares due to crosses x Loc and their partitions, lines x Loc., testers x Loc and the two- way interaction lines x testers x Loc were significant or highly significant for all the studied traits, except testers x loc. for days to 50% silking and ear height and L x T x Loc for plant and ear heights, indicating that these crosses and their partitions presented differential performance from location to another in most studied traits. Our results are in agreement with reports of Atif *et al* (2012), Kamara *et al* (2014), Sultan *et al* (2016) and Abdel-Moneam *et al* (2020).

Type of gene action:

The results in Table 3 showed that specific combining ability (SCA) variance was higher than general combining ability (GCA) variance for all traits, except days to 50 % silking, indicating that non-additive gene effects were more important than additive gene effects in the inheritance of plant and ear heights and grain yield while the reverse was obtained for days to 50 % silking. These results are similar to those reported by Venugopal *et al* (2002) and Ibrahim *et al*. (2007). The variance due to SCA x L was higher than that due to GCA x L for all studied traits, indicating that the non-additive gene effects were interacted more with locations than additive gene effects for these traits. Similar results are reported by Ibrahim *et al* (2007).

Table 3. Estimates of genetic parameters for four traits across two locations.

Genetic parameters	Days to 50% silking	Plant height	Ear height	Grain yield
GCA variance	**0.56**	**75.53**	**17.91**	**1.21**
SCA variance	**0.30**	**93.47**	**21.51**	**1.91**
GCA x Loc variance	**0.56**	**75.53**	**17.41**	**1.21**
SCA x Loc variance	**0.6**	**186.94**	**43.03**	**3.83**

GCA = general combining ability, SCA = specific combining ability, Loc. = Location.

The proportional contributions of lines, testers and their interaction to the total variance of crosses are presented in Table (4). The results showed that the proportional contribution of lines to the total variance of crosses was higher than that of testers and the interaction between lines and testers for all the studied traits. Also, the proportional contributions of the interaction between lines and testers to the total variance were higher than that of the testers for all the traits under study, except days to 50 % silking, These results indicated that the studied new three-way crosses were affected more by the inbred lines than by the testers (two single crosses; i.e. S.C. 162 and S.C. 168).

Table 4. Proportional contribution of lines, testers and their interaction to total variance.

Source	Days to 50% silking	Plant height cm	Ear height cm	Grain yield ard/fad
Due to lines	**49.93**	**49.80**	**73.78**	**61.93**
Due to testers	**29.47**	**21.27**	**7.13**	**10.76**
Due to lines x testers	**20.60**	**28.93**	**19.09**	**27.31**

Mean performance

Mean performance of the 26 three-way crosses and the check TWC 368 for days to 50% silking, plant height, ear height and grain yield across two locations, is presented in Table (5). For number of days to 50% silking, 22 out of the 26 studied crosses were significantly earlier than the check TWC 368, with is range from 59.25 days for cross L_7 x SC 168 to 62.13 days for cross L_6 x SC 162, compared to 63.25 days for the check TWC 368. The earliest crosses were; L_7 x SC 168, L_6 x SC 168, L_9 x SC 168 and L_{11} x SC 168. For plant height, means of studied crosses ranged between 227.50 cm for cross L_9 x SC 168 to 281.25 cm for cross L_1 x SC 162. Also, 12 crosses out of 26 crosses were significantly shorter than the check TWC 368 (256.88 cm). The tallest crosses were L_1 x SC162, L_9 x SC162 and L_{10} x SC162, while the shortest hybrids were L_9 x SC168, L_7 x SC168 and L_4 x SC168. With respect to ear height (cm), means of studied crosses for this trait ranged from 113.75 cm for cross L_6 x SC 168 and to 148.785 cm for cross L_1 x SC 162.

Table 5. Mean performance of 26 new yellow maize crosses for all studied traits across two locations.

Inbred line	Days to 50% silking		Plant height (cm)		Ear height (cm)		Grain yield (ard fed^{-1})	
	SC 162	SC 168	SC 162	SC 168	SC 162	SC 168	SC 162	SC 168
L_1	62.50	62.38	281.25	259.38	148.75	141.25	36.36	35.66
L_2	62.00	61.13	264.38	262.50	144.38	142.50	30.31	28.87
L_3	60.50	61.75	248.75	240.63	126.25	125.63	30.61	27.96
L_4	61.25	60.63	249.38	236.88	121.25	118.13	30.96	29.62
L_5	62.63	61.63	240.00	240.00	126.88	132.50	30.90	31.15
L_6	62.13	59.38	246.25	243.75	131.88	113.75	30.11	31.30
L_7	60.38	59.25	248.75	228.75	130.63	123.13	33.81	29.37
L_8	61.75	60.25	251.25	245.00	135.00	139.38	30.76	34.19
L_9	61.50	59.50	274.38	227.50	140.63	117.50	31.84	29.88
L_{10}	62.25	60.88	276.88	244.38	140.63	129.38	32.67	31.14
L_{11}	60.75	59.50	236.25	245.00	121.88	123.13	31.16	26.88
L_{12}	61.88	60.38	251.25	245.63	121.88	120.00	29.99	29.90
L_{13}	61.38	60.13	250.00	240.00	125.63	125.00	34.28	29.01
Check TWC 368	63.25		256.88		133.13		32.63	
LSD 0.05	1.07		11.69		10.55		2.78	
LSD 0.01	1.39		15.16		13.67		3.60	

Also, there were 7 crosses out of the 26 studied crosses exhibited significantly lower ear position than the check TWC 368 (133.13 cm). The highest crosses for ear height, were L_1 x SC 162, L_2 x SC162 and L_2 x SC168 while the lowest hybrids for ear height were L_6 x SC168, L_9 x SC168 and L_4 x SC168. For grain yield (ard/fed) the results in Table (5), revealed that the differences among crosses in this trait were highly significant and ranged from 26.88 ard/fed for the cross L_{11} x SC 168 to 36.36 ard/fed for the cross L_1 x SC 162. Two crosses (L_1 x SC 162 and L_1 x SC 168), surpassed significantly in grain yield/fed the check TWC 368 (32.63 ard/fed). Meanwhile, four crosses (L_7 x SC 162, L_8 x SC 168, L_{10} x SC 162 and L_{13} x SC 168) were insignificantly out- yielded the check TWC 368.

General combining ability effects

High positive general combining ability (GCA) effects would be useful for grain yield, while for days to 50 % silk, plant height and ear height, high negative GCA effects would be useful from plant breeders' point of view. Estimates of general combining ability effects of the new 13 inbred lines and the two testers under study across two locations (Gemmeiza and Mallawy) are presented in Table (6).

Table 6. Estimates of general combining ability (GCA) effects for 13 inbred lines and two testers across two locations.

Inbred line		Days to 50%silking	Plant height (cm)	Ear height (cm)	Grain yield (ard fad^{-1})
L_1		1.38**	21.15**	15.50**	4.90**
L_2		0.50	14.28**	13.94**	-1.52*
L_3		0.06	-4.47	-3.56	-1.82**
L_4		-0.13	-6.03*	-9.81**	-0.81
L_5		1.06**	-9.16**	0.19	-0.08
L_6		-0.31	-4.16	-6.68*	-0.40
L_7		-1.25**	-10.41**	-2.62	0.49
L_8		-0.06	-1.03	7.69**	1.37
L_9		-0.56*	1.78	-0.43	-0.24
L_{10}		0.50	11.47**	5.50*	0.80
L_{11}		-0.94**	-8.53**	-7.00**	-2.08**
L_{12}		0.06	-0.72	-8.56**	-1.16
L_{13}		-0.31	-4.16	-4.18	0.54
LSD gi	0.05	0.536	5.845	5.273	1.388
	0.01	0.695	7.579	6.837	1.799
LSD gi-gij	0.05	0.758	8.267	7.458	1.963
	0.01	0.982	10.718	9.669	2.544
Testers	SC 162	0.543**	6.130**	2.476*	0.724**
	SC 168	-0.543**	-6.130**	-2.476*	-0.724**
LSD gi	0.05	0.210	2.293	2.068	0.544
	0.01	0.272	2.973	2.682	0.706
LSD gi-gj	0.05	0.297	3.242	2.925	0.770
	0.01	0.385	4.204	3.792	0.998

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

For days to 50% silking, three out of 13 inbred lines; namely: L_7, L_9 and L_{11}, and one tester (S.C 168) exhibited negative and significant or highly significant general combining ability effects towards earliness, therefore these inbred lines and the tester SC 168 are considered the best general combiners for earliness. However, the inbred lines L_1 and L_5, and one tester S.C 162 exhibited positive and highly significant general combining ability effects towards lateness. With respect to plant height, four inbred lines L_4, L_5, L_7 and L_{11}, and one tester SC 168 exhibited negative and significant or highly significant general combining ability effects towards plant shortness. This means that these four lines and the tester SC 168 could be considered as the best general combiners for plant height trait (shortness). On the other side, the inbred lines L_1, L_2 and L_{10}, and one tester (SC 162) showed positive and highly significant general combining ability effects towards plant tallness. Regarding to ear height, results showed that four lines namely; L_4, L_6, L_{11} and L_{12}, and one tester (SC 168) exhibited negative and significant or highly significant general combining ability effects towards lower ear position. This means that these four lines and this tester can be considered as the best general combiners for ear height trait (lower ear position). On the other hand, the inbred lines L_1, L_2, L_8 and L_{10}, and the tester SC 162 showed positive and significant or highly significant general combining ability effects towards high ear position on the plant. For grain yield/fad, results in Table (6) showed that there was only one inbred line (L_1) and one tester (SC 162) showed positive and highly significant general combining ability effects, indicating that this inbred line and this tester could be considered as the best general combiners for increasing grain yield. On the other side, there were three inbred lines (L_2, L_3 and L_{11}) and one tester (SC 168) which exhibited negative and significant or highly significant general combining ability effects, indicating that these three inbred lines and this tester could be considered as the worst general combiners for grain yield. Similar results were reported by Soliman and Osman (2006), Sultan *et al.* (2012 and 2013), Attia *et al.* (2013 and 2015), Abdel-Moneam *et al.* (2014, a, b and c), and Abdel-Moneam, *et al.* (2020).

Specific combining ability effects

Estimates of SCA effects for the studied traits across the two locations are presented in Table (7). For days to 50% silking, results revealed that, there were two out of the studied 26 test crosses namely; L_3 x SC 162 and L_6 x SC 168 that exhibited desirable specific combining ability effects towards earliness, as they recorded negative and significant or highly significant SCA effects for this trait, indicating that these two crosses were the best specific three-way combinations for earliness.

Table 7. Estimates of specific combining ability (SCA) effects of crosses for days to 50% silking, plant and ear heights and grain yield across two locations.

Line		Days to 50% silking		Plant height (cm)		Ear height (cm)		Grain yield (ard fed^{-1})	
		SC 162	SC 168	SC 162	SC 168	SC 162	SC 168	SC 162	SC 168
L_1		-0.48	0.48	4.81	-4.81	1.27	-1.27	-0.38	0.38
L_2		-0.11	0.11	-5.19	5.19	-1.54	1.54	-0.01	0.01
L_3		-1.17**	1.17**	-2.07	2.07	-2.16	2.16	0.60	-0.60
L_4		-0.23	0.23	0.12	-0.12	-0.91	0.91	-0.05	0.05
L_5		-0.04	0.04	-6.13	6.13	-5.29	5.29	-0.85	0.85
L_6		0.83*	-0.83*	-4.88	4.88	6.59	-6.59	-1.32	1.32
L_7		0.02	-0.02	3.87	-3.87	1.27	-1.27	1.49	-1.49
L_8		0.21	-0.21	-3.00	3.00	-4.66	4.66	-2.44*	2.44*
L_9		0.46	-0.46	17.31**	-17.31**	9.09*	-9.09*	0.26	-0.26
L_{10}		0.14	-0.14	10.12*	-10.12*	3.15	-3.15	0.04	-0.04
L_{11}		0.08	-0.08	-10.50*	10.50*	-3.10	3.10	1.42	-1.42
L_{12}		0.21	-0.21	-3.32	3.32	-1.54	1.54	-0.68	0.68
L_{13}		0.08	-0.08	-1.13	1.13	-2.16	2.16	1.91	-1.91
LSD Sij	0.05	0.758		8.267		7.458		1.963	
	0.01	0.982		10.718		9.669		2.544	
LSD Sij-Sk	0.05	1.071		11.691		10.547		2.776	
	0.01	1.389		15.157		13.674		3.598	

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

For plant height, out of the studied 26 crosses, there were three crosses (L_9 x SC 168, L_{10} x SC 168 and L_{11} x SC 162) exhibited desirable specific combining ability effects towards shortness. On the other side, there were also three crosses (L_9 x SC 162, L_{10} x SC 162 and L_{11} x SC 168) showed positive and significant or highly significant SCA effects for this trait, indicating that these three crosses had the highest specific combining ability effects for maize plant height. For ear height, only one cross (L_9 x SC 168) exhibited desirable specific combining ability effects towards lower ear position, as it showed significant and negative SCA effects for this trait, also one cross (L_9 x SC 162) showed positive and significant SCA effects for this trait, indicating that this cross had the highest specific combining ability effects for such trait. For grain yield, results showed that, out of the studied 26 crosses, there was only one cross (L_8 x SC 168) at combined data across both locations, exhibited desirable specific combining ability effects towards high grain yield. Similar results were reported by other authors such as, Sultan *et al*. (2012 and 2013), Attia *et al*. (2013 and 2015), Abdel-Moneam *et al*. (2014, a, b and c) and Abdel-Moneam *et al.* (2020).

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تقييم بعض الهجن الثلاثية الصفراء الجديدة من الذرة الشامية الناتجة باستخدام طريقة التزاوج بين السلالة والكشاف تحت ظروف موقعين

رفيق حليم عبد العزيز السباعى، أحمد مصطفي أبوشوشة، هيثم مصطفي الشاهد ومحمد موسي بدوي درويش

قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعيـــة – مصر.

أجريت تجربتين حقليتين خلال الموسم ٢٠١٩ بمحطتي البحوث الزراعية بالجميزة (محافظة الغربيـــة) وملوي (محافظة المنيا) التابعة لمركز البحوث الزراعية بمصر، وذلك بهدف تقييم ٢٦هجين ثلاثي جديـد ناتجـة بطريقة التلقيح القمي بين ثلاثة عشر سلالة نقية مع هجينين فرديين همـا هــــ.ف ١٦٢و هــــ.ف ١٦٨وكـذلك لمقارنة أداء وسلوك هذه الهجن الثلاثية الجديدة مع الهجين الثلاثي التجاري هـ.ث ٣٨٦. أوضـــــحت النتائج أن التباين الراجع للمواقع كان معنوي أو عالي المعنوية لكل الصفات المدروسة، أيضاً كان التباين الراجـع للهجن عالي المعنوية لجميع الصفات المدروسة وكذلك التباينات الراجعة للسلالات و للكشـافات والتفاعـل بيـنهم معنوي أو عالي المعنوية لكل الصفات المدروسة٠ كان الفعل الجيني غير المضيف الاكثر تحكما في وراثة جميـع الصفات ما عدا صفة عدد الأيام حتي ظهور ٥٠% من النورة المؤنثة. تفوق الهجينين الثلاثين (السلالة جميزة ١ × هــــ.ف ١٦٢) و (السلالة جميزة ١ × هــــ.ف ١٦٨) معنوياً على الهجـين التجـاري هـــ.ث ٣٦٨ فـي محصول الحبوب للفدان. كانت الآباء الأفضل قدرة عامة على التآلف هي السلالات جميزة ٧، جميـزة ٩، جميـزة ١١، الكشاف هــ.ف ١٦٨ لصفة التبكير، والسلالات جميزة ٤، جميزة ٥، جميزة ٧، جميزة ١١، الكشاف هــ.ف ١٦٨ لصفة ارتفاع النبات، والسلالات جميزة ٤، جميزة ٦، جميزة ١١، جميزة ١٢ ، الكشاف هــ.ف ١٦٨ لصفة ارتفاع الكوز، والسلالة جميزة ١ ، الكشاف هــ.ف ١٦٢ لصفة محصول الحبوب .كما كانت أفضل الهجـن قـدرة خاصة على التآلف هي :هجينين (هـــ.ف ١٦٢ × جميزة ٣، هـــ.ف ١٦٨ × جميزة ٦) لصفة التبكير، وثلاثة هجن (هـــ.ف ١٦٨ × جميزة ٩ ، هـــ.ف ١٦٨ × جميزة ١٠، هـــ.ف ١٦٢ × جميزة ١١) لصفة ارتفـاع النبات، والهجين (هـــ.ف ١٦٨ × جميزة ٩) لصفة ارتفاع الكوز؛ والهجين (هـــ.ف ١٦٨ × جميزة ٨) لصفة محصول الحبوب.