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RESEARCH ARTICLE :

Heterosis analysis for grain yield traits in maize (*Zea mays* L.)

Y. SRINIVASA REDDY, V. KRISHNAN, V. VENGADESSAN, K. PARAMASIVAM AND A.L. NARAYANAN

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SUMMARY : We undertook 6 Inbreds as parents and made crosses in all possible cross combination in full diallel fashion to obtain total 30 possible F_1 hybrids. These 30 F_1's are subjected to heterosis analysis using midparental, heterobeltiosis and standard heterosis, where 900M a prominent hybrid was used as standard chek. For judging good F_1 hybrids, negative heterosis was considered to be better for five traits (days to tasseling, days to silking, anthesis silking interval, days to maturity and plant height), while positive heterosis was considered to be desirable for the remaining traits (ear length, ear girth, number of kernel rows per ear, number of kernels per row, ear weight, shelling per cent, 100 grain weight and grain yield per plant) A perusal of standard heterosis revealed that out of 30 crosses studied, none of the hybrids were found to possess significant standard heterosis for all the traits studied. A total of eight hybrids have exhibited significant and favourable standard heterosis for grain yield and its component traits. Among the eight hybrids, the hybrid UMI 133 x UMI 122 for seven traits and the remaining hybrids *viz* UMI 112 x UMI 66, UMI 112 x UMI 122, UMI 112 x UMI 133, UMI 122 x UMI 66, UMI 133 x UMI 112, UMI 133 x UMI 213 and UMI 213 x UMI 112 for five traits have recorded significant and favourable standard heterosis and these could be adjudged as the best hybrids. Though the hybrids UMI 213 x UMI 176, UMI 133 x UMI 66 showed significant and favorable standard heterosis for maximum number of seven traits, they were not considered as best ones due to the non significant standard heterosis of those hybrids for most important trait grain yield per plant. The extent of heterosis for grain yield per plant over check hybrid was found to be the maximum followed by ear weight. The heterosis over check hybrid recorded for anthesis silking interval was the maximum among the traits for which negative heterosis was favourable and was followed by plant height.

KEY WORDS :
Maize, Heterosis, Diallel, Inbred, Standard heterosis

Author for correspondence :

Y. SRINIVASA REDDY
Department of Genetics and Plant Breeding, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, PUDUCHERRY (U.T.) INDIA
Email : sri.yerva@gmail.com

See end of the article for authors' affiliations

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BACKGROUND AND OBJECTIVES

Few agronomic improvements during the 20thcentury rival the development of hybrid maize (*Zea mays* L.) (Duvick, 2001). Yields increased dramatically as breeders moved away from open-pollinating cultivars (OPVs) and began developing hybrids. The pure-line hybrid concept traces its roots back to experiments on heterosis and its complement inbreeding conducted by Shull (1908). They observed that when maize plants are selfed, their vigor and grain yield declines rapidly. However, when two inbred lines are crossed, both vigor and grain yield of the F1 hybrid often exceeds the mean of the two parents. It was this observation, made over 90 yr ago, and methodology outlined by Shull (1908) that gave rise to the modern maize industry. The phenomenon of heterosis was defined by Shull (1952) as "the interpretation of increased vigor, size, fruitfulness, speed of development, resistance to disease and to insect pests, or to climatic rigors of any kind manifested by crossbred organisms as compared with corresponding inbreds, as the specific results of unlikeness in the constitution of the uniting parental gametes". For our purposes, we will define heterosis as the difference between the hybrid and the mean of its two parents (Schnell, 1961). Heterosis has been extensively studied in maize because of (i) its large expression for grain yield (100-200%), (ii) its intensive exploitation in hybrid breeding of maize, and (iii) the favorable biological prerequisites such as large multiplication co-efficient and ease of both self- and controlled cross-fertilization. Although many hypotheses have been suggested to explain heterosis, its genetical, physiological, and biochemical bases still remain largely unexplained. Heterosis is a major yield factor in all breeding categories except line breeding. To systematically exploit heterosis in hybrid breeding, the concept of heterotic groups and patterns was suggested. Melchinger and Gumber (1998) defined a heterotic group "as a group of related or unrelated genotypes from the same or different populations, which display similar combining ability and heterotic response when crossed with genotypes from other genetically distinct germplasm groups. By comparison, the term heterotic pattern refers to a specific pair of two heterotic groups, which express high heterosis and consequently high hybrid performance in their cross." The concept of heterotic patterns includes the subdivision of the germplasm available in a hybrid breeding programme in at least two divergent populations, which are improved with inter-population selection methods. Heterotic patterns have a strong impact in crop improvement because they predetermine to a large extent the type of germplasm used in a hybrid breeding programme over a long period of time. Our objective was study of heterotic pattern of grain yield parameters in maize.

RESOURCES AND METHODS

A field experiment was conducted in the Department of Plant Breeding and Genetics, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during 2012-2013 in maize. The materials used and methods adopted for the conduct of the experiment is given in detail below. The materials used for the study includes six maize inbreds *viz.*, UMI 66, UMI 112, UMI 122, UMI 133, UMI 176 and UMI 213 (Table 1). These inbreds were crossed by adopting full Diallel mating design. A total of thirty hybrid combinations including direct, reciprocals and six parental combinations was obtained by during *Rabi* season, 2012. Methods for Crossing, The six parental inbreds were raised during *Rabi* season, 2012 in two staggered sowings at five days interval to get the synchronization of flowering. All the recommended cultural practices were followed. Tassel bag method was used for hybridization. Ear shoot of maize emerging from the leaf sheath was bagged by using butter paper cover was placed over the tassel to protect the silk from contamination of alien pollen through wind pollination. Ear shoots were covered two days before silk emergence. Brown paper cover was covered over the tassel of the male parents on the day previous to pollination to collect pollen. The pollen collected from the desired male tassel bag was dusted over the silk of the corresponding females after removing the butter paper cover and it was replaced immediately to avoid other pollen contamination. The tassel bag was replaced on the same plant for further pollen collection. The manual hand pollination was carried out between 9 am and 10 am during the hours of bright sunshine. The selfing was done by dusting the pollen collected from the same plant. All the three types of heterosis for each of the 30 hybrids were estimated using the following formulae (Fonseca and Patterson, 1968). For Relative heterosis (di) = F1-MP/MP X 100, Heterobeltiosis (dii) = F1-BP/BP X 100 and Standard heterosis (diii) = F1-SV/SV X 100 Where, F = mean value of the F1 hybrid, MP = mid parental value, BP = mean of better parental value, SV = mean of the standard check hybrid (900 M). Test of significance Significance of heterosis was tested by t test as per the following formula. t for mid parent $= \frac{\text{parameter}}{\sqrt{3/2\sigma 2_e}}$, t for better and standard parent= $\frac{\text{parameter}}{\sqrt{2EMS/r}}$.

OBSERVATIONS AND ANALYSIS

Variable magnitude of three types of heterosis *viz*., relative heterosis, heterobeltiosis and standard heterosis for 30 hybrids for all the traits are presented in a traitwise here under. For Days to tasseling, the range of heterosis over mid parent for this trait was between -11.82 per cent (UMI 66 x UMI 213, UMI 213 x UMI 66) and 2.58 per cent (UMI 122 x UMI 66). Fifteen out of 30 hybrids recorded significantly negative relative heterosis. Eighteen hybrids recorded significant heterosis over better parent in negative direction which ranges from -14.29 per cent (UMI 66 x UMI 213, UMI 213 x UMI 66) to 2.58 per cent (UMI 122 x UMI 66). The heterosis over standard check hybrid varied between -9.27 per cent (UMI 133 x UMI 66) and 10.60 per cent (UMI 112 x UMI 66). Ten out of 30 hybrids recorded significantly negative heterosis over the standard check (Table 10). For Days to silking, the highest and the lowest value of 5.39 per cent and -13.20 per cent was exhibited by the crosses UMI 122 x UMI 213 and UMI 122 x UMI 176, respectively for mid parental heterosis. A total of 20 cross combinations were assumed negative significance for this trait. Negatively significant heterosis over better parent was observed in 24 cross combinations. Out of 30 hybrids evaluated for standard heterosis, seven combinations have deviated towards negative direction than the standard parent. The range of relative heterosis for Anthesis silking interval was from -54.84 per cent (UMI 133 x UMI 213) to 40.74 per cent (UMI 122 x UMI 213). Negatively significant heterosis over mid parent observed in 15 cross combinations. The heterobeltiosis ranged from -58.82 per cent (UMI 122 x UMI 66) to 31.25 per cent (UMI 213 x UMI 176). A total of 17 hybrids registered significant negative heterosis over better parent. For standard heterosis, the highest and lowest value was recorded by the hybrids UMI 213 x UMI 176, UMI 122 x UMI 112 (75.00 %) and UMI 122 x UMI 66 (-41.67 %). Three hybrids were showed significant negative heterosis over standard check hybrid (Table 1). The mid parental heterosis for Days to maturity trait was between -4.55 per cent (UMI 133 x UMI 122) and 7.63 per cent (UMI 112 x UMI 122). The hybrids UMI 133 x UMI 176 and UMI 213 x UMI 133 expressed significant negative heterosis against the mid parent. The range of heterobeltiosis was from -9.47 per cent (UMI 213 x UMI 176) to 7.42 per cent (UMI 112 x UMI 122). A total of 16 hybrids were manifested by significant negative heterosis against better parents. For the standard heterosis, the heterotic values ranged from -6.67 per cent (UMI 133 x UMI 122) to 5.56 per cent (UMI 66 x UMI 112, UMI 66 x UMI 112). Eight hybrids exhibited significant negative heterosis against the standard check (Table 1). For plant height (cm), the heterosis over mid parent for this trait was between -13.29 per cent (UMI 176 x UMI 122) and 26.29 per cent (UMI 112 x UMI 133). Seven out of 30 hybrids recorded significant negative relative heterosis. The range of heterobeltiosis was from -21.54 per cent (UMI 176 x UMI 122) to 25.98 per cent (UMI 112 x UMI 133). Significant negative heterosis was observed in 16 hybrids against the better parent. The magnitude of standard heterosis varied from -9.41 per cent (UMI 176 x UMI 122) to 14.57 per cent (UMI 213 x UMI 133). Heterosis over standard check was observed to be significant and negative in direction for 10 hybrids. The heterosis over mid parent for this trait was between -8.32 per cent (UMI 213 x UMI 176) and 39.47 per cent (UMI 133 x UMI 66) for ear length (cm). Out of 30 hybrids, 23 hybrids showed positively significant mid parent heterosis. The better parent heterosis ranged from -16.40 per cent (UMI 122 x UMI 112) to 36.88 per cent (UMI 213 x UMI 122). Significant positive heterosis over its better parents was expressed by 20 out of 30 hybrids. Heterosis over standard check was least in the hybrid UMI 122 x UMI 112 (-19.79 %) and high in UMI 213 x UMI 122 (30.47 %). Out of 30 hybrids studied, 11 hybrids expressed positively significant heterosis over the standard parent. The trait ear girth shown the range of relative heterosis for this trait was from -20.74 per cent (UMI 112 x UMI 122) to 26.83 per cent (UMI 213 x UMI 112). Out of 30 hybrids 17 have registered significant mid parent heterosis in positive side. The better parent heterosis ranged from -25.26 per cent (UMI 112 x UMI 122) to 20.60 per cent (UMI 213 x UMI 133). Seven hybrids have registered significant heterosis in positive side than the better parent. The highest and the lowest standard heterosis were recorded by the hybrids UMI 213 x UMI 112 (21.59 %) and UMI 112 x UMI 122 (-16.21 %). Significant standard heterosis was observed in six hybrids. Number of kernel rows per ear have Maximum positive significant relative heterosis was recorded by the hybrid UMI 213 x UMI 66 (40.20 %). The relative heterosis ranged from -13.79 per cent (UMI 112 x UMI 122) to 40.20 per cent (UMI 213 x UMI 66). Out of 30 hybrids studied, 13 hybrids showed significant positive relative heterosis. The maximum and minimum heterobeltiosis of 31.85 per cent and -22.67 per cent was recorded by UMI 213 x UMI 66 and UMI 213 x UMI 122, respectively. Significant positive heterobeltiosis was shown by seven hybrids. The extent of heterosis over standard check ranged between -13.63 per cent (UMI 176 x UMI 133) and 17.86 per cent (UMI 66 x UMI 112). Out of seven hybrids showing significant value, six hybrids attained positively significant heterosis over standard check. The relative heterosis of the hybrids for number of kernels per row exhibited a range from -9.74 per cent (UMI 176 x UMI 112) to 29.64 per cent (UMI 112 x UMI 66). Out of 30 hybrids, 16 hybrids showed significant positive relative heterosis. Heterosis over better parent varied from -12.34 per cent (UMI 176 x UMI 66) to 24.84 per cent (UMI 112 x UMI 66). Out of 30 hybrids, 16 hybrids were found to exhibit positively significant heterobeltiosis. Out of 15 hybrids with significant standard heterosis, 12 hybrids exhibited positive significant standard heterosis over standard hybrid check. For ear weight, the minimum and the maximum relative heterosis was -11.47 and 24.74 per cent as manifested by the hybrids UMI 122 x UMI176 and UMI 133 x UMI176, respectively. Out of 30 hybrids, 22 hybrids expressed significant relative heterosis positive side. Out of 30 hybrids, 21 hybrids have recorded significant heterobeltiosis in positive direction and the range was from -12.54 per cent (UMI 122 x UMI 176) to 23.22 per cent (UMI 133 x UMI 66). A total of 16 hybrids have recorded positively significant heterotic value against the standard check. The hybrid UMI 122 x UMI 66 has expressed the highest heterotic values for relative heterosis, heterobeltiosis and standard heterosis with an extent heterotic values of 24.04 per cent, 17.15 per cent and 20.91 per cent, respectively, while the hybrid UMI 122 x UMI 213 exhibited the least heterotic values for relative heterosis, heterobeltiosis and standard heterosis with heterotic values of -27.51 per cent, -34.46 per cent and -25.63 per cent, respectively. Out of 30 hybrids studied, ten each for relative heterosis, standard heterosis and five for heterobeltiosis exhibited significant heterosis positively. For shelling per cent, the highest relative heterosis was recorded by the hybrid UMI 122 x UMI 176 (28.35 %) and the least relative heterosis was expressed by the hybrid UMI 112 x UMI 176 (-5.70). Out of 30 hybrids studied, 21 hybrids showed significant positive relative heterosis. The maximum and the minimum heterobeltiosis value of 26.91 per cent and -12.34 per cent were recorded by UMI 122 x UMI 176 and UMI 133 x UMI 213, respectively. Significant positive heterobeltiosis was explored by 17 hybrids. The extent of heterosis over standard check ranged between -15.69 per cent (UMI 112 x UMI 176) and 15.10 per cent (UMI 133 x UMI 122). Ten hybrids attained positively significant standard heterosis. The trait grain yield per plant has the heterosis over mid parent for this trait was ranged between -22.25 per cent (UMI 122 x UMI 213) and 42.42 per cent (UMI 122 x UMI 66). 18 out of 30 hybrids recorded significant positive relative heterosis . The range of heterobeltiosis was from -28.84 per cent (UMI 122 x UMI 213) to 39.59 per cent (UMI 122 x UMI 66). Significant positive heterosis was observed in 13 hybrids against the better parent. The magnitude of standard heterosis varied from -24.86 per cent (UMI 122 x UMI 112) to 30.01 per cent (UMI 122 x UMI 66). Heterosis over standard check was observed to be significant and positive in direction for 15 hybrids (Table 1).

Extent of heterosis :

The objective of hybridization is to exploit the magnitude of heterosis on commercial basis by selecting promising cross combinations. Cross pollinated crops like maize offers tremendous scope for heterosis breeding owing to its out crossing nature. Heterosis in cross pollinated crop has long been known to offer good potentialities for increased yield. In the present investigation, the heterosis of direct and reciprocal cross combinations derived from the six parental inbreds through diallel mating was estimated over mid parent (di), better parent (dii) and standard hybrid (diii). However, the productive hybrids are weighed not merely by the expression of heterosis over the parents but also in relation to the standard check hybrid. Hence the standard heterosis (diii) was taken as an important criterion for evaluation of hybrids. The commercial hybrid 900M from Monsanto was used as the standard check to estimate the standard heterosis. The 30 hybrids in the present study were evaluated based on the standard heterosis. For judging good F1 hybrids, negative heterosis was considered to be better for five traits (days to tasseling, days to silking, anthesis silking interval, days to maturity and plant height), while positive heterosis was considered to be desirable for the remaining traits (ear length, ear girth, number of kernel rows per ear, number of kernels per row, ear weight, shelling per cent, 100 grain weight and grain yield per plant) A perusal of standard heterosis revealed that out of 30 crosses studied, none of the hybrids were found to possess significant standard heterosis for all the traits studied. A total of eight hybrids have exhibited significant and favourable standard heterosis for grain yield and its component traits. Among the eight hybrids, the hybrid UMI 133 x UMI 122 for seven traits and the remaining hybrids *viz.*, UMI 112 x UMI 66, UMI 112 x UMI 122, UMI 112 x UMI 133, UMI 122 x UMI 66, UMI 133 x UMI 112, UMI 133 x UMI 213 and UMI 213 x UMI 112 for five traits have recorded significant and favourable standard heterosis and these could be adjudged as the best hybrids. The same trend of high standard heterosis was reported by Dodiya and Joshi (2003). Though the hybrids UMI 213 x UMI 176, UMI 133 x UMI 66 showed significant and favourable standard heterosis for maximum number of seven traits, they were not considered as best ones due to the non significant standard heterosis of those hybrids for most important trait grain yield per plant. The extent of heterosis for grain yield per plant over check hybrid was found to be the maximum followed by ear weight. The heterosis over check hybrid recorded for anthesis silking interval was the maximum among the traits for which negative heterosis was favourable and was followed by plant height. This is in line with the findings of Nagda *et al*. (1994), Revilla *et al.* (2006), Saidaiah *et al.* (2006) and Amiruzzaman *et al*. (2011).

Table 1 : Extent of heterois (per cent) for grain yield per plant in maize

Sr. No.	Hybrids	Relative heterosis (di)	Heterobeltiosis (dii)	Standard heterosis (diii)
1.	UMI 66 x UMI 112	24.62**	14.82**	6.93**
2.	UMI 66 x UMI 122	19.74**	17.36**	9.30**
3.	UMI 66 x UMI 133	-9.53**	-12.57**	-12.71**
4.	UMI 66 x UMI 176	-13.07**	-14.91**	-17.25**
5.	UMI 66 x UMI 213	10.57**	3.09**	11.03**
6.	UMI 112 x UMI 66	26.15**	16.22**	8.24**
7.	UMI 112 x UMI 122	25.67**	17.98**	5.51**
8.	UMI 112 x UMI 133	17.97**	5.34**	5.18**
9.	UMI 112 x UMI 176	-6.60**	-15.61**	-17.94**
10.	UMI 112 x UMI 213	18.23**	2.19*	10.05**
11.	UMI 122 x UMI 66	42.42**	39.59**	30.01**
12.	UMI 122 x UMI 112	-10.49**	-15.97**	-24.86**
13.	UMI 122 x UMI 133	4.13**	-1.30	-1.25
14.	UMI 122 x UMI 176	5.62**	1.38	-1.42
15.	UMI 122 x UMI 213	-22.25**	-28.84**	-23.36**
16.	UMI 133 x UMI 66	0.06	-3.30**	-3.45**
17.	UMI 133 x UMI 112	18.85**	6.13**	5.96**
18.	UMI 133 x UMI 122	19.72**	13.47**	13.30**
19.	UMI 133 x UMI 176	6.29**	4.91**	4.74**
20.	UMI 133 x UMI 213	9.15**	5.17**	13.27**
21.	UMI 176 x UMI 66	11.24**	8.89**	5.89**
22.	UMI 176 x UMI 112	4.71**	-5.39**	-8.00**
23.	UMI 176 x UMI 122	-4.45**	-8.29**	-10.82**
24.	UMI 176 x UMI 133	0.36	-0.95	-1.10
25.	UMI 176 x UMI 213	1.32	-3.60**	3.82**
26.	UMI 213 x UMI 66	-14.01**	-19.83**	-13.65**
27.	UMI 213 x UMI 112	11.71**	-3.45**	3.98**
28.	UMI 213 x UMI 122	2.64**	-6.07**	1.17
29.	UMI 213 x UMI 133	-11.81**	-15.03**	-8.49**

SE for (di) = 0.93 SE for (dii) and (diii) =1.0 * and ** indicate significance of values at P=0.05 and 0.01, respectively

Evaluation of hybrids based on *per se*, SCA and standard heterosis :

Exploitation of hybrid vigour is considered as an outstanding accomplishment of plant breeding. The magnitude of heterosis shown by the hybrids depends largely on the heterotic pattern and genetic divergence between parental inbred lines. Development of single cross hybrids in maize depends on the *per se* performance of the inbred lines and their combining ability for important traits. Selection based on *per se* performance, SCA effects and heterotic pattern individually led to the identification of different hybrids, but considering all the three parameters together will facilitate the breeder to choose best hybrids for the commercial exploitation of F1 heterosis. The importance of considering the three parameters *per se*, SCA effects and standard heterosis also reported by Dodiya and Joshi (2003) and Premalatha *et al.* (2011). Considering these views, the 30 hybrids involved in the present investigation were ranked based on the three criteria. A score chart has been prepared for hybrids by scoring significant parameters to each trait. The hybrid UMI 122 x UMI 176 recorded the highest total score (25) followed by UMI 133 x UMI 122, UMI 213 x UMI 176 with total score 19 but have failed to show significant for grain yield per plant with respect to *per se*, SCA and standard heterosis. For grain yield per plant as shown in Table 1, hybrids *viz.*, UMI 112 x UMI 213, UMI 122 x UMI 66, UMI 66 x UMI 112, UMI 133 x UMI 176, UMI 112 x UMI 133 and UMI 66 x UMI 122 expressed favourable significant performance for all the three parameters. Hence these hybrids could be better exploited for heterosis breeding.

Conclusion :

The study was conducted to evaluate the hybrids which are suitable for coastal region of Pondicherry and Tamil Nadu, where soil conditions are saline in nature. We have identified some superior hybrids in terms of grain yield from the 30 cross combinations with commercial heterotic analysis (Standard check - 900M Hybrid from Monsanto) using prominent maize hybrid of these region

Authors' affiliations :

V. KRISHNAN, V. VENGADESSAN AND K. PARAMASIVAM, Department of Genetics and Plant Breeding, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, PUDUCHERRY (U.T.) INDIA

A.L. NARAYANAN, Department of Agronomy, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, PUDUCHERRY (U.T.) INDIA

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