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RESEARCH ARTICLE

Commercial heterosis for yield and yield related components in test crosses of yellow maize

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Abstract
An experiment on commercial heterosis for yield and yield related components in test crosses of yellow maize (*Zea mays* L.) was conducted in summer cropping season 2020, at Cereal Crops Research Institute (CCRI) Pirsabak, Nowshera. Data were recorded on 50% pollen shedding, 50% silking, plant height, ear height, earshectare^{-1}, plant population ha^{-1}, and grain yield. Minimum50% pollen shedding (60 days) was recorded for the genotypes, G-10, G-17, G-29 and G-30. Minimum commercial heterosis (-0.81%) was recorded for the genotypes G-10 and G-17 for the trait of 50% pollen shedding. Lowest value for 50% silking (63 days) was exhibited by the genotypes, G-10, and G-29. Minimum commercial heterosis (-0.76%) for the trait of 50% silking was calculated for the genotype, G-10 (-2.30%). Plant height trait indicated shortest plants for the genotype G-5 with a numerical value of 126.7cm. Minimum commercial heterosis was recorded for the genotype, G-5 (-22.0%) for the aforementioned quantitative trait. Among the genotypes, G-10exhibitedhighest ear height (85.8cm). Maximum commercial heterosis was recorded for the plants of the genotype, G-10for the trait of ear height with a value 17.04%. Greatest plant populationhectare^{-1}(64667 ha^{-1})was indicated by the genotype, G-44.Highest commercial heterosis was revealed for the genotype, G-44 (5.43%) for plant population hectare^{-1}. Maximum earshectare^{-1} was found for the genotype, G-56 (67333 ha^{-1}). Maximum commercial heterosis was founded by the genotype G-56 (9.78%). Highest grain yieldhectare^{-1} (8590 kg ha^{-1}) was produced by the genotype, G-62.

Keywords: Commercial heterosis; Test cross; Yellow maize; Genotypes

Introduction

Maize (*Zea mays* L.) also known as corn (north American and Australian English), belongs to Poaceae. Maize has a diploid chromosomes number of 2n=20 while genome is n=10. It is a cereal grain first domesticated by indigenous peoples in southern Mexico about 10,000 years ago. The leafy stalk of the produces pollen inflorescences and separate ovuliferous inflorescences called ears that yield kernels or seeds, which are fruits. Maize has become a staple food in many parts of the world, with the total production of maize surpassing that of wheat or rice.

Maize is used for corn ethanol, animal feed and other maize products, such as corn starch and corn syrup. The six major types of maize are dent corn, flint corn, pod corn, popcorn, flour corn, and sweet corn. Sugar-rich varieties called sweet corn are usually grown for human consumption as kernels, while field corn varieties are used for animal feed, various corn-based human food uses (including grinding into cornmeal or masa, pressing into corn oil, and fermentation and distillation into alcoholic beverages like bourbon whiskey), and as chemical feedstocks. Maize is also used in making ethanol and other bio-fuels. Maize ranks third in cereals after wheat and rice crops, with a cultivated area of about 100 million tons hectare [1],and having an annual production of 1009 million metric tons (USDA FAO). In Pakistan, it is cultivated on around 1413 thousand hectares, having a total production of 7236 thousand tons with an average yield of 5121 kg ha[1] (PBS.2020). Around 39% of the total area under maize and 30% of the total produce is contributed by Punjab, whereas KP contributes 56% of the total area and 63% of the production. Provinces of Sindh, and Baluchistan contribute just 5% of the total area under cultivation of maize and only 3% of its production (PBS. 2017).

It plays a vital role in human and animal nutrition. It is one of the important crops being used as a staple food for millions of human populations particularly in the rural societies of the developing countries. It is used as a forage crop besides it is used in the preparation of animal feeds. It plays vital role in food security in various regions of the world. It contributes 2.6% to value addition in agriculture and 0.5% to GDP (GoP.2019). Maize accounts for 4.8% of the total cropped area and 3.5% of the value of agricultural output. In Khyber Pakhtunkhwa, maize is often grown as a dual-purpose crop, producing grain as well as fodder.

Keeping in view the importance of maize hybrids the current experiment was designed with objectives to determine high yielding test cross hybrid of yellow maize and to determine early maturity in the test crosses.

Materials and methods

Experimental site and Treatments

The experiment on commercial heterosis for yield and yield related components in test crosses of yellow maize was conducted at Cereal Crops Research Institute (CCRI) Pirsabak, Nowshera, Pakistan during 2020. A total of 61 tests crosses of yellow maize along with one commercial hybrid (CS-2Y10) as a check, were evaluated in triplicate trial using RCBD design. The plot size was 1.12m for each genotype and comprised of two rows. Row length was kept 3 meters with plant to plant spacing of 0.25 meters and with a row to row spacing of 0.75 meters. All necessary Cultural practices (hoeing, weeding, irrigation and fertilizer application) for maize were performed in order to reduce experimental error.

The data were recorded on the following traits.

Procedures for Data Measurement

Data on 50% Pollen shedding was recorded **w**hen more than 50% plants in a plot produced tassels. Likewise, 50 % silking was recorded by observing the plants having more than 50% silking in each plot. Pollens shedding was visually observed and 50% pollen shedding data was recorded. In addition, for plant height data, five plants from each plots were selected and were measured with the help of meter rod. Ear height was measured in centimeters (cm) from ground level to node bearing the upper most ears. Data on plant population hectare^{-1} was noted by multiplying space between plants with spacing between the rows. We converted cm to m, multiply distance between plants spacing and the between rows spacing, divide are of 1 hectare by 0.27 m^2. For grain yield data, the cobs from each plant were harvested and fresh ear weight was recorded.

With the help of moisture tester, moisture percentage of each grain sample taken from all the plots was determined. Finally gain yield hectare^{-1} was determined with the help of following formula.

Grain yield = $\underline{\text{FW (kg plot}^{-1}) \times (100\text{-MC}) \times S \times \quad 10000\text{m}^2}$ (85) × Area harvested (plot size)

Where

FW= Fresh ear weight at harvest
S = Shelling coefficient = 0.8
Area harvested plot^{-1} = 1.12m^2
1 hectare = 10,000 m^2
MC = Percent grain moisture at harvest
85 = Standard value of grain moisture at 15%

Statistical analysis

To get conclusive results of this experiment the field data was subjected to analysis of variance (ANOVA) procedure as recommended for alpha lattice design by Barreto *et al*. (1997). Least significant differences (LSD) test was used for means separation.

Results and discussion

Pollen shedding of 50%

Data regarding, 50% pollen shedding indicated significant ($P<0.05$) differences among the test crosses of yellow maize. Minimum value for 50% pollen shedding (60 days) was recorded for the genotype G-29. Smallest value of commercial heterosis for 50% pollen shedding (-1.63%) was manifested by the genotype, G-29. Mean of 50% pollen shedding of all the genotypes was 64.50 days. Coefficient of variation (CV) for 50% pollen shedding was 0.1%. The results of our experiment are in close coordination with Khan *et al*. (2013) who had reported significant differences for 50% pollen shedding in maize hybrids. They also reported smallest value (63.33 days) for 50% pollen shedding among maize genotypes in their experiment.

Measurements of Silking

Analysis of variance indicated non-significant differences ($P>0.05$) for data concerning 50% silking among the genotypes of yellow maize. Data on 50% silking indicated a smallest value of 63 days for the genotypes, G-10 and G-29. Calculation of commercial heterosis for 50% silking among the studied genotypes exhibited a meager value (-2.30%) of for the genotype, G-10. All the studied genotypes indicated a mean value of 65.98 days 50% silking. Coefficient of variation (CV) for 50% silking was 0.1%. The results of our experiment are in close coordination with Khan *et al*., (2013) who had reported significant differences for 50% pollen shedding in maize hybrids. They also reported smallest value (62.33 days) for 50% silking among maize genotypes in their experiment.

Plant height

The data pertaining to plant height indicated significant ($P<0.05$) differences among the test crosses of yellow maize (Table 1). Plant height was ranging in maize test crosses of yellow maize from 126.70 to 165.08 cm. Among the genotypes of yellow maize, short stature plants with a height of 126.70 cm were recorded for the genotype, G-5. Coefficient of variation (CV) for plant height was 3%. Least significant difference for the aforesaid trait was 3% (Table 2). Slightest value of -22.00% for the trait of plant height, was recorded in the plants of the genotype, G-5 among the evaluated candidate hybrids of yellow maize (Table 3). Our results are in line with the findings of legesu *et al*., (2017). They also observed significant differences for the trait of plant height.

Table 1: Mean squares for 50%pollen shed, 50% silking, plant height, ear height, plant population, number of ears and grain yield of maize genotypes.

SOV	Replication	Genotypes	Error	CV%
D.F	2	62	124	
50%PS	0.07	5.94*	3.87	0.1
50%S	0.12	5.37	3.67	0.1
PTHT	1237.1	230.70*	110.5	3
EHT	617.29	131.14*	67.98	4.6
PPH^{-1}	1.35	$1.82^{N.S}$	7.26	8.8
EH^{-1}	8.67	1.94*	7.62	7.1
GY	10.89	1.95*	0.75	6.1

*significant at 5% level of probability PS= Pollen shedding, S= Silking' PTHT= Plant height, EHT= Ear height, PPH^{-1}= Plant Population hectare^{-1} , EH^{-1}= Ears hectare^{-1} GY= Grain yield

Ear height

Analysis of variance for ear height indicated significant ($P<0.05$) differences among the genotypes of yellow maize. Data relating to ear height indicated maximum value of 85.80 cm for the genotype, G-10 among the genotypes of yellow maize. It was followed by genotypes G-29 and G-38 with values of 82.50 cm and 80.80 cm respectively for the trait of ear height. Among the candidate maize hybrids the range for ear height was from 55.00 to 85.80 cm. Coefficient of variation (CV) for ear height was 4.6% (Table 2). Maximum value (17.04%) of commercial heterosis was recorded for the genotype, G-10 for the above mentioned trait (Table 3). The results of our experiment are fully supported by Hossein *et al*., (2012) who had also reported significant differences for the trait of ear height. Lengthy ears are more desirable for grain yield.

Plant population hectare^{-1}

Analysis of variance for the trait of plant population hectare^{-1} revealed non-significant differences among the candidate hybrids of maize (Table.1). Coefficient of variation (CV) for plant population hectare^{-1} was 8.8%. Range among the genotypes for plant population hectare^{-1} was from 9333 to 64000 plants hectare^{-1}. Mean value plant population was 36666 plants hectare^{-1}for plant population hectare^{-1}. Minimum plant population (9333 plants ha^{-1}) was observed for the genotype, G-23, where the highest value of 64333 plants hectare^{-1} were recorded for genotype, G-51 (Table 2). Highest value of commercial heterosis was recorded for the genotype, G-41 (Table3). The findings of the present research are in line with Qamar*et al.* (2007) who have been reported results which are similar to our findings. According to their study plant population hectare^{-1} was observed with non-significant differences among maize hybrids in their experiment.

Table 2. Mean performance of test crosses (yellow maize) for 50% pollen shedding, 50%silking, plant height, ear height, plant population, number of ears and grain yield at CCRI during 2020.

Genotype	50% PS (Days)	50% S (Days)	PH (cm)	EH (cm)	PPH^{-1}	EH^{-1}	GY (Kg ha^{-1})
G-1	63	67	152.5	75.0	43333	42000	6200
G-2	61	65	155.8	79.2	34000	32000	6310
G-3	62	66	157.5	79.2	60000	59333	7500
G-4	62	65	155.0	75.0	57333	57333	7210
G-5	64	67	126.7	63.3	45333	44000	6980
G-6	62	65	167.5	79.2	58667	57333	7070
G-7	61	65	159.2	76.7	56000	56000	6800
G-8	61	65	151.7	73.3	55333	54667	6910
G-9	63	66	130.8	68.3	50667	48667	6210
G-10	60	63	151.7	85.8	56667	55333	6900
G-11	62	65	145.0	65.0	57333	52000	6740
G-12	61	64	150.0	71.7	60667	60667	7420
G-13	63	66	150.0	68.3	59333	58000	6580
G-14	61	65	145.0	74.2	54667	54667	6960
G-15	62	65	154.2	69.2	49333	49333	6520
G-16	64	66	146.7	75.0	56000	54000	6610
G-17	60	64	131.7	65.0	49333	49333	6190
G-18	62	65	140.0	60.0	52667	50000	6820
G-19	64	66	145.8	70.8	53333	51333	7040
G-20	62	65	151.7	73.3	62000	61333	7160
G-21	63	66	147.5	63.3	62000	60667	7730
G-22	63	66	145.8	71.7	48667	46667	6390
G-23	70	73	130.0	61.7	9333	8667	1390
G-24	62	65	164.2	73.3	53333	53333	7440
G-25	63	66	148.3	55.0	30000	30000	5900
G-26	62	65	173.3	75.0	52000	52000	6970
G-27	62	65	154.2	70.0	51333	51333	6480
G-28	63	66	144.2	63.3	47333	43333	6260
G-29	60	63	164.2	82.5	58667	58667	7270
G-30	60	64	165.8	80.8	58000	58000	7190
G-31	61	65	141.7	57.5	40667	39333	6290
G-32	60	64	156.7	70.0	59333	58000	6790
G-33	61	65	157.5	76.7	57333	56667	7330
G-34	61	64	165.0	80.8	56667	56667	7110
G-35	62	65	154.2	70.0	58000	58000	7900

G-36	66	69	142.5	67.5	33333	32000	3910
G-37	64	67	128.3	57.5	39333	38667	5820
G-38	62	66	161.7	80.8	52000	51333	8090
G-39	62	65	134.2	62.5	41333	38667	6380
G-40	63	67	142.5	63.3	56667	56667	6410
G-41	62	65	164.2	80.0	56000	56000	7410
4 G-2	63	65	158.3	77.5	56667	55333	7080
G-43	64	67	148.3	55.0	46667	46000	6130
G-44	62	65	158.3	77.5	64667	63333	7360
G-45	62	66	141.7	64.2	62667	62667	6990
G-46	63	66	145.0	68.3	55333	54667	6890
G-47	63	67	132.5	55.0	62000	61333	7140
G-48	61	64	143.3	66.7	61333	60667	7050
G-49	63	66	150.0	65.8	58000	54667	6830
G-50	63	66	153.3	70.0	59333	58667	7910
G-51	62	65	157.5	76.7	64000	64000	7470
G-52	63	67	127.5	55.8	57333	57333	6890
G-53	67	71	141.7	56.7	44667	43333	6200
G-54	62	66	141.7	58.3	56667	56667	7410
G-55	62	65	149.2	65.8	58000	56667	7860
G-56	61	65	137.5	65.0	60667	67333	6800
G-57	67	70	134.2	55.0	62000	60000	6590
G-58	62	65	145.8	70.8	58667	58667	7410
G-59	62	66	147.5	67.5	54667	54667	7140
G-60	61	64	151.7	72.5	50000	50000	8390
G-61	63	66	150.8	67.5	62000	60667	6980
CS-2y10	61	65	162.5	73.3	61333	61333	8590

PS= Pollen shedding, S= Silking' PTHT= Plant height, EHT= Ear height, PPH^{-1}= Plant Population hectare^{-1} , EH^{-1}= Ears hectare^{-1} GY= Grain yield

Ears hectare^{-1}

Data regarding ears hectare^{-1}on analysis of variance revealed significant variation (P<0.05) among the genotypes of maize (Table 1). Maximum ears hectare^{-1}(67333 ears ha^{-1}) was recorded for the genotype, G-56 while lesser number of ears hectare^{-1} for the genotype, G-1. Range of the data for ears hectare^{-1} was from 42000 to 67333 ears hectare^{-1} among the studied genotypes. Mean for the trait for ears hectare^{-1} was 54666 (Table 2). Results of commercial heterosis on computation indicated highest value of 9.78% for the genotype, G-56 for ears hectare^{-1} in the evaluated maize genotypes during the study (Table 3). Our results in lined with the findings of Soza *et al*. (1996). They have been reported highly significant differences for ears hectare^{-1}.

Grain yield

Data relating to grain yield among the evaluated genotypes manifested significant differences (P<0.05) on analysis of variance which provided justification that all candidate hybrids were highly different from one another (Table 1). Among the studied genotypes range for the data of grain yield was from1392 to 8592 kg ha^{-1} while mean for the aforementioned trait was 6839 kg ha^{-1}. Highest grain yield was recorded for the genotype, G-62 in the evaluated genotypes while a very low value of 1392 kg ha^{-1}for the above said trait was exhibited by the genotype, G-23.Coefficient of variation for grain yield was 6.1% (Table 2).As the yield of commercial hybrid was more from all the candidate hybrids as the heterotic effect was in negative which was undesirable for grain yield (Table 3).Results of our experiment are fully supported by the research study of (Sleper and Phoelman, 2006) and (Russel, 1986) who have been reported in their research study that hybrid with high yield potential is the primary and most important objective in breeding maize crop. Hybrids generally have higher yield potential than open pollinated varieties and have long ears with more grain rows and greater grain yield. According to them current maize hybrids have greater yield potential as compared to older hybrids. Findings of our experiment are also in close proximity with the experimental results of Chandel and Mankotia (2014). They have reported highly significant differences among the test crosses of maize for various traits including grain yield. They evaluated test crosses to determine the relative potential of maize inbred lines in a hybrid breeding program.

Table 3: Commercial heterosis (%) for 50%pollen shed, 50%silking, plant height, earheight, plant population hectare^{-1}, ear hectare^{-1} and grain yield

Genotype	50%PS (Days)	50%S (Days)	PH (cm)	EH (cm)	PPH^{-1}	EH^{-1}	GY (Kg ha^{-1})
G-1	4.09	3.07	-6.15	2.27	-29.34	-31.52	-27.77
G-2	0.81	0	-4.10	7.95	-44.56	-47.82	-26.52
G-3	2.45	1.53	-3.07	7.95	-2.17	-3.26	-12.62
G-4	2.45	0.76	-4.61	2.27	-6.52	-6.52	-15.99
G-5	4.91	3.07	-22.0	-13.63	-26.08	-28.26	-18.72
G-6	1.63	0.76	3.07	7.95	-4.34	-6.52	-17.66
G-7	0	0	-2.05	4.54	-8.69	-8.69	-20.75
G-8	0.81	0	-6.66	0	-9.78	-10.86	-19.56
G-9	3.27	2.30	-19.48	-6.81	-17.39	-20.65	-27.68
G-10	-0.81	-2.30	-6.66	17.04	-7.60	-9.78	-19.61
G-11	2.45	0.76	-10.76	-11.36	-15.21	-15.21	-21.55
G-12	0	-1.53	-7.69	-2.27	-1.08	-1.08	-13.61
G-13	4.09	2.30	-7.69	-6.81	-3.26	-5.43	-23.34
G-14	0.81	0.76	-10.76	1.13	-10.86	-10.86	-18.88
G-15	2.45	0.76	-5.12	-5.68	-19.56	-19.56	-24.06
G-16	4.91	2.30	-9.74	2.27	-8.69	-11.95	-22.99
G-17	-0.81	-1.53	-18.97	-11.36	-19.56	-19.56	-27.92
G-18	2.45	0.76	-13.84	-18.18	-14.13	-18.47	-20.56
G-19	4.91	2.30	-10.25	-3.40	-13.04	-16.30	-18.05
G-20	2.45	0.76	-6.66	0	1.08	0	-16.57
G-21	3.27	2.30	-9.23	-13.63	1.08	-1.08	-9.92
G-22	3.27	2.30	-10.25	-2.27	-20.65	-23.91	-25.61
G-23	14.75	12.30	-20	-15.90	-19.56	-85.86	-83.79
G-24	1.63	0	1.02	0	-13.04	-13.04	-13.39

G-25	3.27	2.30	-8.71	-25	-51.08	-51.08	-31.33
G-26	2.45	0.76	6.66	2.27	-15.21	-15.21	-18.83
G-27	1.63	0.76	-5.12	-4.54	-16.30	-16.30	-24.53
G-28	3.27	1.53	-11.28	-13.63	-22.82	-29.34	-27.12
G-29	-1.63	-2.30	1.02	12.50	-4.34	-4.34	-15.31
G-30	-0.81	-1.53	2.05	10.22	-5.43	-5.43	-16.24
G-31	0	0	-12.82	-21.59	-33.69	-35.86	-26.75
G-32	-0.81	-1.53	-3.58	-4.54	-3.26	-5.43	-20.91
G-33	0	0	-3.07	4.54	-6.52	-7.60	-14.58
G-34	0.81	-0.76	1.53	10.22	-7.60	-7.60	-17.17
G-35	2.45	0.76	-5.12	-4.54	-5.43	-5.43	-7.99
G-36	8.19	6.15	-12.30	-7.95	-45.65	-47.82	-54.45
G-37	5.73	3.84	-21.02	-21.59	-35.86	-36.95	-32.22
G-38	2.45	1.53	-0.51	10.22	-15.21	-16.30	-5.83
G-39	1.63	0.76	-17.43	-14.77	-32.60	-36.95	-25.69
G-40	3.27	3.07	-12.30	-13.63	-7.60	-7.60	-25.31
G-41	2.45	0.76	1.02	10.22	-8.69	-8.69	-13.65
4 G-2	3.27	0.76	-2.56	5.68	-7.60	-9.78	-17.51
G-43	4.91	3.84	-8.71	-25	-23.91	-24.99	-28.59
G-44	1.63	0.76	-2.56	5.68	5.43	3.26	-14.23
G-45	2.45	1.53	-12.82	-12.49	2.17	2.17	-18.62
G-46	3.27	1.53	-10.76	-6.8	-9.78	-10.86	-19.75
G-47	4.09	3.84	-18.46	-25	1.08	0	-16.80
G-48	0	-0.76	-11.79	-9.09	0	-1.08	-17.93
G-49	3.27	2.30	-7.69	-10.22	-5.43	-10.86	-20.48
G-50	3.27	2.30	-5.64	-4.54	-3.26	-4.34	-7.85
G-51	1.63	0.76	-3.07	4.54	4.34	4.34	-13.01
G-52	3.27	3.07	-21.53	-23.86	-6.52	-6.52	-19.73
G-53	10.65	9.23	-12.82	-22.72	-27.17	-29.34	-27.78
G-54	2.45	2.30	-12.82	-20.45	-7.60	-7.60	-13.72
G-55	1.63	0.76	-8.20	-10.22	-5.43	-7.60	-8.41
G-56	0.81	0	-15.38	-11.36	-1.08	9.78	-20.76
G-57	10.65	8.46	-17.43	-31.81	1.08	-2.17	-23.23
G-58	2.45	0.76	-10.25	-3.40	-4.34	-4.34	-13.74
G-59	1.63	1.53	-9.23	-7.95	-10.86	-10.86	-16.79
G-60	0.81	-0.76	-6.66	-1.13	-18.47	-18.47	-2.30
G-61	3.27	1.53	-7.17	-7.95	1.08	-1.08	-18.69
CS-2y10	0	0	0	0	0	0	0

PS= Pollen shedding, S= Silking' PTHT= Plant height, EHT= Ear height, PPH^{-1}= Plant Population $hectare^{-1}$, EH^{-1}= Ears $hectare^{-1}$ GY= Grain yield

Conclusion

It was concluded from the current study that G62 and G56 were found potential maize genotypes with higher grain and greater commercial heterosis. The genotypes (G-10, G-17, G-29 and G-30) were found early pollen shedding as well as poor with commercial heterosis (-0.81%). Lowest value for 50% silking (63 days) was exhibited for the genotypes, G-10, and G-29.

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