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Comparison of hybrid maize obtained from inbred lines that are selected via top-crossing and discriminant analysis

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Abstract: This research was done at the Black Sea Agricultural Research Institute in Samsun, in 2006 and 2007. The study was conducted to determine the effectiveness of discriminant analysis in determining the parents among inbred lines in hybrid corn breeding. Grain yield and some yield components of the hybrid maize, which was obtained from inbred lines that were selected in accordance with top-crossing and discriminant analysis, was examined in the research. According to the average of 2 years, the average grain yield of 11 maize hybrids obtained via top-crossing was 9160 kg ha⁻¹, whereas the average grain yield of 8 maize hybrids obtained in accordance with discriminant analysis was 8550 kg ha⁻¹. Among the hybrid maize obtained via top-crossing, the TK-120 × TK-108 hybrid gave the highest yield (10,820 kg ha⁻¹). Among the hybrid maize obtained in accordance with discriminant analysis, the TK-169 × TK-413 hybrid gave the highest yield (9340 kg ha⁻¹). Some of the hybrids that used inbred lines selected via discriminant analysis had a higher grain yield than some of those that used inbred lines selected via top-crossing. In view of the obtained results, it can be stated that determining parents via discriminant analysis can supplement the deficient aspects of the top-crossing method.

Key words: Discriminant analysis, grain yield, maize, top cross, yield components

Introduction

The importance of maize is progressively increasing in Turkey and the world. Maize is an important species owing to the fact that it has many areas of use: it can provide products for different branches of industry, it is significant in human nutrition and especially animal nutrition, and it has potential to be bred (by benefitting from its hybrid vigor) and the ability to develop new cultivars with superior traits. Moreover, the use of maize in biofuel and bioethanol production and starch-based sugar production in recent years has increased its importance still more (Özcan 2009). Heterosis describes the difference between hybrids and their parents. Hybrid vigor is

one of the most practical contributions of genetics to agriculture. However, these benefits have not been completely clarified (Elisa et al. 2001). Determining the genetic and morphological differences among the inbred lines in hybrid maize breeding holds a great importance in developing a source population and forming high-yielding combinations.

The combination abilities of the developed inbred lines are required to be high in hybrid maize breeding. If the differences among the source materials from which the inbred lines are developed are high, the level of heterosis that will occur in the hybrid is expected to be high. Appropriate combinations have to be found among the inbred lines in order to obtain

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high-yielding hybrids. The effect of genetic difference on heterosis level increases in line with the differences among the gene frequencies of parent lines (Hallauer and Miranda 1988). The top-crossing method has been used for many years in determining the inbred lines that are to be used as parents.

Çeçen et al. (1998) researched the dependence of 10 inbred maize lines and their top crosses on the lines, and the similarity between line groups and the hybrid groups. In that study, it was reported that the parents' selection can be performed by generally examining yield, plant, and ear traits of the lines, but the top-crossing process must be performed in order to make a reliable selection.

Aydın et al. (2007a) examined 30 inbred maize lines in the study that they conducted for the purpose of determining the combination abilities via the top-crossing method in terms of grain yield and some other traits. It was stated that the lines that exhibited a positive combination ability at a significant level in terms of plant height, ear height, and 1000-grain weight also took first place in terms of grain yield, and these traits could be used as important selection parameters for the materials studied.

Sezer and Sürmeli (2003) diallel-crossed 6 lines for the purpose of researching the combination abilities that belong to some plant traits of inbred lines that are suitable for main crop hybrid maize production in the Black Sea Region of Turkey. The general and special combination abilities of the parents were researched using a fixed model analysis that was conducted on the population composed of diallel hybrid progenies, whereas the general and special combination abilities belonging to the plant traits of the lines that could be used in main crop hybrid maize production in the Black Sea Region, where the sampling was conducted, were researched using a random model analysis, and heredity degrees were estimated.

Kara (2001) examined yield and some yield components of inbred maize lines and their hybrids, their general and special adaptabilities, and heterosis in hybrids in accordance with the line \times tester analysis. It was stated that the variation between F_1 hybrids and parent lines is important in terms of all traits that were examined in the research. Average heterosis was important in all studied traits, and it

was positive except for tasseling duration. The unit area grain yield of hybrids was 79.8% higher than the parent average.

Özkaynak and Samancı (2003) determined yield and yield-related traits of 15 inbred popcorn lines and the top crosses that were obtained from them. The researchers stated that the hybrids gave higher values than the lines in terms of other studied traits except for tasselling and silking time, 100-grain weight, and expansion volume. They stated that the hybrids obtained from crosses of the high-yielding lines were not high yielding per se.

Turgut et al. (2003) crossbred 18 lines with FRMo 17 in their study, in which they determined yield, yield components, heterosis, and combination ability in inbred maize lines and their hybrids. Grain yield ranged from 8822 kg ha⁻¹ to 15,212 kg ha⁻¹ in hybrids. The heterosis rate ranged from -1.80% to 128.1% in grain yield. The grain yield average of the hybrids was found to be 11,930 kg ha⁻¹ in the test where the inbred line average was 7586 kg ha⁻¹.

Tezel and Soylu (2009) performed crossbreeding among 9 inbred maize lines (6 \times 3) according to the line \times tester method in order to determine hybrid vigor values for yield and yield components in maize. They stated that the examined material presented a hopeful condition thanks to the fact that it exhibited high heterosis in terms of grain yield, its yield values were high, hybrids had a tendency toward earliness, and it was a source that could meet species candidate requirements for the Central Anatolian Region.

Öz and Kapar (2003) stated that grain yields of new hybrid maize ranged on average from 9160 kg ha⁻¹ to 12,530 kg ha⁻¹ in a study that they conducted under the conditions of Samsun, Amasya, and Sakarya. Plant height values of the genotypes examined in that study ranged from 251 cm to 282 cm, their ear heights ranged from 103 cm to 129 cm, their grain moisture values in the harvest ranged from 23.2% to 30.9%, and their grain-to-ear ratio values ranged from 80.0% to 85.1%.

Materials and methods

The study was conducted in the experimental field of the Black Sea Agricultural Research Institute in 2006 and 2007 in Samsun. Parents selected from among

31 maize lines that were evaluated in accordance with top-crossing and discriminant analysis in 2003 and 2004 were crossbred in 2005. The combination ability of the inbred lines was considered in selecting parent lines via top-crossing. Therefore, according to the results regarding combining ability, lines TK-120 and TK-157 are probably in a different heterotic group than the other selected inbred lines. Lines TK-120 and TK-157 were hybridized with the other 6 selected lines. The flowering time of the inbred lines was taken into account at hybridization combination. The hybridization was done based on the values of D^2 , canonical distribution of lines, and flowering time, which were considered in selecting parent lines. As a result of this crossbreeding, 8 maize hybrids were obtained from the lines that were selected in accordance with discriminant analysis, whereas 11 maize hybrids were obtained from the lines that were selected in accordance with top-crossing. Two experiments were sowed side by side, and the same standard cultivars (TTM.8119, ADA.95-16, and OSSK.602) were used as controls in both. Plot length was 5 m, row spacing was 0.70 m, and the top row was 0.25 m in the tests. Each plot was composed of 4 rows and the total plot area was 14 m². Tests were conducted under main crop conditions. Fertilization was performed such that 20 kg of N and 6 kg of P₂O₅ was present per 0.1 ha. Grain moisture and the grain-to-ear ratios of the plants were measured during the

harvest, and grain yield was calculated according to 15% moisture.

The temperature and precipitation values were lower for 2006 than for 2007 and the average of both years (Table 1).

Results

The test sets, which were composed of the parents determined by top-crossing and discriminant analysis, were sowed side by side with 3 standard cultivars. The obtained findings were analyzed separately.

Hybrids obtained from the lines selected via top-crossing

Data for the hybrids obtained from the parent lines that were selected via top-crossing in 2006 are given in Table 2. The differences among the values obtained for all examined characteristics were statistically significant. The average grain yield of the genotypes was 9830 kg ha⁻¹. The TK-120 × TK-108 hybrid gave the highest yield. The grain yield of the hybrids ranged from 7260 kg ha⁻¹ to 13,490 kg ha⁻¹. The inbred TK-108 line had the highest and the TK-120 line had the lowest values for combining ability.

Flowering time values ranged from 60.0 days to 73.3 days. The standard cultivars flowered later than the candidate hybrids. There was a 13-day difference

Table 1. The values of the weather conditions* during the study period.

Months	Average temperature (°C)			Relative humidity (%)			Total precipitation (mm)		
	2006	2007	Average of both years	2006	2007	Average of both years	2006	2007	Average of both years
April	11.1	9.7	11.1	80.1	74.2	79.5	30.7	28.0	58.3
May	14.4	17.2	15.3	82.7	77.3	80.6	58.0	43.2	50.6
June	20.8	22.1	20.0	75.4	69.8	76.3	37.7	32.8	47.9
July	22.0	23.8	23.1	73.3	71.8	73.4	16.4	13.9	31.3
August	24.9	24.4	23.2	75.5	76.3	73.7	0.2	146.6	50.9
September	19.7	20.3	19.8	77.2	79.3	74.7	150.2	89.3	87.4
Mean	18.8	19.58	18.75	77.4	74.8	76.4	-	-	-
Total	-	-	-	-	-	-	293.2	353.8	326.4

*Data from the Regional Directorate of Meteorology, Samsun, Turkey.

Table 2. Data of hybrids obtained according to top-crossing (2006).

Hybrids/Cultivars	Grain yield (kg ha ⁻¹)	Flowering time (days)	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain-to-ear ratio (%)
TK-175 × TK-157	9750 dc **	63.3 c**	247 dc**	85 bc **	19.8 h**	85.3 c**
TK-157 × TK-347	8650 de	63.7 c	238 cf	90 bc	21.1 e	83.9 i
TK-175 × TK-120	11,020 bc	63.7 c	255 bc	93 bc	19.1 i	83.9 i
TK-13 × TK-157	7690 e	64.0 c	223 ef	77 de	20.6 g	84.2 g
TK-120 × TK-13	7260 e	64.0 c	225 ef	78 dc	21.1 e	84.0 h
TK-120 × TK-347	10,230 dc	64.3 c	222 f	72 e	22.4 c	86.8 a
TK-13 × TK-120	7490 e	64.0 c	222 f	70 e	21.4 d	84.5 e
TK-120 × TK-110	10,240 dc	65.3 c	245 ce	90 bc	22.4 c	83.2 l
TK-120 × TK-108	13,490 a	68.7 b	270 ab	80 dc	19.8 h	85.0 d
TK-120 × TK-175	10,090 dc	64.0 c	243 cf	70 e	20.8 f	84.4 f
TK-157 × TK-13	8310 de	60.0 d	225 df	82 dc	20.6 g	85.7 b
TTM.8119	7810 e	71.7 a	270 ab	100 ab	23.4 b	83.8 j
ADA.95-16	13,280 a	73.3 a	283 a	107 a	26.2 a	83.4 k
OSSK.602	12,340 ab	72.7 a	268 ab	95 ac	23.4 b	82.9 m
Mean	9830	66.7	246	84.9	21.6	84.4 f
CV (%)	10.5	2.26	4.76	11.1	3.1	1.35

**Different letters in a column indicate significant difference at $P < 0.01$; CV = coefficient of variation.

among the genotypes in terms of flowering duration. Plant heights of the genotypes ranged from 222 cm to 283 cm. Cultivar ADA.95-16 had the highest value. Ear height values ranged from 70 cm to 107 cm, and ADA.95-16 again had the highest value. The new hybrids had lower values than the standard cultivars in terms of ear height. Grain moisture values in the harvest, which is an important trait for the Black Sea Region, ranged from 19.1% to 26.2% in this test. The standard cultivars had higher values than the new hybrids. The grain-to-ear ratio ranged from 82.9% to 86.8%. The TK-120 × TK-347 hybrid had the highest value. When the plant height, flowering time, and grain moisture values of the genotypes were examined, it was understood that the standard cultivars were in a later maturation group than the new hybrids.

Data for the hybrids obtained from the parent lines that were selected via top-crossing in 2007 are given in Table 3. The differences among the values

obtained for all examined traits except ear height were statistically significant. The average grain yield of the genotypes was 8490 kg ha⁻¹ in the trial. The ADA.95-16 cultivar gave the highest yield. The grain yield of the new hybrids ranged from 5610 kg ha⁻¹ to 10,030 kg ha⁻¹. An approximately 14% decrease on average was observed in the grain yield values of 2007 compared to the values of 2006. Extreme temperatures experienced in 2007 could be the reason for this condition (Table 1). Here, the most interesting case was that the TK-120 × TK-108 hybrid, which had given the highest yield in 2006, gave a yield below average in 2007. Flowering time ranged from 59.0 days to 69.7 days. The standard cultivars flowered later than the others, as in the previous year. Plant height and ear height values were found to be lower than the values in 2006. Plant height values ranged from 190 cm to 271 cm. Ear height values ranged from 60 cm to 94 cm. Grain moisture values in the harvest ranged from 16.5% to 23.9%. Similar to the

Table 3. Data of hybrids obtained according to top-crossing (2007).

Hybrids/Cultivars	Grain yield (kg ha ⁻¹)	Flowering time (days)	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain-to-ear ratio (%)
TK-175 × TK-157	9710 ac**	62.3 bd**	238 bd**	73 ns	19.9 c**	84.8 de**
TK-157 × TK-347	9200 ad	62.7 bd	242 bc	75	20.7 bc	83.8 fg
TK-175 × TK-120	9990 ab	62.7 bd	242 bc	73	20.5 bc	84.4 de
TK-13 × TK-157	6700 ef	59.0 e	200 ef	80	17.5 e	85.6 b
TK-120 × TK-13	7840 be	62.3 bd	190 f	60	20.7 bc	84.3 ef
TK-120 × TK-347	7560 ce	59.7 de	200 ef	63	18.7 d	86.3 a
TK-13 × TK-120	8170 be	62.7 b	238 bd	72	20.1 bc	85.0 cd
TK-120 × TK-110	10,030 ab	62.3 bd	210 ef	80	19.9 c	84.6 de
TK-120 × TK-108	8140 be	63.7 bc	213 df	73	16.5 e	85.5 bc
TK-120 × TK-175	7270 de	60.3 ce	200 ef	77	17.5 e	86.1 ab
TK-157 × TK-13	5610 f	59.0 e	210 ef	73	16.5 e	84.5 de
TTM.8119	7570 ce	69.7 a	271 a	94	21.3 b	84.5 de
ADA.95-16	10,970 a	65.3 b	260 ab	92	23.9 a	84.6 de
OSSK.602	10,510 a	63.3 bc	220 ce	82	21.6 b	83.6 g
Mean	8490	62.5	224	76	19.5	84.9
CV (%)	13.9	2.79	6.49	15.7	3.39	0.39

**Different letters in a column indicate significant difference at $P < 0.01$; ns = nonsignificant; CV = coefficient of variation.

values obtained in 2006, moisture of the new hybrids was found to be lower than that of the standard cultivars. Grain-to-ear ratio values ranged from 83.6% to 86.3%. The average was found to be 84.9%. It was observed that the grain-to-ear ratio values of some of the new hybrids were higher than those of the standard cultivars. A 2-year combined analysis of the data for the examined traits of the hybrids obtained from the lines that were selected via top-crossing is given in Table 4. According to the analysis, the statistical difference among the genotypes in all traits was found to be significant. The 2-year average grain yields of the genotypes ranged from 6720 kg ha⁻¹ to 12,120 kg ha⁻¹. The average grain yield was recorded to be 9160 kg ha⁻¹. Cultivar ADA.95-16 gave the highest grain yield. Among the new hybrids, the TK-175 × TK-120 hybrid gave the highest grain yield (10,510 kg ha⁻¹). The flowering duration of the genotypes ranged from 59.5 days to 70.7 days. In

view of these values, it can be stated that there is a great difference among the maturing groups of the maize, and the maturing groups might be different because the standard cultivars flowered later than the new hybrids. Average plant height values ranged from 208 cm to 272 cm. It was observed that the hybrids with a shorter plant height flowered earlier and had lower grain yield and grain moisture values. Average ear height values ranged from 68 cm to 99 cm. It was observed that the taller maize generally also had higher ear height values. Grain moisture values in the harvest ranged from 18.2% to 25.1%. Grain-to-ear ratio values ranged from 83.3% to 86.6%.

Hybrids obtained from the lines selected via discriminant analysis

Data for the hybrids obtained from the parent lines that were selected via discriminant analysis in 2006 are given in Table 5. The differences among the

Table 4. Data of hybrids obtained according to top-crossing (years combined).

Hybrids/Cultivars	Grain yield (kg ha ⁻¹)	Flowering time (days)	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain-to-ear ratio (%)
TK-175 × TK-157	9730 ac**	62.8 ce**	243 bc**	79 ce**	19.8 ce**	85.1 c**
TK-157 × TK-347	8930 ce	63.2 ce	240 bc	83 be	20.9 bc	83.8 ef
TK-175 × TK-120	10,510 ac	63.2 ce	248 ab	83 be	19.8 ce	84.2 de
TK-13 × TK-157	7200 ef	61.5 de	212 d	78 ce	19.1 ce	84.9 c
TK-120 × TK-13	7550 ef	63.2 ce	208 d	69 de	20.9 bc	84.2 de
TK-120 × TK-347	8900 ce	62.0 de	211 d	68 e	20.6 bd	86.6 a
TK-13 × TK-120	7830 ef	63.3 dc	230 bd	71 de	20.8 bd	84.7 cd
TK-120 × TK-110	10,130 bd	63.8 cd	228 bd	85 ad	21.2 bc	83.9e
TK-120 × TK-108	10,820 ab	66.2 bc	242 bc	77 ce	18.2 e	85.3 c
TK-120 × TK-175	8680 de	62.2 de	222 bd	73 ce	19.2 ce	85.3 c
TK-157 × TK-13	6720 f	59.5 e	218 cd	78 ce	18.6 de	85.9 b
TTM.8119	7690 de	70.7 a	270 a	97 ab	22.4 b	84.1 de
ADA.95-16	12,120 a	69.3 ab	272 a	99 a	25.1 a	84.0 e
OSSK.602	11,430 ab	68.0 ab	244 bc	88 ac	22.5 b	83.3 f
Mean	9160	64.2	235	81	20.6	84.6
CV (%)	14.6	4.33	8.59	15.1	8.24	0.62

**Different letters in a column indicate significant difference at P < 0.01; CV = coefficient of variation.

Table 5. Data of hybrids obtained according to discriminant analysis (2006).

Hybrids/Cultivars	Grain yield (kg ha ⁻¹)	Flowering time (days)	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain-to-ear ratio (%)
TK-145 × TK-413	10,450 b**	70.7 ab**	227 bc**	97 ab*	24.9 c**	82.6 d**
TK-169 × TK-413	10,740 b	63.7 b	263 a	95 ac	21.9 f	82.4 e
TK-120 × TK-284	6950 c	60.0 c	217 c	77 c	20.0 i	80.9 f
TK-68 × TK-284	10,430 b	66.0 b	252 ab	98 ab	21.8 g	76.5 i
TK-120 × TK-68	7560 c	63.5 b	220 c	80 bc	20.2 h	82.6 d
TK-304 × TK-68	11,210 ab	70.3 ab	275 a	98 ab	23.3 e	79.3 h
TK-304 × TK-413	10,380 b	70.3 ab	230 bc	103 a	26.7 a	80.9 f
TK-120 × TK-413	6950 c	58.7 c	207 c	77 c	20.2 h	80.8 g
TTM.8119	7810 c	71.7 ab	270 a	100 a	23.4 d	83.8 a
ADA.95-16	13,280 a	73.3 a	283 a	107 a	26.2 b	83.4 b
OSSK.602	12,340 ab	72.7 a	268 a	95 ac	23.4 d	82.9 c
Mean	9900	67.3	247	94	23.0	81.5
CV (%):	12.55	2.51	6.83	10.83	0.16	1.15

*, **Different letters in a column indicate significant difference at P < 0.05 and P < 0.01, respectively; CV = coefficient of variation.

values obtained in all examined traits were found to be statistically significant. The average grain yield of these hybrids was 9900 kg ha⁻¹. Cultivars ADA.95-16 and OSSK.602 gave the highest yields. The grain yield of the genotypes ranged from 6950 kg ha⁻¹ to 13,280 kg ha⁻¹. Among the new hybrids, hybrid TK-304 × TK-68 gave the highest grain yield.

The genotypes flowered between 58.7 days and 73.3 days. It was observed that the new hybrids, except for the TK-145 × TK-413 hybrid, flowered earlier than the standard cultivars. Plant height values ranged from 207 cm to 283 cm. The average was found to be 247 cm. Standard cultivars had the highest values in terms of plant height and ear height. However, some new hybrids fell into the same group with the standard breeds. Ear height values ranged from 77 cm to 107 cm. Grain moisture values ranged from 20.0% to 26.7%. The TK-120 × TK-284 hybrid exhibited the lowest grain moisture. The standard cultivars exhibited grain moisture values above the average. The grain-to-ear ratio values ranged from 76.5% to 83.8% and the average was 81.5%. It was observed that the grain-to-ear ratio values belonging

to the standard breeds were above the average and represented the highest values, and the new hybrids followed these cultivars.

Data for the hybrids obtained from the parent lines that were selected via discriminant analysis in 2007 are given in Table 6. The differences among the values obtained in all examined traits were found to be statistically significant. Average grain yield was 7240 kg ha⁻¹ in the trial, and cultivars ADA.95-16 and OSSK.602 gave the highest yield. The grain yield of the new hybrids ranged from 5260 kg ha⁻¹ to 7930 kg ha⁻¹. On average, a 27% decrease was observed in the grain yield values from 2007 compared to the values from 2006. This decrease was also clearly observed in the flowering time, plant height, ear height, and grain moisture values. Unfavorable weather conditions like the extreme temperatures and insufficient precipitation experienced in 2007 could be the reason for this condition. Flowering time ranged from 56.3 days to 69.7 days. As in 2006, a remarkably high day range (about 13 days) was detected among the flowering dates of the genotypes. Plant height values ranged from 187 cm to 271 cm. The genotypes that

Table 6. Data of hybrids obtained according to discriminant analysis (2007).

Hybrids/Cultivars	Grain yield (kg ha ⁻¹)	Flowering time (days)	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain-to-ear ratio (%)
TK-145 × TK-413	7600 c**	63.7 b**	210 df**	85 ad*	19.9 e**	86.1 b**
TK-169 × TK-413	7930 bc	61.3 bc	260 ab	107 a	19.0 g	85.9 b
TK-120 × TK-284	5260 c	58.7 cd	187 f	68 d	16.6 i	83.6 d
TK-68 × TK-284	6200 c	62.3 bc	240 ad	97 ab	21.0 d	82.2 g
TK-120 × TK-68	6510 c	61.0 bc	243 ad	93 ac	17.1 h	83.1 e
TK-304 × TK-68	6220 c	64.7 b	253 ac	83 bd	19.3 f	82.8 f
TK-304 × TK-413	5760 c	64.7 b	227 be	98 ab	23.0 b	83.1 e
TK-120 × TK-413	5080 c	56.3 d	197 ef	73 cd	17.2 h	88.4 a
TTM.8119	7570 c	69.7 a	271 a	94 ac	21.3 c	84.5 c
ADA.95-16	10,970 a	65.3 b	260 ab	92 ac	23.9 a	84.6 c
OSSK.602	10,510 ab	63.3 b	220 ce	82 bd	21.6 C	83.6 d
Mean	7240	62.8	233	88	19.7	84.3
CV (%)	16.7	3.85	7.87	12.97	0.36	0.17

*, **Different letters in a column indicate significant difference at $P < 0.05$ and $P < 0.01$, respectively; CV = coefficient of variation.

were taller in 2006 were also taller than the others in 2007. Ear height ranged from 68 cm to 107 cm. The grain moisture of the genotypes was found to be lower than in the previous year. As mentioned above, the reason for this could be that the growth period was arid. Moisture values ranged from 16.6% to 23.9%. The TK-120 × TK-284 hybrid exhibited the lowest grain moisture, as in the previous year. The grain-to-ear ratio values ranged from 82.2% to 88.4%. The TK-120 × TK-413 hybrid exhibited the highest grain-to-ear ratio.

A 2-year combined analysis of the data for the examined traits of the hybrids obtained from the lines that were selected via discriminant analysis is given in Table 7. According to the analysis, the statistical difference among the genotypes in all traits was found to be significant. The 2-year average grain yields of the genotypes ranged from 6020 kg ha⁻¹ to 12,120 kg ha⁻¹ and averaged 8550 kg ha⁻¹.

Cultivar ADA.95-16 had the highest grain yield. Among the new hybrids, the TK-169 × TK-413

hybrid had the highest grain yield (9340 kg ha⁻¹). Five hybrids had an equally high yield as cultivar TTM.8119 in terms of average grain yield. Flowering time values ranged from 57.5 days to 70.7 days. In view of these values, it can be stated that there is a great difference among the maturing groups of the maize, and the maturing groups might be different because the standard cultivars flowered later than the new hybrids. Average plant height values ranged from 202 cm to 272 cm. It was observed that the shortest hybrids flowered earliest and had the lowest values in terms of ear height, grain yield, and grain moisture.

Average ear height values ranged from 73 cm to 101 cm. It was observed that the tallest maize generally also had high ear height values. Grain moisture values in the harvest ranged from 18.3% to 25.1%. It was observed that maize with a high grain moisture value also had high values in terms of the other traits. Grain-to-ear values ranged from 79.4% to 84.6%.

Table 7. Data of hybrids obtained according to discriminant analysis (years combined).

Hybrids/Cultivars	Grain yield (kg ha ⁻¹)	Flowering time (days)	Plant height (cm)	Ear height (cm)	Grain moisture (%)	Grain-to-ear ratio (%)
TK-145 × TK-413	9020 bc**	67.2 ab**	218 de**	91 a**	22.4 b**	84.4 a**
TK-169 × TK-413	9340 bc	62.5 dc	262 ab	101 a	20.5 bc	84.2 a
TK-120 × TK-284	6100 d	59.3 de	202 e	73 c	18.3 c	82.3 ab
TK-68 × TK-284	8320 cd	64.2 bc	246 ac	98 a	21.4 b	79.4 c
TK-120 × TK-68	6930 cd	62.2 dc	232 cd	87 ac	18.7 c	82.9 ab
TK-304 × TK-68	8720 cd	67.5 ab	264 ab	91 a	21.3 b	81.1 bc
TK-304 × TK-413	8070 cd	67.5 ab	228 cd	101 a	24.9 a	82.0 ab
TK-120 × TK-413	6020 d	57.5 e	202 e	75 bc	18.7 c	84.6 a
TTM.8119	7690 dc	70.7 a	270 a	97 a	22.4 b	84.1 a
ADA.95-16	12,120 a	69.3 a	272 a	99 a	25.1 a	84.0 a
OSSK.602	11,430 ab	68.0 ab	244 bc	88 ab	22.5 b	83.3 ab
Mean	8550	65.1	240	91	21.3	82.9
CV (%)	16.6	5.29	7.41	12.98	9.48	2.41

**Different letters in a column indicate significant difference at P < 0.01; CV = coefficient of variation.

Discussion

The traits belonging to the hybrids obtained via top-crossing are similar to the traits obtained from the studies previously conducted by Öz and Kapar (2003) and Aydın et al. (2007a), with similar materials in the same location. The grain yield values of the hybrids obtained in the top-crossings that were conducted with one tester could be lower than those of the inbred lines. For that reason, top-crossing must be conducted with testers from different groups in order to determine the heterotic groups of the lines. Discriminant analysis is a method that has been used to group genetic materials by many researchers (Ilarslan et al. 2002; Öz et al. 2003; Aydın et al. 2007b). In the studies conducted by Turgut et al. (2003), Tezel and Soylu (2010), Çeçen et al. (1998), and Kara (2001), it was observed that the values belonging to the new hybrids showed a wide distribution, and lower yield values could be obtained from some hybrids compared to the inbred lines.

The overall average values of the hybrids obtained via top-crossing were found to be higher than the

overall average values of the hybrids obtained via discriminant analysis. However, when the hybrids were examined separately, it was observed that some of the hybrids formed via discriminant analysis had a higher grain yield than the hybrids obtained via top-crossing. The TK-169 × TK-413 and TK-145 × TK-413 hybrids, which were formed using discriminant analysis, exhibited higher values than 7 of the 11 new hybrids that were formed using top-crossing in terms of their grain yield values.

In terms of the other examined traits, it was observed that some hybrids that were obtained using discriminant analysis exhibited higher values than the new hybrids that were formed using top-crossing. In view of these results, it is believed that top-crossing does not give conclusive results in determining the parent lines in maize and that discriminant analysis can supplement the deficient aspects of the top-crossing method. Some of the lines whose properties can be determined by discriminant analysis in early inbreeding generations, such as S_3 or S_4 , can be discarded.

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