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HETEROSIS AND FACTOR ANALYSIS FOR SOME IMPORTANT TRAITS IN NEW MAIZE HYBRIDS

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ABSTRACT

The present study was performed to determine the extent of standard heterosis in forty five crosses resulting from a 10 × 10 diallel analysis system. The obtained crosses along with two checks (S.C. 10 and S.C. 30k8) were evaluated in two different planting dates *i.e.,* May, 15th and June 15th. Standard heterosis were computed for days to 50% tasseling, days to 50% silking, plant height, ear height, chlorophyll content, grain yield / plant, protein (%) and oil (%) in each planting date as well as combined analyses. Results indicated that the single cross $P_5 \times P_6$ expressed the highest desirable heterotic values for days to 50% tasseling and chlorophyll content relative to both checks. The hybrid $P_4 \times P_5$ gave the best standard heterotic effects for days to 50% silking relative to both checks. The best standard heterosis for plant height and ear height relative to both checks was obtained for the cross $P_1 \times P_8$ in the second planting date and combined data. For grain yield/plant, the most desirable standard heterotic effects were obtained for the cross $P_6 \times P_8$ relative to S.C. 10 and S.C. 30k8, recording 20.10% and 17.72% in the combined analyses, respectively. The best standard heterosis effects for protein (%) were detected in the cross $P_4 \times P_7$ relative to both checks in the second planting date and the combined analyses. For oil (%), the best heterosis values relative to both checks were detected for the cross $P_1 \times P_2$ in the combined analyses. The correlation coefficient values between grain yield/plant and each of chlorophyll content, ear length, ear diameter, number of rows/ear, number of grains/row, 100 grain weight and shelling (%) were positive and highly significant. The factor analysis technique divided the studied variables into four main factors accounted for 77.83% of the total variance. The first factor included four variables *i.e.,* ear length, number of rows/ear, number of grains/row and shelling (%) and accounted for 21.15%. While, the second factor consisted of two variables *i.e.,* plant and ear heights and accounted for 19.73% of the total variance. The third factor included two variables namely, days to 50% tasseling and silking and accounted for 19.00% of total variance. Three variables were loaded in the fourth factor *i.e.,* chlorophyll content, ear diameter and 100 grain weight and accounted for 17.95% of the total variance of the dependence structure.

Key words: Maize, standard heterosis, correlation, factor analysis.

INTRODUCTION

Maize (*Zea mays*, L.) is one of the most important cereal crops in Egypt and the world. It ranks the third among the world cereal crops, surpassed only by wheat and rice. In 2013 the area allotted to this crop in Egypt was 1.724 million faddans and total production was 5.788.000 million tons of grains with an average yield of 23.98 ardab/faddan. However, the total production is far less than that required for local consumption. Recently, efforts have been made to increase food and agricultural production, mainly through developing new hybrids characterized by high yielding potentiality and better quality to fill the gap between maize production and consumption. This depends mainly upon the exploitation of heterosis in maize breeding program.

Heterosis is the phenomenon in which the cross of two parents produces hybrid that is superior in growth, size, yield, or vigor of the F_1

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over the better parent. It 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 favourable biological prerequisites such as large multiplication coefficient and easy of both self and controlled cross- fertilization (Ram *et al.*, 2015). The magnitude of heterosis provides formation on extent of genetic diversity of parents in developing superior F_1's so as to exploit hybrid vigour and has direct bearing on the breeding methodology to be adapted for varietal improvement (Rajesh *et al.,* 2014). Several investigators calculated heterosis in maize over mid-parent (relative heterosis), over better-parent (heterobeltiosis) and over check (standard heterosis). Among those are (Ali *et al*., 2014; Abrha, 2014; Ram *et al*., 2015). In this concern, significant standard heterosis for grain yield and its contributing traits were detected and revealed that it can be used as a tool for high productivity in maize (Zaid *et al*., 2014; Reddy *et al*., 2015). Abrha (2014) concluded that the presence of substantial heterotic potential could be exploited in maize breeding program for the developing of desirable cross combinations and synthetic varieties through crossing and/ or recombination of inbred lines with desirable traits of interest.

Also, maize breeders are interested in studying the nature of relationship between maize grain yield and its contributing traits which help the breeders to select the best genotypes based on yield and related characters. Therefore, applying simple correlation and factor analysis are very helpful since factor analysis is a type of multivariate analysis that can be used to reduce a large number of correlated variables to a smaller number of main factors (Beshay, 2010; Beiragi *et al.* 2012; Khodarahmpour, 2013). Factor analysis is used by plant breeders because it has the potential of increasing the comprehension of causal relationship of variables and can help to determine the nature and sequence of traits to be selected in breeding program. Filipovic *et al.* (2014) determined the interrelationships of yield and yield components of 15 commercial maize hybrids using factor analysis and extracted two main factors responsible for 60.51% of total variability. The first factor accounted for 47.71%, while the second factor accounted for 12.8% of the total variance in the dependence structure. Sayedzavar *et al.* (2015) studied factor analysis and found that two factors justified 78% of total variance. The first factor (50.8%) had the great coefficient on 300-grain weight, plant height, length of ear, ear leaf area, ear diameter and cob diameter. The second factor (27.2%) had the great coefficient on plant dry weight, number of grains per row, number of leaves per plant, number of rows per ear and grain yield. Therefore, the objectives of this investigation were to: 1- Identify superior hybrids to improve the yielding ability in maize breeding program. 2- Studying correlation and factor analysis for several variables related to maize grain yield.

MATERIALS AND METHODS

Ten diverse parental inbred lines of white maize (*Zea mays* L.) were used in this study *i.e.* P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8, P_9 and P_{10}. These parental inbred lines were isolated from different genetic resources and were at S_8 stage of inbreeding. All these parental inbreds were developed at the Department of Agronomy, Faculty of Agriculture, Benha University, by Prof. Dr. S.A. Sedhom and represented a wide range of variability for yield and most of its attributes. The names, origin and characteristics of these inbred lines are presented in Table 1. A half diallel set of crosses was carried out in 2013 season. The ten inbred lines were split planted on May 15th, 25th and June 5th to avoid differences in flowering time and to secure enough hybrid seeds. In 2014 summer season, the resultant 45 crosses along with two checks (S.C. 10 and S.C. 30 k 8) were planted in a randomized complete block design with three replications on two planting dates, *i.e.,* 15th May and 15th June at the Agricultural Research and Experimental Station of the Fac. Agric., Benha University. On each planting date, experimental plot consisted of one ridge of three m length and 70 cm width. Hills were spaced by 25 cm with three seeds per hill on one side of the ridge. The seedlings were later thinned to one plant per hill. The cultural practices were followed properly for ordinary maize field in the area.

Table 1. The name, origin and characteristics of the studied ten parental inbred lines

Parent code	Parent name	Origin	Days to 50% silking	Plant height (cm)	No. of rows ear^{-1}	Grain yield (g) plant^{-1}
P1	M2	Cairo 1	66.80±0.37	251.20±0.80	12.40±0.40	35.60±1.96
P2	M3	Cairo 1	68.40±0.51	260.40±0.51	12.40±0.97	32.40±1.12
P3	M5	Cairo 1	57.20±0.58	234.00±1.18	14.40±0.40	40.80±1.02
P4	M10	Giza 2	60.00±0.71	195.00±2.54	12.00±0.63	64.20±0.97
P5	M12	Giza 2	57.50±0.37	140.00±1.70	14.00±0.63	89.60±1.63
P6	M14	Giza 2	64.80±0.37	158.20±1.85	12.40±0.40	62.40±1.36
P7	M19	Giza 2	62.80±0.37	162.00±2.02	12.00±0.63	40.80±1.32
P8	M20	Pioneer 514	64.20±0.58	187.20±1.16	13.60±0.74	78.60±2.04
P9	M21	Pioneer 514	61.80±0.58	214.00±1.87	12.00±0.63	52.20±1.24
P10	M24	Pioneer 514	68.20±0.37	176.00±1.87	12.40±0.40	45.60±1.12

Data Recorded

Earliness traits

In each experimental plot, days to 50% tasseling and days to 50% silking were estimated.

Morphophysiological traits

Plant height (cm), ear height (cm) and chlorophyll content (SPAD value) of ear leaf were measured from 10 random plants in each plot in each replicate.

Yield and its attributes

Random sample of 10 guarded plants in each plot was taken to evaluate ear length (cm) ear diameter (cm), No. of grains/row, No. of rows/ ear, shelling (%), 100-grain weight, and grain yield/plant which was adjusted for 15.5% moisture.

Quality traits

Protein (%) and oil (%) were determined according to AOAC (1990).

Statistical Analysis

The obtained data were statistically analyzed for each planting date and the combined analysis was performed whenever homogeneity of variance was detected (Gomez and Gomez, 1984). Standard heterosis was calculated for days to 50% tasseling, days to 50% silking, chlorophyll content, grain yield / plant, protein (%) and oil (%) as follows:

$$\text{Standard heterosis} = \left[\frac{F_1 \text{ - check variety}}{\text{check variety}} \times 100\right]$$

Appropriate LSD values were computed according to the following formulae to test the significance of heterotic effects.

LSD for heterosis relative to check variety =

$$t \text{ x } \sqrt{\frac{2MSe}{r}}$$

Where:

t: is the tabulated t value at a stated level of probability for the experimental error degree of freedom.

r: is the number of replications.

Simple correlation coefficient was estimated according to Snedecor and Cochran (1967). Correlation coefficients were used to calculate factor analysis according to Cattell (1965).

RESULTS AND DISCUSSION

Standard Heterosis

Superiority of studied crosses over both checks (S.C. 10 and S.C. 30k8) in the first and second planting dates as well as combined analysis were calculated for different traits as follows:

Earliness traits

Standard heterosis values for days to 50% tasseling and days to 50% silking in each planting date as well as combined data are presented in Tables 2 and 3. For days to 50% tasseling, sixteen, twenty six and twenty six crosses exhibited significant and negative standard heterotic values relative to S.C. 10; eleven, twenty three and twenty three hybrids relative to S.C. 30k8 in the first, second planting dates and combined analysis, respectively (Table 2). However, the single cross P_5 x P_6 expressed the most desirable heterotic effect for this trait recoding -11.54, -11.76 and -11.65% relative to S.C. 10 and -10.56, -11.24 and -10.89 relative to S.C. 30k8 in the first, second planting dates and combined data, respectively.

For days to 50% silking, seven, thirty six and thirty one crosses expressed significant and negative standard heterotic values relative to S.C. 10 in the first, second planting dates and combined analysis, respectively. While, six, fourteen and sixteen hybrids exhibited significant and negative heterotic effects relative to S.C. 30k8 in the same order (Table 3). However, the hybrid $P_4 \times P_5$ gave the best standard heterotic effects being -10.94, -17.53 and -14.25% relative to S.C. 10 and -10.47, -12.57 and -11.50% relative to S.C. 30k8 in the first and second planting dates as well as combined data, respectively.

Earliness if found in corn crosses is favourbale for escaping destructive injuries caused by *Sesamia cretica ledi chilo simplex* and *Pyrausta nubilalis*. Similar results were obtained by Abd-Elaziz (2014), Abrha (2014), Al- Falahy (2015) and Reddy *et al*. (2015) who found significant and negative standard heterosis for days to 50% tasseling and days to 50% silking.

Morphophysiological traits

Standard heterosis for plant height, ear height and chlorophyll content relative to both checks in the first and second planting date as well as combined analysis are presented in Tables 4, 5 and 6.

Regarding plant height, standard heterosis relative to S.C. 10 ranged from -22.59 to 3.67; -27.82 to -2.59 and -21.42 to 0.51 in the first, second planning dates as well as combined analysis, respectively. The respective heterotic values for the check S.C. 30k8 ranged from -18. 67 to 8.92; -26.32 to -0.57 and -18.65 to 4.06%. However, the single cross $P_5 \times p_7$ exhibited the best heterotic values in the first planting date, while the cross $P_1 \times P_8$ expressed the most desirable standard heterosis for plant height in the second planting date as well as combined analysis relative to both checks.

For ear height, heterotic effects relative to S.C. 10 ranged from -19.87 to 8.04; -26.83 to -0.44 and -21.25 to 1.67% in the first, second planting dates as well as combined data, respectively. The heterotic values relative to S.C. 30 k8 ranged from -13.91 to 16.07; -20.29 to 8.45 and -14.80 to 9.99% for the respective cases. However, the best standard heterosis effects were detected for the cross $P_5 \times P_7$ in the first plant date relative to S.C. 10 (-19.87%) and S.C. 30 k8 (-13.91%). Meanwhile, the cross P_1 x P_8 gave the best heterotic effect in the second planting date (-26.83 and -20.29%) as well as combined analysis (-21.25 and -14.80%) relative to S.C. 10 and S.C. 30 k8, respectively. These results of plant and ear heights are in agreement with those reported by Abd-Elaziz (2014), Abdel-Moneam *et al.* (2014), Abrha (2014) and Zaid *et al.* (2014).

For Chlorohphyll content, eight, nine and twelve crosses exhibited significant and positive heterotic effects relative to S.C. 10 in the first, second planting dates and combined data, respectively. Significant and positive standard heterosis relative to SC 30k 8 were detected for six, five and eight crosses in the same manner. However, the most desirable heterotic effects for chlorophyll content were detected for the cross $P_5 \times P_6$ recording 14.36; 27.38 and 20.61% relative to S.C. 10 and 10.56, 21.20 and 15.70% relative to SC 30k8, in the first, second planting date and combined data, respectively (Table 6). Moreover, the best heterotic effect for this trait was recorded by the cross $P_5 \times P_6$ (20.61 and 15.70%) followed by the cross $P_6 \times P_8$ (16.40 and 11.66%) then the cross $P_6 \times P_{10}$ (16.24 and 11.51%) relative to S.C. 10 and SC 30k8 in the combined data. These results are in accordance with Ulaganathan and Ibrahim (2014).

Table 2. Heterosis for days to 50% tasseling relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Days to 50% tasseling					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	D1	D2	Com.	D1	D2	Com.
P1 × P2	-8.24*	-8.82**	-8.52**	-7.22*	-8.28**	-7.74**
P1 × P3	-6.04	-8.24**	-7.10**	-5.00	-7.69**	-6.30**
P1 × P4	-6.04	-5.88*	-5.97**	-5.00	-5.33*	-5.16*
P1 × P5	-3.30	-5.29*	-4.26	-2.22	-4.73	-3.44
P1 × P6	-1.10	-6.47*	-3.69	0.00	-5.92*	-2.87
P1 × P7	-4.40	-4.71	-4.55*	-3.33	-4.14	-3.72
P1 × P8	-2.75	0.00	-1.42	-1.67	0.59	-0.57
P1 × P9	-3.30	-11.18**	-7.10**	-2.22	-10.65**	-6.30**
P1 × P10	6.04	-2.35	1.99	7.22*	-1.78	2.87
P2 × P3	11.54**	-8.24**	1.99	12.78**	-7.69**	2.87
P2 × P4	-6.04	-10.59**	-8.24**	-5.00	-10.06**	-7.45**
P2 × P5	-4.40	-3.53	-3.98	-3.33	-2.96	-3.15
P2 × P6	3.30	-7.06**	-1.70	4.44	-6.51*	-0.86
P2 × P7	-2.20	-5.88*	-3.98	-1.11	-5.33*	-3.15
P2 × P8	-7.69*	-8.24**	-7.95**	-6.67	-7.69**	-7.16**
P2 × P9	-3.85	-11.76**	-7.67**	-2.78	-11.24**	-6.88**
P2 × P10	-8.24*	-8.24**	-8.24**	-7.22*	-7.69**	-7.45**
P3 × P4	-7.14*	-9.41**	-8.24**	-6.11	-8.88**	-7.45**
P3 × P5	-2.75	-1.76	-2.27	-1.67	-1.18	-1.43
P3 × P6	-6.59	-6.47*	-6.53**	-5.56	-5.92*	-5.73*
P3 × P7	-8.79*	-5.29*	-7.10**	-7.78*	-4.73	-6.30**
P3 × P8	-9.89**	-5.88*	-7.95**	-8.89*	-5.33*	-7.16**
P3 × P9	-1.65	-10.00**	-5.68*	-0.56	-9.47**	-4.87*
P3 × P10	-7.14*	-7.06**	-7.10**	-6.11	-6.51*	-6.30**
P4 × P5	-11.54**	-11.18**	-11.36**	-10.56**	-10.65**	-10.60**
P4 × P6	-9.34**	-10.00**	-9.66**	-8.33*	-9.47**	-8.88**
P4 × P7	-9.89**	-5.29*	-7.67**	-8.89*	-4.73	-6.88**
P4 × P8	-10.99**	-6.47*	-8.81**	-10.00**	-5.92*	-8.02**
P4 × P9	-9.89**	-11.76**	-10.80**	-8.89*	-11.24**	-10.03**
P4 × P10	-6.59	-1.76	-4.26	-5.56	-1.18	-3.44
P5 × P6	-11.54**	-11.76**	-11.65**	-10.56**	-11.24**	-10.89**
P5 × P7	-8.24*	-3.53	-5.97**	-7.22*	-2.96	-5.16*
P5 × P8	-4.95	-0.59	-2.84	-3.89	0.00	-2.01
P5 × P9	-2.20	-7.65**	-4.83*	-1.11	-7.10**	-4.01
P5 × P10	-3.30	10.59**	3.41	-2.22	11.24**	4.30
P6 × P7	-5.49	-3.53	-4.55*	-4.44	-2.96	-3.72
P6 × P8	-7.14*	-3.53	-5.40*	-6.11	-2.96	-4.58*
P6 × P9	-3.30	0.59	-1.42	-2.22	1.18	-0.57
P6 × P10	-3.30	5.29*	0.85	-2.22	5.92*	1.72
P7 × P8	-6.59	-1.76	-4.26	-5.56	-1.18	-3.44
P7 × P9	-7.69*	-4.12	-5.97**	-6.67	-3.55	-5.16*
P7 × P10	-2.75	8.82**	2.84	-1.67	9.47**	3.72
P8 × P9	-6.04	-1.18	-3.69	-5.00	-0.59	-2.87
P8 × P10	10.44**	10.00**	10.23**	11.67**	10.65**	11.17**
P9 × P10	1.65	8.82**	5.11*	2.78	9.47**	6.02**

D1 , D2 and com. refer to first , second planting dates and combined data, respectively.

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

Table 3. Heterosis for days to 50% silking relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Days to 50% silking					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	D1	D2	Com.	D1	D2	Com.
P1 × P2	-3.13	-7.73*	-5.44*	-2.62	-2.19	-2.41
P1 × P3	-0.52	-11.34**	-5.96**	0.00	-6.01	-2.94
P1 × P4	-4.69	-12.37**	-8.55**	-4.19	-7.10*	-5.61*
P1 × P5	1.04	-7.22*	-3.11	1.57	-1.64	0.00
P1 × P6	1.56	-10.82**	-4.66*	2.09	-5.46	-1.60
P1 × P7	-2.60	-10.31**	-6.48**	-2.09	-4.92	-3.48
P1 × P8	1.04	0.00	0.52	1.57	6.01	3.74
P1 × P9	0.52	-17.01**	-8.29**	1.05	-12.02**	-5.35*
P1 × P10	5.73	-8.76**	-1.55	6.28*	-3.28	1.60
P2 × P3	9.90**	-12.37**	-1.30	10.47**	-7.10*	1.87
P2 × P4	-4.69	-16.49**	-10.62**	-4.19	-11.48**	-7.75**
P2 × P5	-1.56	-9.79**	-5.70**	-1.05	-4.37	-2.67
P2 × P6	2.08	-12.89**	-5.44*	2.62	-7.65*	-2.41
P2 × P7	2.60	-10.82**	-4.15	3.14	-5.46	-1.07
P2 × P8	-4.69	-12.37**	-8.55**	-4.19	-7.10*	-5.61*
P2 × P9	-3.13	-7.22*	-5.18*	-2.62	-1.64	-2.14
P2 × P10	-4.69	-13.92**	-9.33**	-4.19	-8.74**	-6.42**
P3 × P4	-3.65	-16.49**	-10.10**	-3.14	-11.48**	-7.22**
P3 × P5	0.00	-4.12	-2.07	0.52	1.64	1.07
P3 × P6	-3.13	-10.31**	-6.74**	-2.62	-4.92	-3.74
P3 × P7	-4.69	-7.73*	-6.22**	-4.19	-2.19	-3.21
P3 × P8	-6.25*	-9.28**	-7.77**	-5.76	-3.83	-4.81*
P3 × P9	1.04	-14.95**	-6.99**	1.57	-9.84**	-4.01
P3 × P10	-4.69	-11.34**	-8.03**	-4.19	-6.01	-5.08*
P4 × P5	-10.94**	-17.53**	-14.25**	-10.47**	-12.57**	-11.50**
P4 × P6	-5.21	-17.01**	-11.14**	-4.71	-12.02**	-8.29**
P4 × P7	-7.29*	-11.34**	-9.33**	-6.81*	-6.01	-6.42**
P4 × P8	-8.33**	-10.82**	-9.59**	-7.85*	-5.46	-6.68**
P4 × P9	-7.29*	-17.01**	-12.18**	-6.81*	-12.02**	-9.36**
P4 × P10	-4.69	-8.25**	-6.48**	-4.19	-2.73	-3.48
P5 × P6	-9.90**	-17.01**	-13.47**	-9.42**	-12.02**	-10.70**
P5 × P7	-7.29*	-9.28**	-8.29**	-6.81*	-3.83	-5.35*
P5 × P8	-3.65	-4.64	-4.15	-3.14	1.09	-1.07
P5 × P9	-0.52	-11.86**	-6.22**	0.00	-6.56*	-3.21
P5 × P10	0.00	3.61	1.81	0.52	9.84**	5.08*
P6 × P7	-3.13	-10.82**	-6.99**	-2.62	-5.46	-4.01
P6 × P8	-5.21	-10.31**	-7.77**	-4.71	-4.92	-4.81*
P6 × P9	-1.04	-4.64	-2.85	-0.52	1.09	0.27
P6 × P10	-1.04	0.52	-0.26	-0.52	6.56*	2.94
P7 × P8	0.00	-6.70*	-3.37	0.52	-1.09	-0.27
P7 × P9	-4.69	-9.79**	-7.25**	-4.19	-4.37	-4.28
P7 × P10	-0.52	1.55	0.52	0.00	7.65*	3.74
P8 × P9	-4.69	-8.76**	-6.74**	-4.19	-3.28	-3.74
P8 × P10	9.38**	5.67	7.51**	9.95**	12.02**	10.96**
P9 × P10	2.08	4.12	3.11	2.62	10.38**	6.42**

D1 , D2 and com., refer to first , second planting dates and combined data, respectively.
* and ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 4. Heterosis for plant height relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Plant height (cm)					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	**D1**	**D2**	**Com.**	**D1**	**D2**	**Com.**
P1 × P2	-3.33	-3.83	-3.58	1.57	-1.84	-0.18
P1 × P3	-9.52*	-8.00	-8.75**	-4.94	-6.09	-5.53
P1 × P4	-8.94*	-9.01	-8.98**	-4.34	-7.13	-5.76
P1 × P5	-8.72	-6.64	-7.67*	-4.10	-4.71	-4.41
P1 × P6	-9.17*	-6.76	-7.95*	-4.58	-4.83	-4.71
P1 × P7	-15.94**	-12.16**	-14.03**	-11.69*	-10.34*	-11.00*
P1 × P8	-14.91**	-27.82**	-21.42**	-10.60*	-26.32**	-18.65*
P1 × P9	-12.27**	-4.17	-8.18*	-7.83	-2.18	-4.94
P1 × P10	-2.52	-13.85**	-8.24*	2.41	-12.07*	-5.00
P2 × P3	3.67	-2.59	0.51	8.92	-0.57	4.06
P2 × P4	-0.23	-3.38	-1.82	4.82	-1.38	1.65
P2 × P5	1.61	-5.86	-2.16	6.75	-3.91	1.29
P2 × P6	3.21	-6.53	-1.70	8.43	-4.60	1.76
P2 × P7	-0.80	-8.11	-4.49	4.22	-6.21	-1.12
P2 × P8	-16.06**	-7.88	-11.93**	-11.81*	-5.98	-8.82*
P2 × P9	3.21	-7.66	-2.27	8.43	-5.75	1.18
P2 × P10	-1.49	-8.33	-4.94	3.49	-6.44	-1.59
P3 × P4	2.18	-6.64	-2.27	7.35	-4.71	1.18
P3 × P5	-2.64	-14.41**	-8.58**	2.29	-12.64**	-5.35
P3 × P6	1.03	-15.20**	-7.16*	6.14	-13.45**	-3.88
P3 × P7	-1.95	-15.09**	-8.58**	3.01	-13.33**	-5.35
P3 × P8	-5.28	-23.76**	-14.60**	-0.48	-22.18**	-11.59*
P3 × P9	1.72	-8.22	-3.30	6.87	-6.32	0.12
P3 × P10	-0.57	-10.47*	-5.57	4.46	-8.62	-2.24
P4 × P5	-7.80	-17.79**	-12.84**	-3.13	-16.09**	-9.76*
P4 × P6	-5.85	-8.00	-6.93*	-1.08	-6.09	-3.65
P4 × P7	-8.83*	-9.35*	-9.09**	-4.22	-7.47	-5.88
P4 × P8	-10.89*	-12.73**	-11.82**	-6.39	-10.92*	-8.71*
P4 × P9	-3.67	-11.49*	-7.61*	1.20	-9.66*	-4.35
P4 × P10	-10.21*	-17.12**	-13.69**	-5.66	-15.40**	-10.65*
P5 × P6	-7.91	-15.43**	-11.70**	-3.25	-13.68**	-8.59*
P5 × P7	-22.59**	-17.68**	-20.11**	-18.67**	-15.98**	-17.29*
P5 × P8	-3.67	-12.84**	-8.30*	1.20	-11.03*	-5.06
P5 × P9	-1.83	-17.12**	-9.55**	3.13	-15.40**	-6.35
P5 × P10	-7.80	-18.47**	-13.18**	-3.13	-16.78**	-10.12*
P6 × P7	-5.39	-13.85**	-9.66**	-0.60	-12.07*	-6.47*
P6 × P8	-5.39	-10.81*	-8.13*	-0.60	-8.97	-4.88
P6 × P9	-1.72	-8.56	-5.17	3.25	-6.67	-1.82
P6 × P10	-3.56	-12.05**	-7.84*	1.33	-10.23*	-4.59
P7 × P8	-7.45	-14.19**	-10.85**	-2.77	-12.41**	-7.71*
P7 × P9	-4.13	-10.47*	-7.33*	0.72	-8.62	-4.06
P7 × P10	-11.01*	-14.64**	-12.84**	-6.51	-12.87**	-9.76*
P8 × P9	-4.01	-8.56	-6.31*	0.84	-6.67	-3.00
P8 × P10	-11.93**	-21.62**	-16.82**	-7.47	-20.00**	-13.88*
P9 × P10	-5.96	-20.83**	-13.47**	-1.20	-19.20**	-10.41*

D1 , D2 and com. refer to first , second planting dates and combined data, respectively.

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

Table 5. Heterosis for ear height relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Ear height (cm)					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	**D1**	**D2**	**Com.**	**D1**	**D2**	**Com.**
P1 × P2	0.22	-9.09*	-4.45	7.67	-0.97	3.37
P1 × P3	-5.58	-11.53**	-8.57**	1.44	-3.62	-1.08
P1 × P4	-12.50**	-12.86**	-12.68**	-6.00	-5.07	-5.54
P1 × P5	-11.16*	-10.20*	-10.68**	-4.56	-2.17	-3.37
P1 × P6	-10.04*	-7.76	-8.90**	-3.36	0.48	-1.44
P1 × P7	-18.53**	-11.97**	-15.24**	-12.47*	-4.11	-8.30*
P1 × P8	-15.63**	-26.83**	-21.25**	-9.35	-20.29**	-14.80**
P1 × P9	-11.16*	-7.98	-9.57**	-4.56	0.24	-2.17
P1 × P10	-8.04	-9.09*	-8.57**	-1.20	-0.97	-1.08
P2 × P3	-6.70	-0.44	-3.56	0.24	8.45	4.33
P2 × P4	1.12	-4.88	-1.89	8.63	3.62	6.14
P2 × P5	0.67	-1.33	-0.33	8.15	7.49	7.82*
P2 × P6	6.92	-3.55	1.67	14.87**	5.07	9.99**
P2 × P7	7.14	-7.54	-0.22	15.11**	0.72	7.94*
P2 × P8	-1.34	-11.53**	-6.45*	6.00	-3.62	1.20
P2 × P9	8.04	-8.43	-0.22	16.07**	-0.24	7.94*
P2 × P10	7.59	-5.54	1.00	15.59**	2.90	9.27**
P3 × P4	0.22	-9.31*	-4.56	7.67	-1.21	3.25
P3 × P5	-1.12	-15.30**	-8.23*	6.24	-7.73	-0.72
P3 × P6	-2.68	-14.63**	-8.68**	4.56	-7.00	-1.20
P3 × P7	0.22	-11.53**	-5.67	7.67	-3.62	2.05
P3 × P8	-1.56	-24.17**	-12.90**	5.76	-17.39**	-5.78
P3 × P9	4.69	-5.10	-0.22	12.47*	3.38	7.94*
P3 × P10	-4.46	-9.98*	-7.23*	2.64	-1.93	0.36
P4 × P5	-3.57	-13.30**	-8.45**	3.60	-5.56	-0.96
P4 × P6	-8.26	-17.29**	-12.79**	-1.44	-9.90*	-5.66
P4 × P7	-11.38*	-13.53**	-12.46**	-4.80	-5.80	-5.29
P4 × P8	-15.85**	-12.64**	-14.24**	-9.59	-4.83	-7.22*
P4 × P9	-5.58	-12.64**	-9.12**	1.44	-4.83	-1.68
P4 × P10	-12.50**	-13.53**	-13.01**	-6.00	-5.80	-5.90
P5 × P6	-12.28*	-14.19**	-13.24**	-5.76	-6.52	-6.14
P5 × P7	-19.87**	-17.07**	-18.46**	-13.91**	-9.66*	-11.79**
P5 × P8	-6.47	-16.19**	-11.35**	0.48	-8.70	-4.09
P5 × P9	-11.83*	-16.41**	-14.13**	-5.28	-8.94	-7.10*
P5 × P10	-6.25	-16.85**	-11.57**	0.72	-9.42*	-4.33
P6 × P7	-5.36	-23.50**	-14.46**	1.68	-16.67**	-7.46*
P6 × P8	-8.04	-10.64*	-9.34**	-1.20	-2.66	-1.93
P6 × P9	-9.15	-10.86*	-10.01**	-2.40	-2.90	-2.65
P6 × P10	-4.46	-10.42*	-7.45*	2.64	-2.42	0.12
P7 × P8	-9.82*	-13.30**	-11.57**	-3.12	-5.56	-4.33
P7 × P9	-7.37	-13.30**	-10.34**	-0.48	-5.56	-3.01
P7 × P10	-8.93	-14.63**	-11.79**	-2.16	-7.00	-4.57
P8 × P9	-6.70	-10.42*	-8.57**	0.24	-2.42	-1.08
P8 × P10	-13.62**	-18.18**	-15.91**	-7.19	-10.87*	-9.03*
P9 × P10	-8.71	-16.85**	-12.79**	-1.92	-9.42*	-5.66

D1 , D2 and com. refer to first , second planting dates and combined data, respectively.

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

Table 6. Heterosis for chlorophyll content relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Chlorophyll content					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	D1	D2	Com.	D1	D2	Com.
P1 × P2	5.72	9.59	7.57*	2.20	4.26	3.20
P1 × P3	4.31	-3.64	0.49	0.84	-8.32	-3.59
P1 × P4	-4.73	-0.64	-2.77	-7.90	-5.47	-6.72
P1 × P5	-1.57	11.09	4.51	-4.84	5.70	0.26
P1 × P6	-11.24*	-0.78	-6.22	-14.20**	-5.60	-10.04**
P1 × P7	-20.71**	4.40	-8.66*	-23.35**	-0.67	-12.38**
P1 × P8	-14.97**	8.56	-3.68	-17.80**	3.29	-7.60*
P1 × P9	-23.02**	-5.87	-14.79**	-25.58**	-10.44	-18.26**
P1 × P10	-5.99	2.00	-2.16	-9.12*	-2.96	-6.14
P2 × P3	8.50	12.74*	10.54**	4.89	7.26	6.04
P2 × P4	12.87**	11.40	12.17**	9.12*	5.99	7.60*
P2 × P5	8.91*	11.54	10.17**	5.28	6.12	5.69
P2 × P6	11.70**	10.84	11.28**	7.98	5.45	6.76
P2 × P7	12.39**	15.86*	14.06**	8.65*	10.24	9.42**
P2 × P8	14.05**	18.33**	16.11**	10.26*	12.59*	11.38**
P2 × P9	7.90	16.44**	12.00**	4.31	10.79	7.44*
P2 × P10	7.95	17.72**	12.64**	4.35	12.01*	8.06*
P3 × P4	1.22	4.48	2.78	-2.15	-0.59	-1.40
P3 × P5	-4.23	-8.73	-6.39	-7.42	-13.17*	-10.20**
P3 × P6	-0.33	4.91	2.18	-3.65	-0.19	-1.97
P3 × P7	0.89	5.04	2.88	-2.47	-0.06	-1.30
P3 × P8	1.89	1.16	1.54	-1.50	-3.76	-2.59
P3 × P9	3.73	4.57	4.13	0.28	-0.51	-0.10
P3 × P10	2.38	10.52	6.28	-1.03	5.15	1.96
P4 × P5	4.64	5.09	4.85	1.15	-0.01	0.59
P4 × P6	2.71	4.59	3.61	-0.71	-0.49	-0.61
P4 × P7	-3.99	5.94	0.77	-7.19	0.80	-3.32
P4 × P8	-4.32	3.35	-0.64	-7.51	-1.67	-4.68
P4 × P9	-8.44	1.86	-3.50	-11.49**	-3.09	-7.42*
P4 × P10	0.52	12.25*	6.15	-2.83	6.80	1.83
P5 × P6	14.36**	27.38**	20.61**	10.56*	21.20**	15.70**
P5 × P7	-3.79	2.96	-0.56	-7.00	-2.04	-4.60
P5 × P8	-0.15	3.89	1.79	-3.47	-1.16	-2.35
P5 × P9	-7.77	6.22	-1.06	-10.84*	1.06	-5.08
P5 × P10	2.93	8.06	5.39	-0.50	2.81	1.10
P6 × P7	-10.55*	-2.07	-6.48	-13.53**	-6.83	-10.29**
P6 × P8	13.94**	19.06**	16.40**	10.15*	13.28*	11.66**
P6 × P9	-12.16**	-1.98	-7.28*	-15.09**	-6.74	-11.05**
P6 × P10	13.41**	19.31**	16.24**	9.63*	13.51*	11.51**
P7 × P8	-5.66	4.89	-0.60	-8.80*	-0.20	-4.64
P7 × P9	-12.53**	2.64	-5.25	-15.44**	-2.35	-9.11*
P7 × P10	-2.12	1.23	-0.51	-5.38	-3.68	-4.56
P8 × P9	-6.31	1.81	-2.41	-9.43*	-3.13	-6.38
P8 × P10	-6.83	0.08	-3.52	-9.93*	-4.78	-7.44*
P9 × P10	1.14	0.78	0.97	-2.23	-4.12	-3.14

D1 , D2 and com. refer to first , second planting dates and combined data, respectively.

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

Grain yield/ plant

Standard heterosis effects for grain yield/ plant relative to S.C. 10 and S.C. 30k8 in both planting dates as well as combined analysis are presented in Table 7. Results indicate that three, four and four crosses expressed significant and positive standard heterosis relative to S.C. 10 in the first, second planting dates as well as combined analysis, respectively. Three single crosses exhibited significant and positive heterotic effects relative to S.C. 30 k8, in the respective case. However, the cross combination $P_6 \times P_8$ gave the most desirable heterotic effects relative to S.C. 10 recording 17.98; 22.81 and 20.10% in the first, second planting dates and combined data, respectively. The respective values for this cross relative to S.C. 30 k8 were 17.18, 18.39 and 17.72%. Moreover, the cross $P_6 \times P_{10}$ ranked the second best for heterosis relative to S.C. 10 (19.23%) and S.C. 30 k8 (16.87%) in the combined data. Also, the cross $P_5 \times P_6$ ranked the third best recording heterotic values of 18.17 and 15.83% relative to S.C. 10 and S.C. 30 k8, respectively in the combined analysis. Similar results were reported by Sedhom *et al*. (2012), El-Badawy (2013), Abd-Elaziz (2014), Abdel-Moneam *et al.* (2014), Zaid *et al.* (2014), Ram *et al*. (2015) and Reddy *et al*. (2015).

Quality traits

Standard heterosis effects for protein (%) and oil (%) relative to S.C. 10 and S.C. 30 k8 in both planting dates as well as combined analysis are presented in Tables 8 and 9. Results indicate that heterosis effects for protein (%) relative to S.C. 10 ranged from -18.80 to 22.02, -18.06 to 18.00 and -16.48 to 19.12% in the first, second planting dates and combined analyses, respectively. The respective values of heterotic effects relative to S.C. 30k8 ranged from -24.74 to 13.10, -19.53 to 15.89 and -20.34 to 13.62%. However, the single cross $P_2 \times P_8$ gave the most desirable heterotic effects in the first planting date recording 22.02% and 13.10% relative to S.C. 10 and S.C. 30k8, respectively (Table 8). Meantime, the cross $P_4 \times P_7$ expressed the highest positive and significant heterotic effects for protein (%) recording 18.00 and 19.12% relative to S.C. 10 and 15.89 and 13.62% relative to S.C. 30k8, in the second planting date and combined analyses, respectively.

In regard to oil content, three, five and one crosses exhibited positive and significant heterotic effects relative to S.C. 10 in the first, second planting dates well as combined data, respectively. One, four and one cross expressed desirable heterotic effects relative to S.C. 30k8 in the three respective cases. However, the cross combination $P_1 \times P_2$ gave the most desirable standard heterosis for oil (%) in the combined analysis (20.02%) relative to S.C. 10 and (16.99%) relative to SC 30 k8. While, the cross $P_1 \times P_4$ gave the best heterotic effects for this trait in the second planting date being 30.11% relative to SC 10 and 28.46% relative to S.C. 30 k8 (Table 9). These results are in agreement with those obtained by Bekele and Rao (2013), Lahane *et al.* (2014) and Ulaganathan and Ibrahim (2014).

From such results, it could be concluded that the single crosses P_5 x P_6, P_6 x P_8 and P_6 x P_{10} are promising and could be used for improving grain yield of maize.

Correlation coefficient and factor analysis

Correlation coefficients between grain yield/ plant and days to 50% tasseling, days to 50% silking, plant height, ear height, chlorophyll content, ear length, ear diameter, number of rows, number of grains/row, 100 grain weight and shelling (%) in the combined data are presented in Table 10. Results indicate that positive and highly significant correlation coefficient values were registered between grain yield/plant and each of chlorophyll content (0.6372**), ear length (0.5116**), ear diameter (0.6074**), number of rows/ear (0.4794**), number of grains/row (0.6909**), 100 grain weight (0.7344**) and shelling (%) (0.4021**). The association between days to 50% tasseling and days to 50% silking (0.9406**) was positive and highly significant. Also, the correlation coefficient between plant height and each of ear height (0.8512**) and chlorophyll content (0.2993*) was positive and significant. Also, the correlation between ear height and chlorophyll content (0.4855**) was positive and highly significant. The association between chlorophyll content and each of number of rows/ear (0.5134**), number of grains/row (0.4235**), 100 grain weight (0.4435**) and shelling (%) (0.3575*) was positive and significant.

Table 7. Heterosis for grain yield/ plant relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Grain yield/ plant (g)					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	D1	D2	Com.	D1	D2	Com.
P1 × P2	-8.90	-7.02	-8.08	-9.52	-10.36	-9.90
P1 × P3	-15.07	1.54	-7.79	-15.65	-2.11	-9.61
P1 × P4	-10.96	-19.08*	-14.52*	-11.56	-21.99*	-16.21**
P1 × P5	-4.28	2.63	-1.25	-4.93	-1.06	-3.20
P1 × P6	-8.90	-3.51	-6.54	-9.52	-6.98	-8.39
P1 × P7	-22.60**	-8.99	-16.63**	-23.13**	-12.26	-18.28**
P1 × P8	-23.46**	-5.92	-15.77**	-23.98**	-9.30	-17.44**
P1 × P9	-30.82**	-12.50	-22.79**	-31.29**	-15.64	-24.32**
P1 × P10	-17.29*	-5.92	-12.31*	-17.86*	-9.30	-14.04*
P2 × P3	-43.15**	-16.89	-31.63**	-43.54**	-19.87*	-32.99**
P2 × P4	-11.30	8.11	-2.79	-11.90	4.23	-4.71
P2 × P5	-3.42	12.72	3.65	-4.08	8.67	1.60
P2 × P6	-4.28	5.26	-0.10	-4.93	1.48	-2.07
P2 × P7	-7.88	-1.97	-5.29	-8.50	-5.50	-7.16
P2 × P8	5.82	21.93*	12.88*	5.10	17.55*	10.65
P2 × P9	-11.99	8.33	-3.08	-12.59	4.44	-5.00
P2 × P10	-3.08	16.01	5.29	-3.74	11.84	3.20
P3 × P4	-11.47	-3.95	-8.17	-12.07	-7.40	-9.99
P3 × P5	-16.44*	-6.80	-12.21*	-17.01*	-10.15	-13.95*
P3 × P6	-2.57	12.72	4.13	-3.23	8.67	2.07
P3 × P7	-15.75	-16.89	-16.25**	-16.33*	-19.87*	-17.91**
P3 × P8	-4.11	-14.04	-8.46	-4.76	-17.12*	-10.27
P3 × P9	-15.41	-15.57	-15.48*	-15.99*	-18.60*	-17.15**
P3 × P10	-31.16**	-6.14	-20.19**	-31.63**	-9.51	-21.77**
P4 × P5	-3.42	-16.23	-9.04	-4.08	-19.24*	-10.84
P4 × P6	-2.91	-23.25*	-11.83*	-3.57	-26.00**	-13.57*
P4 × P7	-9.59	-14.91	-11.92*	-10.20	-17.97*	-13.67*
P4 × P8	-3.60	-16.89	-9.42	-4.25	-19.87*	-11.22
P4 × P9	-4.79	-9.21	-6.73	-5.44	-12.47	-8.58
P4 × P10	-4.97	-23.46**	-13.08*	-5.61	-26.22**	-14.80*
P5 × P6	16.95*	19.74*	18.17**	16.16*	15.43	15.83**
P5 × P7	-8.90	-14.69	-11.44	-9.52	-17.76*	-13.20*
P5 × P8	3.94	10.09	6.63	3.23	6.13	4.52
P5 × P9	-5.31	-26.75**	-14.71*	-5.95	-29.39**	-16.40**
P5 × P10	4.28	-9.21	-1.63	3.57	-12.47	-3.58
P6 × P7	-2.57	-9.87	-5.77	-3.23	-13.11	-7.63
P6 × P8	17.98*	22.81*	20.10**	17.18*	18.39*	17.72**
P6 × P9	-29.45**	-26.32**	-28.08**	-29.93**	-28.96**	-29.50**
P6 × P10	16.95*	22.15*	19.23**	16.16*	17.76*	16.87**
P7 × P8	-14.73	-11.84	-13.46*	-15.31	-15.01	-15.17*
P7 × P9	-23.46**	-23.46**	-23.46**	-23.98**	-26.22**	-24.98**
P7 × P10	-5.48	0.88	-2.69	-6.12	-2.75	-4.62
P8 × P9	-17.81*	-7.24	-13.17*	-18.37*	-10.57	-14.89*
P8 × P10	-11.82	-7.89	-10.10	-12.41	-11.21	-11.88*
P9 × P10	-3.25	3.07	-0.48	-3.91	-0.63	-2.45

D1 , D2 and com. refer to first , second planting dates and combined data, respectively.

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

Table 8. Heterosis for protein (%) relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Protein (%)					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	D1	D2	Com.	D1	D2	Com.
P1 × P2	12.68**	-5.97	3.31	4.44	-7.65*	-1.46
P1 × P3	0.15	-1.97	-0.91	-7.18	-3.72	-5.49*
P1 × P4	18.50**	1.73	10.08**	9.83*	-0.09	4.99*
P1 × P5	14.07**	-3.40	5.29*	5.72	-5.13	0.43
P1 × P6	21.09**	10.30**	15.67**	12.23**	8.33**	10.33**
P1 × P7	-0.75	-9.97**	-5.38*	-8.01*	-11.58**	-9.75**
P1 × P8	-8.83*	5.70	-1.53	-15.50**	3.81	-6.08*
P1 × P9	2.68	-2.27	0.19	-4.83	-4.02	-4.43
P1 × P10	14.46**	1.73	8.07**	6.09	-0.09	3.07
P2 × P3	12.96**	10.00**	11.47**	4.69	8.03*	6.32*
P2 × P4	12.77**	-1.37	5.67*	4.52	-3.14	0.79
P2 × P5	14.07**	-2.99	5.50*	5.72	-4.72	0.63
P2 × P6	10.73*	-1.37	4.65	2.62	-3.14	-0.19
P2 × P7	-0.45	-2.99	-1.72	-7.74	-4.72	-6.26*
P2 × P8	22.02**	4.60	13.27**	13.10**	2.73	8.04**
P2 × P9	12.47**	-9.67**	1.35	4.24	-11.29**	-3.33
P2 × P10	2.68	2.84	2.76	-4.83	1.00	-1.99
P3 × P4	12.38**	-12.39**	-0.06	4.16	-13.95**	-4.68
P3 × P5	2.68	9.88**	6.30*	-4.83	7.92	1.39
P3 × P6	-8.53*	9.04**	0.30	-15.22**	7.09*	-4.33
P3 × P7	-8.53*	-16.75**	-12.66**	-15.22**	-18.24**	-16.69**
P3 × P8	10.73*	-2.69	3.99	2.62	-4.43	-0.82
P3 × P9	-15.79**	-17.16**	-16.48**	-21.95**	-18.65**	-20.34**
P3 × P10	2.68	-6.27	-1.81	-4.83	-7.94*	-6.35*
P4 × P5	6.99	6.90*	6.94**	-0.84	4.98	2.00
P4 × P6	2.68	1.73	2.20	-4.83	-0.09	-2.52
P4 × P7	20.25**	18.00**	19.12**	11.45**	15.89**	13.62**
P4 × P8	-18.80**	8.30*	-5.19*	-24.74**	6.36*	-9.57**
P4 × P9	-1.66	6.90*	2.64	-8.85*	4.98	-2.10
P4 × P10	-5.09	-1.67	-3.37	-12.04**	-3.43	-7.84**
P5 × P6	16.45**	-5.07	5.64*	7.93*	-6.77*	0.76
P5 × P7	-8.74*	2.33	-3.18	-15.41**	0.50	-7.65**
P5 × P8	-15.67**	9.70**	-2.92	-21.84**	7.74*	-7.41**
P5 × P9	16.24**	13.82**	15.02**	7.74	11.79**	9.71**
P5 × P10	-5.09	-12.45**	-8.79**	-12.04**	-14.01**	-13.00**
P6 × P7	-10.73*	-1.07	-5.88*	-17.26**	-2.84	-10.23**
P6 × P8	-8.53*	-0.93	-4.71	-15.22**	-2.70	-9.11**
P6 × P9	-0.45	-9.37**	-4.93	-7.74	-10.99**	-9.32**
P6 × P10	-1.36	-1.97	-1.66	-8.57*	-3.72	-6.21*
P7 × P8	-3.89	-18.06**	-11.01**	-10.92**	-19.53**	-15.12**
P7 × P9	6.69	-7.46*	-0.42	-1.12	-9.12**	-5.02*
P7 × P10	-16.87**	-1.67	-9.24**	-22.95**	-3.43	-13.43**
P8 × P9	-8.23	-12.36**	-10.30**	-14.94**	-13.93**	-14.45**
P8 × P10	16.45**	14.42**	15.43**	7.93*	12.37**	10.10**
P9 × P10	-8.23	10.60**	1.23	-14.94**	8.62**	-3.45

D1 , D2 and com. refer to first , second planting dates and combined data, respectively.
* and ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 9. Heterosis for oil (%) relative to S.C. 10 and S.C. 30 K8 in two planting dates as well as combined data

Trait	Oil (%)					
	Heterosis (%) relative to S.C. 10			Heterosis (%) relative to S.C. 30 K 8		
Cross	D1	D2	Com.	D1	D2	Com.
P1 × P2	23.17*	17.10	20.02**	18.43	15.61	16.99*
P1 × P3	0.15	14.45	7.56	-3.70	12.99	4.84
P1 × P4	-8.85	30.11**	11.35	-12.36	28.46**	8.53
P1 × P5	-2.00	12.88	5.71	-5.77	11.44	3.04
P1 × P6	3.08	6.22	4.71	-0.89	4.87	2.06
P1 × P7	3.93	-12.80	-4.75	-0.07	-13.91	-7.16
P1 × P8	7.54	-1.29	2.97	3.40	-2.54	0.36
P1 × P9	4.31	-3.93	0.04	0.30	-5.16	-2.49
P1 × P10	-4.93	-0.93	-2.86	-8.59	-2.19	-5.31
P2 × P3	-19.78	9.94	-4.38	-22.87*	8.55	-6.79
P2 × P4	-14.40	7.94	-2.82	-17.69	6.57	-5.28
P2 × P5	-7.54	14.09	3.67	-11.10	12.64	1.05
P2 × P6	14.01	13.81	13.90	9.62	12.36	11.02
P2 × P7	0.69	22.17*	11.83	-3.18	20.62*	9.00
P2 × P8	-1.39	4.08	1.45	-5.18	2.75	-1.12
P2 × P9	-42.11**	3.08	-18.69*	-44.34**	1.77	-20.74**
P2 × P10	-14.01	-6.37	-10.05	-17.32	-7.56	-12.32
P3 × P4	-6.08	-5.08	-5.56	-9.70	-6.29	-7.95
P3 × P5	8.62	17.81	13.39	4.44	16.31	10.52
P3 × P6	14.47	-4.94	4.41	10.07	-6.14	1.77
P3 × P7	-9.39	16.81	4.19	-12.88	15.32	1.55
P3 × P8	0.85	16.02	8.71	-3.03	14.55	5.96
P3 × P9	5.31	15.24	10.46	1.26	13.77	7.66
P3 × P10	1.62	16.02	9.08	-2.29	14.55	6.32
P4 × P5	0.08	9.59	5.01	-3.77	8.19	2.35
P4 × P6	18.09	1.29	9.38	13.55	0.00	6.61
P4 × P7	17.17	7.01	11.90	12.66	5.65	9.07
P4 × P8	3.16	13.38	8.45	-0.81	11.94	5.71
P4 × P9	-17.01	18.88*	1.59	-20.21	17.37	-0.98
P4 × P10	19.09	9.30	14.02	14.51	7.91	11.13
P5 × P6	-11.24	2.07	-4.34	-14.66	0.78	-6.76
P5 × P7	28.25*	-5.72	10.64	23.32*	-6.92	7.84
P5 × P8	19.86	7.15	13.27	15.25	5.79	10.41
P5 × P9	3.39	22.10*	13.09	-0.59	20.55*	10.23
P5 × P10	0.23	21.10*	11.05	-3.63	19.56*	8.24
P6 × P7	-22.63*	-6.29	-14.16	-25.61*	-7.49	-16.34*
P6 × P8	9.08	9.59	9.34	4.89	8.19	6.58
P6 × P9	21.71	-2.43	9.20	17.02	-3.67	6.43
P6 × P10	4.08	4.94	4.52	0.07	3.60	1.88
P7 × P8	-5.31	12.66	4.00	-8.96	11.23	1.37
P7 × P9	2.69	-32.55**	-15.57*	-1.26	-33.40**	-17.71*
P7 × P10	21.48	-19.96*	0.00	16.80	-20.97*	-2.53
P8 × P9	0.08	-11.44	-5.90	-3.77	-12.57	-8.28
P8 × P10	25.02*	-16.81	3.34	20.21	-17.87	0.72
P9 × P10	10.32	-3.43	3.19	6.07	-4.66	0.58

D1 , D2 and com., refer to first , second planting dates and combined data, respectively.

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

Table 10. Correlation matrix between grain yield/plant and other important agronomic characters in maize hybrids combined over two planting dates

Trait	1	2	3	4	5	6	7	8	9	10	11	12
1- Grain yield/ plant	1.0000											
2- Days to 50% tasseling	-0.0415	1.0000										
3- Days to 50% silking	-0.0390	0.9406 **	1.0000									
4- Plant height	0.0176	-0.1353	-0.1416	1.0000								
5- Ear height	0.1771	-0.1228	-0.1030	0.8512 **	1.0000							
6- Chlorophyll content	0.6372 **	-0.1731	-0.1722	0.2993 *	0.4855 **	1.0000						
7- Ear length	0.5116 **	0.0181	0.0806	0.0717	0.0200	0.2054	1.0000					
8- Ear diameter	0.6074 **	0.0659	0.0424	-0.1738	-0.2066	0.2580	0.1580	1.0000				
9- No. of rows/ ear	0.4794 **	-0.1840	-0.1757	0.0274	0.0554	0.5134**	0.3638 *	0.2633	1.0000			
10- No. of grains/ row	0.6909 **	-0.1511	-0.1164	0.0761	0.1516	0.4235**	0.7720**	0.3531 *	0.4148**	1.0000		
11- 100 grain weight	0.7344 **	0.0793	0.0428	-0.0973	0.0422	0.4435**	0.0465	0.5978**	0.0713	0.1650	1.0000	
12- Shelling (%)	0.4021 **	0.1920	0.2009	0.0377	0.2266	0.3575 *	0.2328	0.1867	0.1832	0.3851**	0.2612	1.0000

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

Significant and positive correlation values were also detected for ear length and each of number of rows/ear (0.3638*) and number of grains/row (0.7720**). The association between ear diameter and each of number of grains/row (0.3531*) and 100 grain weight (0.5978**) was positive and significant. Furthermore, positive and significant correlation coefficient was found between number of grains/ row and each of number of rows/ear (0.4148**) and shelling (%) (0.3851**). In this connection, significantly positive correlation coefficients between grain yield and its contributing traits were previously reported by several investigators, among those Beshay (2010), El-Badawy and Mehasen (2011), Filipovic *et al.* (2014) and Sayedzavar *et al.* (2015).

Many statistical methods are used to study the relation between independent and dependent variables. Factor analysis is different; it is used to study the patterns of relationship among many dependent variables, with the goal of discovering something about the nature of the independent variables that affect them, even though those independent variables were not measured directly. The inferred independent variables are called factors. Thus, factor analysis is a statistical method used because of its power to elicit underlying multivariate structures (Walton, 1972).

The factor analysis technique divided the studied variables into four main factors (Tables 11, 12 and Fig. 1). These four factors accounted for 77.83% of the total variability in the dependence structure of maize grain yield. The first factor included four variables and accounted for 21.15%. These variables were ear length (32.15%), number of rows ear (22.09%), number of grains row^{-1} (32.01%) and shelling (%) (13.75%). It is clear that these variables had a high loading coefficients and participate much more on the dependence structure. Most of these variables exhibited positive and significant correlation values with maize grain yield as previously mentioned .

The second factor consists of two variables and accounted for 19.73% of the total variability of maize grain yield. These two variables were plant height (48.02%), and ear height (51.98%) as shown in Table 12.

The third factor included two variables and accounted for 19.00% of total variance. These variables were days to 50% tasseling (49.79%) and days to 50% silking (50.21%).

Three variables were loaded in the fourth factor and accounted for 17.95% of the total variance of the dependence structure. These variables were chlorophyll content (25.36%), ear diameter (34.54%) and 100 grain weight (40.11%).

It could be concluded that selection for the most important yield traits particularly number of rows/ear, number of grains/row, 100 grain weight and shelling (%) would lead to maximizing total maize grain yield. These results agree with those obtained by Beshay (2010) El-Badawy and Mehasen (2011), Beiragi *et al.* (2012), Khodarahmpour (2013), Filipovic *et al.* (2014) and Sayedzavar *et al.* (2015).

Table 11. Principal factor matrix after orthogonal rotations for studied characters of maize

Variable	Common factors coefficient				Communality (%)
	Factor 1	Factor 2	Factor 3	Factor 4	
Days to 50% tasseling	-0.085	-0.085	0.957	0.040	0.933
Days to 50% silking	-0.032	0.081	0.965	-0.003	0.939
Plant height (cm)	0.023	0.896	-0.076	-0.139	0.829
Ear height (cm)	0.039	0.970	-0.032	0.011	0.944
Chlorophyll content	0.362	0.518	-0.170	0.569	0.752
Ear length (cm)	0.898	-0.017	0.119	-0.080	0.828
Ear diameter (cm)	0.224	-0.026	0.021	0.775	0.718
No. of rows/ ear	0.617	0.046	-0.243	0.234	0.497
No. of grains/ row	0.897	0.081	-0.059	0.176	0.840
100 grain weight (g)	-0.021	0.021	0.064	0.900	0.815
Shelling (%)	0.384	0.262	0.354	0.356	0.468
Variance ratio	21.15	19.73	19.00	17.95	77.83

Table 12. Summary of factor loading for some important traits of maize

Variable	Loading	Percentage of total communiality	
Factor 1			21.15
Ear length (cm)	0.898	32.15	
No. of rows/ ear	0.617	22.09	
No. of grains/ row	0.894	32.01	
Shelling (%)	0.384	13.75	
Factor 2			19.73
Plant height (cm)	0.896	48.02	
Ear height (cm)	0.970	51.98	
Factor 3			19.00
Days to 50% tasseling	0.957	49.79	
Days to 50% silking	0.965	50.21	
Factor 4			17.95
Chlorophyll content	0.569	25.36	
Ear diameter (cm)	0.775	34.54	
100 grain weight (g)	0.900	40.11	
Cummulative variance			77.83

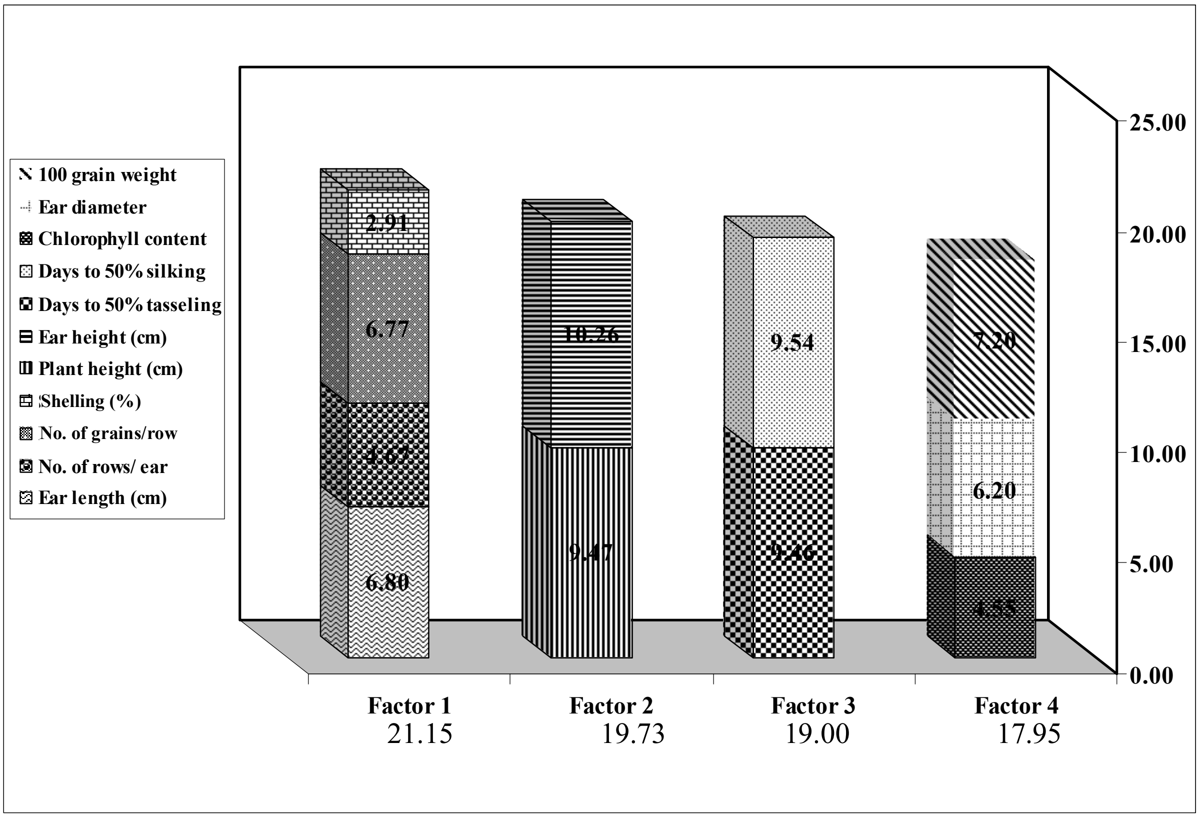

Fig. 1. Factor loading for some important characters of maize

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قــوة الهجيــن والتحليــل العاملى لبعض الصفات الهامة فى هجـــن جـديــدة مــن الــذرة الشــامية

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أجريت هذه الدراسة بمركز البحوث والتجارب الزراعية بكلية الزراعة جامعة بنها بهدف تقدير الزيادة والتفوق فى الجيل الأول لخمسة وأربعون هجيناً عن هجن المقارنة باستخدام عشرة سلالات نقية هى $P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8, P_9, P_{10}$، استخدم لذلك نظام الهجن التبادلية ١٠ × ١٠ وتم تقييم الهجن الناتجة (٤٥ هجينا) مع هجينين للمقارنة (هـ.ف ١٠ و هـ.ف ٣٠ك٨) وذلك فى ميعادين مختلفين للزراعة (١٥ مايو و١٥ يونيه)، وتم تقدير قوة الهجين لعدد الايام حتى ظهور ٥٠% من النورة المذكرة، عدد الأيام حتى ظهور ٥٠% من الحريرة، ارتفاع النبات، ارتفاع الكوز، محتوى كلوروفيل ورقة الكوز، محصول الحبوب/ نبات، نسبة البروتين والزيت وذلك فى كل ميعاد للزراعة وفى التحليل التجميعى للميعادين معاً، وأظهرت النتائج أن الهجين الفردى $P_5 \times P_6$ أعطى أعلى قيمة للتفوق بالنسبة لصفة عدد الأيام حتى طرد ٥٠% من النورة المذكرة ومحتوى ورقة الكوز من الكلوروفيل مقارنة بهجيني المقارنة وذلك فى الميعاد الأول والثانى والتحليل التجميعى، وأعطى الهجين $P_4 \times P_5$ أعلى قوة هجين لصفة عدد الأيام حتى ظهور ٥٠% من الحريرة مقارنة بهجيني المقارنة، بينما اظهر الهجين $P_1 \times P_8$ اعلى تفوق بالنسبة لصفتى ارتفاع النبات وارتفاع الكوز مقارنة بالهجينين فردى ١٠ و ٣٠ك٨ فى ميعادى الزراعة والتحليل التجميعى، وأمكن الحصول على أعلى تفوق لمحصول الحبوب/ نبات مع الهجين $P_6 \times P_8$ والذى بلغ ٢٠,٠١ و ١٧,٧٢% فى التحليل التجميعى نسبة إلى هجين فردى ١٠ وهجين فردى ٣٠ك٨ على الترتيب، وأمكن الحصول على أعلى قيمة تفوق لنسبة البروتين فى الهجين $P_4 \times P_7$ فى ميعاد الزراعة المتآخر والتحليل التجميعى، بينما أعطى الهجين $P_1 \times P_2$ أعلى تفوق لنسبة الزيت فى التحليل التجميعى مقارنة بهجيني المقارنة، كانت قيم معامل الارتباط موجبة ومعنوية بين محصول الحبوب/ نبات وكل من محتوى ورقة الكوز من الكلوروفيل، طول الكوز، قطر الكوز، عدد صفوف الكوز، عدد حبوب الصف، وزن ١٠٠ حبة ومعدل التصافى، قسم التحليل العاملى المتغيرات تحت الدراسة الى أربعة عوامل كانت مسئولة عن ٧٧,٨٣% من التباين الكلى حيث اشتمل العامل الأول على أربعة متغيرات (طول الكوز، عدد صفوف الكوز، عدد حبوب الصف، نسبة التصافى) وساهم بمقدار ٢١,١٥% من التباين الكلى، واشتمل العامل الثانى على متغيرين (ارتفاع النبات وارتفاع الكوز) وساهم بمقدار ١٩,٧٣% من التباين الكلى والعامل الثالث (١٩,٠٠%) على متغيرين فقط (عدد الأيام حتى ظهور ٥٠% من النورة المذكرة، عدد الأيام حتى ظهور ٥٠% من الحريرة)، بينما اشتمل العامل الرابع على ثلاثة متغيرات (محتوى ورقة الكوز من الكلوروفيل، قطر الكوز، وزن ١٠٠ حبة) ساهمت بمقدار ١٧,٩٥% من التباين الكلى.

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