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Heterosis, Combining Ability and Gene Action, for Yield and Yield Component Traits in Maize-Teosinte Hybrids

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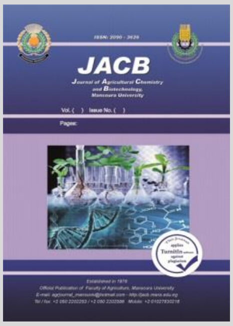

ABSTRACT

Six hybrids were obtained from three male parents of teosinte and two commercial hybrids from maize as female parents, using factorial mating design in the season of 2018. In the two seasons of 2019 and 2020, the five parents and their six F_1 hybrids were evaluated in Randomized Complete Block Design with three replicates. The results showed that the mean squares due to genotypes and their partitions to parents, crosses and their interactions with years; G x Y, P x Y and C x Y were highly significant for all the studied traits except stem diameter for G x Y and P x Y and silking date for C x Y. Crosses were found to be higher than parents in mean performance for most studied traits. The cross P_2 x P_5 exhibited positive and highly significant heterosis relative to mid-parent for number of tillers per plant (81.2%), plant height (61.6), number of leaves per plant (90.7) and total leaf chlorophyll (9.3%). This cross P_2 x P_5 had the best desirable SCA effects for number of tillers per plant, number of leaves per plant, green fodder yield per plant, crude protein and total digestible nutrients. The magnitudes of non-additive genetic variance were larger than their corresponding estimates of additive genetic variance with respect to all studied traits except for fifth leaf area, dry fodder yield per plant, crude protein and total digestible nutrients. The results illustrated that the heritability value in broad sense were ranged from 11.01 % for stem diameter to 97.23 % for fifth leaf area.

Keywords: Heterosis, combining ability, additive and non-additive gene action, Maize- Teosinte hybrids, quantitative traits

INTRODUCTION

The need for green fodder for farm animals has increased in Egypt, especially in the summer season, where the area of fresh fodder is very limited. Therefore, great efforts have been made to increase the quality and quantity of forage yield per unit area. Teosinte is more related to Maize, the hybrids Maize x Teosinte could provide an answer to overcome the problem of shortage in the production of summer forages. The Maize-Teosinte or Teosinte-Maize hybrids have been of considerable interest to Maize and teosinte breeders. Maize-Teosinte or Teosinte-Maize hybrids have also received attention for increasing the potential for teosinte forage production by taking advantage of the hybrid vigor shown by the hybrids. Chaudhuri and Prasad (1969) evaluated the crosses between Maize (*Zea mays* L.) and teosinte for forage production. They indicated that hybrids could be more easily obtained when maize is used as the female parent. The F_1 hybrids possessed the characteristics that contributed to higher forage yields. They had a slightly longer vegetative period than Maize, but had a flowering habit much earlier than teosinte. The hybrids grew faster than both parents and on average had 2-3 producers of plant and consequently more leaves of plant than corn. The forage of the hybrids had a much higher crude protein and sucrose content than either parent and had a higher nutritional value. Therefore, hybrids were considered a potentially valuable forage crop.

Heterosis is a special genetic mechanism in which distant genotypes come together in a specific pattern to express their ability to make a radical change in the extent of a particular trait. The presence of sufficient hybrid vigor is an important prerequisite for the successful production of hybrid varieties. In this regard, Khan (1957) found an appreciable increase in the forage yield of the Maize x Teosinte hybrids, which showed an increase in dry weight compared to the parents of maize and teosinte. Barriere *et al*., (1984) studied protein content and agronomic value in progenies from the cross Maize × Teosinte and reported that the top cross was high fodder yield and protein yield per ha.

A breeding program usually used the information concerning the relative importance of genetic variance components. When the additive gene action represents the main component in the genetic variation, a maximum progress must be expected in the selected character. On the other hand, the presence of a relatively high non-additive gene action indicates that a hybrid program would perform good prospects for the considered character, as results of the direct relationship between the non-additive gene actions. IIchovska *et al*., (1995), in Maize × Teosinte hybrids, Abd El-Maksoud *et al*., (2001), in Teosinte and Aly and Mousa (2008) in Maize, reported that the additive genetic variance played an important role in the inheritance of plant height, grain yield and other traits. Recently, Sakr (2009); Sakr *et al*., (2009) and Sakr and Ghazy (2010), presented information about the nature of gene action for green fodder yield in Teosinte × Maize crosses.

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MATERIALS AND METHODS

The present investigation was carried out during seasons 2018, 2019 and 2020 at farm of Genetic Department, Faculty of Agricultural Mansoura University, Egypt. The genetic materials which used in this investigation were two commercial hybrids of maize (*Zea mays* L.); SC-30K8 (P_1) and SC-2031 (P_2) as female parents and three teosinte genotypes divided from segregated generation; Balsas with Guatemala (P_3), Local variety with Central plateau (P_4) and Domiata (Durra rayyana) (P_5).

During the season of 2018 the three male parents were mated to the two female parents in factorial mating design (two females x three males) by manual pollination to produce their six F_1 hybrids. In the growing season 2019 and 2020, all 11 genotypes (two female, three male parents and their six F_1 hybrids) were evaluated in a Randomized Complete Blocks Design with three replications. Each block contained 11 experimental plots, which included five parents and their six F_1 hybrids. Plot size was one row, 6 m. long and 0.8 m. a part. Data were recorded on ten guarded randomly chosen plants per plot for all genotypes at the two years. The agronomic traits were number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N.L./P.), fifth leaf area (5^{th} L.A.) according to Owen (1968), total leaf chlorophyll (L.Ch.C.), stem diameter (S.d.) in cintimeter, green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.). The forage quality traits, random samples of plants were shopped into 1-2 cm pieces and thoroughly mixed. A 300 g sample of fresh chopped roots was dried in an oven 40^0 c for 2 days and at 70^0 c for 3 days. According to AOAC (2019), Determination of crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

The combined analysis of variance was applied using the procedure (GLM) of SAS (1996). The F-test was used in order to test the significance of difference among the five parental genotypes and their six F_1 hybrids. The amounts of heterosis was determined as the deviation of the F_1 hybrids (F_1) mean over the average of its parents (M.P) and /or the better parent (B.P) for each trait. The significance of Heterosis was determined using least significance differences value (LSD) at 0.05 and 0.01 levels of probability which was suggested by Steel and Torrie (1960). Also, general combining ability (GCA) and specific combining ability (SCA) were estimated. Heritability in broad (H^2_b %) and narrow (H^2_n %) senses were calculated according to Mather (1949) and Allard (1960).

RESULTS AND DISCUSSION

Analysis of variance:

The combined analyses of variance for the agronomic traits are shown in Table 1.

Table 1. Combined analysis of variance and the mean squares of all agronomic traits over two years.

S.O.V	**d.f**	**N.T./P.**	**P.H.**	**N.L./P.**	**5th L. A.**	**L.Ch.C.**
Years (Y)	1	13.2**	38694.36**	86.25*	15904.59**	1343.62**
Rep./Years	4	0.39	62.27	126.42**	21.52	2.44
Genotypes (G)	10	12.196**	31714.063**	12361.246**	122846.012**	206.951**
Parents (P)	4	26.231**	2630.247**	26082.081 **	212516.657**	454.390**
Crosses (C)	5	2.469**	294.768**	2988.640**	18789.066**	42.547**
P. vs. C.	1	4.695	305145.803**	4340.929**	284448.156**	39.218
Females (F)	1	5.617**	205.779**	8734.460**	81655.920**	62.779**
Males (M)	2	2.246**	61.312	767.759**	1841.473**	7.578
F x M	2	1.118**	572.71731**	2336.613**	4303.232**	67.399**
G x Y	10	2.193**	3151.825**	1451.522**	11813.914**	224.316**
P x Y	4	3.982**	3712.074**	659.043**	16891.1889**	283.297**
P vs. C x Y	1	0.384	10800.3096 **	9019.436**	11579.9473 **	986.141**
C x Y	5	1.124**	1173.931**	571.922**	7798.888**	24.766*
F x Y	1	0.635	2351.118**	497.513**	3500.891**	2.811
M x Y	2	1.690**	663.404**	365.305**	16854.148**	17.461
(F x M) x Y	2	0.803*	1095.864**	815.743**	892.625**	43.049**
Error	40	0.309	39.418	35.2735	53.014	8.4205
S.O.V	d.f	S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
Years (Y)	1	0.003	2507232.58**	45721.525**	20776.378**	28272.061**
Rep./Years	4	0.019	15166.03	4.1682	38.087**	8.742
Genotypes (G)	10	0.438**	4905084.25**	12351.896**	6665.367**	5792.145**
Parents (P)	4	0.467**	1036346.780**	13495.312**	14727.992**	14107.216 **
Crosses (C)	5	0.063 *	1444607.769**	4433.166**	174.095**	56.466**
P. vs. C.	1	2.203**	37682416.53**	47371.878**	6871.228**	1210.254
Females (F)	1	0.18346**	2957803.763**	451.350*	327.006**	40.111*
Males (M)	2	0.006	599136.380 **	9688.438**	166.520**	73.083**
F x M	2	0.0593*	1533481.160**	1168.802**	105.215**	48.027*
G x Y	10	0.048	1488492.27**	10867.682**	325.337**	436.127**
P x Y	4	0.017	118693.054**	16283.956 **	588.092**	1011.883**
P vs. C x Y	1	0.01١	6281117.30 **	3103.232	373.969	290.184
C x Y	5	0.081**	1625806.645**	8087.552**	105.406**	4.711
F x Y	1	0.0191	731184.609**	9313.858**	351.563**	16.0
M x Y	2	0.1335**	2210642.729**	3591.563**	71.548**	2.027
(F x M) x Y	2	0.0592*	1488281.579**	11970.389**	16.188	1.750
Error	40	0.035	16812.28	118.6402	11.483	14.109

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

Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).

The results revealed that the mean squares due to genotypes and their partitions to parents, crosses and their interactions with years; G x Y, P x Y and C x Y were highly significant for all the studied traits except stem diameter for G x Y and P x Y and silking date for C x Y. Mean squares due to males and female, their interaction between them (F x M) and their interactions with Y were significant and highly significant for all the studied traits except males for plant height and total leaf chlorophyll, F x Y for plant height, total leaf chlorophyll and stem diameter, M x Y for total leaf chlorophyll and silking date, F x Y for number of tillers per plant, total leaf chlorophyll, stem diameter and silking date and F x M x Y for total leaf chlorophyll, tasseling date and silking date. These results suggests that genotypes of teosinte may have different combining ability pattern and performed differently in crosses depending on type of females and the crosses gave different performances at different environments conditions from year to other. These findings agree with the results obtained by Sakr (2009) and Abdel-Aty *et al*., (2013).

The combined analysis of variance and mean squares of all genotypes for the forage quality traits are presented in Table 2. The results indicated that the magnitude of the mean squares of genotypes, parents, crosses were highly significant for all studies traits except crosses for crude lipid. Moreover, the magnitudes of the mean squares of females were highly significant for all traits except for crude lipid and carbohydrates. The mean squares of males were highly significant for all traits except crude protein and total digestible nutrients and the mean squares of F x M interaction were highly significant for crude protein and total digestible nutrients. Several researchers found that significant difference for all studied traits not only between parents, but also between their F_1 hybrids among those researchers Sakr (2009), Ghazy (2016) and Sakr (2017) in some Maize-Teosinte hybrid.

Table 2. Combined analysis of variances and the mean squares of the forage quality traits over two years.

S.O.V	d.f	C.P.	C. L.	C.F.	Car.	T.D.N.
Years (Y)	1	8.260**	0.142	0.227	3.042	8.669**
Rep./Years	4	1.037	0.172	9.163**	9.711*	1.271
Genotypes(G)	10	7.763**	1.408**	226.711**	146.345**	12.603**
Parents (P)	4	7.253**	2.580**	534.228**	350.267**	18.703**
Crosses (C)	5	3.147**	0.558	19.411**	10.548**	4.046**
P. vs. C.	1	32.887**	0.964	33.143	9.642	30.982**
Females (F)	1	9.080**	0.250	55.328**	5.282	13.395**
Males (M)	2	0.038	0.969*	16.752**	20.129**	0.077
F x M	2	3.291**	0.302	4.112	3.601	3.342**
G x Y	10	1.206*	0.822*	15.405 **	12.304**	1.430*
P x Y	4	1.661**	1.244**	14.999**	17.967**	1.375*
P vs. C x Y	1	0.705	1.092	8.595	0.626	1.165
C x Y	5	0.943	0.430	17.093**	10.110**	1.526*
F x Y	1	0.70	0.031	68.090**	32.928**	2.093**
M x Y	2	0.656	0.112	0.824	1.939	0.787
(F x M) x Y	2	1.352	0.947*	7.863*	6.873*	1.982*
Error	40	0.554	0.376	2.731	3.547	0.655

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**
Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

Mean performance:

The mean of five parents and their six F_1 hybrids for all agronomic traits are presented in Table 3. The mean showed that there were differences between parents and crosses, also between females and males in all studied traits.

There were no one of the parental genotypes was significantly superior in all studied traits. For tasseling date and silking date, no significant differences between the two female parents. While, the P_5 had the best desirable means for these traits with mean values of 154.33 and 160.33 day, respectively. According to females, the P_2 has the best desirable means for all traits except for total leaf chlorophyll, stem diameter and dry fodder yield per plant. For male parents, the P_3 exhibited the highest mean values for plant height (253.17 cm.), total leaf chlorophyll (22.49) and green fodder yield per plant (1973.25 g). While, the P_4 exhibited the highest means for number of leaves per plant (145.65 L.), fifth leaf area (447.68 cm^2.) and stem diameter (1.68 cm.).

Crosses were found to be higher than their parents in most studied traits. The mean performance of the six crosses cleared that, the cross P_2 x P_5 had the best desirable for number of tillers per plant, plant height, number of leaves per plant, stem diameter and green fodder yield with mean values 5.00 t., 387.50 cm., 135.67 L., 2.28 cm. and 3707.22 g., respectively. The cross P_1 x P_5 had the best desirable means for Fifth leaf area (762.03 cm^2.), tasseling date (91.17 day) and silking date (113.00). While, the hybrid P_2 x P_3 had the greatest mean values for dry fodder yield (505.25 g.). Several researchers found significant difference between parents and their F_1 hybrids all studied traits, among those researchers Ghazy (2016) and Sakr (2017) in Maize-Teosinte hybrid and Singh *et al.*, (2020) in Maize.

Table 3. Mean performances of parents and their six F_1 hybrids for all agronomic traits over two years.

Traits Genotypes	N.T./P.	P.H.	N.L./P.	5^{th} L.A.	L.Ch.C.
females P_1	1.00	248.42	14.33	688.94	36.40
P_2	1.00	266.41	15.50	832.14	33.26
males P_3	4.38	253.17	131.42	440.95	22.49
P_4	5.37	229.17	145.65	447.68	17.46
P_5	4.52	213.24	126.79	404.31	18.41
Crosses P_1 x P_3	3.24	385.63	107.24	758.59	30.57
P_1 x P_4	3.43	374.11	79.37	706.21	27.02
P_1 x P_5	3.52	369.00	75.74	762.03	27.84
P_2 x P_3	3.58	376.50	111.44	642.00	22.46
P_2 x P_4	3.98	379.08	108.69	654.68	26.78
P_2 x P_5	5.00	387.50	135.67	644.38	28.25
L.S.D $_{0.05}$	0.92	12.68	9.79	12.01	4.79
L.S.D $_{0.01}$	1.23	16.95	13.09	16.05	6.39
Traits Genotypes	S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
females P_1	6.43	888.33	477.19	65.67	68.50
P_2	4.41	1560.83	463.24	65.75	69.50
males P_3	1.63	1973.25	543.71	158.83	163.83
P_4	1.68	1450.28	522.23	155.17	160.67
P_5	1.56	1131.51	578.49	154.33	160.33
Crosses P_1 x P_3	2.11	3055.74	486.70	102.67	121.50
P_1 x P_4	2.07	2518.96	454.51	95.50	115.33
P_1 x P_5	2.01	2320.42	437.67	91.17	113.00
P_2 x P_3	2.11	3100.64	505.25	102.00	119.00
P_2 x P_4	2.24	2807.08	438.80	106.08	119.50
P_2 x P_5	2.28	3707.22	304.05	99.33	117.67
L.S.D $_{0.05}$	0.309	213.855	17.965	5.589	6.195
L.S.D $_{0.01}$	0.412	285.846	24.012	7.470	8.281

P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).

The mean performances for forage quality traits are presented in Table 4. The results showed that the P_2 was the best and had the highest mean values of crude protein (6.62%) and total digestible nutrients (55.23). While, the P_5 was the best and had the highest mean values for crude fiber (46.47%). Also, the P_1 showed the highest grand mean values for crude lipid (3.04%) and carbohydrates (53.21%). Concerning, the mean values of hybrids, the results indicated that the hybrid P_1 x P_4 was the best and had the highest grand mean for crude protein (7.75%), crude lipid of (2.13%) and total digestible nutrients (55.66). In addition, the hybrid P_1 x P_5 exhibited the highest mean value for carbohydrates (44.83%). The hybrid P_2 x P_3 was the highest mean value for crude fibers (41.99%). These results are in agreement with those obtained by Abdel-Aty *et al*., (2013), Ghazy (2016) and Sakr (2017).

Table 4. Mean performances of parents and their six F_1 hybrids for the forage quality traits over two years.

Traits Genotypes	C.P.	C.L.	C.F.	Car.	T.D.N.
Female P_1	6.43	3.04	27.01	53.21	55.21
P_2	6.62	2.43	29.51	49.28	55.23
Male P3	4.63	1.50	46.44	36.92	51.97
P4	4.18	1.57	42.58	41.92	51.77
P5	4.94	1.79	46.47	35.76	52.29
Crosses P_1 x P_3	7.39	1.81	38.36	43.06	55.41
P_1 x P_4	7.75	2.13	40.14	41.20	55.66
P_1 x P_5	6.69	1.79	37.24	44.83	54.76
P_2 x P_3	6.29	1.28	41.99	41.92	54.01
P_2 x P_4	5.75	2.09	41.43	41.67	53.49
P_2 x P_5	6.78	1.85	39.77	43.20	54.68
L.S.D $_{0.05}$	1.29	1.03	3.12	3.46	1.34
L.S.D $_{0.01}$	1.74	1.38	4.1718	4.62	1.78

P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

Heterosis:

The estimated amounts of heterosis relative to mid-parent (M.P %) were determined for all agronomic studied traits over two years and obtained results are shown in Table 5. The results showed that most of studied crosses exhibited different heterotic values in all traits, which could be due to the difference in the performance of the genotypes when subjected to different environment. In the case of tasseling date and silking date the negative value is desirable as a heterotic effect forward early maturity. Therefore, it could be considered the F_1 hybrid P_1 x P_5 was the best combination for tasseling date and silking date with negative heterotic values -17.1 and -1.2 %. In addition, the results showed that all crosses had positive and highly significant heterosis for number of tillers per plant, plant height and stem diameter. The cross P_2 x P_5 exhibited positive and highly significant heterosis for number of tillers per plant (81.2 %), plant height (61.6 %), number of leaves per plant (90.7 %), total leaf chlorophyll (9.3 %). These results were agreement with these obtained by Sakr and Ghazy (2010), Ghazy (2016) and El-Adl *et al*., (2018).

The estimated amounts of heterosis relative to better parents (B.P %) was determined for all agronomic studied traits over the two years and the obtained results are shown in Table 6. The results showed that there was positive and highly significant heterosis for plant height in all crosses. These values ranged from 41.3 % (P_2 x P_3) to 55.2 (P_1 x P_3). For, number of tillers per plant, number of leaves per plant and total leaf chlorophyll the magnitude of heterosis were negative and highly significant for all crosses except P_2 x P_5 in number of tillers per plant (10.7) and number of leaves per plant (7.0). In the case of tasseling date and silking date, the cross P_1 x P_5 is considered the best combination. These results agree with Sakr and Ghazy (2010), Ghazy (2016) and El-Adl *et al*., (2018).

Table 5. Estimates of heterosis relative to mid-parent (M.P %) of each cross for all agronomic traits.

Traits crosses	N.T./P.	P.H.	N.L./P.	5^{th} L. A.	L.Ch.C.
P_1 x P_3	20.4**	53.8**	47.2**	34.3**	3.8
P_1 x P_4	7.6**	56.7**	-0.8	24.3**	0.3
P_1 x P_5	27.5**	59.9**	7.3	39.4**	1.6
P_2 x P_3	32.9**	46.5**	52.1**	1.0	-18.4**
P_2 x P_4	25.0**	53.0**	34.9**	2.3	5.6
P_2 x P_5	81.2**	61.6**	90.7**	4.2	9.3**
L.S.D $_{0.05}$	0.79	8.97	8.48	10.39	4.15
L.S.D $_{0.01}$	1.06	11.99	11.34	13.90	5.54
Traits crosses	S.d.	G.F.Y./P.	DFY/P.	T.D.	S.D.
P_1 x P_3	26.5**	113.6	-4.7	-8.5**	4.6
P_1 x P_4	22.5**	115.4	-9.0	-13.5**	0.7
P_1 x P_5	22.7**	129.8	-17.1**	-17.1**	-1.2
P_2 x P_3	9.6**	93.2	0.3	-9.2**	2.0
P_2 x P_4	13.8**	86.4	-10.9	-4.0	3.8
P_2 x P_5	19.1**	175.4	-41.6**	-9.7**	2.4
L.S.D $_{0.05}$	0.27	185.20	15.56	4.84	5.37
L.S.D $_{0.01}$	0.36	247.55	20.79	6.47	7.17

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**
P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./ P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).

Table 6. Estimates of heterosis relative to better parent (B.P %) of each cross for all agronomic traits.

Traits crosses	N.T./P.	P.H.	N.L./P.	5^{th} L. A.	L.Ch.C.
P_1 x P_3	-26.0**	55.2**	-18.4**	10.1	-16.0**
P_1 x P_4	-36.2**	50.6**	-45.5**	2.5	-25.8**
P_1 x P_5	-22.2**	48.5**	-40.3**	10.6	-23.5**
P_2 x P_3	-18.4**	41.3**	-15.2**	-22.8**	-32.5**
P_2 x P_4	-25.9**	42.3**	-25.4**	-21.3**	-19.5**
P_2 x P_5	10.7**	45.5**	7.0	-22.6**	-15.1**
L.S.D $_{0.05}$	0.92	12.68	9.79	12.01	4.79
L.S.D $_{0.01}$	1.23	16.95	13.09	16.05	6.39
Traits crosses	S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
P_1 x P_3	23.8**	54.9	-10.5	56.3**	77.4**
P_1 x P_4	21.3**	73.7	-13.0	45.4**	68.4**
P_1 x P_5	17.5**	105.1	-24.3**	38.8**	65.0**
P_2 x P_3	-6.7**	57.1	-7.1	55.1**	71.2**
P_2 x P_4	-0.9**	79.8	-16.0	61.3**	71.9**
P_2 x P_5	0.8**	137.5	-21.2*	51.1**	69.3**
L.S.D $_{0.05}$	0.31	213.86	17.97	5.59	6.19
L.S.D $_{0.01}$	0.41	285.85	24.01	7.47	8.28

***,** Significant at 0.05 and 0.01 levels of probability, respectively**
P_1: SC-30k8, P_2: SC- 2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).

The estimated amounts of heterosis relative to mid-parent (M.P %) and better parent (B.P %) were determined for the forage quality traits over two years and obtained results are shown in Table 7. The results showed that there was positive and highly significant heterosis relative to mid-parent estimates and better parent for crude protein, crude fibers except few cases. The cross P_1 x P_4 exhibited positive and highly significant for crude proteins and crude fibers relative to mid-parents (46.2 and 15.4 %) and better parents (20.5 and 48.6 %). Also, it had positive and highly significant relative to mid-parent (M.P %) for total digestible nutrients (4.1%). On the other hand, there were negative and highly significant heterosis relative to mid-parent estimates and better parent for crude lipid and carbohydrates in most crosses.

Table 7. Estimates of heterosis relative to mid- parent (M.P %) and better parent (B.P %) of each cross for forage quality traits.

Crosses		Heterosis %	C.P.	C.L.	C.F.	Car.	T.D.N.
P_1 x P_3		M.P	33.6**	-20.5**	4.5**	-4.4**	3.4**
		B.P	14.9**	-40.5**	42.1**	-19.1**	0.4
P_1 x P_4		M.P	46.2**	-7.5**	15.4**	-13.4**	4.1**
		B.P	20.5**	-29.9**	48.6**	-22.6**	0.8
P_1 x P_5		M.P	17.7**	-25.9**	1.40	0.8	1.9*
		B.P	4.0**	-41.1**	37.9**	-15.8**	-0.8
P_2 x P_3		M.P	12.1**	-30.5**	10.9**	-2.6	0.8
		B.P	-4.9**	-47.6**	42.3**	-14.9**	-2.2**
P_2 x P_4		M.P	6.6**	4.5**	14.9**	-8.6**	-0.02
		B.P	-13.1**	-14.1**	40.4**	-15.4**	-3.1**
P_2 x P_5		M.P	17.4**	-12.4**	4.7**	1.6	1.7*
		B.P	2.5**	-23.9**	34.8**	-12.3**	-1.0
LSD	5%	M.P 2.69	1.06	0.88	2.36	2.69	1.16
		B.P 3.11	1.23	1.01	2.73	3.11	1.34
	1%	M.P 3.59	1.42	1.17	3.16	3.59	1.55
		B.P 4.15	1.64	1.35	3.64	4.15	1.78

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**
P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

General combining ability effects:

General combining ability effects of parents for all agronomic studied traits from the combined data are shown in Table 8. The results revealed that the P_2 had positive and highly significant GCA effects for number of tillers per plant, number of leaves per plant and green fodder yield per plant. While, P_1 have negative and highly significant GCA effects for tasseling date toward earliness. For males, the P_3 was the best general combiner which exhibited positive largest magnitude values for number of leaves per plant (6.32), green fodder yield per plant (159.85) and dry fodder yield per plant (32.81). While, the P_5 was the best general combiner which exhibited positive largest magnitudes for number of tillers per plant (0.48), fifth leaf area (8.56 cm^2) and total leaf chlorophyll (0.89).

General combining ability effects of five genotypes for all forage quality traits from the combined data are presented in Table 9. Regarding the females, the P_1 had positively and significant GCA effects for crude proteins and total digestible nutrients. For males, the results indicated that the male parent P_4 had the highest positive GCA effects for crude lipids (0.29%) and crude fiber (0.96). The male parent P_5 had the highest positive GCA effects for the carbohydrates (1.37%).

Table 8. General combining ability effects of the parental genotypes for all studied traits studied traits.

Traits / Parents		N.T./P.	P.H.	N.L./P.	5^{th} L. A.	L.Ch.C.
Females	P_1	-0.40**	-2.39	-15.58**	47.63**	1.32
	P_2	0.40**	2.39	15.58**	-47.63**	-1.32
L.S.D 0.05		0.28	2.99	2.83	3.47	1.38
L.S.D 0.01		0.37	4.00	3.78	4.63	1.85
Males	P_3	-0.38*	2.43	6.32**	5.65**	-0.64
	P_4	-0.09	-2.04	-8.99**	-14.20**	-0.25
	P_5	0.47**	-0.39	2.68	8.56**	0.89
L.S.D 0.05		0.34	3.66	3.46	4.25	1.69
L.S.D 0.01		0.45	4.89	4.63	5.68	2.26
Traits / Parents		S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
Females	P_1	-0.07	-286.64**	-3.54	-3.01**	-1.06
	P_2	0.07	286.64**	3.54	3.01**	1.06
L.S.D 0.05		0.09	62.70	5.19	1.64	1.80
L.S.D 0.01		0.12	83.80	6.94	2.20	2.41
Males	P_3	-0.03	159.85**	32.81**	2.88**	2.58*
	P_4	0.02	-255.32**	-16.51**	1.33	-0.25
	P_5	0.01	95.48*	-16.30**	-4.21**	-2.33*
L.S.D 0.05		0.11	76.79	6.36	2.01	2.20
L.S.D 0.01		0.15	102.64	8.50	2.69	2.95

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**
P_1: SC-30k8, P_2: SC-2031), P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).

Table 9. General combining ability effects of the parental genotypes for forage quality traits.

Traits/ Parents		C.P.	C.L.	C.F.	Car.	T.D.N.
Females	P_1	0.50**	0.08	-1.24**	0.38	0.61**
	P_2	-0.50**	-0.08	1.24**	-0.38	-0.61**
L.S.D 0.05		0.35	0.29	0.79	0.90	0.39
L.S.D 0.01		0.47	0.39	1.05	1.20	0.52
Males	P_3	0.06	-0.28	0.36	-0.16	0.04
	P_4	-0.02	0.29	0.96	-1.21*	-0.09
	P_5	-0.04	-0.003	-1.32**	1.37*	0.05
L.S.D 0.05		0.43	0.36	0.96	1.10	0.47
L.S.D 0.01		0.58	0.48	1.29	1.47	0.63

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**
P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

Specific combining ability effects (SCA):

Specific combining ability effects (SCA) of six crosses for agronomic traits are presented in Table 10. The results cleared that significant positive specific combining ability effects were obtained for some crosses. Results showed that the cross P_1 x P_3 had positively (desirable) and significant or highly significant for plant height, number of leave per plant, fifth leaf area, leaf chlorophyll total and green fodder yield per plant traits. Highly significant and desirable positive values SCA were found in the cross P_2 x P_4 for fifth the leaf area. The best desirable estimates of SCA effects for number of tillers per plant, number of leaves per plant and green fodder yield per plant were obtained by the cross P_2 x P_5. The most height crosses that showed high SCA effects had one or two good combiner parent. These results are in harmony with those obtained by Sakr and Ghazy (2010), Abdel-Aty *et al*., (2013) and El-Adl *et al*., (2018).

Table 10. Estimations of specific combining ability effects for six crosses for all the studied traits

Traits Crosses	N.T./P.	P.H.	N.L./P.	5^{th} L. A.	L.Ch.C.
P_1 x P_3	0.23	6.96*	13.47**	10.67**	2.73*
P_1 x P_4	0.12	-0.10	0.91	-21.87**	-1.20
P_1 x P_5	-0.35	-6.86*	-14.39**	11.20**	-1.53
P_2 x P_3	-0.23	-6.96*	-13.47**	-10.67**	-2.73*
P_2 x P_4	-0.12	0.10	-0.91	21.87**	1.20
P_2 x P_5	0.35	6.86*	14.39**	-11.20**	1.53
L.S.D $_{0.05}$	0.48	5.18	4.90	6.00	2.39
L.S.D $_{0.01}$	0.64	6.92	6.55	8.03	3.20
Traits Crosses	S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
P_1 x P_3	0.07	264.19**	-5.74	3.35*	2.31
P_1 x P_4	-0.01	142.58**	11.40*	-2.28	-1.03
P_1 x P_5	-0.06	-406.76**	-5.66	-1.07	-1.28
P_2 x P_3	-0.07	-264.19**	5.74	-3.35*	-2.31
P_2 x P_4	0.01	-142.58**	-11.40*	2.28	1.03
P_2 x P_5	0.06	406.76**	5.66	1.07	1.28
L.S.D $_{0.05}$	0.15	106.93	8.98	2.79	3.10
L.S.D $_{0.01}$	0.21	142.92	12.01	3.74	4.14

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**
P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).

The values of specific combining ability effects (SCA) for all forage quality traits obtained from combined data and results are shown in Table 11. The results revealed that only three out of six crosses in all forage quality traits exhibited positive specific combining ability effects, cross $P_2 \times P_5$ for crude protein (0.55), cross $P_1 \times P_4$ for crude fiber (0.60) and the hybrid $P_2 \times P_4$ for carbohydrates (0.62). The hybrid $P_2 \times P_5$ had the highest positive SCA effects for total digestible nutrients (0.57). Similar results were also found by Sakr (2009) and Sakr and Ghazy (2010) in some teosinte-maize hybrids.

Table 11. Estimations of specific combining ability effects for forage quality traits across combined data.

Traits Crosses	C.P.	C.L.	C.F.	Car.	T.D.N.
P_1 x P_3	0.05	0.18	-0.57	0.19	0.09
P_1 x P_4	0.50	-0.06	0.60	-0.62	0.48
P_1 x P_5	-0.55	-0.12	-0.02	0.43	-0.57
P_2 x P_3	-0.05	-0.18	0.57	-0.19	-0.09
P_2 x P_4	-0.50	0.06	-0.60	0.62	-0.48
P_2 x P_5	0.55	0.12	0.02	-0.43	0.57
L.S.D $_{0.05}$	0.61	0.51	1.36	1.55	0.67
L.S.D $_{0.01}$	0.82	0.68	1.82	2.08	0.89

P_1: SC-30k8, P_2: SC-2031, P_3: Balsas with Guatemala, P_4: Local variety with Central plateau and P_5: Domiata (Durra rayyana).
Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

Proportion contribution:

The relative contributions of females, males, and female × male interaction for all agronomic and forage quality traits are presented in Table 12.

Table 12. Proportion contributions of females, males and their interactions for all studied traits

Traits / Parents	N.T./P.	P.H.	N.L./P.	5^{th} L. A.	L.Ch.C.
Females	45.50	13.96	58.45	86.92	29.51
Males	36.39	8.32	10.28	3.92	7.12
Females x Males	18.11	77.72	31.27	9.16	63.36
Traits / Parents	S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
Females	58.37	40.95	2.04	37.57	14.21
Males	3.85	16.59	87.42	38.26	51.77
Females x Males	37.78	42.46	10.55	24.17	34.02
Traits / Parents	C.P.	C.L.	C.F.	Car.	T.D.N.
Females	57.70	8.94	57.01	10.01	66.10
Males	0.48	69.27	34.52	76.33	0.76
Females x Males	41.82	21.56	8.47	13.66	33.04

Number of tillers per plant (N.T./P.), plant height in centimeters (P.H.), number of leaves per plant (N. L./P.), fifth leaf area (5^{th} L.A.), total leaf chlorophyll (L.Ch.C.), stem diameter in centimeters (S.d.), green fodder yield per plant in grams (G.F.Y./P.), dry fodder yield per plant in grams (D.F.Y./P.), tasseling date (T.D.) and silking date (S.D.).
Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

The results indicated that females was higher than those males and interaction between females × males for the number of tillers per plant, number of leaves per plant, fifth leaf area, stem diameter, crude protein, crude fiber and total digestible nutrients. While, males were higher than those females and interaction between females × males for dry fodder yield per plant, tasseling date, silking date, carbohydrates and crude lipid. Moreover, the females × males interaction were higher than those females and males in their relative contributions for plant height total leaf chlorophyll and green fodder yield per plant.

Nature of gene action and heritability:

To know the nature of gene action with respect to the relative magnitudes of additive genetic variance requires the determination of different variance components due to general and specific combining ability variances. Thus, the variance components obtained from the factorial mating design could be translated into genetic parameters with respect to additive genetic variances (σ^2A) and non-additive genetic variances including dominance (σ^2D).

Estimation of different genetic parameters; additive, dominance variances, heritability in broad (h^2_b %) and heritability in narrow (h^2_n %) senses for all the studied agronomic traits are presented in Table 13. The negative values obtained for variance were considered equal to zero during the calculations of heritability and dominance degree.

Table 13. The relative magnitude of different genetic parameters for all agronomic traits.

Traits Genetic parameters	N.T./P.	P.H.	N.L./ P.	5^{th} L. A.	L.Ch.C.
σ^2 A	0.11	-22.06	51.75	1149.67	-1.97
σ^2 D	0.129	88.88	383.56	708.27	9.83
$(\sigma^2 D/ \sigma^2 A)^{1/2}$	1.08	>1.0	2.72	0.785	>1.0
H^2_b%	41.19	69.28	92.50	97.23	53.56
H^2_n%	18.75	0.00	11.00	60.16	0.00
Traits Genetic parameters	S.d.	G.F.Y./P.	D.F.Y./P.	T.D.	S.D.
σ^2 A	0.00	-7053.4	259.08	5.47	0.67
σ^2 D	0.004	252778.2	175.03	15.62	5.65
$(\sigma^2 D/ \sigma^2 A)^{1/2}$	>1.0	>1.0	0.822	1.69	2.91
H^2_b%	11.01	93.76	78.54	64.75	30.95
H^2_n%	0.71	0.00	46.87	16.78	3.28

Number of tillers per plant^{-1} (N T / P.), plant height in centimeters (P.H), number of leaves per plant (N L / P.), fifth leaf area (5^{th} L.A), total leaf chlorophyll (L.Ch.C), leg diameter in centimeters (L.D.cm.), green fodder yield per plant in grams (G F Y / P), dry fodder yield per plant in grams (D F Y /P), tasseling date (T.D.) and silking date (S.D.).

The results indicated that the magnitudes of non-additive genetic variance were larger than their corresponding estimates of additive genetic variance for all the studied traits except fifth leaf area and dry fodder yield per plant. Suggests that both additive and non-additive (dominance) genetic variance contributed in the inheritance of these traits, while the dominance genetic variance predominant in the inheritance of number of tillers per plant, plant height, number of leaves per plant, total leaf chlorophyll, stem diameter, green fodder yield per plant, tasseling date and silking date. For fifth leaf area and dry fodder yield per plant, the additive gene effects play the major role in its inheritance of these traits. Similar results were reported by El-Adl *et al.*, (2018), Ahmed *et al.*, (2020) and Rathod *et al*., (2021). While, these result are disagreement with the results obtained by Ghazy (2016), who found that the non-additive variance played the major role in the inheritance of the all studied traits in maize -teosinte hybrids. The dominance degree ratio $(\sigma^2 D/ \sigma^2 A)^{1/2}$ which were less than unity except for number of tillers per plant, number of leaves per plant, tasseling date and silking date, revealing the importance of incomplete dominance and additive effects played the major role in the inheritance of these traits. Hence heritability studies are important to judge whether the observed phenotypic variation is heritable or not. Narrow sense heritability is more useful in breeding than broad sense heritability which is influenced by dominance heterosis and epistasis. The results also illustrated that high heritability value in broad sense (H^2_b %) were detected for all agronomic traits. These values ranged from 11.01 to 97.23 % for stem diameter and fifth leaf area, respectively .The heritability in narrow sense (H^2_n %) ranged from 0.00 for plant height, total leaf chlorophyll and green fodder yield per plant to 60.16 % for fifth leaf area, respectively.

The genetic variance component, dominance degree ratio, and heritability values were calculated for Forage quality traits and the results are presented in Table 14. For crude protein and total digestible nutrients, the results illustrated that the non-additive genetic variance including dominance (σ^2D) was higher than that additive genetic variance (σ^2A). These results indicated that non-additive genetic effects played a major role in the genetic expression of this trait, indicating that the hybridization program would be effective in improvement of this trait. Similar results were also found by Sakr (2017) .For the crude fiber %, carbohydrates and crude lipid% the additive genetic variance (σ^2A) was higher than that non-additive genetic variance (σ^2D).

The heritability values in broad sense (H^2_b %) were larger than those the corresponding values of narrow sense heritability (h^2n %) for all studied trait. These values of H^2_b % ranged from 5.13 to 45.16 % for crude lipid and crude protein, respectively.

Table 14. The relative magnitudes of different genetic parameters for forage quality traits

Traits Genetic parameters	C.P.	C.L.	C.F.	Car.	T.D.N.
σ^2 A	-0.01	0.02	1.21	0.55	0.06
σ^2 D	0.456	-0.012	0.230	0.009	0.448
$(\sigma^2 D/ \sigma^2 A)^{1/2}$	>1.00	>1.00	0.436	0.128	2.733
H^2_b	45.16	5.13	34.59	13.64	43.47
H^2_n	0.00	5.13	29.08	13.42	4.83

Crude protein content (C.P.), crude lipid (C.L.), crude fiber content (C.F.), carbohydrates (Car.) and total digestible nutrients (T.D.N.).

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قوة الهجين ، القدرة على الإئتلاف وطبيعة الفعل الجينى لصفات المحصول ومكوناته فى هجن الذرة الشامية والريانة

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تم الحصول على ستة هجن ناتجة من التهجين بين ثلاثة (تراكيب وراثية) من الذرة الريانة كأباء وهجينين من الذره الشاميه كإناث ، باستخدام نظام التزاوج العاملي في الموسم ٢٠١٨ في مزرعة قسم الوراثة بكلية الزراعة - جامعة المنصورة - مصر. وفي الموسمين الزراعيين ٢٠١٩ و ٢٠٢٠ تم تقييم الآباء الخمسة والستة هجن F_1 الناتجة في تجربة بتصميم القطاعات الكاملة العشوائية فى ثلاثة مكررات. أظهرت النتائج أن متوسط المربعات الراجع الى التراكيب الوراثية والاباء والهجن والتداخل بينها مع السنوات كانت عالية المعنوية لجميع الصفات المدروسة ما عدا صفة قطر الساق للتداخل بين التراكيب الوراثية والسنوات و صفة تاريخ ظهور الحريرة للتداخل بين الهجن والسنوات. أظهرت المتوسطات أن الهجن كانت أفضل من الاباء في معظم الصفات المدروسة. كان الهجين P_2 x P_5 ذات قوة هجين موجبة وعالية المعنوية لصفات عدد الخلفات لكل نبات (٨١,٢) ، ارتفاع النبات (٦١,٦) ، عدد الأوراق لكل نبات (٩٠,٧) ، الكلوروفيل الكلي للأوراق (٩,٣). لوحظت أعلى تأثيرات للقدرة الخاصة على التآلف (SCA) في الهجين P_2 x P_5 لصفات عدد الخلفات لكل نبات، عدد الاوراق لكل نبات،محصول العلف الاخضر، نسبة البروتين و صفة T.D.N . كما أشارت النتائج إلى أن قيم التباين الوراثى الغير المضيف كانت أكبر من تقديراتها للتباين الوراثي المضيف فى جميع الصفات المدروسة فيما عدا صفات مساحة الورقة الخامسة ومحصول العلف الجاف للنبات , نسبة البروتين و نسبة االعناصر الغذائية الذائبة. كما اوضحت النتائج أن معامل التوريث فى المدى الواسع يتراوح من ١١,٠١% لصفة قطر الساق الى ٩٧,٢٣ % لصفة مساحة الورقة الخامسة.