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Diallel Crossing Analysis for Body Weight and Egg Production Traits of Two Native Egyptian and Two Exotic Chicken Breeds

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Abstract: Crossbreeding is one of the tools for exploiting genetic variation. The main purpose of crossing in chicken is to produce superior crosses (i.e. make use of hybrid vigor), improve fitness and fertility traits. This study was carried out at South Sinai Research Station located at Ras Suder, Egypt. Two local breeds namely Fayoumi (F) and Sinai (S) and two exotic ones named Rhode Island Red (RIR) and White Leghorn (WL) were used in 4x4 diallel mating system. Breeds of RIR and WL are the best spread and adapted to the environmental conditions of Egypt, while F and S might be regarded as the principal well characterized local breeds of chicken. All possible purebreds (4 groups) and crossbreds (12 groups) were made among the four breeds. Body weights of 1149 chicks were recorded at 0, 1, 2, 3, 4 and 5 month of age. Also, egg production traits were determined. The present results showed that the RIR breed had heaviest body weight at 0, 2 and 3 month of age compared to remaining breeds. However, the Sinai breed had heaviest body weight at 1 and 4 month of age compared to other ones. With respect to crosses, it could be noticed that the FxS and SxWL crosses recorded heaviest body weight at all ages compared to other crosses. With respect to egg production parameters, the White Leghorn (WL) and Sinai (S) hens gave the heaviest egg weight 45.5g and 44.1g, respectively. Inversely, Fayoumi (F) hens were the lowest values of egg weight (42.2g). However, the Rhode Island Red (RIR) was intermediate (43.4g). Results of heterosis estimates indicated that crossing between Sinai (S) males and White Leghorn (WL) females as well as between Fayoumi (F) males and Sinai (S) females gave the highest heterotic effect for body weight. In accordance to egg production traits, the result indicated that FxS and SxRIR crosses and SxF and RIRxS reciprocal crosses recorded positive and high heterotic effects for egg weight. Crossing between RIR dams and either S or WL sires improved egg weight. With respect to the average of egg number in first 10 days laying, it could be noticed that FxS cross and SxF reciprocal cross achieved the highest H% for egg number (12.49 and 8.12%, respectively). However, crossing between WL dams and F, S or RIR sires resulted in high and positive heterosis percentage (H%) for egg number (4.71, 5.81 and 1.72%, respectively). General combining ability (GCA) was found to be the largest source of variation contributing to differences between crosses for body weights and egg production traits. The SxWL cross achieved the superior estimates of maternal effect (ME) for body weight at all studied ages. In conclusion, we need more crossbreeding programs in Egypt using native and exotic breeds to promote the expansion of superior breeds to develop highly specific (either meat or egg production) strains to be including in further breeding programs.

Key words: Native breeds, exotic breeds and Crossbred chickens

Introduction

Native chickens play an important role household food supply in rural Africa (Kitalyi, 1998) and recently have been raised in semi-intensive systems with more efficient output per bird. In many developing countries, the local gene pool still provides the basis for the poultry sector. The genetic resource base of the indigenous chickens could form the basis for genetic improvement and diversification to produce breeds adapted to local conditions. However, breeding programs for local chicken will be difficult to set-up because of the competition with commercial breeding companies which have access to technology advantages and economics of scale (Hoffmann, 2005). Crossbreeding is one of the tools for exploiting genetic variation. The main purpose of crossing in chicken is to produce superior crosses (i.e. make use of hybrid vigor), to improve fitness and fertility traits and to combine different characteristics in which the crossed breeds were valuable (Willham and Pollak, 1985; Hanafi and Iraqi, 2001). Crossbreeding uses pure- or line-breeding to improve economic traits through the use of complementarily traits or economic heterosis. Complementarily is often very important to success the crossbreeding programs. Often positive complementarily arises because of a multiplier trait, e.g., reproduction and viability traits. Moreover, as with single trait heterosis, however, economic heterosis may be negative (Van Vleck, 1993). Heterosis caused by dominance is proportional to heterozygosity and dominance was broadly believed to be the sole cause of heterosis in animals. However, epistasis was shown to be a major mechanism of heterosis in chicken (Sheridan, 1981). For the most part, heterosis resulting from epistasis is complicated or hardly attainable to predict because of the number and type of interactions are usually unknown and it could also be affected by dominance. The exploitation of genetically diverse stocks for improving economic traits, such as body weight is one of the approaches in the breeding programmes of chickens. The combining ability analyses help to identify the desirable combiners that may be utilized to exploit heterosis. General combining ability (GCA) is a consequence of additive genetic effects, while specific combining ability (SCA) is a consequence of non-additive genetic effects (Etso and Nordskog, 1961). The latter, commonly referred to as nicking ability, which may involve dominance, over dominance and epistasis. Many reports showed that general combining ability and therefore, additive variations were high and important to specific combing ability for body weight at different ages (Wearden *et al*., 1965; Hill, 1959; Singh *et al.,* 1983). The objectives of the present study were to evaluate genetically traits of body weight and egg production in 4x4 diallel mating system among two local (Fayoumi and Sinai) and two exotic (Rhode Island Red and White Leghorn) ones, evaluate heterotic effects to identify superior breeds and estimate purebreds, general and specific combining abilities and maternal effects of body weight and egg production traits.

Materials and Methods

This study was carried out at South Sinai Research Station located at Ras Suder, Desert Research Center, Ministry of Agriculture, Egypt. The region had a desert climate; an average annual temperature is 29.7°C with range from 19.6°C in February to 37.6°C in August. The data used in the study were collected during three years period from 2003 to 2006. Two local breeds namely Fayoumi (F) and Sinai (S) and two exotic ones named Rhode Island Red (RIR) and White Leghorn (WL) were used in 4x4 diallel mating system. Breeds of RIR and WL are the best spread and adapted to the condition of Egypt, while F and S might be regarded as the principal well characterized local breeds of chicken. All possible purebreds (4 groups) and crossbreds (12 groups) were made among the four breeds. Each five pullets from each type were assigned randomly to be mated was one cockerel of each breed. Insemination was done twice a week and each rooster was mated to the same five hens. The eggs were hatched separately according to breeds and crossbreds. The hatched chicks were wing-banded until 8 weeks of age followed by leg-banded to keep their breed and crossbred groups. The chicks were placed in a confined area of artificial heat (37°C) and continuously lighting program. They were reared separately by genetic groups. They were housed in semi closed house building (4x6x3.5m) with metal cage yard (4x7x2.5m) with side windowed ventilation. At 4 weeks of age the birds were allowed the whole pens place (stocking density of 8birds/m^2) and then moved to rearing house. The chicks were sexed at 4 weeks of age via external characteristics. The feed and water were supplied ad libitum. They were fed a commercial starter diet (21% CP and 3000 kcal ME/kg) from hatching time to 4 weeks of age followed by a grower diet (18% CP and 2900 kcal ME/kg) to 12 weeks of age and a diet with 16% CP and 2850 kcal ME/kg during the final growth phase. Up to 22 weeks of age, the layers mash contained 2900 kcal ME / kg feed and 18% crude protein.

Measurements: Body weights of 1149 chicks were recorded at 0, 1, 2, 3, 4 and 5 months of age. Birds were weighted individually on an electronic balance, within 0.1g precision. For birds that died or lost their wing or leg-bands before the end of a full record were not included. Egg production was recorded for each cage and measured as egg number from age at first egg to 15 weeks of egg production. The data were adjusted by removing dead birds and birds that had less than 20% of production in the 15 weeks. The data on the egg production were collected for parts of the experiment period. The egg production period started when each group reached 5% of the egg production. The egg production was recorded daily by cage. Laying rate production was computed as total of the egg number divided by laying period days. The individual traits measured included hen housed egg number to 15 weeks of age average weight of the eggs at 15 weeks of age and the rate of production. Egg production from 15 weeks (105 days) was calculated on a hen housed basis and as egg production rate.

Statistical analysis: Data were analyzed with analysis of variance. The General Linear Model (GLM) of the Statistical Analysis System (SAS, 2000) was used for the statistical processing of data. Difference were considered significant were compared by Duncan test. Following linear model was used to analyze the data.

$$y_{ijkl} = \mu + G_i + H_j + Y_k + (GH)_{ij} + (HY)_{jk} + (GHY)_{ijk} + e_{ijkl}$$

Where y_{ijkl} = the 1^{th} observation on the bird hatched of the k^{th} year in the j^{th} hatch of the i^{th} breed group, μ = the overall mean, G_i = the fixed effect of the i^{th} breed group, H_j = the fixed effect of the j^{th} hatch, Y_k = the fixed effect of the k^{th} year, $(GH)_{ij}$ = the fixed effect of interaction between i^{th} breed group and k^{th} year, $(HY)_{jk}$ = the fixed effect of interaction between j^{th} hatch and k^{th} year, $(GHY)_{ijk}$ = the fixed effect of interaction among i^{th} breed group, j^{th} hatch and k^{th} year and e_{ijkl} = the random error of the 1^{th} bird assumed to be independently randomly distributed. The two way interaction between hatch and year, breed group and hatch and the three was interaction between breed, hatch and year were not found to be significant.

Table 1: Body weights of pure breeds, crosses and reciprocal crosses chickens.

	Age (month)					
	0	1	2	3	4	5
Pure breed						
F	35.93^{c}	219.29^{c}	704.73^{c}	1055.91^{a}	1331.65^{a}	1561.41^{b}
S	37.87^{d}	248.98^{b}	778.94^{c}	1080.88^{a}	1316.38^{a}	1512.60^{b}
WL	35.58^{c}	198.48^{d}	746.62^{c}	1059.38^{a}	1284.60^{b}	1472.19^{c}
RIR	43.04^{a}	237.89^{c}	958.08^{a}	1155.35^{a}	1288.88^{b}	1557.82^{b}
Crosses						
FxS	42.22^{a}	242.71^{b}	610.57^{d}	632.18^{d}	1211.05^{b}	1349.04^{e}
FxWL	31.73^{f}	89.91^{e}	362.57^{f}	622.09^{d}	916.18^{e}	1175.64^{e}
FxRIR	37.06^{d}	210.28^{c}	553.89^{e}	821.81^{b}	1005.14^{d}	1188.47^{e}
SxWL	40.45^{b}	291.02^{b}	702.53^{c}	757.90^{c}	1330.13^{a}	1902.37^{a}
SxRIR	34.71^{e}	108.45^{d}	430.09^{f}	745.68^{c}	1106.72^{c}	1415.74^{c}
WlxRIR	37.06^{d}	210.28^{c}	821.81^{b}	1005.14^{a}	1007.14^{d}	1257.25^{d}
Reciprocal crosses						
SxF	40.45^{b}	291.02^{a}	702.53^{c}	764.36^{c}	1323.56^{a}	1585.74^{b}
WlxF	33.82^{e}	96.82^{e}	383.11^{f}	720.63^{c}	1102.04^{c}	1439.56^{c}
RIRxF	35.27^{c}	219.71^{c}	537.57^{e}	819.69^{b}	1034.56^{d}	1249.43^{d}
WlxS	42.22^{a}	242.71^{b}	610.57^{d}	632.18^{d}	1211.05^{b}	1487.07^{c}
RIRxS	33.54^{e}	117.46^{d}	400.68^{f}	680.36^{b}	1007.50^{d}	1289.11^{d}
RIRxWL	35.27^{c}	219.71^{c}	819.69^{b}	1196.34^{a}	1292.24^{b}	1438.21^{c}
Pooled SE	0.67	14.50	22.51	40.79	52.34	84.15
Prob.	0.001	0.001	0.001	0.001	0.001	0.001

$^{a-f}$ Means within the same column with the same letters did not significantly differ. F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red.

Heterosis was calculated according to Fairfull (1990) by application of the following formula: H% = AB-(0.5AA+0.5BB)/(0.5AA+0.5BB) x 100. General combining ability is defined as the average performance of a breed, strain or line in a cross combination. The values of general combining ability for purebreds (F, S, RIR and WL) were calculated as means (Falconer, 1988). Specific combining ability was calculated according to the following formula: SCA = {(AB)+(BA)}/2-{GCA(A)+GCA(B)}/2. Maternal effects of body weight (expressed as the differences between reciprocal crosses) were calculated according to Dickerson (1992).

Results and Discussion

Body weight: Within pure breed, data summarized in Table 1 showed that the RIR breed had heaviest body weight at 0, 2 and 3 month of age compared to remaining breeds. However, the Sinai breed had heaviest body weight at 1 and 4 month of age compared to other ones. With respect to crosses, it could be noticed that the FxS and SxWL crosses were heaviest body weight at all ages compared to other crosses. Similar trend was noticed within reciprocal crosses, whereas the SxF and WLxS crosses were heaviest body weight compared to other reciprocal crosses.

Table 2: Egg production traits of pure breeds, crosses and reciprocal crosses of chickens.

	Trait		
Pure line	EW	EP	EN
F	42.24^{d}	63.68^{c}	65.63^{d}
S	44.12^{b}	57.51^{e}	59.23^{f}
WL	45.57^{a}	62.12^{d}	64.73^{d}
RIR	43.43^{c}	68.12^{a}	73.89^{a}
Crosses			
FxS	44.48^{b}	62.23^{d}	70.23^{b}
FxWL	41.65^{e}	66.35^{b}	68.25^{c}
FxRIR	41.92^{e}	62.90^{d}	63.40^{e}
SxWL	44.35^{b}	62.02^{d}	65.58^{d}
SxRIR	45.66^{a}	61.82^{d}	68.70^{c}
WLxRIR	44.69^{b}	64.01^{c}	73.94^{a}
Reciprocal crosses			
SxF	45.70^{a}	63.27^{c}	73.74^{a}
WLxF	42.23^{d}	62.13^{d}	63.13^{e}
RIRxF	41.90^{e}	59.43^{e}	58.88^{f}
WLxS	42.74^{d}	63.29^{c}	58.82^{f}
RIRxS	45.78^{a}	55.11^{f}	57.21^{f}
RIRxWL	43.64^{c}	68.08^{a}	70.50^{b}
Pooled SE	0.86	2.51	3.16
Prob.	0.001	0.001	0.001

$^{a-f}$ Means within the same column with the same letters did not significantly differ. F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red, EW: Egg weight, EP: Egg production rate, EN: Egg number.

Egg production: Means ± standard errors of egg production of purebreds, crosses and reciprocal of chickens are presented in Table 2. The results showed that White Leghorn (WL) and Sinai (S) hens gave the heaviest egg weight (EW) 45.5 and 44.12g, respectively. Inversely, Fayoumi (F) hens were the lowest values of egg weight (42.24 g). However, the Rhode Island Red (RIR) was intermediate (43.43g). These results are in agreement with those reported by Zaky (2005) who showed that the egg produced by (WL) hens were

Table 3: Heterosis (%) of body weight for crosses and reciprocal crosses chickens.

	Age (month)					
	0	1	2	3	4	5
Crosses						
FxS	14.4	3.7	-17.7	-40.8	-8.5	-12.2
FxWL	-11.3	-57.0	-50.0	-41.2	-30.0	-22.5
FxRIR	-6.1	-8.0	-33.4	-25.7	-23.3	-23.8
SxWL	10.1	30.1	-7.9	-29.2	2.3	27.5
SxRIR	-14.2	-55.5	-50.5	-33.3	-15.0	-7.8
WLxRIR	-5.72	-3.6	-3.6	-9.2	-21.7	-17.0
Reciprocal crosses						
SxF	9.6	24.30	-5.3	-28.5	-0.03	3.2
WLxF	-5.4	-53.70	-47.2	-31.9	-15.8	-5.1
RIRxF	-10.7	-3.90	-35.3	-25.9	-21.0	-19.9
WLxS	15.0	8.48	-20.0	-40.9	-6.9	-0.4
RIRxS	-17.1	-51.80	-53.9	-39.2	-22.7	-16.0
RIRxWL	-10.3	0.70	-3.9	8.0	0.4	-5.1

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red.

heavier by about 6.0 g than those of the (F) hens with significant differences between them. Soltan (1991) found that the Sinai fowl laid heavier eggs (43.3g) than both Fayoumi (37.3g) and Baladi (39.2g) and the differences were statistically significant. Yoo *et al.* (1983) and Merat *et al.* (1994) reported considerable differences between layer strains in egg weight.

Nordskog and Festing (1962) in White Leghorn and Fayoumi showed that selection in egg weight cited 4 and 10g increase in egg weight for Fayoumi and White Leghorn, respectively. El-Wardany (1987) recorded an increase of 2g in egg weight of Norfa strain control during developing egg weight strain of Norfa chicks through 2 generation. Zaky (2005) indicated that (RIR) and Mandra breeds produced heavier eggs 52.1 and 51.4 g, respectively. While, Fayoumi and Dandarawi eggs were lighter in weight 42.1 and 43.0 g, respectively. Where egg weight is of highly heritable trait, differences may be accepted among genetically different breeds. With respect to crosses, it could be noticed that SxRIR hens had the heaviest egg weight compared to other crosses. While, F x WL and F x RIR crosses were the lowest values of egg weight. The WLxRIR, FxS and SxWL were intermediate. When comparison was held among reciprocal crosses for egg weight, it could be noticed that RIRxS and SxF hens achieved the heaviest egg weight compared to RIRxF fowls which had the lowest values of egg weight. However, RIRxWL, WLxS and WLxF crosses were intermediate. With respect to egg production rate, the Rhode Island Red hens recorded the highest mean of egg production (EP) compared to Sinai hens. However, both F and WL were intermediate. These results are in agreement with those reported by Zaky (2005) who showed that the rate of lay egg was higher in Fayoumi than Sinai hens. It could be seen that FxWL cross gave higher egg production than other genetic groups. The SxRIR hens had the lowest percentages of egg production. However, the WlxRIR, FxRIR, FxS and SxWL crosses were intermediate. With respect to reciprocal crosses, the RIRxWL gave the highest egg production rate compared to other genetic groups. However, the RIRxS hens were the lowest percentage of egg production rate. Moreover, the WLxS, SxF, WLxF and RIRxF crosses were intermediate. The average number of egg in first 105 days of laying was 73.89, 65.63, 64.73 and 59.23 eggs for RIR, F, WL and S hens, respectively. Abdou and Kolstad (1984) cited that the egg number till first 90 days of egg production were 54, 44 and 41 eggs in White Leghorn, Fayoumi and White Baladi, respectively. The average number of eggs in first 105 days of laying was 73.94 eggs/hen for WLxRIR hens, which gave the highest average of egg number compared to other genetic groups. However, FxRIR hens had the lowest values of egg number. Concerning reciprocal crosses, the SxF hens achieved the highest average of egg number in first 105 days of laying (73.74egg/hen). However, RIRxS fowls gave the lowest values of egg number (57.21egg/hen).

Heterosis (H %): Heterosis estimates for body weight (computed as a percent increase of the crossbreds or reciprocal crosses above their parental breeds) are presented in Table 3. Results within crosses revealed that SxWL had positive and high heterotic percentage at all ages, except of at 2 and 3 month of age. These results may be an encouraging factor for the poultry breeders in Egypt to cross these two breeds (Sinai male and White Leghorn female), also two native breeds (Fayoumi male and Sinai female) to get hybrid vigor in growth traits. Sabra (1990) found that crossbreds obtained from crossing between local breeds (Silver Montazah and Dandarawi) have positive and high magnitude of heterosis for body weights at different ages. Iraqi *et al.* (2002) indicated that heterosis estimates were generally positive and high for body weights of crossbreds obtained from crossing between Mandarah (MN) and Matrouh (MA) strains. Results for reciprocal crosses indicated that SxF recorded positive and high heterotic percentage for body weight at one month of age only. Most reviewed studies showed that body weights at different ages of crossbred chickens were associated with positive heterotic effects for growth traits (Sabri and Hataba, 1994; Khalil *et al.,* 1999; Sabri *et al.,* 2000). Percentage of heterosis recorded by Khalil *et al.* (1999) and Sabri *et al.* (2000) were higher than those obtained in our study. Afifi *et al.* (2002) indicated that when combining each two reciprocal crosses, H% show that crossing between exotic Leghorn (LL) and native Fayoumi (FF) breeds gave the highest and positive heterotic estimates for body weight at early ages (from hatch to 6 weeks of age). Also, crossing between LL and DD (as native breed) gave the highest heterotic effects for body weight at the later ages (8 and 12 weeks of age). Several studies obtained significant heterotic effects on body weights (Singh *et al.,* 1983 and Sabri *et*

Table 4: Heterosis (%) of egg production for crosses and reciprocal crosses of chickens.

Crosses	Trait EW	EP	EN
FxS	3.01	2.70	12.49
FxWL	-5.14	5.48	4.71
FxRIR	-2.14	-4.55	-9.12
SxWL	-1.10	3.69	5.81
SxRIR	4.31	-1.58	3.22
WLxRIR	0.43	-1.70	6.68
Reciprocal crosses			
SxF	5.84	4.41	18.12
WLxF	-3.82	-1.22	-3.15
RIRxF	-2.18	-9.82	-15.60
WLxS	-4.69	5.81	-5.10
RIRxS	4.58	-12.27	-14.05
RIRxWL	-1.93	4.55	1.72

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red, EW: Egg weight, EP: Egg production rate, EN: Egg number.

al., 2000). Inversely, Hanafi and Iraqi (2001) found non-significant heterotic effects on body weight at 8 weeks of age. Concerning to reciprocal crosses, results revealed that SxF cross had positive and high H% of body weight at hatching time and one month of age. Theoretically, the magnitude of heterosis is inversely related to the degree of genetic resemblance between parental populations (Willham and Pollak, 1985) and is expected to be proportional to the degree of heterozygosity of the crosses (Sheridan, 1981); thus heterosis is a result of non-additive genetic effects and may be viewed as overall fitness as well as expression of a specific trait. Heterosis is measured by crossing populations to produce an F1 generation, which is compared to the parental populations. It may reflect specific or general combining ability and is not permanent because of recombination, among other factors, in subsequent generations. Heterosis for BW was observed in chickens when there were small differences in BW between the parental lines (Yalcin *et al.,* 2000) and when there were large differences between the parental lines used in the cross (Liu *et al.,* 1993). Heterosis is usually greater for reproductive traits than for growth traits (Fairfull, 1990), is influenced by maternal and dietary effects (Liu *et al.,* 1995) and may vary with regard to complex traits (Gram and Pirchner, 2001). In addition, Lamont and Deeb (2001) reported that heterosis for BW was age dependent. It may be beneficial to view heterosis for economic traits as coefficients of variation and as deviations from parental means. This approach may enhance improvements in performance as well as uniformity, which is becoming increasingly important with greater mechanization in production and processing. Table 4 revealed heterosis percentage of egg weight, egg production and egg number for crosses and reciprocal crosses of chickens. The result indicated that FxS and SxRIR crosses and SxF and RIRxS reciprocal crosses of egg weight recorded positive and high heterotic effects. Utilize Fayoumi dams with (WL) and RIR sires did not achieve any increase of egg weight. While, crossing between RIR dams and S and WL sires improved egg weight. Concerning egg production rate, it could be seen that utilize WL dams with F, S and RIR sires achieved positive and high heterosis percentage for egg production rate (5.48, 3.69 and 4.55%, respectively). The same trend was observed when crossing between S dams and WL and F sires. Also, utilize Sinai dams with Fayoumi sires scored positive heterosis percentage for egg production rate (2.7%). However, crossing between F dams and WL and RIR sires did not give any increase in egg production rate. With respect to the average of egg number in first 105 days laying, our results indicate that FxS cross and SxF reciprocal cross achieved the highest H% for egg number (12.49 and 8.12%, respectively). However, utilize WL dams with F, S and RIR sires gave high and positive H% for egg number (4.71, 5.81 and 1.72%, respectively).

Table 5: General combining ability (GCA) for body weight of chickens at different ages

Breed	Age (month) 0	1	2	3	4	5
F	36.6	195.7	550.7	776.7	1132.0	1364.2
S	38.8	220.3	605.1	756.2	1215.2	1506.0
RIR	36.6	189.1	646.0	917.8	1106.0	1342.3
WL	36.6	192.7	635.3	856.2	1163.3	1453.2

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red.

General combining ability (GCA): The combining ability analyses help to identify the desirable combiners that may be utilized to exploit heterosis. Gardner and Eberhardt (1966) defined general combining ability (GCA) as an average performance of a line in different hybrid combinations. Lin (1972) also defined GCA as a numerical value expressing the influence of one of the lines on its progeny. The estimates of general combining ability (GCA) reflect the importance of additive gene effects of breeds on body weight at different ages (Afifi *et al.,* 2002). The general combining ability of body weight for breed is presented in Table 5. Results showed that Sinai (S) breed gave the highest (best) positive effect of GCA all al studied periods, except at 60 and 90 days of age. However, the RIR breed had the lowest estimates of GCA during studied ages, except of at 2 and 3 months of age. The four breeds varied in their GCA. This variability gives a good chance to select among these breeds to improve their sizes. Specific combining ability (SCA) defined as a numerical value that expresses the deviation of a specific cross compared to what would be expected from the average performance of the lines involved in that cross. General combining ability (GCA) for egg weight, egg production rate and egg number are summarized in Table 6. The result showed that the Sinai hens gave the highest

Table 6: General combining ability (GCA) for egg production traits of chickens.

Breed	Trait EW	EP	EN
F	42.87	62.86	66.18
S	44.69	60.75	64.79
WL	43.55	64.00	66.42
RIR	43.86	62.78	66.65

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red, EW: Egg weight, EP: Egg production rate, EN: Egg number.

Table 7: Specific combining ability (SCA) for body weight of chickens at different ages.

Crosses	Age (month) 0	1	2	3	4	5
FxS	3.6	58.9	78.6	-68.18	93.7	32.33
FxWL	-3.8	-100.8	-220.1	145.1	-138.6	-101.10
FxRIR	-0.4	22.6	-52.6	-26.5	-99.2	-134.30
SxWL	3.7	60.4	36.4	-111.2	81.3	215.20
SxRIR	-3.6	-91.8	-210.2	-124.0	-103.5	-71.70
WLxRIR	-0.4	24.1	180.1	213.7	15.0	-50.00

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red.

values of GCA for EW compared to Fayoumi hens which had the lowest values of GCA for EW. However, Rhode Island Red and White Leghorn hens were intermediate. Concerning egg production rate, the WL hens had the highest values of GCA compared to other breeds. However, Sinai hens were the lowest values of GCA for egg production. The F and RIR hens were intermediate. With respect to egg number, it could be noticed that RIR, WL and F hens achieved the highest values of GCA for egg number followed by Sinai hens.

Specific combining ability (SCA): The SCA also refers to the degree to which the average performance of a specific cross departs from the additive (Griffing, 1956a, b) and it has been used to denote the degree of non-additive genetic effect in a population (Gardner and Eberhardt, 1966). As such, SCA is a result of either dominance or epistasis, or a combination of the two (Gardner and Eberhardt, 1966). Specific combining ability (SCA) was significant source of body weight among crossbreed groups for body weight during all studied ages (Table 7). This indicated that importance of non-additive genetic components on growth performance during this experimental. Specific combining ability (SCA) was significant source of egg production among cross-bred groups for egg production traits during the tested periods. Estimates of SCA for egg weight (EW), egg production (EP) and egg number (EN) are given in Table 8. The results indicated that SxRIR, FxS and WLxRIR hens gave positive estimates of SCA for egg weight. This indicates that non - additive genetic effects (e.g. dominance, over-dominance and epitasis) of those crossbreds were high on egg weight. However, FxRIR, FxWL and SxWL hens had the lowest

Table 8: Specific combining ability (SCA) for egg production traits of chickens.

Crosses	Trait EW	EP	EN
FxS	1.31	0.95	6.50
FxWL	-1.27	0.81	-0.61
FxRIR	-1.46	-1.66	-5.28
SxWL	-0.57	0.28	-3.41
SxRIR	1.45	-3.30	-2.77
WLxRIR	0.46	2.66	5.69

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red, EW: Egg weight, EP: Egg production rate, EN: Egg number.

Table 9: Maternal effects for body weight of chickens at different ages.

Crosses	Age (month) 0	1	2	3	4	5
FxS	4.1	-25.6	-74.8	-183.7	-171.2	-274.5
FxWL	-1.2	-4.7	-3.7	-73.8	-151.5	-221.6
FxRIR	1.8	-7.5	23.4	15.3	23.2	31.1
SxWL	-4.1	23.4	76.3	146.6	195.1	443.8
SxRIR	0.5	-3.1	22.4	75.1	120.5	160.9
WLxRIR	1.8	-7.5	15.3	23.2	-63.2	-52.3

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red.

Table 10: Maternal effects of egg production traits for chickens.

Crosses	Traits EW	EP	EN
FxS	-1.22	-1.04	-3.51
FxWL	-0.58	4.22	5.12
FxRIR	0.02	3.47	4.52
SxWL	1.61	-1.27	6.76
SxRIR	-0.12	6.71	11.49
WLxRIR	1.05	-4.07	3.44

F: Fayoumi, S: Sinai, WL: White Leghorn, RIR: Rhode Island Red, EW: Egg weight, EP: Egg production rate, EN: Egg number.

estimates of SCA for EW. Concerning egg production rate, it could be seen that WLxRIR, FxS, FxWL and SxWL revealed positive estimates of SCA for egg production. Moreover, SxRIR recorded the lowest values of SCA for EP. With respect to egg number in first 105 days of laying, it could be noticed that FxS and WLxRIR hens recorded positive estimates of SCA for EN.

Maternal effects (ME): Maternal effects (ME) of body weight for breed are illustrated in Table 9. Data showed that SxWL cross achieved the superior estimates of ME for body weight at all studied ages. It could be noticed that the ME was significantly effect on body weight of chickens at different ages. Similar results were obtained by (Hanafi and Iraqi, 2001; Singh *et al.,* 1983). This would reveal that among the six crosses used, SxWL males exhibited the best maternal effect. Thus, it could be recommended that SxWL cross is to be used as a dam breed in crossbreeding programs using local and exotic breeds of the study. Estimates of maternal effect for egg production traits of chickens are illustrated in Table 10. These results indicated that SxWL, WLxRIR and FxRIR hens gave positive estimates of (ME) for egg weight. However, FxS, FxWL and SxRIR did not give any positive estimates of (ME) for egg weight. Concerning egg production, it could be showed that SxRIR, FxWL and FxRIR hens achieved positive and high estimates of (ME) for egg production. With respect to the average of egg number (EN) in first 105 days of laying, it could be noticed that SxRIR hens scored the highest positive estimates of (ME) for egg number. Also, SxWL, FxWL, FxRIR and WLxRIR hens recorded positive and high estimates of ME for EN.

In conclusion, we need more crossbreeding programs in Egypt using native and exotic breeds to promote the expansion of superior breeds to develop highly specific (either meat or egg production) strains to be including in further breeding programs.

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