Genetic components and heterotic effect of growth traits in 3x3 diallel crossing experiment in chickens

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Abstract: Three genotypes of chickens [one local strain named Mandarah (MM) and two exotic parental commercial meat type strains Saso (SS) and Italian (II)] were crossed in a 3 x 3 diallel mating (nine combinations) throughout two successive years to estimate their crossbreeding effect for body weight (BW) at 0, 4, 8 and 12 wks of age, body weight gain (BWG) at different intervals (0-4, 4-8, 8-12 and 0-12wks) for males and females and combined body weight gain (CBWG), feed intake (FI), feed conversion (FC) and viability percentage (V%) at interval 0-12wks. Combining ability, general (GCA) and specific (SCA), heterotic effect (H%), reciprocal effect) R_E (maternal effect) M_E (and, direct additive effect) D_A (were estimated for purebred parental and their crosses, moreover, using GCA and SCA to prediction of hybrid performance, breeding (BV) and genetic values (GV) for purebred parental and their crosses. All chicks tested in this experiment originated from parents divided into 3 groups included 756 hens from three genotypes (252 hens each) and 108 cocks from the genotype used in sire position (1 male: 7 females). Approximately 2160 unsexed day old chicks were used. At 28 days of age, chicks were sexed phenotypically via external characteristics. The SS strain had the highest significant values of all traits studied except FC and V % compared to the other strains, followed by II strain. The males of the crossbreed I×S were the heaviest at hatch, and 8 and 12 wks of age, followed by the S×I cross at 8 and 12 wks of age. No significant differences between S×I and I×S crosses for female BW at hatch and 12 wks of age, while the S×I crossbred was significantly higher than that of I×S cross at 4 wks and at 8 wks of age. Moreover, males and females at the interval 4-8 wks (1326.3 and 1162.9g, respectively) followed by I×S. The SS strain had the highest males and females BW gains the interval 0-12 wks followed by S×I and I×S crossbreds. The strains (SS, II) and reciprocal crossbreds (I×M and M×I) had the best FC followed by M×S but, the MM strain had the lowest FC. The purebreds (MM and II) showed better viability than the strain (SS). Diallel crossing of II and MM with SS strain achieved an increase in viability. Both SS and II strains had positive and highly significant of GCA for BW and BWG in males, and combined sexes at all ages studied. The best of SCA is the combination (S×I) for BW and BWG and FI for males and females, followed by IxS. In contrast, the worst SCA were combinations of (I×M) and (M×I) of the previous traits. Both of S×I crossbred and its reciprocal I×S had the highest percentage of heterotic effect (H %) at the interval 0-12 wks. The S×I crossbred had positive significant effects of H% for male and female BW at 0,4, 8 and 12 weeks of ages and BWG (except interval 4-8wks) at all intervals studied, moreover, CBWG, FI,FC and V% at the interval 0-12 wks. The same trend was found for the reciprocal crossbred I×S (except BW in male at 8 wk of age and BWG at the interval 4-8 wks). The reciprocal effect (R_E) was significant for males and females BW at 4, 8 and 12 wks of ages and BWG at the intervals 4-8, 8-12 and 0 -12 wks for both of S× I and S×M crosses. But I×M cross had significant R_E for males and females BW at 12 weeks of ages, males BWG at intervals 0-4, 4-8, 8-12 and 0 -12 wks. Maternal effect) M_E (of BW and BWG in male and female were positive and significant at 4, 8 and 12 weeks of ages and all intervals for MM strain. Direct additive effect (D_E) had a reverse trend about maternal effects, the SS strain had highly positive significant values for male and female BW and BWG, CBWG, FI and V% at 4, 8 and 12 weeks of age and different intervals. The values of M_E and D_E showed superiority of SS and II as sires which suggest that using of those strains as a terminal sire breed in cross breeding programs, including MM dams would be beneficial for improving the BW and BWG in males and females, CBWG, FI and V% traits. The differences for in the actual and expected means and in relation to actual % for all hybrid genotypes were approximately equal zero. The SS had the highest BV for BW and BWG in male at all ages and intervals compared to the other genotypes followed by II strain. Moreover, it had highest BV for female BW and BWG at 12 wks of age and CBWG. The S×I cross had the highest positive values for BW and BWG in male and female, CBWG and FI traits at all ages and intervals studied. The reciprocal crosses (S×I and I×S) had the highest positive values of GV for all trait studied [except V% for (S×I) and FC for (I×S) were lowest negative values]. The S×I cross surpassed its reciprocal cross (I×S) for all trait studied (except BWG in male, and female at 8-12 wks and V %).

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1. Introduction

During the past 40 years, more than 15 local Egyptian strains of chickens have been developed, through crossing native and standard breeds. Commercial foreign breeds of chickens play an important role in grading and improvement of economic traits (growth and egg production traits) of native strains in Egypt **(Mohamed, 2003**). A breeding program for local chickens in developing countries is still out of competition with commercial breeding company which has access to technology advantages and economics of scale. It was strongly needed to establish breeding programs that allows improved performance of local chickens. Genetic improvement of poultry is based on two alternative approaches: crossbreeding and selection. Crossbreeding can be used as a tool that allows manipulating genetic variation to change the populations in a fashion that attempts to optimize desired phenotype. The main purpose of crossing is to produce superior crosses to improve performance of local chickens and to combine different characteristics in which the crossed breeds were valuable for growth or egg production traits (**Saadey *et al.*, 2008 and Lalev *et al*., 2014).**

The poultry industry has a history of using diallel crossing to establish a broad genetic basis for the development of new breeds or lines and to find superior crossbreds (**Shebl *et al*., 1990; Nawar and Abdou, 1999 and Aly *et al*., 2005).** High positive heterosis percentages for body weight at different ages among crossbreds and reciprocal crossbreds were obtained in chickens (**Mandour *et al*,. 1992 and 1996)**. Hybrid vigor has become a routine tool for poultry breeders to produce progeny that exhibit more desirable phenotype than those of their parental populations **(Williams *et al*., 2002).** The estimation of crossbreeding effects [combining ability, general (GCA) and specific (SCA), direct genetic effect, heterotic effect, maternal effect and reciprocal effect] is therefore of major importance **(Shebl et al., 1999; Wolf and Knizetova, 1994)**.

Full diallel crossing is used to test the combining ability of parental populations. The term GCA is used to designate the average performance of an inbred line in hybrid combinations while SCA is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved (**Kabir *et al*., 2011)**. According to **(Sprague and Tatum, 1942),** GCA is due to genes which are largely additive in their effects and the SCA is due to genes with dominance or epistatic effect. Combining ability provides useful information on the best line, breed or strain combinations necessary for optimal performance of crossbred animals (**Razuki and AL-Soudi, 2005).** The combining ability also helps to identify the most desirable combiner that may be used to exploit hybrid vigor (**Saadey *et al.*, 2008 and Amin 2007).** Many reports showed that general combining ability (additive genetic effects) was high and important as well as specific combining ability (nonadditive effects that involve dominance and epitasis) for body weight at different ages in chickens (**Shebl *et al*., 1990; Mohamed *et al*., 2005; Saadey *et al.*, 2008; Razuki and AL-Shaheen, 2011 and Lalev *et al.*, 2014).**

The objectives of this study were to investigate the difference in body weight traits and viability percentage due to crossing of two exotic standard meat type strains (Saso and Italian chickens) and one local Egyptian chicken strain (Mandarah) in a full 3×3 diallel design to estimate crossbreeding effects (combining abilities, general (GCA) and specific (SCA), direct genetic effect, heterotic effect, maternal effect and reciprocal effect) for purebred parental and their reciprocal crosses and predict of hybrid performance and breeding values.

2. Materials and Methods

This experiment was conducted at Maryout Experimental Station, belonging to the Desert Research Center, Ministry of Agriculture, through the period from two successive years**.**

Experimental Flock History:

One local strain (Mandarah, MM) and two exotic parental commercial meat types' strains, Saso (SS) and Italian (II) chickens were used. The local breed was obtained from the Poultry Improvement Project (Ferhash, Behaira Governorate), while the commercial two exotic strain were obtained from the General Poultry Company, Cairo, Egypt. Birds were apparently healthy, vaccinated and medicated against the common diseases (according to the vaccination program, in the corresponding centers) and being tested against these diseases. The mating design was made in 3x3 full diallel and all possible combinations (nine crosses) among these genotypes had been done (3 purebreds and 6 crossbreds), Table 1.

All chicks tested in this experiment originated from parents were divided into 3 groups in sire and dam position. Each group included 756 hens from three genotypes (252 hens from each genotype) and 108 cocks from the genotype used in sire position (1 male: 7 females) divided into 36 replicates (nine crosses) among these genotypes had been done (3 purebreds and 6 crossbreds) each cross was allocated on 4 replicates.

The eggs were collected for 7 days, marked with combination mating (cross type) and set in the incubator. The hatched were 2160 chicks and reared in floor pens with wood shavings. Each cross was allocated on 4 pens (replicates) with about 60 chicks per pen (3.2 x 3.5 m^2). The chicks were provided with heat and light program according to the recommendations of growing management. At 28 days of age, the chicks were sexed phenotypically via external characteristics. At hatch, all chicks were weighed using an electronic scale within 0.1 g precision and reared according to each cross in floor pens till 12 weeks of age.

All chicks were fed *ad libitum* basis on the commercial starting diet (up to 4 wks) of 21% protein and 2700 kcal / kg, grower (4-12 wks) diet of 18% protein and 2700 kcal /kg, and a layer (16 wks-up) diet of 16% protein and 2700 kcal/kg.

Table 1: Mating design

Females / Males*	SS	II	MM
Saso (SS)	S×S	I×S	M×S
Italian (II)	S×I	I ×I	M×I
Mandarah (MM)	S×M	I×M	M×M

* Male parent was given the first letter.

Studied traits:

Body weight in males and females (BW) was recorded for each genotype at 1 day, 4, 8 and 12wks of age. Body weight gain (BWG) in males and females was calculated at hatch-4, 4-8, 8-12 and hatch-12wks intervals. Combine body weight gain (CBWG), feed intake (FI), feed conversion (FC) and viability percentage (VI%) was estimated for the whole period studied (from 0 to12 weeks) from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chickens strains.

Genetic parameter and statistical analyses:

Data were analyzed for variation between the crosses and within crosses (between progeny) using the general linear model procedure of SAS Software **(SAS Institute, 2000)** and CBE program package **(Wolf, 1996)**. Differences which considered significant were compared by Duncan Test **(Duncan, 1955).** Following a linear model was used to analyze the data:

$Y_{ij} = \mu + G_i + e_{ij}$

Where

Y_{ij} = the observed value of the ij^{th} chick,

μ = the overall mean,

G_i = the effect of the i^{th} genotype,

e_{ij} = the effect of random error.

1-Body Weight Gain (BWG):-

$BWG = (LW_{ti} - LWt_0)/ (t_i - t_0)$

Where, BWG is weight gain per time period, LW_{ti} live weight at particular weeks, LWt_0 is live weight for the previous period = t_0

2-General Combining Ability (GCA):-

The GCA values were calculated as the deviation of a specific genotype means from the overall mean for giving trait estimated for nine diallel crosses [i.e. $GCA_i = (\sum yi/n) - \mu$].

Where

GCA_i= the GCA for strain (SS, II and MM genotypes), yi = trait for a progeny with either one of his or her parents or both parents from line i, and μ = overall mean for gave trait estimated from all nine diallel crosses.

The GCA for (S×S) calculated from the formula as:-

GCA for (S×S) = {0.2*[(SS) + (SxI) +(S×M) + (IxS)+(M×S)]–0.11*[(SS)+(II)+(MM) +(S×I) +(S×M) +(I×M) +(I×S)+(M×S)+(M×I)]}

3- Specific Combining Ability (SCA):-

The SCA was calculated as follows: SCA_{ij}= cross effect- (GCA_i + GCA_j), where the cross effect = certain trait mean of given cross-overall mean of certain trait, GCA_j = the GCA for line j (SS, II and MM genotypes) (**Odeh *et al*., 2003**).

The SCA for (S×I) calculated from formula as:-

SCA for (S×I)={[(S×I)–0.11*[(SS)+(II)+ (MM)+ (S×I)+(S×M)+(I×M)+ (I×S)+(M×S)+ (M×I)]}-[(GCA for SS+ GCA for II)]

4-Heterosis and Reciprocal Heterosis Percentages:-

Heterosis was calculated on percentage of midparents: {F_1-[(P_1 + P_2)/2] / [(P_1 + P_2) / 2] x 100} using mean,

Where F_1 = the first cross and P_1 or P_2 is a parent in diallel and reciprocal crosses (**Williams *et al.*, 2002**).

Heterosis % for crosses (S×I) = {(S×I) - [(SS + II)/2] / [(SS + II) / 2] x 100}

5-Reciprocal Effect (R_E) and Maternal Effect (M_E):-

Reciprocal effect for the combination i x j was calculated as rij = (y_{ij}-y_{ji})/2.

Reciprocal effect for cross(S×I) = [(S×I)-(I×S)]/2.

Maternal effect was calculated as the mean deviation of progeny for a particular dam from mean estimated from a particular sire line (i.e. mj= (y.i-yi), where y.i=mean of dam line and yi=mean of sire line.

Maternal effect for SS= 1/3[(SS) + (I×S) + (M×S)] –1/3[(SS) +(S×I) +(S×M)]

6-Direct Additive Effect (D_E) (i.e. line group of sire differences):-

D_E for (SS) =1/3[(SS) + (SxI) + (S×M)] – ¼ [(II) + (MM) + (IxS) + (M×S)]

D_E for (II) =1/3[(II) + (IxS) + (I×M)] – ¼ [(SS) + (MM) + (SxI) + (M×I)]

D_E for (MM) =1/3[(MM) + (MxS) + (M×I)] – ¼ [(SS) + (II) + (SxM) + (I×M)]

7- Expected of Hybrid Performances

The expected full-sib family (cross) mean is the sum of four components were μ = overall mean for given trait estimated from all nine diallel crosses, GCA for male, and for female, and SCA for male and female**(Gowda *et al.*, 2012)**. Hybrid mean for (S×I) calculated from the formula as:-

$\bar{x}_{S \times I}$ = μ + GCA for (SS) + GCA for (II) + SCA for (SI)

8-Expected Breeding Values (BV) and Genetic Values (GV)

Breeding value of a parent or half-sib family is 2 times of its general combining ability. BV = 2GCA.

Any cross between two parents has an expected breeding value, which is the sum of the GCA of male and female.

BVFM = GCAF + GCAM.

The expected full-sib family (cross) mean may deviate from above sum. This deviation is called specific combining ability (SCA) of two parents. The sum of three components is called genetic value of the cross: -

GV = GCAF + GCAM + SCAFM.

Where, GCAF, GCAM, and SCAFM are general combining ability of female, male and the specific combining ability of the cross between both sexes. **(Isik, 2009).**

3. Results and Discussion

1- Body weight (BW):-

Means of body weight for males (BW) of all genotypes (purebred, crossbred, and reciprocals) tended to increase as the chicks advanced in ages (Table2). The increasing in body weight as the chicks advanced in age was, also, noticed by many investigators **(Sabra, 1990; Nawar *et al.*, 2003; Mohamed, 2003Amin, 2007and Razuki and Al-Shaheen, 2011).** There were highly significant differences among the different genotypes for male BW at all of the different ages studied. The males at hatch, 8wks and 12 wks of age for Saso strain SS and its cross with Italian chicken I×S were the heaviest followed by the reciprocal crossbreds S×I at 8and 12 wks of age, while the Mandarah strain MM had the lowest body weight at all ages studied followed by reciprocal crossbreds M×I at 12wks of age.

The males of SS chicks had a significantly higher BW at hatch (42.2g), 4wks (703.5g), 8 wks (2060.7g) and 12 wks (3103.9g) of age followed by males of II strain. On the opposite, MM strain had the lightest chicks at hatch (337.3g), 4wks (318.8g), and 8wks (790.3g) and 12 wks (1403.7g) of studied age. Similar results were obtained by **Nawar *et al.* (2003)**, who reported that Saso chickens were significantly heavier than Mandarah ones, Golden Montazah (G) and Rod Island (R) at the different ages studied.

The S×I cross and reciprocal crossbred I×S expressed the heaviest BW among all the different genotypes (crossbred & reciprocals) at hatch (43.0 and 42.9g), 4 wks (704.8and 700.6 g), 8wks (2031.1and 1789.4g), 12 wks (3002.2 and2898.2g), respectively, while the lowest values were for both crossbreds I×M and the reciprocal M×I were (38.6and 39.1 g) at the hatch, (525.8and 488.3g), at the corresponding ages.

Concerning body weight of females (BW), results in Table 3 showed that there were highly significant differences among the different genotypes for BW in females at all ages studied. The same trend was found among the three purebred lines, the SS maintained it's significant ($P<0.001$) highest BW in females followed by II, while MM females had the lightest BW at all ages studied. No significant differences between S×I cross and reciprocal crossbred I×S for BW at hatch (40.5 and 40.8g) and 12 wks of age (2353.5 and 2323.8g) were found. On the other hand, means of BW in females of S×I cross were significantly higher than that of I×S reciprocal at 4wks, (592.9and 562.9g), and (1755.6 and 1664.7g) at 8 wks of age. While the reciprocal crossbred M×S 12 weeks of age. Therefore, corresponding between strains in the present study improved body weight at different ages. The results were confirmed in the literature (**Nawar *et al.*, 2003**; **Saadey *et al.*, 2008** and **Razuki and Al-Shaheen 2011**). Significant differences between purebreds and crossbreds in body weights was reported by many reports (**Razuki and AL-Shaheen, 2011;Abou El-Ghar *et al.*, 2012; Amin *et al.*, 2013 and Lalev *et al.*, 2014).**

2- Body weight gain (BWG):-

Highly significant differences between the different genotypes for both of male and female concerning body weight gain (BWG) during the period at all ages studied, Tables 4and 5. The male and female BWG of SS strain had higher averages than II or MM at all ages. The BWG of crosses resulted from three genotypes (six crosses) was significantly different. This was because of the type of sire and/or dam position in the diallel mating. The S×I cross and its reciprocal I×S expressed the highest BWG_{0-4}(661.7and 657.7g) for male compared with the other genotypes (crossbred & reciprocals), while S×I cross had the highest BWG_{0-4} (554.2) for female. Male and female of the cross S×I had the highest BWG_{4-8} (1326.3and 1162.9g, respectively) followed by reciprocal crossbreds I×S (1088.8 and 1101.8g, respectively). In the day old to 12 wks interval, SS strains had the highest BWG_{0-12} for males and females followed by the cross of S×I and its reciprocal I×S. While males of reciprocal crossbred M×I had the light (BWG_{0-12}), females of reciprocal crossbred (M×S) had the lightest (BWG_{0-12}).

Concerning body weight gain of the combined of the two sexes, the results in Table 6 showed that respect to $BWG_{0-12,}$ it could be observed that the SS strain recorded significantly (P<0.001) highest values compared to all the rest genotypes. As for the crossbreds and reciprocal crossbreds, it was noticed that S×I cross had the highestBWG_{0-12} followed by its reciprocal I×S, while no significant differences between S×M and I×M crosses for (BWG_{0-12}). Similar results were obtained by **Amin (2008**) who found that SS strain had the highest BWG than the other studied strains at the different ages studied followed by II strain were significant differences between strains and crossbreds in body weights was confirmed by several reports **(El-Sayed *et al*., 2001; Younis and Abdel-Ghany (2003); Ghanem *et al*., 2008; Mohamed, 2003; Amin, 2007and Amin *et al*., 2013).**

3- Feed intake (FI) and feed conversion (FC):-

Birds of SS strain and S×I cross consumed more amount of ration flowed by I×S cross, while birds M×S and M×I crosses consumed the lowest amount of ration throughout the 12 weeks compared with the other genotypes, Table 6. On the other hand, birds of SS, II strains, I×M cross and its reciprocal M×I had the best feed conversion (g feed / g gain) (2.55, 2.55, 2.49 and 2.50, respectively), followed by M×S cross but, the MM birds had the lowest FC (3.43). Significant differences between strains, lines and crossbreds in feed intake and feed conversion were reported by **Nawar *et al.* (2003**) who reported that Saso chicks consumed amount of ration twice of that consumed by the other three pure strains during all the ages studied. The FC of Saso strain was the best values (1.49) followed by S×M cross (1.95) at 0-4 weeks. In general, using Saso strain as a sire or dam improved feed conversion for R, G and M strains at all intervals studied. **Amin (2008**) found significant differences between strains in the average of FI and FC during 4-8 and 8-12 wks of age. Generally, SS and II had the highest FI (101.61 and 105.06 g/hen/d) and better FC (2.44 and 2.80), respectively, during these intervals while the other strains had the lowest FI. These results were in agreement with **Saleh *et al.* (1994), El Sayed *et al.* (2001) and Younis and Abdel-Ghany (2003)** who reported significant differences between local stains for FI during different periods of age.

5-Viability percentage (V %)

Viability percentage (V %) during hatch–12 weeks of age for different genotypes are listed in Table 6. The SS chicks among genotypes had significantly the least viability (90%).However, diallel crossing of II and MM with SS chickens gave an increase in viability. Differences in viability and mortality% among purebreds were recorded by **Nawar *et al.* (2003).** The improving in viability % for crossbreds under investigation was detected by **Mohamed (2003).**

6-The general and specific combining abilities (GCA and SCA)

The GCA for males and females as well as combined body weight gain (CBWG), FI, FC and V% are presented in Tables 2,3,4,5 and 6. The GCA of BW and BWG in males, CBWG and FI both of the SS and II strains were positive and highly significant at all ages. In general, the MM strain had significant negative GCA. The SS strain had the highest value compared to the other genotypes followed by II one but the MM strain had the lowest negative values for GCA for all previous traits. The SS chicks had negative values for GCA in FI and V%. Because of GCA is the average performance of a line in different hybrid combinations **(Gardner and Eberhart, 1966**) or the numerical value that expresses the influence of the lines on its progeny, the GCA reflects the importance of the additive gene effect of genotype on BW**(Afifi *et al*., 2002)**. The differences in BW between those genotypes give good chance to select among them to improve their growth. Significant GCA of BW was found by **Razuki and Al-Soudi (2005) and Saadey *et al.* (2008). Razuki and AL-Shaheen (2011)** found that the GCA of BW in New Hampshire (NH) breeds was positive and significant at all ages, while, the White Leghorn and Brown line genotypes, had significant and negative GCA. Concerning SCA it was the best SCA combinations was for S×I followed by IxS at all ages studied and the worst combinations of I×M and M×I for BW and BWG in males, BW and BWG in females, CBWG and FI. The best SCA for V% was for combinations of S×M and I×S.The non additive genetic effects (SCA) being involved in the inheritance of body weights were also reported by **Shebl *et al.* (1990) and Mohamed *et al.* (2005).**The SCA was significant source of body weight among crossbreed groups for body weight during all studied ages**.** Many reports showed that general combining ability (additive genetic effects) was high and important as well as specific combining ability (non additive effects that involve dominance and epitasis) for body weight at different ages (**Mohamed *et al*., 2005; Amin, 2007; Saadey *et al.*, 2008; El-Bayomi *et al.,* 2009; Razuki and AL-Shaheen, 2011and Lalev *et al*., 2014.**

7-Specific and reciprocal heterosis (H %):-

Heterosis is measured by crossing populations to produce the 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. The estimates of the individual heterosis percentage (H%) for both males and females BW and BWG and CBWG, FI, FC and V% are presented in Tables 2,3,4,5 and 6. Both of the S×I crossbred and its reciprocal I×S had the heaviest birds and better body weight gain and showed the highest H% through the whole experimental period. The S×I crossbred had positive significant H% effects of BW male (3.70%, 5.12%, 6.81% and 5.33%) and female (0.05%, 16.43%, 11.16% and 5.75%) at 0,4, 8 and 12 wks of age, respectively, and BWG in male and in females (except 4-8wks) at all intervals studied, moreover, CBWG, FI, FC and V % at 0-12 wks. Moreover, it had positive significant H% effects of BWG in both of male and female, CBWG, FI, FC and V % at the whole experimental period (5.30%, 5.94 %, 210.2%, 870.4%, 0.16% and 0.20 %, respectively). The same trend was found for the reciprocal crossbred I×S, it had positive and significant H% effects for previous traits (except BW in male at 8 week of age and BWG in male at 4-8 wks). The I×M crossbred had positive and significant H% effects for the former traits (except for BW in male and female at hatch, BWG in male at 4-8 wks, FI, FC and V% had negative H%). **Nawar *et al.* (2003**) reported that progeny which produced from Sasso with Gimmizah strains mating or reciprocal between Sasso and other three strains showed negative estimates of H% for BW at the different ages studied. Moreover, using SS strain as a sire, the highest of H% was realized for S×M cross (0.05%), while, the lowest value was for Saso×Gimmizah (-14.64%) at 6 wks of age. Percentage of heterosis recorded by **Khalil *et al.* (1999)** and **Sabri *et al.* (2000)** were lower than those obtained in this study. (**Yalcin *et al.*, 2000)**.**Sabra (1990)** found that crossbreds obtained from crossing between local breeds (Silver Montazah and Dandarawi) had 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 and Matrouh strains. 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**). Some studies obtained significant heterotic effects on body weights **(Singh *et al*., 1983 and Sabri *et al*., 2000).** Inversely, **Hanafi and Iraqi (2001)** found non-significant heterotic effects on body weight at 8 weeks 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 heterozygosis 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 an expression of a specific trait. Heterosis is usually greater for reproductive traits than for growth traits **(Fairfull, 1990). Saadey *et al.*, 2008** showed that the crossing between either local Egyptian chickens named Sinai (S) in sire (male) position with White Leghorn in dam (female) position or Fayoumi (F) in sire (male) position with Sinai in dam (female) position gave the highest positive heterosis for of body weight. The SxF cross had positive and high H% of body weight at hatching time and at one month of age. **Razuki and AL-Shaheen (2011)** found highest positive heterosis occurred in crosses of Brown line x New Hampshire and New Hampshire x White Leghorn, whereas, the other crosses ranged from negative sign to positive sign between one day old to 112 days of age.

8-Reciprocal effect (R_E): -

Positive high reciprocal (sex linkage) effects for body weight and body weight gain were detected for all crosses at different ages (Tables 2,3,4,5 and 6). Significant reciprocal (sex chromosomal) effect on body weight gain in the different genetic groups for diallel crossing of Saso, Italian and Mandarah chickens were estimated at the intervals 0-4, 4-8, 8-12 and 0 -12wks. Reciprocal effects were significant for BW in male and in females at 4, 8 and 12 weeks of ages at for crosses of S×I and S×M. The same trend was found for BWG in both of males and females at intervals 4-8, 8-12 and 0 -12 wks. The I×M cross had reciprocal effects which were significant for BW in males and females at 12 weeks of age and for BWG in males at the intervals 0-4, 4-8, 8-12 and 0 -12wks. In addition, BWG in females at the intervals 8-12 and 0 -12wks, moreover, CBWG at intervals 0 -12wks. Reciprocal effects were non significant for FI, FC and V% in the whole experimental period for crosses S× I, S×M and I×M. Reciprocal effects were at least as important as heterosis and the magnitude of it tended to be greater in the case of heterosis was small **(Fairfull *et al.,* 1983).** Significant reciprocal effects for BW were found by **Jakubec *et al.* (1987) and Vitek *et al*. (1994)**.**Rdzuki and AL-Shaheen (2011)** reported that reciprocal effects were significant for BW at day old for crosses of White Leghorn (WL) x Brown line (BL), WLx New Hampshire (NH) and B l x NH and at 28 days of age for WL x NH and BlxN H crosses and at 56 days of age for Bl xNH.

9-Maternal (M_E) and direct additive effect (D_A):-

Maternal effect of BW in male and female were positive and significant at 4, 8 and 12 weeks of ages for MM, while it was negative and significant for SS. Moreover, was positive and significant for BWG in male and female at the intervals 0-4, 4-8, 8-12 and 0-

12wks for MM, while, it was negative and significant (except BWG in male at 4-8 wks) for SS at the same intervals. On the other hand, direct additive effect had a reverse trend about maternal effects, the SS strain had highly positive and significant value for BW in males and females, BWG in males and females, CBWG, FI and V% at 4, 8 and 12 wks of age and whole interval while the MM strain had highly negative and significant values in the same ages and intervals. The values of maternal additive and direct additive effects showed superiority of SS and II as sires which suggest that using of this variety as a terminal sire breed in crossbreeding programs including MM dams would be beneficial for improving the BW in males and females, BWG in males and females, CBWG, FI and V% traits. Similar results were obtained by **Saadey *et al.*(2008)** who found that SxWL cross achieved the superior estimates of maternal effects for body weight at all studied ages and it was significantly effect at different ages. **Iraqi, (2008)** showed that direct additive effect for growth traits was significant for all body weights. **Khalil *et al*., (1999)** found that direct additive effect ranged from 4.9 to 10.2% for body weights. **Saadey *et al.* (2008)** found that estimates of maternal effect for body weight at all studied ages were significant**. Razuki and AL-Shaheen (2011)** found that maternal effects of BW were highly significant at hatch for WL and Bl dams. After hatch, maternal effects were significant in B l dams with negative influence on BW at 28 and 56 days of age, while **Abdel-Hamed *et al.* (2004) and Nofal (2005)** reported that maternal additive effects of all growth traits were not significant. **Amin *et al*. (2013)** crossed in a 2x2 diallel mating using two local strains (Egg line E and Meat line M) and two crosses and found that estimates of direct additive and direct maternal genetic effect for BW at hatch (BW0) were – 0.71 and 0.44, respectively. Opposite trend compared to the BW at 4 wks and at 8 wks of ages was found which take the same trend for direct additive and maternal effect. Direct additive were 22.43 and 56.16 for BW4 and BW8, respectively. All direct additive and maternal effect estimates were highly significant values. Egg line was better as a sire than meat line for BW0, but the meat line was better for each of BW4 and BW8 traits.

10-Using general and specific combining ability to expect of hybrid performances, breeding and genetic values:-

The expected of hybrid performances for BW male and female, BWG in male female, CBWG, FC, FI and V % traits, difference between the actual and expected previous traits and the percentages differences are presented in Tables 7, 8, 9, 10 and 11. The differences (g and %) for the actual and expected all genotypes were generally small and ranged from -0.05 to 1.11g and from -0.04 to 0.00% for the actual performances and the percentage difference(in relation to actual Y%), respectively. The present result showed that the small difference may be due to figures rounded entering in the prediction equations**.** The breeding and genetic values of BW at the different studied ages and BWG at the different intervals studied for diallel crossing of SS, II and MM chickens are presented in Tables 7, 8,9,10 and 11. The SS had the highest breeding values for BW in males (1.92, 111.32, 58.82 and 573.91g) at 0, 4, 8 and 12, weeks of age and BWG in males (109.44, 247.77, 247.77and 572.52g) at the intervals 0-4, 4-8, 8-12 and 0 -12 wks compared to the other genotypes followed by II (1.47,98.63, 240.40 and 274.73g) for BW in males at 0, 4, 8 and 12, weeks of age and (97.12, 141.42, 33.99 and 272.59g) for BWG in males at the intervals 0-4, 4-8, 8-12 and 0 -12 wks. Moreover, it had highest breeding values for BW in females at 12 weeks of age and BWG in females and CBWG at the whole experimental period. On the opposite, the MM strain had the lowest negative values for former traits. As for breeding values for crosses results showed that the progeny of S×I cross had the highest positive values BW in males and females, BWG in males and females, CBWG and FI traits at all ages and intervals studied. Contrary, the crosses S×M and I×M had the lowest negative values for the former traits (except in female at 8-12 wks for cross S×M which had the highest positive values).Considering genetic values for crosses, results showed that the progeny of S×I cross and reciprocal cross I×S had the highest positive values for all trait studied [except V% for S×I and FC for I×S were lowest negative values]. Fortunately, progeny of S×I cross surpassed its reciprocal cross I×S for all traits studied (except BWG in males, BWG in females at 8-12 wks and V %). Results can be summarized diallel crossing of Italian and Mandarah with Saso strains gave an increase in viability. Superiority of Saso and Italian strains as sires which suggest that using of those strains as a terminal sire breed in crossbreeding programs including Mandarah dams would be beneficial for improving the BW and BWG in males and females, CBWG, FI, FC and V% traits.

Table (2): Means± SE for actual (Y) male body weight, general and specific combining ability, heterosis percentages, reciprocal, maternal and direct additive effects at the different studied ages from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Genotypes	Body weight at different ages (weeks)			
	Hatch	**4**	**8**	**12**
Purebreds				
SS	42.2 ^{a}±3.5	703.5 ^{a}±64.8	2060.7 ^{a}±280.2	3103.9 ^{a}±204.1
II	40.7 ^{b}±3.0	637.5 ^{b}±52.6	1742.5 ^{c}±139.3	2600.6 ^{d}±251.0
MM	37.3 ^{d}±2.6	318.4 ^{f}±86.6	790.3 ^{f}±58.60	1403.7 ^{h}±109.5
Crosses				
S×I	43.0 ^{a}±2.2	704.8 ^{a}±98.6	2031.1 ^{a}±240.8	3002.2 ^{a}±204.7
S×M	38.1 ^{c}±2.2	525.9 ^{c}±52.4	1384.2 ^{d}±96.8	2258.3^{c}±195.4
I×M	38.6 ^{c}±2.1	525.8 ^{c}±77.3	1398.6 ^{d}±168.6	2100.9 ^{f}±361.0
Reciprocal				
I×S	42.9 ^{a}±2.2	700.6 ^{a}±73.9	1789.4 ^{b}±164.6	2898.2^{b}±314.5
M×S	39.3 ^{b}±1.9	454.0 ^{e}±42.1	1292.3 ^{e}±140.0	2051.7 ^{f}±242.8
M×I	39.1 ^{b}±1.7	488.3 ^{d}±47.3	1300.1^{e}±88.80	1960.4^{g}±230.2
Overall mean	40.1±3.2	562.1±144.0	1532.3±436.8	2375.4±601.1
Significance	***	***	***	***
General Combining Ability (GCA)				
SS	0.96±0.01 *	55.66±2.02 **	179.41±20.00 **	286.95±30.02 **
II	0.73±0.01 *	49.32±5.01 **	120.20±18.00 **	137.37±12.12 **
MM	-1.66±0.01 ns	-99.60±10.2 *	-299.04±30.10 *	-420.09±9.21 **
Specific Combining Ability(SCA)				
S×I	1.19±0.01	37.72±11.1**	199.3±10.20**	202.80±20.1**
S×M	-1.37±0.02 ns	7.75±1.10 ns	-28.31±9.01**	16.34±2.20*
I×M	-0.58±0.01 ns	14.01±0.02*	45.28±1.01*	8.55±4.50 ns
I×S	1.05±0.01 ns	33.53±3.02**	-42.31±8.01 ns	98.77±7.04**
M×S	-0.14±0.01 ns	-64.18±0.01 ns	-120.17±12.20	-190.25±9. **
M×I	-0.11±0.01 ns	-23.46±2.20**	-53.23±7.01**	-131.99±13. **
Specific heterosis				
S×I	3.70±0.90*	5.12±0.70**	6.81±0.10**	5.33±0.50*
S×M	-4.28±0.80 ns	2.93±0.02 ns	-2.90±0.01 ns	0.29±0.01 ns
I×M	-1.01±0.02*	10.01±1.01*	10.43±1.02*	4.94±0.07*
Reciprocal heterosis				
I×S	3.37±0.80*	4.49±0. 80*	-5.90±0.10 ns	1.68±0.01*
M×S	-1.17±0.02 ns	-11.15±0.9*	-9.34±1.08*	-8.88±0.70 ns
M×I	0.21±0.01 ns	2.17±0.08 ns	2.66±0.09 ns	-2.08±0.01 ns
Reciprocal effect				
S×I	0.1±0.01 ns	2.1±0.06*	120.8±123.20*	52.0±4.98*
S×M	-0.6±0.02 ns	36.0±2.05*	45.9±4.12*	103.3±10.2*
I×M	-0.2±0.01 ns	18.7±3.01 ns	49.3±5.50 ns	70.3±6.25*
Maternal effect				
SS	0.37±0.04 ns	-25.37±2.21**	-111.17±11.25**	-103.54±9.24**
II	0.20±0.01 ns	-11.09±1.27 ns	47.71±4.28*	-12.17±1.02*
MM	-0.57±0.02*	36.47±2.98**	63.46±5.55**	115.71±10.25**
Direct additive effect				
SS	1.0±0.08 ns	117.1±12.20**	421.7±12.50**	548.2±50.21**
II	0.3±0.02*	67.5±6.98*	98.0±9.250*	166.7±13.25*
MM	-1.3±0.2 ns	-177.9±14.21**	-518.9±49.20**	-709.7±80.25**

(a-h)= Means within a column with no common superscripts differ significantly (p<0.001),
* P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, ns: not significant.

Table (3):Means± SE for actual (Y) female body weight, general and specific combining ability, heterosis percentages, reciprocal, maternal and direct additive effects at the different studied ages from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Genotypes	Body weight (weeks)			
	Hatch	4	8	12
Purebreds				
SS	41.3 [a] ±3.4	525.6 [c] ±42.2	1645.7 [b] ±141.8	2600.6 [a] ±232.9
II	39.7 [c] ±2.7	492.9 [d] ±43.6	1513.1 [c] ±117.6	1850.4 [c] ±204.7
MM	36.9 [f] ±2.0	306.5 [h] ±29.0	692.6 [g] ±67.3	1139.5 [h] ±125.8
Crosses				
S×I	40.5 [b] ±2.5	592.9 [a] ±103.7	1755.6 [a] ±292.5	2353.5 [b] ±427.1
S×M	38.6 [d] ±2.5	406.3 [f] ±77.7	900.7 [f] ±92.2	1428.3 [f] ±90.2
I×M	37.5 [e] ±1.8	432.0 [e] ±90.7	1202.1 [d] ±134.8	1605.5 [d] ±129.0
Reciprocal				
I×S	40.8 [b] ±2.1	562.9 [b] ±84.0	1664.7 [b] ±153.3	2323.8 [b] ±295.2
M×S	38.4 [d] ±1.8	351.1 [g] ±66.6	873.9 [f] ±100.6	1260.0 [g] ±97.6
M×I	37.5 [e] ±1.7	423.2 [e] ±96.0	1158.1 [e] ±105.1	1505.3 [e] ±265.5
Overall mean	39.0±2.8	454.8±117.4	1267.6±398.7	1785.4±547.6
Significance	***	***	***	***
General Combining Ability (GCA)				
SS	0.91±0.01 ns	32.93±3.25**	100.72±12. 1**	208.03±36.2**
II	0.17±0.04 ns	45.98±5.25**	191.35±25.2**	142.49±19.2**
MM	-1.24±0.07 ns	-71.01±9.24**	-301.91±41.2**	-397.50±75.2**
Specific Combining Ability(SCA)				
S×I	0.41±0.02*	59.18±7.25**	196.1±30.21**	217.77±45.26**
S×M	-0.06±0.01 ns	-10.48±2.25 ns	-165.53±25.2**	-167.43±17.20**
I×M	-0.48±0.04 ns	2.24±0.80 ns	45.33±6.24**	75.28±9.25**
I×S	0.68±0.01 ns	29.20±5.28*	105.25±11.25*	188.05±25.01**
M×S	-0.29±0.02 ns	-65.64±9.24 ns	-192.33±25.2 ns	-335.76±77.25**
M×I	-0.43±0.07 ns	-6.59±2.24	1.30±0.028 ns	-24.90±5.24**
Specific heterosis				
S×I	0.05±0.00 ns	16.43±1.24*	11.16±1.10**	5.75±0.80*
S×M	-1.19±0.01 ns	-2.35±0.07 ns	-22.96±2.27 ns	-23.62±0.88 ns
I×M	-2.096±0.07 ns	8.084±0.10*	9.006±1.80*	7.393±0.89*
Reciprocal heterosis				
I×S	0.71±0.04*	10.54±1.12*	5.40±1.01*	4.42±0.71*
M×S	-1.78±0.09 ns	-15.61±1.50*	-25.26±4.20*	-32.62±3.25*
M×I	-1.97±0.07 ns	5.88±0.50 ns	5.01±0.89 ns	0.69±0.08 ns
Reciprocal effect				
S×I	-0.1±0.01 ns	15.0±2.21*	45.5±0.80*	14.9±2.24*
S×M	0.1±0.01 ns	27.6±5.24*	13.4±1.20*	84.2±10.21*
I×M	0.0±0.00 ns	4.4±0.80 ns	22.0±2.24 ns	50.1±10.20*
Maternal effect				
SS	0.01±0.01 ns	-28.38±4.21**	-39.23±4.28**	-66. 1±4.50**
II	-0.07±0.00 ns	7.05±1.21 ns	15.62±2.24 ns	-23.5±6.21**
MM	0.06±0.01 ns	21.33±4.21**	23.61±5.21**	89.5±8.55**
Direct additive effect				
SS	1.2±0.02*	79.9±10.24**	247.9±30.20**	484.1±33.24**
II	0.3±0.01*	33.9±6.27*	147.0±16.20*	26.8±2.60*
MM	-1.7±0.08*	-103.9±11.25**	-407.2±44.2**4	-569.6±78.14**

(a-h)= Means within a column with no common superscripts differ significantly (p<0.001),
* P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, ns: not significant.

Table (4): Means± SE for actual (Y) male bodyweight gain at different intervals, general and specific combining ability, heterosis percentages, reciprocal, maternal and direct additive effect at the different studies ages from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Genotypes	Body weight gain (weeks)			
	Hatch - 4wks.	4wks.-8wks.	8wks.-12 wks.	Hatch -12 wks.
Purebreds				
SS	661.5 [a]±64.7	1358.7 [a] ±381.0	1040.5 [b]±209.0	3060.7 [a] ±301.8
II	596.8 [b]±53.3	1105.0[b] ±133.6	857.8 [e]±215.40	2559.7[d]±351.1
MM	281.1f±86.8	471.9 [e] ±96.50	613.4[h]±115.50	1366.4[h]±109.6
Crosses				
S×I	661.7 [a]±98.8	1326.3 [a] ±318.3	971.2 [c]±202.10	2959.2 [b]±304.6
S×M	487.8 [c]±51.6	858.3 [c]±105.9	874.1 [e] ±208.70	2220.3[e] ±195.6
I×M	487.2 [c]±77.7	872.8 [c]±149.3	702.4 [fg]±249.80	2062.6 [f]±361.1
Reciprocal				
I×S	657.7 [a]±74.2	1088.8 [b] ±160.0	1108.8 [a]±220.4	2855.3[c] ±314.8
M×S	414.6[e]±41.8	838.4 [cd] ±136.5	759.4 [f]±233.60	2012.4 [f]±242.7
M×I	449.2 [d]±46.9	811.7 [d] ±79.600	660.3[gh]±180.90	1921.3[g] ±229.8
Overall mean	522.0±142.5	970.4±330.1	843.2±318.7	2335.7±599.8
Significance	***	***	***	***
General Combining Ability (GCA)				
SS	54.72±5.21**	123.88±14.2**	107.69±17.2**	286.26±29.2**
II	48.56±4.80**	70.71±9.10**	16.99±3.2**	136.29±40.2**
MM	-97.98±10.2**	-199.6±18.2**	-121.17±14.2**	-418.72±55.2**
Specific Combining Ability(SCA)				
S×I	36.50±3.65*	161.47±15.2**	3.4±1.010*	201.33±23.0**
S×M	9.11±0.90 ns	-36.20±3.68*	44.51±4.12**	17.39±1.92*
I×M	14.62±2.25*	31.44±4.25**	-36.56±5.25 ns	9.73±1.250 ns
I×S	32.45±3.25*	-75.98±8.92**	140.99±12.25	97.43±23. **
M×S	-64.06±6.25 ns	-56.13±6.50**	-70.22±8.25**	-190.44±18. **
M×I	-23.32±11.20	-29.60±11.25*	-78.59±14.5**	-131.61±14**
Specific heterosis				
S×I	5.18±1.21**	7.66±.078*	2.32±0.09*	5.30±1.20*
S×M	3.51±0.90 ns	-6.23±1.20 ns	5.70±1.02	0.30±0.02 ns
I×M	10.99±0.28*	10.69±2.25**	-4.52±10.2*	5.07±1.04 ns
Reciprocal heterosis				
I×S	4.54±0.09*	-11.61±2.58*	16.82±2.25*	1.61±0.02*
M×S	-12.02±1.90 ns	-8.41±1.95 ns	-8.17±2.05 ns	-9.09±1.25 ns
M×I	2.34±0.08 ns	2.95±.09 ns	-10.24±2.250 ns	-2.13±0.10 ns
Reciprocal effect				
S×I	2.0±0.04 ns	118.7±20.25*	-68.8±12.24*	51.9±7.23*
S×M	36.6±2.95 ns	10.0±1.24*	57.4±10.27*	103.9±10.24*
I×M	19.0±5.20*	30.5±3.25*	21.0±5.24*	70.7±20.36*
Maternal effect				
SS	-25.74±2.95*	-85.79±10.24*	7.62±1.24*	-103.91±20.28*
II	-11.30±2.24	58.80±10.28	-59.88±9.20*	-12.48±1.28*
MM	ns37.04±4.95*	26.99±2.98*	52.25±10.25*	116.39±13.80*
Direct additive effect				
SS	116.1±12.24**	305.1±30.24**	127.1±12.4**	548.3±50.28**
II	67.2±9.25**	30.0±6.24 ns	68.3±8.23*	165.6±20.25**
MM	-176.7±20.28**	-341.4±60.12**	-191.0±21.5**	-709.1±105.2**

(a-h)= Means within a column with no common superscripts differ significantly (p<0.01),
* P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, ns: not significant.

Table (5): Means± SE for actual (Y) female body weight gain at different intervals, general and specific combining ability, heterosis percentages, reciprocal, maternal and direct additive effect at the different studies ages from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Genotypes	Female body weight gain (g)			
	Hatch - 4wks.	4wks.-8wks.	8wks.-12 wks.	Hatch -12 wks.
Purebreds				
SS	484.3^{c} ±42.3	1120.1^{b} ±139.8	954.9^{a} ±272.2	2559.3^{a} ±232.7
II	453.3^{d} ±43.5	1020.1^{c} ±108.3	337.3^{g}±222.0	1810.8^{d} ±204.7
MM	270.5^{h} ±32.2	389.1^{h} ±78.0	447.3^{e} ±99.3	1106.9^{l}±141.2
Crosses				
S×I	554.2^{a} ±105.5	1162.9^{a}±248.4	597.7^{c}±315.3	2314.8^{b}±427.1
S×M	367.8^{f}±76.7	494.6^{g}±63.7	527.6^{d} ±110.9	1390.1^{g}±90.3
I×M	394.6^{e}±90.6	770.1^{d} ±160.0	403.3^{f}±154.2	1568.0^{e} ±129.2
Reciprocal				
I×S	522.2^{b} ±84.3	1101.8^{b} ±153.0	659.1^{b} ±293.5	2283.0^{c}±294.9
M×S	312.7^{g}±66.7	522.7^{f}±126.8	386.1^{f} ±110.9	1221.6^{h} ±97.3
M×I	385.7^{e} ±95.8	734.9^{e}±135.4	347.4^{g} ±268.5	1467.8^{f}±265.3
Overall mean	416.1±116.7	812.9±316.7	517.9±289.1	1746.9±546.3
Significance	***	***	***	***
General Combining Ability (GCA)				
SS	32.09±5.21**	67.50±10.22**	107.22±20.2**	206.84±44.2**
II	45.84±6.25**	145.03±18.20**	-48.90±9.02**	141.95±18.2**
MM	-69.87±8.23**	-230.64±40.2**	-95.52±9.25**	-396.04±41.0**
Specific Combining Ability(SCA)				
S×I	60.10±7.20**	137.44±13.20**	21.5±2.980**	219.09±39.2**
S×M	-10.53±1.9 ns	-155.16±15.2**	-1.97±0.080 ns	-167.63±16.2**
I×M	2.46±0.08 ns	42.79±4.25**	29.87±3.020*	75.18±10.21**
I×S	28.09±2.014*	76.29±8.56**	82.89±10.21*	187.30±19.30**
M×S	-65.64±6.2**	-127.05±12.56	-143.46±16.2**	-336.13±50.2**
M×I	-6.42±1.02*	7.58±1.20 ns	-26.05±2.60**	-25.05±3.50*
Specific heterosis				
S×I	18.22±2.21*	8.67±1.02*	-7.49±1.02*	5.94±0.9**
S×M	-2.53±0.08 ns	-34.45±12. ns	-24.75±2.5 ns	-24.17±0.9 ns
I×M	9.024±1.21*	9.2981.24*	2.80±.020*	7.4831.20*
Reciprocal heterosis				
I×S	11.39±1.95*	2.96±0.02*	2.00±0.02*	4.48±0.84*
M×S	-17.14±1.1 ns	-30.72±3.35 ns	-44.93±3.25*	-33.36±3. ns
M×I	6.57±2.02 ns	4.30±0.50 ns	-11.45±1.25 ns	0.61±0.02
Reciprocal effect				
S×I	16.0±1.80*	30.6±4.14*	-30.7±3.21 *	15.9±2.24*
S×M	27.6±3.52*	-14.1±1.24*	70.7±5.68*	84.2±7.21*
I×M	4.4±0.18 ns	17.6±15.5 ns	28.0±0.12*	50.1±4.25*
Maternal effect				
SS	-29.04±3.28*	-11.01±1.12*	-26.71±2.65**	-66.76±6.65 *
II	7.71±1.28*	8.65±1.35 ns	-39.09±4.28*	-22.81±4.21 ns
MM	21.33±2.24*	2.36±0.09*	65.80±3.56*	89.57±8.22*
Direct additive effect				
SS	79.1±10.25**	167.5±20.23**	235.9±22.14**	482.5±45.11**
II	33.0±4.28**	112.3±22.1**	-120.3±12.25**	25.1±2.53**
MM	-102.0±18. **	-302.3±33.21**	-162.2±18.4**	-566.688.21**

(a-l)= Means within a column with no common superscripts differ significantly ($p<0.01$),
* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, ns: not significant.

Table (6): Means± SE for actual (Y) combine body weight gain, feed intake (Kg /bird/12weeks), feed conversion (g feed /g gain), viability%, general and specific combining ability, heterosis percentages, reciprocal effect, maternal effect and direct additive effect at the whole period studies (from 0 to12 weeks) from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Traits / Genotypes	Body weight gain	Feed intake (Kg /bird/12wks)	Feed conversion (g feed/ g gain)	Viability% (V %) Actual	Viability% (V %) Corrected
Purebreds					
SS	2810 [a] ±210	7165.5 [a] ±700	2.55 [ab]±0.02	90.00[b]	71.6±5.19
II	2185[d]±240	5572.3[c] ±450	2.55 [ab] ±0.09	94.60 [a]	75.8±6.36
MM	1236±750	4241.9[d] ±420	3.43 [e] ±0.07	94.54 [a]	75.7±6.34
Crosses					
S×I	2637 [b] ±210	7146.3 [a] ±650	2.71 [c d] ±0.10	93.20 [a]	74.7±7.17
S×M	1805[e] ±71	4928.2[d]±456	2.73 [d] ±0.05	93.40 [a]	74.5±7.36
I×M	1815[e] ±75	4520.1[e] ±400	2.49 [a] ±0.09	94.00 [a]	75.8±5.63
Reciprocal					
I×S	2569 [c] ±190	6731.3[b]±550	2.62 [b c] ±0.09	93.50 [a]	74.5±6.50
M×S	1617[g]±90	4382.1[f] ±410	2.71 [c d] ±0.07	92.83[a]	73.6±7.86
M×I	1694[f]±170	4236.[f] 3±420	2.50 [a] ±0.04	93.00 [a]	74.4±5.10
Overall mean	2041.12±200	5508.8±570	2.70±0.28	93.23	73.6±6.97
Significance	**	***	**	*	
General Combining Ability (GCA)					
SS	246.5±42.2**	634.7±74.21**	-0.036±0.02	-0.64±0.04ns	
II	139.1±20.2**	205.3±42.36**	-0.124±0.01	0.43±0.01*	
MM	-407.4±45.5**	-974.3±90.2**	0.074±0.03	0.32±0.03 ns	
Specific Combining Ability(SCA)					
S×I	210.2±30.2**	870.4±100.0**	0.163±0.007	0.20±0.09	
S×M	-75.1±102**	-168.2±22.32**	-0.005±0.11	0.49±0.20	
I×M	42.5±5.26*	-146.9±14.58**	-0.156±0.06	0.02±0.02	
I×S	142.4±18.2**	455.4±50.24**	0.084±0.05	0.48±0.02	
M×S	-263.3±32.2**	-714.3±112.2**	-0.025±0.05	0.08±0.10	
M×I	-78.3±9.20**	-430.7±42.2**	-0.147±0.06	-0.98±0.04	
Specific heterosis					
S×I	5.6±0.81*	12.2±2.21**	6.27±1.20*	0.98±0.08*	
S×M	-11.9±1.2ns	-13.6±1.39 ns	-8.70±0.4 ns	1.22±0. 9 ns	
I×M	6.3±0.81*	-7.8±0.81*	-16.72±1. 4*	-0.60±0.01 ns	
Reciprocal heterosis					
I×S	3.0±0.08*	5.70±0.81*	2.75±0.0*	1.30±0.09*	
M×S	-21.2±1.25 ns	-23.1±2.90 ns	-9.36±0.7ns	0.61±0.07 ns	
M×I	-0.8±0.01 ns	-13.6±1.80 ns	-16.39±1.8 ns	-1.66±0.10 ns	
Reciprocal effect					
S×I	33.9±0.28 ns	207.5±22.12*	0.04±0.01 ns	-0.15±0.02 ns	
S×M	94.1±8.24*	273.1±33.63 ns	0.01±0.00 ns	0.29±0.03 ns	
I×M	60.4±7.21*	141.9±20.21 ns	0.00±0.00 ns	0.50±0.04 ns	
Maternal effect					
SS	-85.33±9.2 ns	-320.36±44.2 ns	-0.04±0.01 ns	-0.09±0.01 ns	
II	-17.65±1.9 ns	43.73±10.2 ns	0.03±0.01 ns	-0.43±0.05 ns	
MM	102.9810.23*	276.6332.25**	0.00±0.00 ns	0.520.09 ns	
Direct additive effect					
SS	515.4±60.2**	1181.4±203.2**	-0.2±0.01 ns	-1.7±0.10**	
II	95.3±12.25**	-89.6±8.25**	-0.2±0.01 ns	1.3±0.12*	
MM	-637.9±56.2**	-1259.8±89.2**	0.3±0.01*	0.5±0.15**	

(a-h)= Means within a column with no common superscripts differ significantly (p<0.01),
* P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, ns: not significant.

Table (7): prediction of male body weight (Ỹi), breeding values and genetic values at the different ages studied from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Prediction traits	Age, wks. / Genotypes	Hatch	4	8	12
Hybrid performance (Ỹi)	**S×I**	43.00	704.80	2031.10	3002.20
	S×M	38.10	525.88	1384.19	2258.32
	I×M	38.63	525.79	1398.57	2100.94
	I×S	42.88	700.58	1789.42	2898.21
	M×S	39.30	453.95	1292.33	2051.73
	M×I	39.10	488.32	1300.06	1960.40
Breeding values	**SS**	1.92	111.32	358.82	573.91
	II	1.47	98.63	240.40	274.73
	MM	-3.32	-199.20	-598.07	-840.19
	S×I	1.70	105.00	299.60	424.30
	S×M	-0.70	-43.90	-119.6	-133.10
	I×M	-0.93	-50.28	-178.84	-282.73
Genetic values	**S×I**	2.90	142.70	498.90	627.10
	S×M	-2.10	-36.20	-147.90	-116.8
	I×M	-1.51	-36.27	-133.56	-274.18
	I×S	2.70	138.50	257.30	523.10
	M×S	-0.80	-108.10	-239.80	-323.40
	M×I	-1.04	-73.74	-232.07	-414.72

The differences (g and %) for the actual and expected and in relation to actual (Y) % for all genotypes were approximately equal zero.

Table (8): prediction of female body weight (Ỹi), breeding values and genetic values at the different ages studied from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Prediction genetic traits	Age, wks. / Genotypes	At hatch	4	8	12
Hybrid performance(Ỹi)	**S×I**	40.50	592.90	1755.60	2353.50
	S×M	38.60	406.27	900.66	1428.28
	I×M	37.46	432.03	1202.14	1605.45
	I×S	40.76	562.93	1664.68	2323.75
	M×S	38.38	351.10	873.85	1259.96
	M×I	37.50	423.20	1158.11	1505.27
Breeding values	**SS**	1.81	65.86	201.44	416.06
	II	0.35	91.95	382.70	284.98
	MM	-2.48	-142.02	-603.82	-795.00
	S×I	1.10	78.90	292.10	350.50
	S×M	-0.30	-38.10	-201.20	-189.50
	I×M	-1.07	-25.03	-110.56	-255.01
Genetic values	**S×I**	1.50	138.10	488.20	568.30
	S×M	-0.40	-48.60	-366.7	-356.90
	I×M	-1.55	-22.80	-65.23	-179.73
	I×S	1.80	108.10	397.30	538.60
	M×S	-0.60	-103.70	-393.5	-525.20
	M×I	-1.50	-31.63	-109.26	-279.91

The differences (g and %) for the actual and expected and in relation to actual (Y) % for all genotypes were approximately equal zero.

Table (9): prediction of male body weight gain (Ỹi), breeding values and genetic values at the different ages studied from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Prediction traits	Interval of age / Genotype	Hatch - 4wks.	4-8wks.	8-12 wks.	Hatch -12 wks.
Hybrid performance (Ỹi)	**S×I**	661.70	1326.30	971.20	2959.20
	S×M	487.80	858.31	874.14	2220.26
	I×M	487.17	872.77	702.37	2062.64
	I×S	657.70	1088.84	1108.79	2855.33
	M×S	414.65	838.38	759.40	2012.43
	M×I	449.22	811.73	660.35	1921.30
Breeding values	**SS**	109.44	247.77	247.77	572.52
	II	97.12	141.42	33.99	272.59
	MM	-195.96	-399.20	-242.35	-837.45
	S×I	103.30	194.6	124.7	422.6
	S×M	-43.30	-75.70	-13.5	-132.5
	I×M	-49.42	-128.89	-104.18	-282.43
Genetic values	**S×I**	139.80	356.10	128.10	623.90
	S×M	-34.10	-111.90	31.00	-115.10
	I×M	-34.80	-97.45	-140.74	-272.70
	I×S	135.70	118.60	265.70	520.00
	M×S	-107.30	-131.80	-83.70	-322.90
	M×I	-72.74	-158.49	-182.77	-414.04

The differences (g and %) for the actual and expected and in relation to actual (Y) % for all genotypes were approximately equal zero.

Table (10): Prediction of female body weight gain (Ỹi), breeding values and genetic values at the different ages studied from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Prediction traits	Interval of age / Genotype	Hatch - 4wks.	4-8wks.	8-12 wks.	Hatch -12 wks.
Hybrid performance (Ỹi)	**S×I**	554.20	1162.90	597.70	2314.80
	S×M	367.80	494.64	527.59	1390.07
	I×M	394.57	770.11	403.31	1567.99
	I×S	522.17	1101.76	659.07	2282.99
	M×S	312.73	522.75	386.10	1221.58
	M×I	385.69	734.91	347.39	1467.77
Breeding values	**SS**	64.19	135.00	214.43	413.68
	II	91.68	290.07	-97.80	283.90
	MM	-139.73	-461.27	-191.03	-792.08
	S×I	77.90	212.50	58.30	348.80
	S×M	-37.80	-163.10	11.70	-189.20
	I×M	-24.03	-85.60	-144.41	-254.09
Genetic values	**S×I**	138.00	350.00	79.80	567.90
	S×M	-48.30	-318.30	9.70	-356.80
	I×M	-21.57	-42.82	-114.55	-178.91
	I×S	106.00	288.80	141.20	536.10
	M×S	-103.4	-290.20	-131.80	-525.30
	M×I	-30.45	-78.02	-170.47	-279.14

The differences (g and %) for the actual and expected and in relation to actual (Y) % for all genotypes were approximately equal zero.

Table (11): Prediction (Ỹi) of body weight gain, feed intake, feed conversion, viability, breeding and genetic values from the diallel crossing of Saso (SS), Italian (II) and Mandarah (MM) chicks strains

Prediction traits	traits / Genotypes	Bodyweight gain	Feed intake	Feed conversion	Viability%
Hybrid performance (Ỹi)	**S×I**	2637.00	7146.30	2.70	93.20
	S×M	1805.20	4928.20	2.73	93.40
	I×M	1815.30	4520.10	2.49	94.00
	I×S	2569.20	6731.30	2.62	93.50
	M×S	1617.00	4382.10	2.71	92.83
	M×I	1694.50	4236.30	2.50	93.00
Breeding values	**SS**	493.10	269.40	-0.07	-1.29
	II	278.20	410.50	-0.25	0.86
	MM	-814.80	-1948.60	0.15	0.65
	S×I	385.70	839.90	-0.16	-0.21
	S×M	-160.83	-339.60	0.04	-0.32
	I×M	-268.26	-769.02	-0.05	0.75
Genetic values	**S×I**	595.90	1710.30	0.01	-0.03
	S×M	-236.00	-507.80	0.03	0.17
	I×M	-225.80	-915.90	-0.21	0.77
	I×S	528.00	1295.30	-0.08	0.27
	M×S	-424.10	-1053.90	0.01	-0.40
	M×I	-346.59	-1199.70	-0.20	-0.23

The differences (g and %) for the actual and expected and in relation to actual (Y) % for all genotypes were approximately equal zero.

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