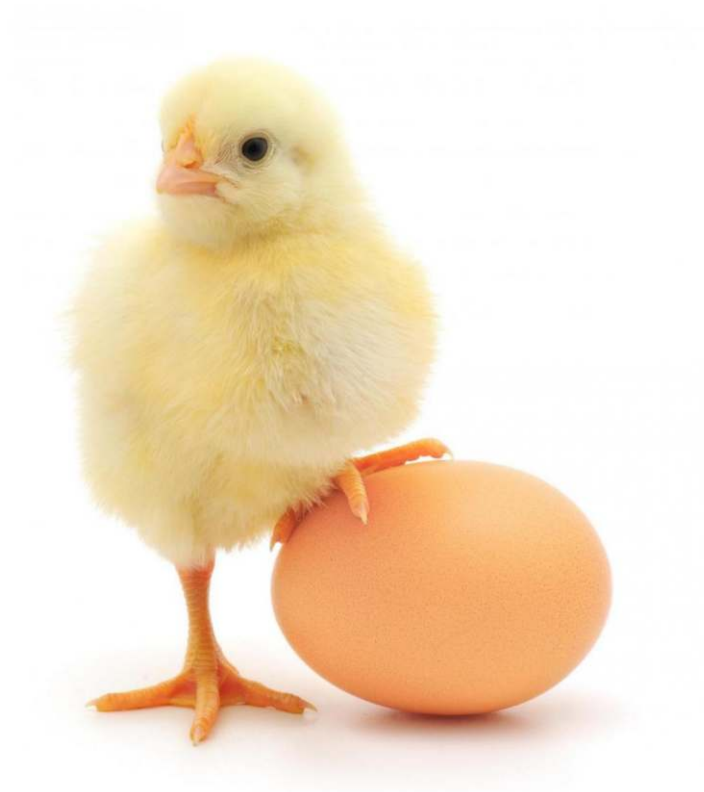
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 10 (3): 197-204, 2011
ISSN 1682-8356

Use of Full Diallel Cross to Estimate Crossbreeding Effects in Laying Chickens

Waleed M. Razuki[1] and Sajida A. AL-Shaheen[2]
[1]Ministry of Agriculture, State Board for Agriculture Research, Baghdad, Iraq
[2]College of Agriculture, University of Basrah, Basrah, Iraq

Abstract: Three genotype of chickens (one Iraqi local named Brown line, BR and two adapted exotic breeds named White Leghorn, WL and New Hampshire, NH) were crossed in a 3 x 3 diallel mating (nine combinations) to estimate their crossbreeding effect for Body Weight (BW), age at Sexual Maturity (ASM), egg production and egg weight. All chicks tested in this experiment originated from parents divided into 3 groups. Each group included 864 hens from three genotypes (288 hens for each genotype) and 108 cocks from the genotype used in sire position (1 male: 8 females). Approximately 3600 unsexed day old chicks (400 chicks per combination) were used. At 28 days of age, chicks were sexed and result about 180 females per combination. Females (45 per pen) were weighed and assigned to their cross in 36 pens (4 pens per combination). At 126 days of age, 25 pullets per pen were housed until the end of experiment. The NH purebred had higher BW compared with WL or BR at all ages. BR x NH cross had heaviest BW at ages 28, 56, 84 and 112 days but not at sexual maturity which exhibited reduction in BW. The ASM in BR purebred was earlier (141.25 days) than WL (153.25 days) and NH (154 days) purebreds. The WL x NH cross and NH x WL reciprocal cross exhibited higher egg number than purebred or other crosses. The WL purebred achieved the highest Egg Weight (EW) than other purebred. The line heterosis is significant only at day old BW in WL breed (positive) and BR line (negative), whereas, the others ages was not showed any line heterosis. Average heterosis of BW was positive at all ages, except at day old which was negative and ranged from -2.03 at day old to 39.58 at sexual maturity. The line heterosis of age at sexual maturity and egg weight was non significant, while, the line heterosis of egg production was significantly positive in NH line and was negative in BR line. All combinations (crosses or reciprocal) showed a positive heterosis in egg production ranged from 2.77 to 8.75% with average heterosis is significant (3.20). All combinations (crosses or reciprocal) showed a negative heterosis in egg weight from -0.15 to -3.66 with significant average heterosis (-1.21). Reciprocal effects were significant for BW and ASM and not in egg production or in egg weight. The GCA of BW was significantly greater and positive for NH breeds at all ages than WL and BR lines were exhibited significantly negative GCA. GCA for ASM, egg production and egg weight of WL breeds gave the highest (positive) significant values compared with the BR line which was exhibited lowest (negative) values of these traits. Maternal effects of BW and ASM were significant for WL and BR dams. There were non significant in egg production and egg weight due to maternal effect. The direct genetic effect on BW were negatively significant for WL and BR and positively significant for NH. Direct genetic effects on ASM and egg production were non significant and significant on egg weight. Estimations of SCA of BW, ASM, egg production and egg weight varied from positive to negative depended on cross type. This study suggested that use the crossbreeding tools to develop new synthetic strains suitable to Iraqi harsh conditions with acceptance performance.

Key words: Diallel cross, cross breeding effects, general combining ability, specific combining ability

INTRODUCTION

Iraqi local chickens are valuable genetic resources due to their adaptability to harsh condition when raised in rural area or when reared in outdoor system as free range chickens (Al-Soudi and Al-Jebouri, 1979; Al-Murrani *et al.*, 1997). The aggregation of local gene pool of Iraqi chickens was adopted from two Iraqi institutions: first, the Scientific Research Council in 1986 and second, from IPA Agricultural research center in 1992-2003. The adoption program aimed to multiplication and purification of the genetic lines of indigenous chickens according to the feather color to produce breeds adapted to the local conditions. Both of them successes to produce six genetic lines named Brown, Barred, Black, White, White neck-naked and Brown neck-naked with purity belonged 99%. After producing these lines, Al-Athari *et al.* (2002) conducted in three different experiments carried out during period from 1992-1995 that these lines responded well to improve their environment conditions, especially, nutrition and exhibited improvement in body weight at sexual maturity and egg weight. They also found that the six lines can be

Corresponding Author: Waleed M. Razuki, Ministry of Agriculture, State Board for Agriculture Research, Baghdad, Iraq

classified as a layer type and the Brown line showed a good performance for egg production among these lines. At that time, two exotic breeds (White Leghorn, WL and New Hampshire, NH) were already found since 1950 and adapted to the local conditions in these institutions which were named then after adapted breeds (Al-Jebouri, 1970).

Because of breeding program for local chickens in developing countries are still out of competition with commercial breeding company which has access to technology advantages and economics of scale (Hoffmann, 2005). It was strongly needed to establish breeding programs that allows improving performance of local chickens. Genetic improvement of livestock and poultry is based on two alternative approaches: crossbreeding and selection. Selection takes long time and needed to the technological advantages that not in our hands. 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. Crossbreeding therefore is an essential part of modern breeding programs in poultry that exploited genetic variations. The main purpose of crossing is to produce superior crosses 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; Mekky *et al*., 2008).

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 (Wolf and Knizetova, 1994). The testing of populations to attain evaluation of their combining ability requires systematic crossbreeding design. The diallel cross is one of these. A diallel cross is a set of possible combinations between lines, breeds or general populations (Jakubec *et al*., 1987). Full diallel crossing is used to testing the combining ability of parental populations. Combining ability provides useful information on the best lines, breed or strain combinations necessary for optimal performance of crossbred animals (Jakubec *et al*., 1987; Razuki and AL-Soudi, 2005). The combining ability also helps to identify the most desirable combiner that may be used to exploit hybrid vigor (Sands *et al*., 1995; Mekky *et al*., 2008). Hybrid vigor (or Heterosis) 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). 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). Diallel analysis allows estimation of maternal effect (Mi) which was needed to determine whether reciprocal crosses are likely to be equivalent. Herein, an experiment was conducted in 3 x 3 full diallel mating system between Iraqi brown chicken with two adapted exotic breeds (White leghorn, WL and New Hampshire, NH) to estimate crossbreeding effects (combining ability, General (GCA) and Specific (SCA), direct genetic effect, heterotic effect, maternal effect and reciprocal effect) for body weight and production traits for purebred parental and their crosses.

MATERIALS AND METHODS

Birds and husbandry: The genetic lines of Iraqi brown line (BR) used in this experiment had undergone 8 generations of segregating parental population (Al-Athari *et al*., 2002). The two exotic breeds (WL and NH) are routinely maintained along with the BR lines at random without selection and founded in Iraq since 1950 (Al-Jebouri, 1970). The data used in this experiment were collected during two years periods from 1996-1997 in Native Chicken Breeding Station, IPA Agricultural Research Center (Al-Shaheen, 1998), now is a Poultry Research Station of State Board for Agricultural Research/Ministry of Agriculture. The mating design was made in 3 x 3 full diallel and all possible combinations (nine crosses) among these genotypes had been done (3 purebreds and 6 crossbreds). All chicks tested in this experiment originated from parents divided into 3 groups in sire and dam position. Each group included 864 hens from three genotypes (288 hens from each breeds or lines) and 108 cocks (1 male to 8 females' ratio). The eggs were collected for 7 days, marked with combination mating (cross type) and set in incubator when age of parents at 31 weeks of age. The hatch chicks, 3600 chicks (400 chicks per combination cross) were reared on floor pens bedded with wood shavings. Each cross (400 chicks) was allocated on 4 pens (replicates) with 100 chicks per pen (2.8 x 1.8 m). The chicks were provided with heat and light program according to the recommendations of layer management. At 28 days of age, only females (180 chicks per cross) that sexed phenotypical via external characteristics were used. Females were weighed in electronic scale within 0.1 g precision and reared according to each cross in floor pens till 126 days of age. At 126 days of age, only 25 pullets were housed until the end of experiment after 100 days from onset of first egg of each cross combination. All chicks were fed *ad libitum* basis on starter diet (2750 ME/kg feed and 18% CP) from 1 day to 28 days of age, grower diet (2700 ME/kg feed and 15% CP) from 28-126 days of age and layer diet (2700 ME/kg feed and 16% CP) from 126 days to the end of experiments.

Body Weight (BW) was recorded at 1, 28, 56, 84 and 112 days of age and at sexual maturity on pen basis. Age at sexual maturity was recorded and considers when the first egg was laid. Average egg production for the test period (100 days) was calculated on hen day basis. Average egg weight from 100 days was recorded weekly.

Genetic parameter calculations and statistical analyses: Data were analyzed for variation between the crosses and within crosses (between progeny) using the general linear model procedure (Proc GLM) of SAS software (SAS Institute, 1998). Differences were considered significant were compared by Duncan test (Duncan, 1955). Following linear model was used to analyze the data:

$$Y_{ijk} = \mu + T_i + e_{ij}$$

Where:

Y_{ij} = The i^{th} observation on the cross of j^{th}

μ = The overall mean

T_i = The fixed effect of i^{th} genotype (line or breed) group

e_{ij} = Random error assumed to be independently randomly distributed

The General Combining Ability (GCA) were calculated as the deviation of specific genotype means from overall mean for given trait estimated for nine diallel crosses [i.e, $GCA_i = (\Sigma y_i/n) - \mu$], where GCA_i = the GCA for line i (the WL, BR and NH Genotype), Y_i = trait for a progeny with either one of his or her parents or both parents from line i and μ = overall mean for given trait estimated from all nine diallel crosses. The Specific Combining Ability (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 (the WL, BR and NH Genotype) (Odeh *et al.*, 2003). Heterosis was calculated on percentage of midparents: {F1-[(P1 + P2)/2] / [(P1 + P2) / 2] x 100} using mean, where F1 = the first filial and P1 or P2 is a parent in diallel and reciprocal crosses (Williams *et al.*, 2002).

Line heterosis (hi) represent the effect of specific line on the progeny performance and was calculated from formula described as follows: $h_i = \{(p-1/p-2) \times [(\Sigma h_{ij}/p-1)-h^-]\}$, where p = number of parents, h_{ij} = specific heterosis obtained by crossing lines i and j; h^- = average heterosis which calculated from formula as $h^- = y^{-}*..- y^{-}p..$, where $y^{-}*..$ is a mean of all crosses without purebred parental lines and $y^{-}p$ the overall mean of all crosses with parents. In the 3 x 3 diallel group, $y^{-}*..$ is a mean of 6 crossbred group and $y^{-}p..$ is a mean of 9 crossbred groups. Reciprocal effect (r_{ij}) for the combination i x j was calculated as $r_{ij} = (y_{ij}-y_{ji})/2$. Maternal effect ($M_j$) was calculated as the mean deviation of progeny for a particular dam from mean estimated from a particular sire line (i.e. $m_j = (y_{.i}-y_{i.})$, where $y_{.i}$ = mean of dam line and $y_{i.}$ = mean of sire line. Direct genetic effect (v_i) was represent the effect of specific line on the progeny performance excluding the overall mean and means of sirs and dams line {i.e., $v_i = [y_{ii}-y_p-m_j]$}, where, v_i = direct genetic effect for line i, y_{ii} = mean of parental line I; y_p = overall mean of the p entries on the leading diagonal in the diallel table (Eisen *et al.*, 1983).

All calculations were done by SAS software (SAS Institute, 1998) and CBE program package (Wolf, 1996).

RESULTS AND DISCUSSION

Body weight (BW): The BW for the nine genotypes from 3 x 3 full diallel cross is presented in Table 1. The BW of NH breed had higher than WL or BR at all ages. The BW of crosses resulted from three genotypes (six crosses) was different. This is because of the type of sire and/or dam position in the diallel mating. With respect to crosses, it could be noticed that at day old the purebred in general had higher BW than their crosses. The cross of BR x NH had higher BW than most cross and purebred of WL x WL and BR x BR, whereas, they not differ from the NH x NH purebred. At ages of 28, 56, 84 and 116 days, there were non significant differences between the NH x NH purebred and BR x NH cross and these two type crosses was dominant than others crosses. In general, it noticed that the BW of WL or BR purebreds or their crosses tend to be lighter at all ages. Al-Jebouri (1970) also noticed that the NH breed had higher BW than WL and Iraqi local chickens. BW at sexual maturity was greater in NH x NH purebred (1626.4 g) and in NH x WL cross (1624.7) and the lowest in BR x BR (1290.2 g) and in WL x WL (1393.9 g) purebreds or their crosses. This result is consistent with Ismail (1997) who found that BW at SM of BR line ranged from 1217.7-1347.8 and with Al-Athari *et al.* (2002) who found that the BW at SM was greater in NH breed (1685.3 g) than WL breed (1400.9 g) or BR lines (1342.8 g).

Age at sexual maturity (ASM): There were a significant differences ($p<0.001$) due to cross type in age at sexual maturity (Table 2). The BR line was attained maturity earlier (141.25 days) than WL breeds (153.25 days) or NH breed (154 days). Furthermore, the pullets in the cross of WL x NH was matured 22, 9 and 10 days later than the BR x BR, NH x NH and WL x WL purebred respectively. With respect of other crosses, the ASM was not differ from the purebreds genotypes. This result is disagreement with Al-Athari *et al.* (2002) who reported that the ASM of BR line was 161.7 days. On the other hand, previous studies (Al-Rawi, 1969; Al-Jebouri, 1970) are consistent with present results.

Egg production and egg weight: The egg production and egg weight of purebred and crosses that recorded for 100 days are presented in Table 2. The means egg number of purebred was not significant with 62.41, 61.15 and 61.49 eggs per birds for WL x WL BR x BR and NH x NH respectively. With respect to crosses, it noticed that the WL x NH cross and NH x WL reciprocal cross achieved greater egg production than other crosses or purebreds. The average egg weight was higher in WL x WL purebred (51.03 g) which was not differ from NH x NH purebred (49.78 g) and the lowest

Table 1: Means of body weight (g) of purebreds, crosses and reciprocal crosses (±SEM)

	Age (day)					
Cross type[1]	1	28	56	84	112	BW at SM
Purebred						
WL x WL	33.3±0.06^{ab}	177.5±3.94^{d}	451.8±10.56^{g}	858.9±28.0^{c}	1208.4±15.7^{bcd}	1393.9±30.5^{cd}
BR x BR	32.1±0.79^{b}	191.7±8.06^{bcd}	488.3±9.72^{def}	849.9±32.1^{c}	1191.2±14.1^{cd}	1290.2±20.9^{e}
NH x NH	34.3±0.23^{a}	224.8±3.95^{a}	536.8±4.42^{a}	984.0±23.2^{a}	1360.6±49.9^{a}	1626.4±31.2^{a}
Crosses						
WL x BR	28.7±0.41^{c}	193.9±6.16^{bcd}	470.8±8.22^{fg}	879.9±32.1^{bc}	1195.1±25.2^{bcd}	1330.5±21.2^{de}
WL x NH	31.9±0.20^{ab}	181.9±4.85^{cd}	502.8±9.88^{bcd}	868.6±47.5^{c}	1276.0±32.9^{abc}	1528.8±31.5^{ab}
BR x NH	31.7±0.12^{bc}	232.9±9.27^{a}	530.8±5.82^{ab}	954.1±19.0^{ab}	1300.5±19.1^{a}	1462.5±30.5^{bc}
Reciprocal						
BR x WL	31.7±0.06^{bc}	190.9±3.31^{bcd}	459.8±5.57^{fg}	855.8±19.9^{c}	1186.1±26.7^{d}	1381.1±36.5^{cde}
NH x WL	34.1±1.25^{a}	203.4±5.76^{b}	520.5±11.7^{abc}	931.3±16.4^{abc}	1324.2±31.2^{a}	1624.7±55.1^{a}
NH x BR	29.7±0.41^{c}	198.9±6.20^{bc}	494.8±5.15^{cde}	900.3±17.2^{bc}	1282.4±16.8^{ab}	1530.9±34.6^{ab}
All crosses	31.9±0.30	199.5±3.43	495.1±5.70	898.0±10.9	1258.3±13.2	1463.2±21.7
Level of Sig.	0.0001	0.0001	0.0001	0.0086	0.0004	0.0001

$^{a-g}$Means within a column with no common superscripts differ significantly ($p<0.05$).

[1]Males are listed first in cross; WL= White Leghorn, BR = Iraqi local Brown, NH = New Hampshire. Sig. = Significant

Table 2: Means of Age at Sexual Maturity (ASM), egg production and egg weight of purebreds, crosses and reciprocal crosses (±SEM)

Cross type[1]	ASM (day)	Egg production (egg/hen)	Egg weight (g)
Purebred			
WL x WL	153.25±3.09^{b}	62.41±0.44^{cde}	51.03±0.41^{a}
BR x BR	141.25±1.03^{c}	61.15±0.72^{e}	47.76±0.71^{d}
NH x NH	154.00±2.45^{b}	61.49±0.47^{de}	49.78±0.48^{ab}
Crosses			
WL x BR	147.25±2.46^{bc}	63.49±0.76^{cde}	49.32±0.41^{bc}
WL x NH	163.50±0.96^{a}	67.37±0.77^{a}	48.73±0.41^{bcd}
BR x NH	152.75±2.72^{b}	64.47±0.80^{bc}	47.43±0.41^{d}
Reciprocal			
BR x WL	148.50±3.09^{bc}	64.03±1.12^{bcd}	48.11±0.41^{cd}
NH x WL	149.50±3.66^{b}	66.51±0.92^{ab}	49.56±0.58^{bc}
NH x BR	148.75±1.89^{bc}	63.46±1.16^{cde}	47.71±0.41^{d}
All crosses	150.94±1.22	63.82±0.41	48.82±0.24
Level of Sig.	0.0002	0.0001	0.0001

$^{a-e}$Means within a column with no common superscripts differ significantly ($p<0.05$).

[1]Males are listed first in cross; WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire. Sig. = Significant

egg weight was observed in BR x BR purebred and in HN x BR reciprocal cross. Al-Athari *et al.* (2002) showed that the egg production and egg weight was greater in WL. Zaky (2005) found the egg produced by WL hens were heavier by about 6 g than those of Fayoumi chickens. Mekky *et al.* (2008) also showed that the WL hens produced heavier egg than local Egypt chickens, Fayoumi (45.57 vs 42.24g) or Sinai (45.57 vs 44.12g).

Heterosis (H%): Heterosis estimated for BW is presented in Table 3. The line heterosis is significant only at day old in WL breed (positive) and BR line (negative), whereas, the others ages was not showed any line heterosis. Average H was positive at all ages, except at day old which was negative and ranged from -2.03 to 39.58. Vitek *et al.* (1994) found the line heterosis; specific heterosis and reciprocal effects were of minor importance in live BW and they found the values of total H was ranged form -1.2 to 5.47% at age of 105 days. Lamont and Deeb (2001) showed that the magnitude of heterosis for BW was age dependent. Heterosis percentage of the midparents for crosses and reciprocal exhibited the highest positive heterosis occurred in crosses of BR x NH and NH x WL, whereas, the other crosses ranged from negative sign to positive sign between one day old to 112 days of age. Furthermore, heterosis of BW at SM exhibited positive sign in all crosses except in WL x BR cross which negative heterosis. Mekky *et al.* (2008) showed that the crossing between either local Egypt chickens named Sinai in sire (male) position with WL in dam (female) position or Fayoumi in sire (male) position with Sinai in dam (female) position gave the highest positive heterosis for BW. The positive heterosis occurred when used WL and NH in dam position may due to difference in egg weight which was high in those dams (Table 2). The negative heterosis that recorded in some cross is reflecting the large differences or unequal contributions between the parental lines (sire and dam) used in the cross (Liu *et al.*, 1993). Willham and Pollak (1985) reported that the magnitude of heterosis is inversely related to the degree of genetic resemblance between parental populations. Williams *et al.* (2002) found that the heterosis for BW differs in magnitude and it may be a positive or negative sign which was cross dependent. Whereas, Merat *et al.* (1994) reported that the heterosis for BW was positive and significant in crosses of White Leghorn x Brown egg and their reciprocal cross in both of dwarf and normal hens.

The line heterosis of age at sexual maturity and egg weight was non significant (Table 4). Heterosis estimated as mean of the specific cross as a percentage of the midparents exhibited a positive heterosis in all crosses, except in NH x WL which was negative. The absolute average heterosis is non significant (1.59 day).

Table 3: Line heterosis (h_i) and Specific heterosis (h_{ij}%), average heterosis (h^-) and reciprocal effect of body weight (g)

	Age (day)					
Items	1	28	56	84	112	BW at SM
Line heterosis (h_i)						
WL	0.62*	-5.22^{ns}	4.03^{ns}	-9.51^{ns}	-8.23^{ns}	1.18^{ns}
BR	-1.08*	10.76^{ns}	-13.10^{ns}	22.21^{ns}	-8.28^{ns}	-27.00^{ns}
NH	0.47^{ns}	-5.52^{ns}	9.03^{ns}	-12.70^{ns}	16.51^{ns}	25.80^{ns}
Specific heterosis						
WL x BR[1]	-12.23	5.04	0.16	2.98	-0.39	-0.86
WL x NH	-6.04	-9.57	1.72	-5.74	-0.66	1.23
BR x NH	-4.95	11.84	3.56	4.05	1.93	0.29
Reciprocal heterosis						
BR x WL	-3.06	3.41	-2.18	0.16	-1.14	2.91
NH x WL	0.44	1.12	5.30	1.07	3.09	7.59
NH x BR	-10.94	-4.63	-3.46	-1.82	0.51	4.98
Average heterosis	-2.03**	2.29^{ns}	4.28^{ns}	0.73^{ns}	7.31^{ns}	39.58^{ns}
Reciprocal effect						
WL x BR	-1.50**	1.50^{ns}	5.50^{ns}	12.05^{ns}	4.50^{ns}	-25.30^{ns}
WL x NH	-1.10**	-10.75**	-8.85^{ns}	-31.35^{ns}	-24.10^{ns}	-47.95*
BR x NH	1.00**	17.15**	18.00*	26.89^{ns}	9.05^{ns}	-34.20^{ns}

ns = non significant; *p<0.05; **p<0.01. [1]Males are listed first in cross; WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire

Table 4: Line heterosis (h_i) and Specific heterosis (h_{ij}%), average heterosis (h^-) and reciprocal effect of Age at Sexual Maturity (ASM), egg production and egg weight

Items	ASM (day)	Egg production (egg/hen)	Egg weight (g)
Line heterosis (h_i)			
WL	-1.11^{ns}	0.56^{ns}	-0.013^{ns}
BR	-0.34^{ns}	-1.79**	0.550^{ns}
NH	1.46^{ns}	1.22*	-0.530^{ns}
Specific heterosis			
WL x BR[1]	0.00	2.77	-0.150
WL x NH	6.43	8.75	-3.320
BR x NH	3.47	5.14	-2.750
Reciprocal heterosis			
BR x WL	0.85	3.64	-2.600
NH x WL	-2.69	7.36	-3.660
NH x BR	0.76	3.49	-2.170
Average heterosis	1.59^{ns}	3.20**	-1.210**
Reciprocal effect			
BR x WL	-0.63^{ns}	-0.27^{ns}	0.610^{ns}
NH x WL	7.00***	0.43^{ns}	-0.420^{ns}
NH x BR	2.00^{ns}	0.51^{ns}	-0.140^{ns}

ns = non significant; *p<0.05. **p<0.01; ***p<0.001.
[1]Males are listed first in cross; WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire

The line heterosis of egg production was significantly positive in NH line and was negative BR line. That mean the attributing the BR in combination lead to reduced egg production. All combinations (crosses or reciprocal) showed a positive heterosis in egg production ranged from 2.77 to 8.75%. The absolute average heterosis is significant (3.20 day). The highest heterosis occurred in cross of WL x NH and its reciprocal (NH x WL). Meanwhile, all combinations (crosses or reciprocal) showed a negative heterosis in egg weight from -0.15 to -3.66 with significant average of absolute heterosis (-1.21). The previous results find in the literatures are in good agreement with this result. Fairfull *et al.* (1987) found an average heterosis of 11.9% for hen housed egg production to 497 days of age in a 4 x 4 diallel of unrelated White Leghorn strains. Verma *et al.* (1987) stated an average of heterosis 5.5% for egg production to 260 days of age in a 4 x 4 diallel mating design. Vitek *et al.* (1994) revealed that an average heterosis was 10.8% for 274 days of production in an 8 x 8 full diallel White Leghorn lines. Merat *et al.* (1994) noticed that the average heterosis for egg number recorded for 7 months period was 7.5% and 10.5% for normal and dwarf genotype lines respectively.

With respect of egg weight, the values of heterosis measured at different ages that given by these authors didn’t exceeded 2.55% when it measured at different ages at production periods, except, Merat *et al.* (1994) who found the heterosis was 4.7% and 5.2% for normal and dwarf genotype lines respectively. Generally it seemed from this and previous results the highest heterosis is observed in egg production and the lowest in egg weight.

Reciprocal effect: Reciprocal effects were significant for BW at day old for crosses of WL x BR, WL x NH and BR x NH and at 28 days of age for WL x NH and BR x NH crosses and at 56 days of age for BR x NH and for WL x NH at sexual maturity, respectively (Table 3). Reciprocal effects were found in ASM and not in egg production or in egg weight (Table 4). Reciprocal effects were at least as important as heterosis and the magnitude of it tended to be greater in case of heterosis was small (Fairfull *et al.*, 1983). In this study the average heterosis were non significant in BW and ASM whereas, is significant in egg production and egg weight. Significant reciprocal effects for BW were found by Jakubec *et al.* (1987) and Vitek *et al.* (1994) and for egg production and egg weight were found by Veram *et al.* (1987), Hagger (1989) and Vitek *et al.* (1994).

Table 5: General Combining Ability (GCA), maternal effect and direct genetic effect of body weight (g) of three genotypes of chickens

	Age (day)					
Items	1	28	56	84	112	BW at SM
GCA for three genotypes[1]						
WL	-0.04^{ns}	-10.00**	14.00*	-19.05^{ns}	-20.30^{ns}	-11.40^{ns}
BR	-1.20**	2.12^{ns}	-6.26^{ns}	-10.22^{ns}	-27.20^{ns}	-64.20*
NH	0.41^{ns}	8.86*	21.99**	29.56**	50.50**	91.43***
Maternal effect (M_i) for three genotypes[1]						
WL	1.73**	6.17^{ns}	2.23^{ns}	12.87^{ns}	13.07^{ns}	48.83^{ns}
BR	-1.67**	-10.43*	-8.33*	-9.90^{ns}	-3.03^{ns}	5.93^{ns}
NH	-1.07^{ns}	4.27^{ns}	6.10^{ns}	-2.97^{ns}	-10.03^{ns}	-54.76*
Direct genetic effect (v_i) for three genotypes[1]						
WL	-1.77**	-26.60^{ns}	-42.70**	-51.60^{ns}	-58.10*	-91.80**
BR	0.43^{ns}	4.23^{ns}	4.33^{ns}	-37.80^{ns}	-59.20**	-152.60**
NH	1.33^{ns}	22.30^{ns}	38.30**	89.40**	117.20**	244.30**

ns = non significant; *p<0.05. **p<0.01; ***p<0.0001. [1]WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire

General combining ability (GCA): The General Combining Ability (GCA) for BW is presented in Table 5. The GCA of BW in NH breed was positive and significant at all ages. The WL and BR genotypes, in general, was negative GCA and significant. Because of GCA is the average performance of a line in different hybrid combinations (Gardner and Eberhart, 1966) or the numerical value that expressing the influence of the lines on its progeny, the GCA reflect the importance of additive gene effect of genotype on BW. The differences in BW between this genotype give good chance to select among them to improve their size. Significant GCA of BW was found by Jakubec *et al.* (1987), Razuki and Al-Soudi (2005) and Mekky *et al.* (2008).

The GCA of ASM, egg production and egg weight are presented in Table 6. The results showed that the WL breeds gave the highest (positive) significant value of GCA for ASM, egg production and egg weight compared with the BR lines which exhibited lowest (negative) value of GCA for ASM, egg production and egg weight. The effect NH breeds on these traits were non significant. Sands *et al.* (1995) noticed that the GCA for ASM ranged from 1.35 for White Leghorn (WL) to -16.35 for White Plymouth Rock (WPR) and for hen housed egg production from 0.90 for Rhode Island Red (RIR) to -9.20 for Araucona (AR). Most of the previous studies (Goto and Nordskog, 1959; Eisen *et al.*, 1967; Fairfull *et al.*, 1983) concluded that the GCA was important and the Goto and Nordskog (1959) found large estimates of GCA which was in agreement with the present study.

Maternal effect: Maternal effects of BW were highly significant at hatch for WL and BR dams (Table 5). After hatch, maternal effects were significant in BR dams with negative influence on BW at 28 and 56 days of age, while the NH dams exhibited negative in BW at sexual maturity. The WL dams exhibited their largest maternal effect from day to sexual maturity even with non significant. Barbato and Vasilatos-Younken (1991) showed that maternal effects in chickens change over time are not isolated to the effects of egg size and hatching weight and they found the reappearance of

Table 6: General Combining Ability (GCA), maternal effect an direct genetic effect of Age at Sexual Maturity (ASM), egg production and egg weight of three genotypes of chickens

Items	ASM (day)	Egg production (egg/hens)	Egg weight (g)
GCA for three genotypes[1]			
WL	1.43^{ns}	0.94*	0.58*
BR	-3.27*	-0.50^{ns}	-0.70**
NH	2.73^{ns}	0.84^{ns}	-0.13^{ns}
Maternal effect (M_i) for three genotypes[1]			
WL	-4.25*	-0.11^{ns}	-0.46^{ns}
BR	-1.75^{ns}	-0.52^{ns}	0.50^{ns}
NH	6.00**	0.62^{ns}	-0.04^{ns}
Direct genetic effect (v_i) for three genotypes[1]			
WL	7.71^{ns}	0.83^{ns}	1.97**
BR	-6.71^{ns}	-0.02^{ns}	-2.26**
NH	-1.00^{ns}	-0.82^{ns}	0.29^{ns}

ns = non significant; *p<0.05; **p<0.01.

[1]WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire

significant maternal effect at later ages may be due to the effect of endoplasmic inheritance which play a role in determine specific maternal effect among these lines.

There were significant effects on ASM in WL and BR lines due to maternal effects, whereas, egg production or egg weight was not affected by maternal ability (Table 6).

Direct genetic (line) effect: Gardner and Eberhart (1966) define the direct genetic effect is a values that contained the additive, dominance and additive x additive interaction effects. By the formula mentioned in material and methods the values may refer to GCA without line heterosis. Results showed that the line effect on BW were negatively significant for WL at ages 1, 56, 112 days and at sexual maturity and positively significant for NH at ages 56, 84, 122 and at sexual maturity. Whereas, the BR line exhibited negatively significant at 112 days of age and at sexual maturity (Table 5). Rank order of lines effect on BW was NH>BR>WL. Barbato and Vasilatos-Younken (1991) found the genotypes differ in their BW due effects of the lines that used in sire or in dam position. Vitek *et al.* (1994) found that the direct genetic effect on BW was significant.

Table 7: Specific combining ability of body weight (g) of three genotypes of chickens

	Age (day)					
Cross type[1]	1	28	56	84	112	BW at SM
Purebred crosses						
WL x WL	1.41	-2.03	-15.30	-1.04	-9.30	-46.51
BR x BR	2.53	-12.07	5.72	-27.70	-12.70	-44.61
NH x NH	1.81	7.55	-2.28	26.84	1.30	-19.67
Crosses						
WL x BR	-2.03	2.25	-4.04	11.13	-15.80	-57.11
WL x NH	-0.44	-16.49	-0.29	-39.95	-12.50	-14.44
BR x NH	0.52	22.39	19.97	36.72	18.90	-27.94
Reciprocal crosses						
BR x WL	0.97	-0.75	-19.04	-12.97	-24.70	-6.51
NH x WL	1.76	5.01	13.41	22.75	35.70	81.46
NH x BR	-1.48	-11.61	-15.04	-17.08	0.90	40.46

[1]Males are listed first in cross; WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire

Table 8: Specific combining ability of Age at Sexual Maturity (ASM), egg production and egg weight of three genotypes of chickens

Cross type[1]	ASM (day)	Egg production (egg/hen)	Egg weight (g)
Purebred			
WL x WL	-3.30	-3.61	1.56
BR x BR	-1.67	-6.21	0.85
NH x NH	-4.01	-5.46	1.73
Crosses			
WL x BR	-0.77	-4.91	1.13
WL x NH	1.77	5.34	-0.03
BR x NH	-0.09	-0.71	-0.05
Reciprocal			
BR x WL	-0.23	-3.66	-0.08
NH x WL	0.91	-0.34	0.80
NH x BR	-0.80	-4.71	-0.03

[1]Males are listed first in cross; WL = White Leghorn, BR = Iraqi local Brown, NH = New Hampshire

Line effects on ASM and egg production were non significant. While, the line effect on egg weight was significant. Rank order of line effect on egg weight was WL>NH>BR. This result is agreement with Vitek *et al.* (1994) who found that the direct genetic effect on egg weigh was significant. The effect of direct (line) genetic effect on BW or in egg weight may be due to these trait had higher heritability (h^2) which mean the inheritance of them is highly additive.

Specific combining ability (SCA): The SCA of BW at different ages is presented in Table 7. The lines with the best SCA are combinations of BR x NH and NH x WL and the worst are combinations of WL x NH and NH x BR from day to 112 days of age. At sexual maturity, all combinations are exhibited negative SCA, except the combinations of NH x WL and NH x BR which exhibited positive SCA. There are several crossbreeding experiments with domestic fowl are reported for BW from 5-12 weeks of age (Eisen *et al.*, 1967; Jakubec *et al.*, 1987; Razuki and Al-Soudi, 2005; Mekky *et al.*, 2008).

The SCA of ASM, egg production and egg weight are presented in Table 8. The SCA for ASM varied from 1.77 for WL x NH cross to -4.01 for NH x NH cross and from 5.34 for WL x NH to -6.21 for BR x BR cross for egg production, whereas, the NH x WL exhibited positive ASM and egg weight. Sands *et al.* (1995) found that the SCA for ASM varied from 2.33 for WL x WPR cross to -5.63 for AR x WPR, for egg production, the SCA was varied from -2.77 for AR x WL to 11.43 for RIR x WL cross.

The SCA refer to the degree to which the average performance of specific cross departs from additively (Griffing, 1956) and it has been used to denote the degree of non additive genetic effect in a population (Gardner and Eberhart, 1966). The specific crosses here may be taken directly to be parent of the next generation. This finding suggests that within each of the diallel crosses, the variation of BW, ASM, egg production or egg weight for some crosses may refer to non-additive genetic effect. This study suggested that the used the crossbreeding tools to develop new synthetic strains suitable to Iraqi harsh conditions with acceptance performance.

REFERENCES

Al-Athari, A.K., A.A. Al-Rawi, F.M. Al-Khilani and Z.H. Al-Bustani, 2002. Performance of indigenous genetic lines of Iraqi chicken. IPA J. Agric. Res., 12: 53-67 (In Arbic).

Al-Jebouri, M., 1970. A comparative study between some standard breeds of chicken and Iraqi strain. M.Sc. Thesis. College of Agric. Univ. of Baghdad.

Al-Murrani, W.K., A. Kassab, H.Z. Al-Sam and A.K. Al-Athari, 1997. Heterophil/lymphocyte ratio as a selection criterion for heat resistance in domestic fowls. Br. Poult. Sci., 38: 159-163.

Al-Rawi, B.A., 1969. Effect of crossbreeding on productive and reproductive characters of Iraqi chicken. M.Sc. Thesis. College of Agric. Univ. of Baghdad.

Al-Shaheen, S.A.M., 1998. Effect of reciprocal crosses for local brown chickens with two adapted standard breeds on productive traits. M.Sc. Thesis. College of Agric. Univ. of Basrah (In Arabic).

Al-Soudi, K.A. and M. Al-Jebouri, 1979. Production potential in subtropical climate of native Iraqi chicken compared to White Leghorn, New Hampshire and their cross. World's Poult. Sci. J., 35: 227-235.

Barbato, G.F. and R. Vasilatos-Younken, 1991. Sex-linked and maternal effects on growth in chickens. Poult. Sci., 70: 709-718.

Duncan, D.B., 1955. Multiple range and Multiple F tests. Biometrics, 11: 1-42.

Eisen, E.J., B.B. Bohren, H.E. McKean and S.C. King, 1967. Genetic combining ability of light and heavy inbred lines in single crosses of poultry. Genetics, 55: 5-20.

Eisen, E.J., G. Horstgen-Schwark, A.M. Saxton and T.R. Bandy, 1983. Genetic interpretation and analysis of diallel crosses with animals. Theor. Appl. Genet., 65: 17-23.

Fairfull, R.W., R.S. Gowe and J.A.B. Emsley, 1983. Diallel cross of six long-term selected Leghorn strains with emphasis on heterosis and reciprocal effects. Br. Poult. Sci., 24: 133-158.

Fairfull, R.W., R.S. Gowe and J. Nagai, 1987. Dominance and epistasis in heterosis of White Leghorn strain crosses. Can. J. Anim. Sci., 67: 663-680.

Gardner, C.O. and S.A. Eberhart, 1966. Analysis and interpretation of the variety cross diallel and related populations. Biometrics, 22: 439-452.

Goto, E. and A.W. Nordskog, 1959. Heterosis in poultry. 4. Estimation of combining ability variance from diallel crosses of inbred lines in the fowl. Poult. Sci., 38: 1381-1388.

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci., 9: 463-493.

Hagger, C., 1989. Genetic effects estimated from crosses and backcrosses of two related lines of White Leghorn chickens. J. Anim. Breed. Genet., 106: 241-248.

Hanafi, M.S. and M.M. Iraqi, 2001. Evaluation of purebreds, heterosis, combining abilities, maternal and sex-linked effects for some productive and reproductive traits in chickens. Second International Conference on Animal Prod. Health in Semi-Arid Areas, 4-6 September, Organized by Faculty of Environmental Agricultural Science, Suez Canal Unvi. El Arish-North Sinai, Egypt, pp: 545-555.

Hoffmann, I., 2005. Research and investment in poultry genetic resources-challenge and options for sustainable use. World's Poult. Sci. J., 61: 57-69.

Ismail, I.H., 1997. Estimation of phenotypic and genetic parameters for some quantitative traits of Iraqi local brown chickens. Ph.D. Dissertation. College of Agric. Unvi. of Baghdad (In Arabic).

Jakubec, V., P. Komender, G. Nitter, D. Fewson and Z. Soukupova, 1987. Crossbreeding in farm animals. 1. Analysis of complete diallel experiments by means of three models with application to poultry. J. Anim. Breed. Genet., 104: 283-294.

Lamont, S.J. and N. Deeb, 2001. Genetics of body composition in a novel broiler cross. In: Proceedings XV European Symposium on Quality of Poultry Meat. WPSA Turkish Branch, Ege Unvi., Izmir, Turkey, pp: 23-28.

Liu, G., E.A. Dunnington and P.B. Siegel, 1993. Maternal effects and heterosis for growth in reciprocal cross populations of chickens. J. Anim. Breed. Genet., 110: 423-428.

Mekky, S.S., A. Galal, H.I. Zaky and A. Zein-El-Dein, 2008. Diallel crossing analysis for body weight and egg production traits of two native Egyptian and two exotic chicken breeds. Int. J. Poult. Sci., 7: 64-71.

Merat, P., F. Minvielle, A. Bordas and G. Coquerelle, 1994. Heterosis in normal versus dwarf laying hens. Poult. Sci., 73: 1-6.

Odeh, F.M., G.G. Cadd and D.G. Satterlee, 2003. Genetic characterization of stress responsiveness in Japanese quail. 1. Analyses of line effects and combining abilities by diallel crosses. Poult. Sci., 82: 25-30.

Razuki, W.M. and K.A. Al-Soudi, 2005. Combining ability and gene action to various strains of broiler parents. 1. Body weight. The Iraqi J. Agric. Sci., 36: 123-132 (In Arabic).

Sands, J.S., J.R. Bartlett and E.J. Smith, 1995. Analysis of combining ability for age at first egg and hen-housed egg production in diallel crosses of four divergent strains of chickens. Poult. Sci., 74 (Suppl. 1): 215 (Abstr.).

SAS Institute, 1998. SAS/STAT User's Guide for Personal Computer. Version 7 ed. SAS Institute Inc. Cary, NC, USA.

Sheridan, A.K., 1981. Crossbreeding and Heterosis. Anim. Breed. Abstr., 49: 131-144.

Verma, S.K., P.K. Pani and S.C. Mohapatra, 1987. Evaluation of additive and non-additive gene effects for some economic traits in White Leghorn chicken. Ind. J. Anim. Sci., 57: 300-305.

Vitek, M., J. Wolf, Z. Soukupova, M. Tyller and V. Jakubec, 1994. Diallel analysis in laying hens. Arch. Geflügelk, 58: 278-284.

Willham, R.L. and E. Pollak, 1985. Heterosis and crossbreeding. Dairy Sci., 68: 2411-2417.

Williams, S.M., S.E. Price and P.B. Siegel, 2002. Heterosis of growth and reproductive traits in fowl. Poult. Sci., 81: 1109-1112.

Wolf, J., 1996. User's Manual for the Software Package CBE, Version 4.0 (A universal program for estimating crossbreeding effects). Research Institute of Animal Production, Prague-Uhri neves, Czech-Republic.

Wolf, J. and H. Knizetova, 1994. Crossbreeding effects for body weight and carcass traits in pekin duck. Br. Poult. Sci., 35: 33-45.

Zaky, H.I., 2005. Genetic differences of some productive and reproductive traits of two local breeds under different conditions. Egypt. Poult. Sci., 25: 781-796.