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Crossbreeding Effects among Two Selected Lines for Increased Feed and Water Consumption on Some Productive and Reproductive Traits in Japanese quail

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ABSTRACT

A crossbreeding experiment was carried out using two selected lines of Japanese quail (HFC_{4-6} & HWC_{4-6} lines) established for high feed and water consumption from 4-6 weeks of age among seven generations. A total number of 1593 birds of Japanese quail (860 purebred, 733 crossbred) produced from four mating groups among three hatches were used for the present study to estimate crossbreeding effects: direct heterosis, direct additive and maternal effects on some productive and reproductive traits. The results could be summarized as follow: A- Feed and water consumption traits: The birds produced from purebred HFC_{4-6} x HFC_{4-6} had the highest feed consumption from 4-6 weeks of age followed by that produced from purebred HWC_{4-6} x HWC_{4-6}, while birds produced from crossbreds had intermediate values for FC_{4-6}. The birds produced from purebred HWC_{4-6} x HWC_{4-6} had the highest water consumption from 4-6 weeks of age followed by that produced from purebred HFC_{4-6} x HFC_{4-6}, while birds produced from crossbreds had intermediate values for WC_{4-6}.. B - Growth traits: The birds produced from purebred HFC4-6 x HFC4-6 had the highest body weights and body weight gains recorded from hatch to 6 weeks of age followed by that produced from purebred HWC4-6 x HWC4-6, while birds produced from crossbreds had intermediate values for body weights and body weight gains recorded from hatch to 6 weeks of age. Highly significant positive direct heterosis effect for most body weights recorded at different ages was observed except BW4, direct heterosis has non-significant effect. Estimates of heterosis percentage for body weights were high at 0, 2 weeks (33.2 and 28.6%) and declined to (18.9 and 17.1 %) for BW4 and BW6. While estimates of heterosis percentage for body weight gains were high at ADG0-2, ADG2-4 (18.6 and 15.5%) and declined to (10.6 and 9.1 %) for ADG4-6 and ADG0-6. -Direct additive effect for body weights recorded at different ages and body weight gains calculated between different growth periods studied were significant and ranged between 4.54 for BW0 and 34.08 for BW4 and between 4.70 for ADG2-4 and 9.00% for ADG4-6.-Maternal additive had a significant negative effect on most body weights and body weight gains studied and they were ranged between -4.28 for BW2 and -12.31 for BW4 and between -3.12 for ADG2-4 and -5.18 for ADG0-2.C- Egg production and reproductive traits: -The birds produced from purebred HFC_{4-6} x HFC_{4-6} had the highest EW, ASM and BWSM, but it had the lowest TEN_{10}, TEW_{10}, DEM, FR% and HA% followed by that produced from purebred HWC_{4-6} x HWC_{4-6}, while birds produced from crossbreds had intermediate values for all egg production and reproductive traits. Highly significant positive direct heterosis effect for all egg production and reproductive traits was observed. Estimates of heterosis percentage for TEW10 and DEM were high (20.6and 21.9%) and declined to (7.7 and 8.4%) for EW and BWSM.

Key words: A crossbreeding, Japanese quail, Feed and Water Consumption, hatches

Introduction

Quails have the advantages of rapid growth rate, good reproductive potential, short life cycle, low feed requirements, good meat taste, better laying ability and shorter time for hatching as compared with different species of poultry, so it is considered as a pilot animal for poultry breeding investigations.

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These advantages encourage genetic studies on growth and body composition traits (Sattci, *et al*., 2003 and Ojedapo and Amao, 2014) and egg production (Minvielle, *et al*., 2000; Vali, *et al*., 2006 and Saatci *et al*., 2006). Poultry breeding programs are aimed to improve genetic potentialities of chicks through selection and crossbreeding plans (Narinc, *et al*., 2014).

Crossbreeding is a major tool to produce favorable individuals which are influenced by various genetic and non-genetic factors. It is also, valuable for averaging of breed effects and achieving intermediate values that are superior to opposite extremes (Kinghorn, 2000 and Yongjun *et al*., 2006). Though, reliable crossbreeding parameters including heterotic, direct and maternal effects are required to design a sound crossbreeding program. Performance comparisons among breeds and their crosses are justified because genetic differences among breeds or strains are large relative to genetic variation within breeds. (Dickerson, 1992). These differences are important potential source of genetic improvement of the flocks through heterotic and complementary breed effects. It appears that there is not a single, simple explanation for heterosis. Instead it is likely that heterosis arises in crosses between genetically distinct individuals as a result of a diversity of mechanisms (Ferdous, 2013). Heterosis generally results from the action of multiple loci and different loci affect heterosis for different traits and in different hybrids. Hence multi-gene models are likely to prove most informative for understanding heterosis.

Crossing procedures usually lead to better economic performance due to the hybrid vigor, however crossbreeding is a very effective method for obtaining different recombination of genetic materials where it results in increased heterozygosis and tend to cover up recessive genes, decreases breeding purity and eliminates families in one generation. Breeding usually improve the performance of the different characters by selection and or crossing, to obtain different degrees of heterosis. That is to say, by directing the additive and non-additive genes to better performance of the different traits. The additive nature of genetic variation for growth has resulted in dramatic body weight improvement in Japanese quail (Marks, 1978 & 1990 and Nestor *et al.,* 1982). Non additive genetic effect is important in meat and laying stocks because of the opportunities to combine stocks that complement each other. This allows development of mating combinations for rapid growth, yield and other important economic traits (Marks, 1995). Most available estimates of heterosis for body weight in Japanese quail were observed in reciprocal crosses of two quail lines, both selected for high body weight (Biak and Marks, 1993 and Marks, 1995) or crossing lines of high and low body weight (Gerken *et al*., 1988; Barden and Marks, 1989 and Marks, 1993).

The main purpose of the present study was to evaluate the importance of heterosis, maternal and direct additive effects arising from crossing two selected lines of Japanese quail, HFC_{4-6} and HWC_{4-6} on some growth and egg production and reproductive traits.

Materials and Methods

Data used in the present study were collected on the flock of Japanese quail maintained by the Department of Animal Production, Faculty of Agriculture, Al-Azhar University.Nasr city, Cairo, Egypt. Two selected lines for high feed and water consumption (HFC_{4-6} & HWC_{4-6}) were used to construct four mating groups, two purebreds (HFC_{4-6} x HFC_{4-6} & HWC_{4-6} x HWC_{4-6}) and two crossbreds (HFC_{4-6} x HWC_{4-6} & HWC_{4-6} x HFC_{4-6}).

Distribution of birds produced in each hatch and breed group are presented in table (1).

Table 1: Distribution of birds produced from crossbreds among different lines and hatches.

Mating groups	HFC x HFC		HWC x HWC		HFC x HWC		HWC x HFC		Total	
Hatch	M	F	M	F	M	F	M	F	M	F
1	90	90	80	70	82	73	65	60	317	293
2	70	70	60	70	58	57	52	54	240	251
3	80	85	45	50	55	90	61	56	241	251
Total	240	245	185	190	195	190	178	170	798	795

M: Males, F: Females.

Birds, management, breeding plan and feeding of the flock were described in previous article (Ramzy, 2016).

Statistical analysis:

Whenever the hatch effects were significant, these effects were corrected before analysis. So, data were subjected to one way analysis of variance to test hatch effect in the study using the following model:

$Y_{ij} = \mu + H_i + e_{ij}$, *where:*

Y_{ij}: observed value in i^{th} hatch, μ: common mean, H_i : hatch effect and e_{ij} : residual error.

Differences between each two means were done according to Duncan's Multiple Range Test (SAS, 1988).

Crossbreeding components for growth and egg production and reproductive traits were estimated according to Dickerson (1992).

Pure lines differences:

$PU_{HFC4\text{-}6 \times HWC4\text{-}6} = [(HFC_{4\text{-}6} \times HFC_{4\text{-}6}) - (HWC_{4\text{-}6} \times HWC_{4\text{-}6})]$.

Direct heterosis effect:

$H^I_{HFC4\text{-}6 \times HWC4\text{-}6} = [(HFC_{4\text{-}6} \times HWC_{4\text{-}6}) + (HWC_{4\text{-}6} \times HFC_{4\text{-}6}) - (HFC_{4\text{-}6} \times HFC_{4\text{-}6}) - (HWC_{4\text{-}6} \times HWC_{4\text{-}6})]$

$H^I\% = H^I$ in units$/0.5[(HFC_{4\text{-}6} \times HFC_{4\text{-}6}) + (HWC_{4\text{-}6} \times HWC_{4\text{-}6})] \times 100$.

Direct additive effect:

$(G^I_{HFC4\text{-}6} - G^I_{HWC4\text{-}6}) = [(HFC_{4\text{-}6} \times HFC_{4\text{-}6}) + (HFC_{4\text{-}6} \times HWC_{4\text{-}6})] - [(HWC_{4\text{-}6} \times HWC_{4\text{-}6}) + (HWC_{4\text{-}6} \times HFC_{4\text{-}6})]$.

Maternal additive effect:

$(G^M_{HFC4\text{-}6} - G^M_{HWC4\text{-}6}) = (HFC_{4\text{-}6} \times HWC_{4\text{-}6}) - (HWC_{4\text{-}6} \times HFC_{4\text{-}6})$, where:

G^I and G^M represent direct additive and maternal additive effects, of the subscript breed (genetic) group.

Results and Discussion

Crossbreeding effects:

Feed and water consumption traits:

Least-squares means and standard errors (S.E) for feed and water consumption traits and direct heterosis, direct additive effect and maternal additive effect are given in (Table, 2). The birds produced from purebred $HFC_{4\text{-}6}$ x $HFC_{4\text{-}6}$ had the highest feed consumption from 4-6 weeks of age followed by that produced from purebred $HWC_{4\text{-}6}$ x $HWC_{4\text{-}6}$, while birds produced from crossbreds had intermediate values for $FC_{4\text{-}6}$. However, the birds produced from purebred $HWC_{4\text{-}6}$ x $HWC_{4\text{-}6}$ had the highest water consumption from 4-6 weeks of age followed by that produced from purebred $HFC_{4\text{-}6}$ x $HFC_{4\text{-}6}$, while birds produced from crossbreds had intermediate values for $WC_{4\text{-}6}$,

However, significant differences due to mating group (MG) on feed and water consumption traits were observed (P≤0.01 or P≤0.001).

Highly significant (P≤0.01 or P≤0.001) positive direct heterosis effect for feed and water consumption from 4-6 weeks of age was observed. Estimates of heterosis percentage for $FC_{4\text{-}6}$ were high (35.2%) and declined to (22.6 %) for $WC_{4\text{-}6}$.

Direct additive effect for $FC_{4\text{-}6}$ and $WC_{4\text{-}6}$ were significant (P≤0.01 or P≤0.001) and they were ranged between 10.14 for $FC_{4\text{-}6}$ and 7.27 for $WC_{4\text{-}6}$.

Maternal additive had a significant (P≤0.01 or P≤0.001) negative effect on FC_{4-6} and WC_{4-6} traits and they were ranged between -5.90 for FC_{4-6} and 3.28 for WC_{4-6} (Table, 2).

Table 2: Least-square means of feed and water consumption traits among the different mating groups ± SE, direct heterosis (H^I), direct additive effect (G^I) and maternal additive effect (G^M).

Mating groups:	FC_{4-6} (g)	WC_{4-6} (cm)
	Mean ± SE	Mean ± SE
HFC x HFC	12.8 ± 0.36	14.2 ± 3.84
HWC x HWC	10.9 ± 0.33	18.0 ± 3.14
HFC x HWC	11.5 ± 0.48	16.1 ± 4.44
HWC x HFC	11.2 ± 0.40	14.6 ± 4.39
Pure breed effect	$12.54 \pm 0.22^{***}$	$8.71 \pm 1.55^{**}$
Direct heterosis (H^i) Unit	$10.86 \pm 0.23^{***}$	$8.16 \pm 1.824^{***}$
Percentage	35.2 %	22.6 %
Direct additive effect (G^i)	$10.14 \pm 0.32^{**}$	$7.27 \pm 0.50^{**}$
Maternal additive effect (G^m)	$-5.90 \pm 0.27^{*}$	$-3.28\pm 0.48^{*}$

*=P≤ 0.05 or **= P≤0.01or ***= P≤ 0.001, ^{ns}=Non- significant.
FC_{4-6}= Feed consumption from 4-6 weeks of age, WC_{4-6}= Water consumption from 4-6 weeks of age.

Growth traits:

Least-squares means and standard errors (S.E) for body weights recorded at different ages and daily weight gain calculated between different growth periods studied are given in (Tables, 3 & 4). The birds produced from purebred HFC_{4-6} x HFC_{4-6} had the highest body weights and body weight gains recorded from hatch to 6 weeks of age followed by that produced from purebred HWC_{4-6} x HWC_{4-6}, while birds produced from crossbreds had intermediate values for body weights and body weight gains recorded from hatch to 6 weeks of age.

However, significant differences (P≤0.01 or P≤0.001) due to mating group (MG) on growth traits were observed. Results of significant effect of MG on growth traits of Japanese quail strains were also confirmed by different authors (Larson *et al.,* 1986, El-Naggar *et al.,* 1992, Barbour and Liibum, 1995; Mandour *et al.*, 1996; Bahie El-Deen *et al.,* 1998; Sherif *et al.*, 1998; Aboul-Hassan, 2001; Abdel-Ghany *et al.,* 2004; Nofal, 2006 and Aboul-Hassan *et al.*, 2009)

Direct heterosis:

Estimates of direct heterosis calculated in units (g) and percentages (%) for body weights recorded at different ages and body weight gains calculated between different growth periods studied are presented in (Tables, 3 & 4) However, these traits showed generally highly significant (P≤0.01 or P≤0.001) positive direct heterosis except BW_4 had non-significant effect. Estimates of heterosis percentage for body weights were high at 0, 2 weeks (31.2 and 25.8%) and declined to (17.2 and 11.9%) for BW_4 and BW_6. The corresponding estimates of heterosis percentage for body weight gains were 15.6, 14.9, 9.6 and 6.1% for ADG_{0-2}, ADG_{2-4}, ADG_{4-6} and ADG_{0-6}, respectively.

Such superiority of cross lines quail over their parental lines points to considerable non-additive genetic line effects. In this respect, Bahie El-Deen *et al.*, (1998); Aboul-Hassan (2001) and Aboul-Hassan *et al.*, 2009) observed that heterosis contrasts were significant for BW_0, BW_2 and BW_4 (P≤0.001) and BW_6 (P≤0.01).

Maeda *et al.*, (1988) and Sato *et al.*, (1990) indicated the presence of heterotic effects in body weights of quail recorded at different ages. Marks (1995) crossing lines of quails selected long-term for increased body weight, found that heterosis was dependent on both environments and age as well as the genetic of populations. He crossed medium weight quails (selected for high BW_4) and quails of heavy strain and reported that considerable heterosis was present for body weights.

Damme (1994) reported heterosis for BW_1 to BW_6 ranged between 0.6 and 2.7% and it was significant for BW_2. Bahie El-Deen *et al.*, (1998) reported that heterosis percentage estimates for body weight were high at BW_2 (30.2%) and declined to (11.8%) at BW_6. Heterosis contrast were significant for BW_2, BW_4 (P≤0.001) and BW_6 (P≤0.01) but non for ADG_{2-6}. Furthermore, Bahie El-

Deen (1994) and Nofal (2006) when crossing two lines of quails, one selected for high BW_6 and the other line was selected for high egg production noticed negative heterosis for growth traits.

On the contrary, Gerken *et al*., (1988) reported that heterosis was not significant for body weight from 25 to 49 days of age in diallel crosses among two randombred control lines and a line selected for large body weight.

Table 3: Least-square means of body weight traits (g) among the different mating groups ± SE, direct heterosis (H^I), direct additive effect (G^I) and maternal additive effect (G^M).

Mating groups:	BW_0	BW_2	BW_4	BW_6
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
HFC x HFC	9.8 ± 0.16	51.0 ± 2.04	101.2 ± 6.45	189.7 ± 11.74
HWC x HWC	8.9 ± 0.13	46.1 ± 3.11	90.3 ± 7.95	180.8 ± 12.84
HFC x HWC	9.5 ± 0.18	48.1 ± 4.89	93.1 ± 8.05	183.9 ± 13.45
HWC x HFC	9.2 ± 0.19	46.8 ± 3.89	92.9 ± 7.55	185.2 ± 11.66
Pure breed effect	$10.12 \pm 0.12^{***}$	$7.71 \pm 0.90^{**}$	2.83 ± 9.83^{ns}	$19.24 \pm 1.37^{***}$
Direct heterosis (H^i) Unit	$10.65 \pm 0.18^{***}$	$9.86 \pm 1.24^{***}$	1.09 ± 13.55^{ns}	$22.42 \pm 1.88^{***}$
Percentage	33.2 %	28.6 %	18.9 %	17.1 %
Direct additive effect (G^i)	$4.54 \pm 0.12^{**}$	$8.01 \pm 1.54^{**}$	$34.08 \pm 12.55^{***}$	$27.02 \pm 1.80^{***}$
Maternal additive effect (G^m)	$-5.99 \pm 0.17^{*}$	$-4.28 \pm 0.81^{*}$	$-12.31 \pm 9.83^{*}$	$-8.99 \pm 1.36^{**}$

*=P≤ 0.05 or **= P≤0.01or ***= P≤ 0.001, ^{ns}=Non- significant.
BW0, 2, 4, 6 = Body weight at 0, 2, 4, 6 weeks of age

Table 4: Least-square means of daily weight gain traits (g/day) among the different mating groups ± SE, direct heterosis (H^I), direct additive effect (G^I) and maternal additive effect (G^M).

Mating groups:	ADG_{0-2}	ADG_{2-4}	ADG_{4-6}	ADG_{0-6}
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
HFC x HFC	2.6 ± 0.12	4.4 ± 0.13	6.7 ± 0.18	4.5 ± 0.14
HWC x HWC	2.0 ± 0.19	3.8 ± 0.19	6.0 ± 0.10	3.5 ± 0.15
HFC x HWC	2.3 ± 0.14	4.0 ± 0.10	6.3 ± 0.17	3.8 ± 0.18
HWC x HFC	2.2 ± 0.10	4.2 ± 0.16	6.2 ± 0.11	4.3 ± 0.11
Pure breed effect	$8.30 \pm 0.18^{***}$	$10.85 \pm 0.11^{***}$	$3.01 \pm 0.09^{*}$	$9.48 \pm 0.04^{***}$
Direct heterosis (H^i) Unit	$9.31 \pm 0.15^{***}$	$5.40 \pm 0.15^{**}$	$1.81 \pm 0.13^{***}$	$10.24 \pm 0.06^{***}$
Percentage	18.6 %	15.5 %	10.6 %	9.1%
Direct additive effect (G^i)	$5.81 \pm 0.14^{**}$	$4.70 \pm 0.15^{**}$	$9.00 \pm 0.13^{**}$	$8.47 \pm 0.16^{**}$
Maternal additive effect (G^m)	$-5.18 \pm 0.17^{*}$	$-3.12 \pm 0.10^{*}$	$-3.16 \pm 0.06^{*}$	$-3.14 \pm 0.17^{*}$

*=P≤ 0.05 or **= P≤ 0.01or ***= P≤ 0.001, ^{ns}=Non- significant.
ADG0-2, 2-4, 4-6, 0-6 = Average daily gain from 0-2 , 2-4 , 4-6, 0-6 weeks of age.

Direct additive effect:

Direct additive effect for body weights recorded at different ages and body weight gains calculated between different growth periods studied were significant (P≤0.01 or P≤0.001) and they were 4.41, 7.91, 32.18 and 23.07% for BW_0, BW_2, BW_4 and BW_6 (Table, 3). The corresponding estimates of direct additive effects were 5.21, 4.74, 9.27 and 7.57% for ADG_{0-2} , ADG_{2-4} , ADG_{4-6} and ADG_{0-6} , respectively (Table, 4).

The same trend was also concluded by Bahie El-Deen *et al.,* (1998) and Nofal (2006). They reported that direct additive effect on body weight at market age of M-sired quails (M: line selected for meat production) was significantly different from quails sired by E-line (E: line selected for meat production). Sire-line linear contrasts indicate that E-sired quails were significantly superior in BW_6 (P≤0.05) and ADG_{2-6} (P≤0.01). At 4 weeks of age, direct genetic effects were also pronounced in favour of E-sires, while at early ages, M-sires were better than E-sires.

Aboul-Hassan (2001) reported that body weights and body weight gains of Brown strain (B) sired quails was significantly different from quails sired by White strain (W). Sire-line linear contrasts indicate that W-sired quails were significantly superior in most growth traits studied (P≤0.01) except BW_0 and BW_2 was in favour of sired by B strain.

Maternal additive effect:

Maternal line effects (expressed as the differences between reciprocal crosses) on most body weights and body weight gains studied were statistically significant ($P \leq 0.05$ or $P \leq 0.01$ or $P \leq 0.001$) except BW_2 and ADG_{2-4}. The same trend was observed by Bahie El-Deen *et al*., (1998). An evidence for the significant maternal effects on body weight was obtained by Biak and Marks (1993). They reported significant reciprocal effects between the HW with LW and LW with HW crosses in diallel crosses of Japanese quail lines divergently selected for BW.

On the contrary, Chahil *et al*., (1975) reported the absence of maternal effects in BW5 in a 3 x 3 diallel cross of 3 random mating populations of quail. Nofal (2006) crossed M line and E line and reciprocal crosses reported that maternal additive had non significant effect on all growth traits (BW_0, BW_6 and ADG_{0-6}). However, this insignificant influence of maternal additive could be expected since this component is being diminished as birds advance in age.

Egg production and reproductive traits:

Least-squares means and standard errors (S.E) for egg production and reproductive traits i.e. EW, ASM, BWSM, TEN_{10}, TEW_{10} and DEM are given in (Table, 5). The birds produced from purebred HFC_{4-6} x HFC_{4-6} had the highest EW, ASM and BWSM, but it had the lowest TEN_{10}, TEW_{10}, DEM, FR% and HA% followed by that produced from purebred HWC_{4-6} x HWC_{4-6}, while birds produced from crossbreds had intermediate values for all egg production and reproductive traits.

However, significant differences ($P \leq 0.01$ or $P \leq 0.001$) due to mating groups (MG) on egg production and reproductive traits were observed. Results of significant effect of MG on egg production and reproductive traits of Japanese quail strains were also confirmed by different authors i.e. (Bahie El-Deen *et al*., 1998; Aboul-Hassan, 2001; Nofal, 2006 and Aboul-Hassan *et al*., 2009).

Table 5: Means of egg production and reproductive traits among the different mating groups ± SE, heterosis (H^I), maternal additive effect (G^M) and direct additive effect (G^I).

Mating groups:	EW (g)	ASM (day)	BWSM (g)	TEN_{10} (egg)	TEW_{10} (g)	DEM (g/day)	FR%	HA%
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
HFC x HFC	10.7 ± 2.32	47.3 ± 1.32	189.0 ± 1.65	50.0 ± 0.99	457.3 ± 6.46	8.0 ± 0.20	80.0 ± 0.57	60.3 ± 0.71
HWC x HWC	9.5 ± 2.64	43.6 ± 1.14	152.1 ± 1.50	55.1 ± 0.85	470.2 ± 5.50	8.9 ± 0.15	88.2 ± 0.39	67.2 ± 0.95
HFC x HWC	9.9 ± 1.54	44.9 ± 6.41	165.0 ± 7.18	51.5 ± 1.90	464.8 ± 10.84	8.2 ± 0.58	84.1 ± 0.87	63.4 ± 0.66
HWC x HFC	10.1 ± 1.40	45.0 ± 5.10	161.2 ± 7.85	51.0 ± 1.13	467.4 ± 11.59	8.6 ± 0.50	86.3 ± 0.56	65.1 ± 0.51
Pure breed effect	-10.6 ± 0.18^{***}	8.7 ± 0.30^{**}	-34.8 ± 1.40^{***}	-4.8± 0.38^{**}	-162.9± 5.26^{***}	-5.4 ±0.18^{**}	-5.2 ±0.27^{**}	-3.8 ±0.37^{*}
Direct <u>heterosis</u> (H^i) Unit	-10.9 ± 0.50^{***}	-3.3 ± 0.71^{**}	-13.0 ± 2.51^{***}	5.9 ± 0.50^{**}	134.8± 0.45^{***}	4.9 ± 0.12^{**}	-3.7 ± 0.38^{**}	-5.3 ± 0.53^{**}
Percentage	7.7%	8.9%	8.4%	12.7%	20.6%	21.9%	17.1%	18.9%
Direct additive effect (G^i)	0.28 ± 0.91^{ns}	0.11 ± 0.48^{ns}	28.3 ± 2.11^{***}	3.1 ± 0.50^{**}	22.5 ± 7.45^{***}	6.20 ± 0.12^{**}	4.7 ± 0.38^{**}	3.9 ± 0.53^{**}
Maternal additive effect (G^m)	9.2 ± 0.40^{**}	6.6 ± 0.34^{**}	5.8 ± 1.49^{**}	7.2 ± 0.35^{**}	75.4 ± 5.26^{***}	5.0 ± 0.18^{**}	5.0 ± 0.27^{**}	4.2 ± 0.37^{**}

**=P≤ 0.05or **= P≤ 0.01or ***= P≤ 0.001, ^{ns}=Non- significant.*
EW= Egg weight, ASM = Age at sexual maturity, BWSM= Body weight at sexual maturity, TEN_{10}= Total egg number produced among the first ten weeks of egg production, TEW_{10}= Total egg weight produced among the first ten weeks of egg production, DEM= Daily egg mass, FP%= Fertility percentage, HA%= Hatchability percentage.

Direct heterosis:

Estimates of direct heterosis calculated in units (g) and percentages (%) for egg production and reproductive traits studied are presented in (Table, 5). However, these traits showed highly significant ($P \leq 0.01$ or $P \leq 0.001$) positive direct heterosis estimated as 5.9, 134.8, 4.9 for TEN_{10}, TEW_{10} and DEM, while EW, ASM, BWSM, FR% and HA% showed highly significant ($P \leq 0.01$ or $P \leq 0.001$) negative direct heterosis estimated as -10.9, -3.3, -13.0, -3.7 and -5.3, respectively. The same trend was observed by Bahie El-Deen *et al*., (1998), where they reported positive heterosis for BWSM estimated as 18.2% and negative heterosis for egg weight, egg number and age at sexual maturity estimated as -1.95, -3.4 and -1.4% respectively.

Gerken *et al*., (1988) reported negative heterosis estimated as -5.5% for age at 50% production. However, Moritsu *et al*., (1997) reported negative heterosis for ASM ranged between -9 and -23% in various crosses of quail.

Aboul-Hassan (2001) reported that B strain was superior for TEW_{10}, DEM and BWSM, but W strain was superior for ASM and TEN_{10}. The same auther found a significant ($P \leq 0.05$ or $P \leq 0.001$) effects for direct heterosis on all egg production and reproductive traits studied. Furthermore, Nofal (2006) found inconsistent trend of superiority ranking for M or E females in sexual maturity traits. The M line differed significantly ($P \leq 0.05$) in superiority for ASM. The E line insignificantly surpassed the M ones in EP_{20}.

Direct additive effect:

Direct additive effect on all egg production and reproductive traits studied were significant ($P \leq 0.05$ or $P \leq 0.001$) and estimated as 28.3, 3.1, 22.5, 4.7 and 3.9, respectively for BWSM, TEN_{10}, TEW_{10}, FR% and HA% except for EW, ASM and DEM were not significant, they estimated as 0.28, 0.11 and 1.20 (Table, 5).

Bahie El-Deen *et al*., (1998) and Nofal (2006) reported that Meat (M) and Egg (E) sired quails were significantly different in egg number ($P \leq 0.05$), egg weight ($P \leq 0.01$), feed conversion ratio ($P \leq 0.001$) and body weight at sexual maturity ($P \leq 0.01$), i.e. sire-line effects were of considerable importance in the variation of most egg production traits, egg number and body weight at sexual maturity were in favour of E-sired quails, while M-sired quails were superior in egg weight and feed conversion ratio.

Such favourable effect leads to conclude that M quails could be used as a sire line to improve egg weight and feed conversion. In contrast, E-line could be used as a sire line to improve egg number and body weight at sexual maturity.

Aboul-Hassan (2001) stated that egg production traits of Brown (B) and White (W) sired quails were significantly different in ASM, BWSM, TEN_{10} ($P \leq 0.01$) and TEW_{10}, DEM ($P \leq 0.001$), i.e. sire line effects were of considerable importance in the variation of most egg production traits. ASM, TEN_{10} and BWSM were in favour of W sired quails, while sired quails were superior in TEW_{10} and DEM. Such favourable effect leads to conclude that B quails could be used as a sire line to improve age at sexual maturity and total egg number during the first ten weeks of laying. In contrast, W-line could be used as a sire line for improving total egg weight during the first ten weeks of laying and daily egg mass.

Maternal additive effect:

Maternal line effects (expressed as the differences between reciprocal crosses) on all egg production and reproductive traits studied were statistically significant ($P \leq 0.001$). Maternal additive had a significant effect on all egg production and reproductive traits studied and they were ranged between 4.2 for HA% and 75.4 for TEW_{10} (Table, 5).

The same trend was observed by Moritsu *et al*., (1997) and Bahie El-Deen *et al*., (1998), they reported that reciprocal effects were significant for BWSM and ASM.

On the contrary, Aboul-Hassan (2001) reported that maternal line effects on TEW_{10}, BWSM were not significant, i.e. both strains studied (Brown and White) could be used as line of dam, but they were mainly in favour of White strain. In contrast, using Brown quails as dam line has been resulted in significant increase (P≤0.01) in BWSM. Nofal (2006) observed that maternal effects on sexual maturity traits were not significant except ASM (P≤0.01). The same author added that, least-square means of his study showed that using E line as a dam-line gave an advantage expressed in earlier ASM.

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