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GENETIC EVALUATION OF ADDITIVE AND HETEROTIC EFFECTS FOR GROWTH TRAITS IN CROSSING FOUR EGYPTIAN STRAINS OF CHICKENS

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SUMMARY

A crossbreeding experiment was performed for four years using four synthesized strains of chickens involving Mandarah (MN), Matrouh (MT), Inshas (IN) and Silver Montazah (SM) to estimate direct additive genetic effects, maternal effects, direct heterosis and maternal heterosis for body weight at hatch (BW0), 4 (BW4), 8 (BW8), 12 (BW12) and 16(BW16) weeks of age as well as daily weight gains during the age intervals from hatch to 4 weeks (DG0-4), 4-8 weeks (DG4-8), 8-12 weeks (DG8-12) and 12 to 16 weeks (DG12-16). A total number of 34 sires and 230 dams from MT strain and 32 sires and 194 dams from MN strain were used to produce purebreds of MT and MN, two-way crossbreds (½MT½MN and ½MN½MT) and three-way crossbreds (½SM¼MT¼MN and ½IN¼MN¼MT). Heritability estimates were ranged from 0.13 to 0.57. The ranges in predicted breeding values (PBV) for body weights and daily gains in MN strain were slightly higher than in MT strain and were slightly higher in ½MN½MT than in ½MT½MN. PBVs were slightly higher in (½IN¼MN¼MT) than (½SM¼MT¼MN). The solutions of direct additive effects for body weights and daily gains were significantly in favour of MT strain, while the solutions of maternal effects were significantly in favour of MN strain. The percentages of direct and maternal heterosis were significant for all the studied traits and ranged from 12.3 to 64.0% and from 6.5 to 21.8%, respectively. The contrasts of three-way crosses were significant and superior in body weights and daily gains compared to two-way crosses.

Keywords: Egyptian chickens, crossbreeding, growth traits, direct additive and maternal effects, direct and maternal heterosis

INTRODUCTION

In the last two decades, the poultry industry in Egypt, particularly in chickens, depends mainly on some exotic breeds, while our local breeds and/or strains are somewhat of less considerable importance in this industry. Crossbreeding could be used to establish broad genetic basis for the development of new strains or lines and to find superior crossbreds. Some Egyptian studies have shown significant (P≤0.05 and P≤0.01) direct genetic and maternal effects on growth traits at different ages of chickens (e.g., Aly and Abou El-Ella 2005; Saadey *et al.*, 2008; Abd El-A'al 2009; Amin *et al.*, 2013*;* Amin 2015; Khattab 2014; Mahmoud and El-Full 2014; Radwan and Mahrous 2018; Saleh *et al.,* 2020a&b). In most of these studies, crossing local breeds of chickens with local and/or exotic ones was generally associated with the existence of considerable heterotic effects on growth traits (Saadey *et al*., 2008; El-Tahawy 2020; Soliman *et al*., 2020). Also, several Egyptian reports (e.g., Iraqi *et al*., 2002; Abou El-Ghar *et al.*, 2007; Roshdy *et al.*, 2007; Saadey *et al.*, 2008; Abd El-A'al, 2009; Iraqi *et al.*, 2011; Taha and Abd El-Ghany 2013; Amin 2015; Radwan and Mahrous 2018; Saleh *et al.,* 2020a&b) have confirmed the superiority of crossbreds over the purebreds regarding body weights and weight gains at different ages. Khattab (2014) reported that estimates of maternal heterosis for body weights were positive and mostly significant. However, little information is available on maternal heterosis for growth traits of chickens in Egypt.

The updated methodologies used to evaluate crossbreeding experiments taking into account direct additive effects, maternal effects, direct and maternal heterosis for growth traits of chickens in developing countries are scarce. Few modern reports on these modern methodologies were documented for growth traits in chickens (Iraqi *et al*., 2013; Taha and Abd El-Ghany 2013; Mahmoud and El-Full 2014; Amin 2015; Radwan and Mahrous 2018; El-Tahawy 2020). Therefore, the objectives of the present study were: (1) To estimate heritability and predicted breeding values for growth traits (body weights and daily weight gains) using single trait animal model, (2) To evaluate crossbreeding effects on growth traits in terms of direct additive genetic effects, maternal effects, direct and maternal heterosis, (3) To detect the superiority of three-way crosses compared to two-way crosses and (4) To decide which local strain could be used as a sire or as a dam in the crossbreeding programs in Egypt.

MATERIALS AND METHODS

Crossbreeding Experiment performed:

A three-way crossbreeding experiment was performed using four pedigreed local strains of chickens named as Mandarah (MN; Abd-El-Gawad 1981), Matrouh (MT; Mahmoud *et al*., 1974a), Inshas (IN; Bakir *et al*., 2002) and Silver Montazah

(SM; Mahmoud *et al.*, 1974b). Two-way crossbreds (½MN½MT and its reciprocal cross ½MT½MN) and three-way crossbreds (½IN¼MN¼MT and ½SM¼MT¼MN) were obtained. The experimental work was carried out for four years starting from February 2013 and terminated in 2016 in the Poultry Breeding Research Station at Inshas, Sharkia Governorate, Animal Production Research Institute (APRI), Agriculture Research Center, Ministry of Agriculture, in cooperation with the Department of Animal Production, Faculty of Agriculture at Moshtohor, Benha University, Egypt. About 34 sires and 230 dams from MT strain and 32 sires and 194 dams from MN strain were chosen randomly to be the sires and dams to produce about 2894 purebred chicks of parental generation (Table 1).

Table 1. Genetic groups and numbers (No) of cocks, hens, pullets and chicks used in the experiment

Generation	Cock genetic group (No)	Hen genetic group (No)	No. of pullets	Chick genetic group (No)
Parental generation				
	MT (34)	MT (230)	357	MT (1479)
	MN (32)	MN (194)	240	MN (1415)
First generation of crossing				
	MT (16)	MN (105)	150	½MT½MN (394)
	MN (17)	MT (77)	194	½MN½MT (259)
Second generation of crossing				
	SM (14)	½MT½MN (64)	156	½SM¼MT¼MN (578)
	IN (11)	½MN½MT (29)	71	½IN¼MN¼MT (231)
Total	**124**	**699**	**1168**	**4356**

*MN, MT, IN and SM: Mandarah, Matrouh, Inshas and Silver Montazah strains, respectively.

In the first generation of crossbreeding, hens of MN and MT strains were divided randomly into two breeding pen groups. The first group of hens of the two strains was artificially inseminated using fresh semen of cocks from the same strain, while the second group was artificially inseminated using fresh semen of cocks from the other strain. The pedigreed eggs produced from the four mating groups (two purebreds of MN and MT and two-way crossbreds of ½MN½MT and ½MT½MN) were collected daily for ten days and incubated thereafter to produce F_1. In the second generation, the crossbred hens of ½MN½MT were artificially inseminated from fresh semen of IN cocks to produce three-way crossbred chicks of ½IN¼MN¼MT, while the crossbred hens of ½MT½MN were artificially inseminated from fresh semen collected from cocks of SM strain to produce three-way crossbred chicks of ½SM¼MT¼MN. The pedigreed eggs produced from hens of all six genetic groups were collected daily for ten days and incubated thereafter. The fresh semen was diluted with saline as 1:1 (1 saline: 1 semen), and each hen was inseminated with 0.2 mL of the diluted semen. The genetic groups produced and number of sires, dams, pullets and chicks used in this experiment are described in Table 1.

Management:

The hatched chicks were wing-banded and reared in floor brooder, then transferred to the rearing pens. In laying period, the pullets of parents were transferred to individual cages. The birds produced were fed *ad libitum* during rearing, growing and laying periods on diets containing 20.4, 16 and 16.5% crude protein, 3.2, 3.9 and 4.4 % crude fiber, and 2950, 2850 and 2700 *kcal/kg* of energy, respectively. The feed requirements were supplied according to NRC (1994). The pullets were exposed to light for 17 hours per day from 22 weeks of age up to the end of the experimental period of egg production. All the birds were treated and medicated similarly throughout the experimental period and they were housed under the same management, hygienic and climatic conditions.

Animal model used:

Records of 4356 birds for body weight at hatch (BW0), 4 (BW4), 8 (BW8), 12 (BW12) and 16 (BW16) weeks of age as well as daily weight gains during the intervals from hatch to 4 weeks (DG0-4), 4-8 weeks (DG4-8), 8-12 weeks (DG8-12) and 12-16 weeks (DG12-16) were used. To estimate the variance components of random effects and heritabilities, the VCE6 software was used (Groeneveld *et al.*, 2010) according to the following model.

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{Z_a u_a} + \boldsymbol{e}$$

Where $\boldsymbol{y}$= the vector of observations of growth trait; $\boldsymbol{\beta}$= the vector of fixed effects of genetic groups (six groups) and sex (three levels of males, females and unsexed chicks); $\boldsymbol{X}$= incidence matrix corresponding to fixed effects; $\boldsymbol{Z_a}$= incidence matrix corresponding to additive random effects of the birds; $\boldsymbol{u_a}$= random effects of birds; $\boldsymbol{e}$= the residual error.

The predicted breeding values (PBVs) for each growth trait were predicted using the BLUPF90 software (Misztal *et al.*, 2014) under single-trait animal model taking into account the pedigree file of birds with and without records. The accuracy (r_A) of predicted breeding values were defined as the correlation between the true and predicted breeding values. For each bird, the accuracy was calculated as:

$r_A = \sqrt{1 - (PEV/\sigma^2_a)}$ where σ^2_a is the additive genetic variance of the trait and PEV is the prediction error variance estimated using elements from the mixed model equations as $PEV = (SEP)^2$ and SEP is the standard error of prediction.

Estimation of crossbreeding effects:

The coefficients (Table 2), relating the genetic crossbreeding effects to the solutions of the genetic groups were used to detect the differences between the strains in terms of direct additive genetic effects (G^I), maternal effects (G^M), direct heterosis (H^I) and maternal heterosis (H^M). Thus, the $\boldsymbol{b}$-vector including four parameters were estimated according to the model of Dickerson (1992) using CBE software of Wolf (1996):

$$\boldsymbol{b} = [(G^I{}_{MN} - G^I{}_{MT})(G^M{}_{MN} - G^M{}_{MT})H^I H^M]$$

The solutions of $\boldsymbol{b}$ were calculated by the method of generalized least squares (GLS) using the following equation: $\hat{b} = \left(XV^-X\right)^{-1} XV^-y$; where X was the matrix of coefficients of estimable crossbreeding effects (Table 2), V^-= the inverse of generalized variance-covariance error matrix, with the variance covariance matrix of $\boldsymbol{b}$ being: $Var\ \hat{b} = \left(XV^-X\right)^{-1}$; the matrix in Table 2 was also used to test the significance of the crossbreeding effects. Estimates of the differences between the two-way crosses and three-way crosses were computed based on contrasts using generalized least-square solutions for genetic groups and adopting BLUPF90 software (Misztal *et al.*, 2014).

Table 2. Genetic groups of chicks with their sires and dams and coefficients of the matrix relating genetic group solutions of chicks with crossbreeding effects

Chick genetic group	Sire	Dam	Coefficients of the matrix			
			G^I	G^M	H^I	H^M
MT	MT	MT	1	1	0	0
MN	MN	MN	1	1	0	0
½MT½MN	MT	MN	0.5	0.5	1	0
½MN½MT	MN	MT	0.5	0.5	1	0
½SM¼MT¼MN	SM	½MT½MN	0.5	0.25	0	1
½IN¼MN¼MT	IN	½MN½MT	0.5	0.25	0	1

G^I, G^M, H^I and H^M: Direct additive genetic effect, maternal effect, direct heterosis and maternal heterosis, respectively.

RESULTS AND DISCUSSION

Overall means, variations and heritabilities:

The overall means of all genetic groups presented in Table (3) were 32.5, 233, 478, 781, 1047, 7.2, 8.8, 10.7 and 9.5 g for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively. In comparison with other Egyptian studies, Khattab (2014) in a crossing experiment of MT and MN chickens reported that means of body weights were 33, 192, 428, 738 and 989 g for chicks at hatch, 4, 8, 12 and 16 weeks of age, respectively. El-Attrouny *et al.* (2017) in Benha line chickens stated that the overall means of body weights were 34, 247, 601, 1055 and 1561 g at hatch, 4, 8, 12 and 16 weeks of age and 7.6, 12.6, 16.2 and 18.1 g for daily gains during the intervals of 0-4, 4-8, 8-12 and 12-16 weeks of age, respectively. Saleh (2019) when crossing Fayoumi and Rhode Island Red chickens found that the overall means of body weights were 34, 237, 662 and 903 g at hatch, 4, 8 and 10 weeks of age and 6.1, 8.3, 14.2, 16.3 and 17.2 g for daily gains during the intervals of 0-2, 2-4, 4-6, 6-8 and 8-10 weeks of age, respectively.

Table 3. Actual means, standard deviations (SD), coefficients of variation (CV %) and heritability estimates ± their standard errors (SE) for body weights and daily gains

Trait	Symbol	No	Mean	SD	CV%	h^2±SE
Body weight (g):						
at hatch	BW0	4356	32.5	3.1	9	0.57±0.02
at 4 weeks	BW4	3560	233	54	23	0.26±0.04
at 8 weeks	BW8	3220	478	121	25	0.24±0.04
at 12 weeks	BW12	2794	781	187	24	0.22±0.04
at 16 weeks	BW16	2290	1047	254	24	0.25±0.05
Daily weight gain (g):						
Hatch to 4 weeks	DG0-4	3558	7.2	1.9	27	0.26±0.04
4-8 weeks	DG4-8	2949	8.8	3.1	35	0.16±0.03
8-12 weeks	DG8-12	2663	10.7	4.1	38	0.13±0.04
12-16 weeks	DG12-16	2135	9.5	4.6	49	0.18±0.03

The coefficients of variation were 9, 23, 25, 24, 24, 27, 35, 38 and 49% for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively. Khattab (2014) found that coefficients of variation for body weights were moderate and they were lower at hatch (9.4%) than at 16 weeks of age (25.8%). El-Attrouny *et al.* (2017) reported that coefficients of variation in Benha line chickens ranged from 10.8 to 20.2% for body weights and from 19.5 to 32.5% for daily weight gains. Moreover, Saleh (2019) mentioned that the coefficients of variation for body weights were 12, 25, 20, 16 and 14% at 2, 4, 6, 8 and 10 weeks of age, respectively, and 29, 36, 25, 18 and 15% for daily weight gains during the intervals of 0-2, 2-4, 4-6, 6-8 and 8-10 weeks of age, respectively.

The heritability estimates were 0.57, 0.26, 0.24, 0.22, 0.25 0.26, 0.16, 0.13 and 0.18 for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively (Table 3), the estimates for body weights and gains decreased as the age advanced. These estimates were generally within the range of those obtained for the same strains by Khattab (2014) who reported estimates of 0.57, 0.26, 0.23, 0.20, 0.24, 0.25, 0.14, 0.13 and 0.04 for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively. Iraqi *et al.* (2002) found that the estimates in crosses of Matrouh and Mandarah chickens were 0.58, 0.21, 0.15, 0.20, 0.14, 0.22, 0.24, 0.35 and 0.44 for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively, i.e., the estimate for body weight at hatch was higher than that for BW12 which may be due to decreasing of maternal effects and non-additive variance effects at later age than at hatch (Iraqi *et al.*, 2013). In general, selection for body weight at early ages may have resulted in fast genetic improvement in growth of these local chicken strains. Furthermore, El-Attrouny *et al.* (2017) stated that the estimates were moderate or high; being 0.52, 0.28, 0.27, 0.33, 0.31, 0.30, 0.23, 0.19 and 0.24 for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively.

Predicted breeding values (PBVs):

The ranges in PBV and their accuracy of predictions (r_A) for growth traits within each genetic group are presented in Table 4. For purebred birds, the ranges in PBV of MN birds were slightly higher than in MT birds; indicating that genetic improvement of body weights in MN strain could be achieved more rapidly through selection compared to MT strain. The ranges in MN and MT being 12 and 12 g for BW0, 71 and 62 g for BW4, 170 and 137 g for BW8, 275 and 233g for BW12, 264 and 335g for BW16, 2.5 and 2.2 g for DG0-4, 3.2 and 2.9 g for DG4-8, 4.7 and 3.8 g for DG8-12 and 2.6 and 2.6 g for DG12-16, respectively. These estimates are in agreement with those obtained by Iraqi *et al.* (2002) and Khattab (2014) who stated that the ranges in PBV for body weights and gains in MN chickens were higher than those in MT.

Table 4. The ranges in predicted breeding values (PBV) for body weights and daily gains in different genetic groups

Trait[+]	MN	MT	½MN½MT	½MT½MN	½IN¼MN¼MT	½SM¼MT¼MN
Body weight (g)						
BW0	12	12	12	10	11	9
BW4	71	62	55	54	59	45
BW8	170	137	129	130	130	130
BW12	275	233	217	211	264	177
BW16	264	335	312	302	299	234
Daily gain (DG) (g)						
DG0-4	2.5	2.2	1.8	1.5	2.0	1.5
DG4-8	3.2	2.9	3.0	2.7	2.6	2.5
DG8-12	4.7	3.8	2.8	2.4	4.7	2.6
DG12-16	2.6	2.6	2.7	2.2	2.6	2.0

[+] Traits as defined in Table (3), The accuracies of predictions (r_A) were high and ranged from 0.6 to 0.9 for body weights and from 0.4 to 0.8 for daily gains.

For two-way crossbred birds, the ranges in PBV recorded by ½MN½MT were slightly higher than those recorded by ½MT½MN (Table 4), the ranges of PBV in ½MN½MT and ½MT½MN being 12 and 10 g for BW0, 55 and 54 g for BW4, 129 and 130 g for BW8, 217 and 211 g for BW12, 312 and 302 g for BW16, 1.8 and 1.5 g for DG0-4, 3.0 and 2.7 g for DG4-8, 2.8 and 2.4 g for DG8-12 and 2.7 and 2.2 g for DG12-16, respectively. These ranges in PBV for body weights and daily gains from hatch to 16 weeks of age are in agreement with those reported by Iraqi *et al.* (2002), while they are somewhat different from those obtained by Khattab (2014) who reported that there was superiority of the crossbred mothered by MT strain (½MN½MT) over the cross mothered by the MN strain (½MT½MN).

For birds of three-way crossbreds, birds of the cross fathered by IN cocks and mothered by ½MN½MT dams had higher ranges in PBV for body weights and gains than those cross fathered by SM cocks and mothered by ½MT½MN dams (Table 4). The ranges in ½IN¼MN¼MT and ½SM¼MT¼MN being 11 and 9 g for BW0, 59 and 45 g for BW4, 130 and 130 g for BW8, 264 and 177 g for BW12, 299 and 234 g for BW16, 2.0 and 1.5 g for DG0-4, 2.6 and 2.5 g for DG4-8, 4.7 and 2.6 g for DG8-12 and

2.6 and 2.0 g for DG12-16, respectively. The high estimates of PBV in ½IN¼MN¼MT cross indicating that improvement of body weight and daily gain in that cross could be achieved through selection. Khattab (2014) reported higher ranges for the cross fathered by IN cocks and mothered by ½MN½MT dams than the cross fathered by SM cocks and mothered by ½MT½MN dams.

Direct additive effects (G^I):

The estimable generalized least square solutions of direct additive effects for all body weights and daily gains presented in Table (5) indicated that the estimates of G^I were highly significant ($P \leq 0.01$) and in favour of MT strain by 4.0, 62.1, 38.5, 20.2, 27.2, 54.6, 12.7, 9.3 and 37.8 % for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively, i.e., growth traits of local chickens in Egypt could be improved by crossbreeding using MT chickens as a sire strain. Iraqi *et al.* (2013) in crossing Golden Montazah with White Leghorn reported that the estimates of direct additive genetic effects for body weights and daily gains were significant ($P \leq 0.01$) and in favour of Golden Montazah strain.

Table 5. Generalized least square solutions for direct additive genetic effects ($G^I = G^I_{MN} - G^I_{MT}$) and their standard errors (SE) and percentages for body weights and daily weight gains

Body weight (g)					Daily gain (DG) (g)				
Trait	**No of chicks**	**G^I solution (units)**	**SE**	**G^I %$^+$**	**Trait**	**No of chicks**	**G^I solution (units)**	**SE**	**G^I %$^+$**
BW0	4356	-1.3**	0.002	-4.0	DG0-4	3558	-4.6**	0.002	-54.6
BW4	3560	-128**	0.08	-62.1	DG4-8	2949	-1.1**	0.004	-12.7
BW8	3220	-167**	0.19	-38.5	DG8-12	2663	-1.0**	0.005	-9.3
BW12	2794	-149**	0.35	-20.2	DG12-16	2135	-3.4**	0.006	-37.8
BW16	2290	-271**	0.54	-27.2					

Direct additive genetic effects were in favour of MT strain, $^+$Percentages were computed as [Estimate of G^I in units /(MN+MT)/2]x100, **: $P \leq 0.01$.

Maternal effects (G^M):

The estimable maternal effects and their percentages for growth traits indicated that most of the solutions were highly significant ($P \leq 0.01$) and in favor of MN strain by 10.2, 50.5, 49.1, 29.7, 29.9, 53.7, 17.7, 13.8 and 26.4 % for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively (Table 6). Therefore, dams of MN chickens could be used to increase growth performance of the Egyptian strains of chickens through crossbreeding programs involving MN strain. In the same context, Khattab (2014) indicated that MN strain had superior maternity in the crossbreeding programs.

Estimates of maternal effects on body weights at early ages were higher than those at later ages (Table 6). Similarly, Iraqi *et al.* (2002) found that maternal effects on body weights and daily gains at early ages were higher than those at later ages. Abdel-A'al (2009) in crossing Inshas with Matrouh chickens reported that percentages of maternal effects were generally low. Iraqi *et al.* (2011) stated that maternal effects on body weights and gains were significant and in favour of Matrouh dams when crossed with Inshas chickens. Saleh *et al.* (2020a) in crossing Fayoumi with Rhode Island Red chickens found that the percentages of maternal effects for body weights and daily gains were moderate and ranged from 2.4 to 13.6 %.

Table 6. Generalized least square solutions for maternal effects ($G^M = G^M_{MN} - G^M_{MT}$) and their standard errors (SE) and percentages for body weights and gains

Body weight (g)					Daily gain (DG) (g)				
Trait	**No of chicks**	**G^M solution (units)**	**SE**	**G^M %$^+$**	**Trait**	**No of chicks**	**G^M solution (units)**	**SE**	**G^M %$^+$**
BW0	4356	3.3**	0.01	10.2	DG0-4	3558	5.2**	0.01	53.7
BW4	3560	146**	0.17	50.5	DG4-8	2949	1.8**	0.01	17.7
BW8	3220	214**	0.42	49.1	DG8-12	2663	1.5**	0.01	13.8
BW12	2794	219**	0.77	29.7	DG12-16	2135	2.4**	0.01	26.4
BW16	2290	298**	1.18	29.9					

Maternal effects were in favour of MN strain, $^+$Percentages were computed as [Estimate of G^M in units /(MN+MT)/2]x100, **: $P \leq 0.01$.

Direct heterotic effects (H^I):

The percentages of direct heterosis were 53.0, 25.7, 12.3, 23.0, 64.0, 27.7, 29.1 and 49.8 % for BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively (Table 7); indicating that crossing MN with MT was associated with the existence of positively high percentages of heterotic effects on body weights and daily gains (Table 7). These results may be an encouraging factor for the poultry breeders in Egypt to cross these two native strains to exploit the obtained hybrid vigor in body weights and daily gains. Iraqi *et al.* (2011&2013) showed that estimates of direct heterosis were positive and highly significant with percentages ranging from 6.9 to 9.1% for body weights and 8.1 to 25.3 % for daily gains. Saleh *et al.* (2020a) in crossing Fayoumi with Rhode Island Red reported that direct heterosis percentages were moderate and ranged from 4.0 to 7.7% for body weights and 1.3 to 6.0% for daily gains.

Table 7. Generalized least square solutions and percentages for direct heterotic effects and their standard errors (SE) for body weights and gains

Body weight (g)					Daily gain (g)				
Trait	No of chicks	H^I solution (units)	SE	H^I %⁺	Trait	No of chicks	H^I solution (units)	SE	H^I %⁺
BW0	4356	1.6^{ns}	0.03	4.9	DG0-4	3558	3.9^{**}	0.04	64.0
BW4	3560	110^{**}	0.12	53.0	DG4-8	2949	2.3^{**}	0.06	27.7
BW8	3220	112^{**}	0.29	25.7	DG8-12	2663	3.2^{**}	0.09	29.1
BW12	2794	91^{*}	0.55	12.3	DG12-16	2135	4.6^{**}	0.09	49.8
BW16	2290	229^{**}	0.84	23.0					

⁺ Direct heterosis percentage were computed as [Estimate of H^I in units/(MN+MT)/2]x100, ns: non-significant, *: P≤0.05, **: P≤0.01.

Maternal heterosis (H^M):

The estimable solutions of maternal heterosis and their percentages indicated that all estimates for body weights and gains were significant and of considerable importance (Table 8), being 9.0, 15.9, 11.3, 8.1, 10.6, 21.8, 7.2, 5.8 and 6.5 % for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively, reflecting the importance and magnitude of maternal heterotic effects on growth traits. Iraqi *et al.* (2013) found that the estimates of maternal heterosis were positive and highly significant (P≤0.01) for BW0, BW16 and DG1216. Similarly, Khattab (2014) reported that estimates of maternal heterosis were positive and significant for most studied body weights, being 1.1, 10.8, 1.9, 2.2 and 4.7 % for BW0, BW4, BW8, BW12 and BW16, respectively (P≤0.01).

Table 8. Generalized least square solutions and percentages for maternal heterotic effects (H^M) and their standard errors (SE) for body weights and gains

Body weight (g)					Daily gain (g)				
Trait	No of chicks	H^M solution (units)	SE	H^M %⁺	Trait	No of chicks	H^M solution (units)	SE	H^M %⁺
BW0	4356	3.0^{*}	0.02	9.0	DG0-4	3558	1.57^{**}	0.002	21.8
BW4	3560	37.3^{**}	0.08	15.9	DG4-8	2949	0.73^{**}	0.004	7.2
BW8	3220	58.5^{**}	0.19	11.3	DG8-12	2663	0.68^{**}	0.005	5.8
BW12	2794	67.7^{**}	0.35	8.1	DG12-16	2135	0.52^{**}	0.006	6.5
BW16	2290	110.3^{**}	0.53	10.6					

⁺ Percentage of maternal heterosis were computed as [Estimate of H^M in units/(MN+MT)/2]x100, *: P≤0.05, **: P≤0.01.

Contrasts between three-way crosses and two-way crosses:

Estimates of the contrasts between three-way crosses and two-way crosses and their standard errors and percentages using BLUPF90 software have shown that three-way crosses were superior in most body weights and gains compared to two-way crosses (Table 9), the superiority percentages were 45.0, 18.6, 6.4, 21.9, 48.6, 12.6 and 55.5 % for BW4, BW8, BW12, BW16, DG0-4, DG4-8 and DG12-16, respectively. In the same context, Khattab (2014) reported significant percentages of superiority of three-way crosses relative to two-way crosses to be 13.6, 5.9, 17.6 and 27.8 % for BW4, BW16, DG0-4 and DG12-16, respectively.

Table 9. Contrasts estimated by BLUPF90 software between three-way crosses and two-way crosses and their standard errors (SE) for body weights and daily gains

Body weight (g)					Daily gain (DG) (g)				
Trait	**No of chicks**	**Contrast (g)**	**SE**	**Contrast as %**	**Trait**	**No of chicks**	**Contrast (g)**	**SE**	**Contrast as %**
BW0	4356	0.4^{ns}	0.03	1.4	DG0-4	3558	3.5**	0.69	48.6
BW4	3560	106**	20.2	45.0	DG4-8	2949	3.3**	0.20	12.6
BW8	3220	96**	8.7	18.6	DG8-12	2663	0.1^{ns}	0.23	1.0
BW12	2794	54**	5.2	6.4	DG12-16	2135	4.4**	0.52	55.5
BW16	2290	227**	25.9	21.9					

ns: non-significant, **: (P≤0.01).

CONCLUSIONS

- Crossing Mandarah (MN), Matrouh (MT), Inshas (IN) and Silver Montazah (SM) chickens was associated with an existence of high percentage of direct and maternal heterosis for body weights and gains (P≤0.01).
- Based on Generalized least square solutions of direct additive genetic effects for growth traits, MT strain could be used as a sire strain and MN as a dam strain to improve body weights and gains in local strains of chickens.
- The superiority of three-way crossbreds over two-way crossbreds for all body weights and gains gave an impression that inter-se mating of three-way crossbreds (½IN¼MN¼MT and ½SM¼MT¼MN) could be practiced to improve growth traits in local chickens.

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التقييم الوراثي للتأثيرات التجمعية وقوة الخلط لصفات النمو في خلط أربع سلالات من الدجاج المصري

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أجريت تجربة خلط لمدة أربعة أعوام بإستخدام أربع سلالات مستنبطة من الدجاج تشمل مندرة، مطروح، إنشاص والمنتزه الفضي لتقدير التأثيرات الوراثية التجمعية المباشرة، التأثيرات الأمية، قوة الخلط المباشرة وقوة الخلط الأمية لصفات وزن الجسم عند الفقس، عند ٤، ٨، ١٢، ١٦ أسبوع من العمر، بالإضافة إلى الزيادة اليومية في الوزن خلال الفترات العمرية من الفقس إلى ٤ أسابيع، من ٤ إلى ٨ أسابيع، من ٨ إلى ١٢ أسبوع ومن ١٢ إلى ١٦ أسبوع من العمر. تم إستخدام عدد ٣٤ أب و ٢٣٠ أم من سلالة مطروح، و ٣٢ أب و ١٩٤ أم من سلالة مندرة لإنتاج السلالات النقية في جيل الأباء (مندرة ومطروح)، الخليط المزدوج في الجيل الأول (½مطروح½مندرة، ½مندرة½مطروح) والخليط الثلاثي في الجيل الثاني (½منتزه فضي¼مطروح¼مندرة، ½إنشاص¼مندرة¼مطروح). تراوحت قيم المكافئ الوراثي للصفات المدروسة من ٠.١٣ إلى ٠.٥٧. كان مدى القيم التربوية المتوقعة لأوزان الجسم ومعدلات الزيادة اليومية في سلالة المندرة أعلى منها في سلالة المطروح، وأيضاً أعلى في الخليط الثنائي (½مندرة½مطروح) عن خليطه العكسي (½مطروح½مندرة). كان مدى القيم التربوية المتوقعة للخليط الثلاثي (½إنشاص¼مندرة¼مطروح) أعلى منها للخليط الثلاثي الآخر (½منتزه فضي¼مطروح¼مندرة). كانت تقديرات التأثيرات التجمعية المباشرة لأوزان الجسم ومعدلات الزيادة اليومية معنوية لصالح سلالة مطروح، بينما كانت تقديرات التأثيرات الأمية معنوية لصالح سلالة مندرة، كانت نسب قوة الخلط المباشرة والأمية معنوية وتراوحت من ١٢.٣ إلى ٦٤.٠% ومن ٦.٥ إلى ٢١.٨% على الترتيب. كانت الفروق بين الخلطان الثلاثية معنوية ومرتفعة عن الخلطان الثنائية لصفات وزن الجسم ومعدل الزيادة اليومية.