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Genetic evaluation of growth traits in a crossbreeding experiment involving two local strains of chickens using multi-trait animal model

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Abstract

A crossbreeding experiment was carried out between two local strains of Mandarah (MN) and Matrouh (MA) chicken. Thirty-four sires and 400 dams from each strain were used to produce four genetic groups. Body weights of 3067 chicks at hatch (BW0), 4 (BW4), 8 (BW8), 12 (BW12) and 16 (BW16) weeks of age and their daily gains in weight during the age intervals from 0-4 (DG4), 4-8 (DG8), 8-12 (DG12) and 12-16 (DG16) weeks were evaluated. Multi-trait animal model (MTAM) was used to estimate direct additive genetic (G^I) and maternal additive genetic (G^M) and direct heterosis (H^I) effects. Heritabilities were estimated and breeding values (PBV) were also predicted.

Estimates of Heritabilities (h^2) for growth traits ranged from 0.14 to 0.58. The percentages of G^M were in favour of the MA dams and ranged from –1.47 to –6.70 % for body weights and from –1.40 to –7.73 % for gains in weight. Estimates of H^I (P<0.001) ranged from –14.97 to 41.79 % for body weights and from 25.30 to 61.86 % for daily gains in weight. For purebreds, the ranges in PBV for all growth traits recorded of MN were higher than those recorded of MA. For crossbreds, the ranges in PBV for all growth traits recorded of MAxMN were relatively greater than those estimates recorded of MNxMA. Accuracies in prediction of breeding values for all growth traits of MN chickens were higher than those estimates of MA (71% vs 65% for body weights and 64% vs 58% for daily gains), while the accuracies in both crossbred groups were nearly the same.

Keywords: Egyptian chickens, heterosis, direct and maternal additive effects, breeding values.

Introduction

Egyptian strains of chickens were not subjected to intensive selection program and consequently, high additive and non-additive genetic variations appeared among them (Khalil et al 1999; Iraqi et al 2000). This concept was an encouraging factor to cross our local strains together. There is a scarce literature concerning estimation of direct and maternal additive effects and direct heterosis for growth traits in crossbreeding experiments carried out under hot climatic conditions. In this respect, some investigators (e.g. Barbato and Vasilatos-Younken 1991; Khalil et al 1999; Sabri et al 2000) estimated the crossbreeding effects for growth traits in chickens using sire and/or dam models. While Van Vleck (1993) reported that a true model for prediction of breeding values from crossbred data, however, also includes the genetic deviations of individual birds from the breed and heterosis constants. Because the breed and heterosis constants usually must be estimated from the same data used to predict the deviations, then including the breed and heterosis constants would be appropriate to evaluate direct and maternal genetic effects. In this respect, Boldman et al (1995) cited that constants and standard errors for fixed effects as well as prediction of genetic deviations could be obtained when the expectations are known based on minimization of error variance. The goal of this study was to estimate direct and maternal additive effects and direct heterosis and heritabilities for growth traits in crossbreeding experiment involving two Egyptian strains of chickens and to predict the breeding values of individual birds using multi-trait animal model.

Material and methods

Breeding plan and management

Two-year crossbreeding experiment was carried out during the period from March 1990 to December 1991 in the Poultry Breeding Research Station at Inshas, Sharkia Governorate, Animal Production Research Institute, Agricultural Research Center, Ministry of Agriculture, Egypt.

Two local strains named Mandarah (MN) and Matrouh (MA) were used in this study. The MN strain originated from crossing Alexandria sires with Dokki-4 dams for four consecutive generations together with selection (Abd El-Gawad 1981). The MA strain was developed from crossing White Leghorn sires with Dokki-4 dams for six consecutive generations together with selection (Mahmoud et al 1974). The Alexandria strain was developed from a diallel crossing system among four breeds (Fayoumi, White Leghorn, Rhode Island Red, Barred Plymouth Rocks) as reported by Kosba (1966).

Thirty-four sires and 400 dams from each strain were chosen randomly from 200 cockerels and 1000 pullets, respectively, to produce purebred and crossbred groups of progeny. Pullets of each of the two strains were divided randomly in two breeding pen groups. The first group of hens of each of the two strains was mated with cocks from one strain, while the second group was mated with cocks from the other strain. Consequently, eggs produced from the four mating groups (two purebreds of MNxMN and MAxMA and two crossbreds of MNxMA and MAxMN) were collected and incubated in one hatch. The number of cocks (sires) and pullets (dams) used and their progenies produced from all genetic groups are given in Table 1. The pedigreed eggs from each individual hen were collected and recorded regularly.

Table 1. Number of sires, dams and their progenies used for the analysis of growth traits of purebred and crossbred groups

Genetic groups+	Cocks (Sires)	Hens (Dams)	Hatched chicks
MN x MN	17	174	799
MA x MA	17	181	825
MN x MA	17	128	659
MA x MN	17	182	784
Total	68	665	3067

+ *First letters denoted to breed of sires and the second denoted to breed of dams.*

On the day of hatch, all chicks were wing-banded, then brooded on the floor and were grown in open houses up to 16 weeks of age. All chicks were medicated similarly and regularly and they were subjected to the same managerial, hygienic and climatic conditions. During growing and rearing periods, all chicks were fed *ad-libitum* using diet containing 20.4% and 16% crude protein and 2997 and 2780 metabolizable energy kcal/kg, respectively.

Data and models of analysis

Data of body weights recorded at hatch (BW0), 4 (BW4), 8 (BW8), 12 (BW12) and 16 (BW16) weeks of age and gains in weight during the periods from 0-4 (DG4), 4-8 (DG8), 8-12 (DG12) and 12-16 (DG16) weeks of age were analysed for 3067 chicks. Multi-trait animal model (MTAM) was used to analyze the data of body weights (five traits included in the model in the same time) and daily gains (four traits included in the model in the same time). The mixed model equations (MME) in MTAM are being too large when we have more than five traits. Using the program of Boldman et al (1995), the animal model in matrix notation was:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e}$$

Where **y**= vector of observed body weight or gain in weight of birds,

b= vector of fixed effects of breed group (4 groups of MNxMN, MAxMA, MNxMA and MAxMN) and sex,

a= vector of random effect of the bird,

X and **Z** are the incidence matrices relating records to fixed effects and the additive genetic effects, respectively, and

e= vector of random residual effects.

Starting values (guessed values) for the estimation of variance and covariance components were obtained using a sire model applying restricted maximum likelihood (REML) and using VARCOMP procedure of SAS (SAS 1996). The MTAM used was considering the relationship coefficient matrix (A) among birds in estimation. Convergence was assumed when the variance of the log-likelihood values in the simplex reached <10^{-6}. Additive genetic variance (s^2_a) and error (s^2_e)and heritabilities were estimated using MTAM. Heritabilities were computed according to Boldman et al. (1995) as:

$$h_a^2 = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_e^2}$$

Estimation of breeding values

Solutions for equations of birds were computed using MTDFREML, the set of programs by Boldman et al (1995) to predict the breeding values (PBV) of birds. The accuracy of predicted breeding value for each individual was estimated according to Henderson (1984) as:

$$r_{A\tilde{A}} = \sqrt{1 + F_j - d_j \alpha}_a$$

Where $r_{A\tilde{A}}$ = the accuracy of prediction of the i^{th} bird's breeding value for birds; F_j= inbreeding coefficient of birds (which equal to zero as calculated using MTDFREML program of Boldman et al. 1995); d_j= the j^{th} diagonal element of inverse of the appropriate block coefficient matrix; and $\alpha = \sigma^2_e/\sigma^2_a$.

Standard error (SE) of predicted breeding value for each individual was estimated as follows: $s.e._y = d_j \sigma_e^2$;
where d_j and σ^2_e were defined above.

Estimation of crossbreeding effects

Estimates of individual direct heterosis, maternal breed additive (i.e. reciprocal crosses differences or breed genetic maternal effect) and direct additive effects for all traits were calculated using the contrast statement in MTDFREML program (Boldman et al 1995). Estimates of each component were calculated according to Dickerson (1992) as follows:

1) Direct additive genetic (G^I): {[MNxMN – MAxMA] – [MAxMN – MNxMA]}

2) Maternal breed additive genetic (G^M): [MAxMN – MNxMA]

3) Direct heterosis (H^I): {[MNxMA + MAxMN] – [MNxMN + MAxMA]}

Each estimate of contrast was tested for significance using student's t-test.

Results and discussion

Means of purebreds

Means and standard errors of purebred and crossbred groups for growth traits are given in Table 2. Means of purebreds indicate that no consistent trend could be to verify the superiority of any strain on the other for body weights and daily gains. This could be attributed to that both purebreds originated from the same breed of dam (Dokki-4), while Alexandria chickens were used as sires for MN and White Leghorn were used as sires for MA (Mahmoud et al 1974; Abd El-Gawad 1981). This may explain why phenotypic variations of growth in both purebred strains are nearly the same. On the other hand, significant differences (P<0.001) between purebreds were obtained for only BW4, DG4, DG8 and DG16 (Table 2). Khalil et al (1999) showed that differences in growth traits between White Leghorn and Saudi chickens were significant (P<0.001).

Variance components and heritability

Estimates of additive genetic and error variances for most body weights and daily gains were moderate and high (Table 3). Heritabilities estimated by MTAM (Table 3) show that the estimate for BW0 was high (0.58), while the estimates for most subsequent growth traits were moderate. Generally, one can conclude that genetic selection at early ages (0-4 weeks) may give rapid improvement in growth of these local strains. Based on MTAM analysis, Iraqi et al (2000) in Egypt reported similar estimates for Golden Montazah chickens. On the other hand, estimates of were high compared to findings obtained by El-Labban et al (2000) for Dokki-4 chickens in Egypt using single- and multiple-trait animal models in analyses.

Table 2. Means of growth traits in different purebreds and crossbreds[+]

Trait	Symbol	Purebreds			Crossbreds[++]	
		MN x MN Mean±SE	MA x MA Mean±SE	Purebred difference ±SE	MN x MA Mean±SE	MA x MN Mean±SE
Body weight (g):						
at hatch	BW0	36.34±0.12	36.58±0.12	-0.097± 0.48 NS	34.18±0.13	33.23±0.12
at 4 weeks	BW4	137.99±1.02	132.58±0.99	6.21± 2.45***	167.89±1.12	158.47±1.03
at 8 weeks	BW8	346.65±2.91	353.23±2.84	-3.60± 6.15 NS	429.48±3.20	407.03±2.98
at 12 weeks	BW12	605.56±4.99	616.41±4.90	-8.79±11.24 NS	739.38±5.49	713.33±5.07
at 16 weeks	BW16	941.89±7.37	947.44±6.94	-7.14±13.59 NS	1113.2±7.77	1105.1±7.24
Daily gain (g):						
hatch to 4 weeks	DG4	7.25±0.07	6.85±0.07	0.463±0.18***	9.55±0.08	8.95±0.07
4 to 8 weeks	DG8	14.88±0.17	15.75±0.17	-0.698±0.46***	18.66±0.19	17.71±0.17
8 to 12 weeks	DG12	18.37±0.23	18.62±0.23	-0.258±0.74 NS	22.04±0.26	21.89±0.24
12 to 16 weeks	DG16	24.09±0.30	23.56±0.28	1.335±1.04***	26.68±0.32	27.90±0.30

[+] *First letters denoted to breed of sires and the second denoted to breed of dams.*
*NS = non-significant; * = P<0.05; ** = P<0.01; *** = P<0.001*

Table 3. Estimates of additive and error variances and heritabilities for growth traits

Trait+	s^2_a	s^2_e	h^2
Body weight (g):			
BW0	5.66	4.04	0.58
BW4	118.47	457.80	0.21
BW8	664.42	3896.65	0.15
BW12	2451.93	9848.56	0.20
BW16	3163.07	18754.02	0.14
Daily gain (g):			
DG4	0.662	2.305	0.22
DG8	4.377	13.585	0.24
DG12	12.275	22.692	0.35
DG16	24.617	31.680	0.44

+*Traits as defined in Table 2.*

Direct additive effect (GI)

Estimates of G^I and their percentages for growth traits are given in Table 4. These results indicate that G^I were high (P<0.001) for all body weights, i.e. a considerable contribution of sire-breed effect in the inheritance of body weights was recorded in favorable of the MN strain. These high direct additive effects on growth traits of the MN strain may lead to suggest that MN strain could be used as a sire-breed to get chicks with heavier weights. The percentages of G^I for body weights at early ages (averaged 6.16% for weights from hatch to 8 weeks) were higher than at later ages (averaged 2.54% for weights from 12 to 16 weeks). Similar trend was obtained for daily gain traits. Results of Bahie El-Deen et al (1998) with two lines of Quails and their crosses raised in Egypt confirmed this trend. In crossing of Saudi chickens with White Leghorn, Khalil et al (1999) found that percentages of G^I ranged from 4.9 to 10.2% for body weights and from 3.5 to 14.6% for daily gains in weight.

Maternal breed effect (GM)

Estimates of G^M and their percentages for most growth traits presented in Table 4 indicate that maternal breed effects were high (P<0.001) and in favor of the MA dams. Therefore, one can recommend that dams of MA could be used to increase growth performance of the Egyptian strains of chickens through crossbreeding programs involving this strain. Khalil et al (1999) and Sabri et al (2000) found that maternal breed effects on body weights and gains were significant (P<0.05 and P<0.001). Percentages of G^M for body weights at early ages (averaged 5.23% for weight from hatch to 8 weeks) were higher than those at later ages (averaged 2.83% for weight from 12 to 16 weeks). Results for daily gain traits verified this trend (Table 4).

Table 4. Estimates of direct additive (G^I) and maternal breed additive (G^M) effects for growth traits.

Trait[+]	Direct additive (G^I)			Maternal breed additive (G^M)		
	Estimate	%[++]	Significance	Estimate	%[+++]	Significance
Body weight (g):						
BW0	0.894± 0.66	2.54	***	-0.992± 0.45	-2.80	***
BW4	16.27± 3.38	10.63	***	-10.06± 2.33	-6.70	***
BW8	20.62± 8.51	5.31	***	-24.22± 5.87	-6.19	***
BW12	19.61±15.52	2.92	***	-28.40±10.69	-4.19	***
BW16	22.33±18.74	2.17	***	-15.19±12.90	-1.47	*
Daily gain (g):						
DG4	1.097±0.25	13.06	***	-0.634±0.17	-7.73	***
DG8	0.380±0.64	2.27	*	-1.006±0.44	-5.85	***
DG12	0.026±1.02	0.13	NS	-0.284±0.70	-1.40	NS
DG16	0.373±1.42	1.47	NS	0.962±0.98	3.83	***

[+]*Traits as defined in Table 2.*
[++] *Percentages of G^I computed as {Estimate of G^I / [(MNxMN + MNxMA)/2] x 100}.*
[+++] *Percentages of G^M computed as {Estimate of G^M / [(MAxMA + MNxMA)/2] x 100}.*
*NS = non-significant; * = P<0.05; ** = P<0.01; *** = P<0.001*

The percentages of G^M ranged from –1.47 to –6.70 % for body weights and from -1.40 to –7.73 % for gains in weight (Table 4). In crossing Saudi chickens with White Legohorn in Saudi Arabia, Khalil et al (1999) found that percentages of G^M were in favour of White Leghorn where the estimates ranged from –7.2 to 1.0 % for body weights and from 6.0 to –12.1 % for daily gains. Chicks of MNxMA crossbred had relatively high performance of growth traits compared to chicks of the MAxMN crossbred (Table 2). This could be due that maternal environmental effects of MA dams on growth of own chicks were better in terms of oviductal factors (pre-ovipositional) such as egg size, egg weight, shell quality, and yolk composition (Aggrey and Cheng 1994). The differences between the two strains in egg size or egg contents could not be the only source for maternal effect and that non-additive genetic effects could be involved (Sabri et al. 2000). In a 4x4 diallel crossing experiment between New Hampshire, White Plymouth Rock, White Cornish and White Leghorn, Hanafi and Iraqi (2001) reported that White Plymouth Rock ranked first in maternal ability for body weights, followed by White Cornish.

Direct heterosis (HI)

Estimates of H^I for growth traits presented in Table 5 revealed that heterosis estimates were generally positive and high (P<0.001). The percentages of H^I ranged from –14.97 to 41.79% (average 30.6%) for body weights and from 25.30 to 61.86% (average 39.7%) for gains in weight. These results may be an encouraging factor for the poultry breeders in Egypt to cross these two native strains to get hybrid vigor in growth traits. Sabra (1990) found that crossbreds obtained from crossing between local breeds (Silver Montazah and Dandarawi) have positive and high magnitude of heterosis (average 20.4%) for body weights at different ages.

Table 5. Estimates of direct heterosis (H^I) for growth traits

Trait[+]	Estimate (H^I)	%[++]	Significance
Body weight (g):			
BW0	-5.46± 0.66	-14.97	***
BW4	55.19± 3.38	40.79	***
BW8	131.11± 8.51	37.52	***
BW12	255.53±15.52	41.82	***
BW16	310.52±18.75	32.87	***
Daily gain (g):			
DG4	4.361±0.25	61.86	***
DG8	5.488±0.64	35.86	***
DG12	6.819±1.02	35.88	***
DG16	6.027±1.42	25.30	***

[+]*Traits as defined in Table 2.*
[++] *Percentages of H^I computed as {Estimate of H^I / [(MNxMN + MAxMA)/2] x 100}.*
*NS = non-significant; * = P<0.05; ** = P<0.01; *** = P<0.001*

Most reviewed studies showed that body weights of crossbred chickens at different ages were associated with positive heterotic effects for growth traits (Sabri and Hataba 1994; Khalil et al 1999; Sabri et al 2000). Percentages of H^I recorded by Khalil et al (1999) and Sabri et al (2000) were higher than those obtained in the present study. This probably due to that: (1) non-additive gene effects in the two local strains are responsible for the manifestation of heterosis of these traits, and (2) the error variance was minimized due to accounting of the relationship coefficient matrix (A) among birds in the MTAM (Schaeffer 1993; Iraqi et al 2000).

Predicted breeding values

The minimum, maximum and ranges predicted breeding values (PBV) for birds in different purebred and crossbred groups are presented in Table 6.

For birds in purebreds, the ranges in PBV for all growth traits in MN chickens were higher than those in MA (Table 6). The high estimates of PBV for growth traits in MN strain indicate that improvement of growth performance of this strain could be achieved through selection compared to MA. These figures indicate that additive genetic effects of MN strain were higher than that for MA strain (Table 4). As stated before, MN strain originated from crossing of Alexandria sires with Dokki-4 dams (Abd El-Gawad 1981), while MA strain originated from crossing of White Leghorn sires with Dokki-4 dams (Mahmoud et al 1974). Accordingly, these two local strains originated from one dam-breed (Dokki-4), while they differed in the sire-breed in terms of Alexandria chickens for MN and White Leghorn for MA. The Alexandria strain is a dual-purpose breed in Egypt and White Leghorn is an egg-type breed all-over the world and this may explain why genetic variation for growth performance in MN strain could be high compared with MA.

Table 6. Minimum, maximum and ranges of predicted breeding values for birds with records (PBV), their standard errors (SE) and accuracy of prediction ($r_{A\tilde{A}}$) estimated by multi-trait animal model for growth traits in purebreds and crossbreds.

Trait[+]	Minimum			Maximum			Range in PBV	Minimum			Maximum			Range in PBV
	PBV	SE	$r_{A\tilde{A}}$	PBV	SE	$r_{A\tilde{A}}$		PBV	SE	$r_{A\tilde{A}}$	PBV	SE	$r_{A\tilde{A}}$	
	MNxMN							**MAxMA**						
Body weight (g):														
BW0	-6.6	1.17	0.76	6.9	1.56	0.87	13.5	-6.4	1.17	0.79	5.7	1.44	0.87	12.1
BW4	-24.3	7.46	0.54	22.3	11.03	0.73	46.6	-18.6	7.90	0.49	18.3	9.50	0.69	36.9
BW8	-90.3	18.87	0.52	76.1	26.90	0.73	166.4	-44.3	18.56	0.47	46.3	22.81	0.69	90.6
BW12	-142.7	27.99	0.70	164.7	50.49	0.82	307.4	-73.4	30.08	0.48	92.8	43.52	0.79	166.2
BW16	-165.2	38.97	0.67	151.5	59.23	0.72	316.7	-132.5	40.71	0.46	122.3	50.04	0.69	254.8
Daily gain (g):														
DG4	-2.0	0.59	0.46	1.6	0.84	0.69	3.6	-1.4	0.63	0.45	1.8	0.73	0.64	3.2
DG8	-5.0	1.50	0.62	4.9	2.15	0.70	9.9	-3.2	1.60	0.45	3.9	1.86	0.65	7.1
DG12	-8.1	2.16	0.64	13.6	3.52	0.79	21.7	-4.5	2.40	0.47	6.1	3.09	0.73	10.6
DG16	-17.3	2.83	0.69	14.4	4.94	0.82	31.7	-9.6	3.20	0.49	9.0	4.31	0.77	18.6
	MNxMA							**MAxMN**						
Body weight (g):														
BW0	-5.2	1.14	0.79	6.6	1.44	0.88	11.8	-6.1	1.14	0.79	5.0	1.46	0.88	11.1
BW4	-17.0	7.26	0.48	17.5	9.52	0.75	34.5	-23.6	7.34	0.47	19.0	9.61	0.74	42.6
BW8	-44.1	17.33	0.46	47.1	22.84	0.74	91.2	-50.7	17.45	0.44	47.4	23.09	0.74	98.1
BW12	-77.9	27.46	0.48	84.4	43.57	0.83	162.3	-101.3	27.55	0.48	88.1	43.54	0.83	189.4
BW16	-93.8	38.20	0.44	79.4	50.49	0.73	173.2	-91.0	38.35	0.43	82.8	50.68	0.73	173.8
Daily gain (g):														
DG4	-1.5	0.57	0.45	1.1	0.73	0.71	2.6	-1.7	0.58	0.43	1.3	0.73	0.70	3.0
DG8	-5.2	1.45	0.45	3.7	1.87	0.72	8.9	-3.5	1.47	0.43	3.3	1.88	0.71	6.8
DG12	-5.5	2.11	0.47	5.5	3.09	0.80	11.0	-6.0	2.12	0.47	5.8	3.10	0.80	11.8
DG16	-8.2	2.74	0.49	6.9	4.32	0.83	15.1	-9.4	2.76	0.48	8.3	4.35	0.83	17.7

\+ *Traits defined in Table 2.*

For birds of crossbreds, the ranges in PBV for all growth traits recorded by MAxMN were nearly similar to those ranges recorded by MNxMA. These findings lead us to state that non-additive genetic effects (e.g. dominance, over-dominance and epistasis effects) and maternal effects could play a large role in the improvement of growth performance of crossbreds of the present study (Fairfull 1990).

Accuracy estimated for PBV in purebreds (Table 6) indicated that accuracy in prediction of breeding values for all growth traits recorded for MN was high compared to that recorded by MA. These results fall within the ranges reported by Iraqi et al (2000), El-Labban et al (2000) and Iraqi and Hanafi (2001). On the other side, accuracy of PBV for growth traits in both crossbreds was nearly the same (Table 6). Accuracy of PBV in MN and MA averaged 71% vs 65% for body weights and 64% vs 58% for daily gains, respectively. This result was expected since estimates of additive genetic effects for MN were higher than for MA.

Conclusions

(1) Based on estimates of maternal additive and direct additive effects for all growth traits, we can recommend that MN could be used as a sire-breed and MA as a dam-breed in any crossbreeding program in Egypt in order to improve the growth performance of local strains of chickens.

(2) High estimates of PBV for growth traits in MN strain could be an encouraging factor for the poultry breeders in Egypt to improve growth performance of this strain through selection.

(3) Using multi-trait animal model leads to a reduction in the percentages of error variance and consequently the heterotic effects as well as heritabilities were unbiased.

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