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Genetic Evaluation for Sexual Maturity and Egg Production Traits in Crossbreeding Experiment Involving Four Local Strains of Chickens

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Abstract

A cross experiment was carried out in Animal Production Research Institute (APRI), in cooperation with Benha University, Egypt for three years starting from February 2013 and terminated 2016. Four pedigreed local strains of chickens Matrouh (MT), Mandarah (MN), Inshas (IN) and Silver Montazah (SM) strains were used. A total of 34 sires and 230 dams from MN strain, 32 sires and 194 dams from MT strain were chosen randomly from 250 cockers and 600 pullets to produce purebreds and crossbreds progenies in the first generation. In the second generation, the crossbred hens of MNxMT were artificially inseminated with fresh semen of Inshas strain (IN), while the crossbred hens of MTxMN were artificially inseminated with fresh semen collected from cocks of Silver Montazah strain (SM) to produce three-way crossbreds (½IN×¼MN¼MT and ½SM×¼MT¼MN). Single trait animal model was used in estimating heritability and in predicting the breeding values (PBV). Crossbreeding effects of direct additive (G^I), maternal effects (G^M), direct heterosis (H^I) and maternal heterosis (H^I) were estimated using the procedure of generalized least-squares. The overall means of all genetic groups were 154 day, 1420 g, 39.38 g, 45 egg, 1957 g, 61 egg, 2727 g, 16 day, 411 g, 18 egg, 784 g, 13.5 egg and 593 g for ASM, BWSM, WFE, EN90D, EM90D, EN120D, EM120D, PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively Estimates of heritability were moderate for ASM and BWSM (0.23 and 0.69), while they were low for egg production and partial egg recording traits. The GLM showed that three-way crossbreds reported the earlier ASM, heavier BWSM and WFE, the highest EN90D, EN120D and EN2DW and the heaviest EM90D, EM120D and EM2DW. The ranges of predicted breeding values (PBV) of MT strain were slightly higher than that for MN birds. Ranges of PBV recorded by ½MT½MN were nearly similar to those ranges recorded by ½MN½MT. Cross fathered by SM cocks and mothered by (½MT½MN) had higher ranges in PBV for egg production and partial egg recording traits than those cross fathered by IN cocks and mothered by (½MN½MT). The effects of G^I on all traits ($p \leq 0.01$) and in favour of MN breed. The percentages of G^M were significant for sexual maturity traits and non-significant for egg production and partial egg recording traits. Percentages of H^I (-3.8, 28.5, -4.6, 29.3, 28.8, 24.9, 19.7, -36.1, -3.2, 17.4, 10.6 and 8.8%) and H^M (-2.6, 1.2, 0.03, 7.8, 8.2, 7.8, 8.1, -10.5, 0.2, 7.2, 0.7, 3.2 and 3.3%) were mostly highly significant for all traits for ASM, BWSM, EN90D, EM90D, EN120D, EM120D, PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively. We can recommend that Mandarah strain (MN) could be used as a sire and Matrouh (MT) as a dam, depending on the estimates of the direct additive genetic effect G^I for the studied traits which were in favor of MN.

Keywords: Egyptian strains of chickens, crossbreeding, sexual maturity, egg production, direct additive and maternal effects, direct and maternal heterosis.

Introduction

Indigenous chickens appear to possess enormous genetic diversity, especially in adaptive traits, and the ability to survive in harsh conditions and under minimum feeding regimens **(Eltanany 2011; Ramadan *et al.*, 2012)**.

Poultry industry has a history of using crossing to establish broad genetic basis for the development of new breeds or lines and to find superior crossbreds. The main purpose of crossing is to produce superior crosses to improve performance of local chickens and to combine different breed characteristics in crosses having valuable performance for growth or egg production (**Saadey *et al.*, 2008; Lalev *et al.*, 2014**). **Khalil *et al.*, 1999; Iraqi *et al.*, 2000; Nawar and Bahie El-Deen, 2000 and Iraqi, 2002** reported that the Egyptian strains of chicken had high additive and non-additive genetic variations appeared among them. And, the results of most crossbreeding experiments showed that crossing between the local breeds of chickens with other local ones was generally associated with the existence of considerable heterotic effects on egg production traits (**Iraqi *et al.*, 2007, 2012; Hanafi and Iraqi, 2001; Saadey *et al.*, 2008).**

In the last twenty years, the poultry industry in Egypt, particularly chickens, depends mainly on some exotic breeds while our local breeds and/or strains are somewhat negligible. Some Egyptian studies (**Sheble *et al.*, 1990 and Iraqi, 2008**) reported that most of the native breeds had high non-additive genetic variance and, therefore the possibility of improvement of these breeds through crossbreeding could be evidenced.

Partial recording of egg production in pullets is used to increase the efficiency of genetic selection as well as to shorten the generation interval. Results of many investigators showed that more genetic gain could be obtained in egg production when using partial recording (**El-Labban *et al*., 2011 and EL-Attrouny, 2011**).

Improving chicken productivity in terms of growth and egg production is a major goal of the poultry breeding, and crossbreeding is one of these tools for exploiting genetic variation. In this concept, most of the Egyptian studies showed significant direct and maternal additive effects on growth and egg production traits in chickens. In addition, some studies reported significant direct and maternal heterotic effect on growth and egg production traits. The information for crossbreeding effect on some egg production traits, e.g. egg partial recording, clutch size, pause periods, .. etc in chickens are scace. In Egypt, few reports on these traits were documented (**Hassan, 2008, El-Labban *et al*., 2011, Iraqi *et al*., 2012 and El-Attrouny *et al.* 2019**).

Therefore, the objectives of the present study were: (1) To estimate additive genetic variance, heritability and predicted breeding values (PBV) for egg production traits using single trait animal model. (2) To estimate crossbreeding components (direct additive effects, maternal genetic effects, direct and maternal heterosis) for the studied traits using **CBE** package **(Wolf, 1996).** (3) To compute the superiority of three-way crosses over two-way crosses. And (4) To decide which strain could be used as a sire or a dam in crossbreeding programs in Egypt.

Materials and Methods

Crossbreeding experiment performed:

A cross experiment was performed between Mandarah (MN), Matrouh (MT), Inshas (IN) and Silver Montazah (SM) to get a two-way cross ½MN½MT and its reciprocal cross ½MT½MN and to get three-way crossbred of ½IN¼MN¼MT and ½SM¼MT¼MN. The experimental work was carried out in the Poultry Breeding Research Station at Inshas, Sharkia Governorate, Animal Production Research Institute (APRI), Agriculture Research Center, Ministry of Agriculture, in cooperation with Department of Animal Production, Faculty of Agriculture at Moshtohor, Benha University, Egypt for three years starting from February 2013 and terminated 2016. Four pedigreed local strains of chickens located in APRI were used; Matrouh strain **(Mahmoud *et al*., 1974a)**, Mandarah strain **(Abd-El-Gawad, 1981)**, Inshas strain **(Bakir *et al*., 2002)** and Silver Montazah strain **(Mahmoud *et al*., 1974b)** were used. About of 34 sires and 230 dams from MN strain and 32 sires and 194 dams from MT strain were used. Sires and dams of the two strains were chosen randomly from 250 cockers and 600 pullets, respectively, to produce purebreds and crossbred groups progenies (Table 1).

Table 1. Numbers of sires, dams, and chicks used in different genetic groups.

Chick genetic group	Breed group of sires	Breed group of dams	No. of sires	No. of dams	No. of chicks produced
Parental generation:					
MT	MT	MT	34	230	1479
MN	MN	MN	32	194	1415
First generation of crossing:					
½MT½MN	MT	MN	16	105	394
½MN½MT	MN	MT	17	77	259
Second generation:					
½SM¼MT¼MN	SM	½MT½MN	14	64	578
½IN¼MN¼MT	IN	½MN½MT	11	29	231
Total			124	699	4356

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

In the first generation, pullets of each of MT and MN strains were divided randomly in two breeding pen groups. The first group of hens of each of the two strains was artificially inseminated using fresh semen of cocks from the same strain, while the second group of the two strains was artificially inseminated using fresh semen of cocks from the other strain. Consequently, pedigreed eggs produced from the four mating groups (two purebreds of MNxMN and MTxMT and two crossbreds of MNxMT and MTxMN) were collected daily for ten days and incubated thereafter.

In the second generation, the crossbred hens of MNxMT were artificially inseminated from fresh semen of Inshas strain (IN) to produce the three-way crossbred chicks (½IN¼MN¼MT), while the crossbred hens of MTxMN were artificially inseminated from fresh semen collected from cocks of Silver Montazah strain (SM) to produce three-way crossbred chicks (½SM¼MT¼MN).

Management practiced:

Upon hatch chicks were wing- banded and reared in floor brooder, then transferred to the rearing houses. In laying period, the pullets of parents were transferred to individual cages. Chicks produced were fed *ad-libitum* during rearing, growing and laying periods on the diet containing 20.4%, 16% and 16.5% crude protein, 3.2%, 3.9% and 4.4% crude fiber, 2950, 2850 and 2700 kcal/kg 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. All birds were treated and medicated similarly throughout the experimental period under the same managerial, hygienic and climatic conditions.

Data and models of analysis:

Records of 747 hens from different genetic groups were collected to study the following traits: age and body weight at first egg, weight of the first egg, weight of the first 10 eggs, number and egg mass recorded during 90 days and 120 days of egg production. The following single-trait animal model (in matrix notation) was used to analyze egg production traits:

$$y = Xb + Za + e$$

Where: y = n×1 vector of observation of the hen, n = number of records; X= design matrix of order n×p, which is related to the fixed effects of genetic groups (6 groups), b = p×1 vector of the fixed effects of genetic groups; a = vector of random effects (additive genetic) of the hen; X and Z are the incidence matrices relating to fixed effects and the additive genetic effects, respectively; and e = n×1 vector of random residual effects, NID (0, $\sigma^2 e$). The VCE6 software was used to estimate the variance components of random effects and heritabilities **(Groeneveld *et al.*, 2010)**.

For each trait, the breeding values (PBV's) were predicted using the BLUPF90 software (**Misztal *et al.*, 2018)** under single-trait animal model. Using the pedigree file, one bird at a time (for both birds with and without records, i.e. hens, sires and dams). The accuracies ($r_{\hat{A}}$) of breeding values defined as the correlation between the true and estimated breeding value were estimated. For each bird, the accuracy was calculated as described by **Meyer (2004)** as: $r_{\hat{A}} = \sqrt{1 - (\mathrm{PEV}/\sigma^2{}_a)}$ where; PEV is the prediction error variance estimated using elements from the mixed model equations as $\mathrm{PEV} = (SEP)^2$ where; SEP is the standard error of prediction and $\sigma^2{}_a$ is the additive genetic variance of the trait.

Estimation of crossbreeding effects:

The variance components estimates were used to solve the corresponding mixed model equations, obtaining solutions for the genetic group effects and their error variance covariance matrix using the PEST software **(Groeneveld, 2006).** According to the theory of **Dickerson (1992)**, the solutions of the crossbreeding genetic group effects were obtained using the procedure of generalized least squares (GLS) and applying the following linear model:

$$y = Xb + e, \mathrm{Var}(y) = V$$

Where y = vector of estimated genetic groups solutions; X = incidence matrix; b = vector of estimable crossbreeding genetic effects; e = vector of random error; V = the error variance-covariance matrix of y.

The coefficients relating genetic crossbreeding parameters to the means of the genetic groups (Table 2) estimated according to **Dickerson (1992)** and **Wolf (1996)** were used to detect the differences between the breeds in terms of direct additive genetic effects (G^I), maternal effects (G^M) direct heterosis (H^I) and maternal heterosis (H^M). Thus, we have four parameters to be estimated (the vector called **b**-vector):

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

The solutions of **b** were calculated by the method of generalized least squares (GLS) using the following equation:

$$\hat{\boldsymbol{b}} = (\mathbf{X}^{/}\mathbf{V}^{-}\mathbf{X})^{-1}\mathbf{X}^{/}\mathbf{V}^{-}\mathbf{y}$$

Where X was the matrix of coefficients of estimable crossbreeding effects, V^- = the inverse of generalized variance covariance matrix error, with the variance covariance matrix of the estimate of b being:

$$\mathrm{Var}\,\hat{\boldsymbol{b}} = (\mathbf{X}^{/}\mathbf{V}^{-}\mathbf{X})^{-1}$$

Matrix in Table 2 was used also to test the significance of the crossbreeding effects.

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

Genetic group			Coefficients of the matrix			
Chick	**Sire**	**Dam**	**G^I**	**G^M**	**H^I**	**H^M**
MT	MT	MT	1	1	0	0
MN	MN	MN	1	1	0	0
½ MT ½ MN	MT	MN	0.5	0.5	1	0
½ MN ½ MT	MN	MT	0.5	0.5	1	0
½ SM¼MT¼MN	SM	½ MT½ MN	0.5	0.25	0	1
½IN¼MN¼MT	IN	½ MN½ MT	0.5	0.25	0	1

G^I, G^M, H^I and H^M = Direct additive genetic effect, direct maternal genetic 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) for egg production traits were 154 day, 1420 g, 39.4 g, 45 egg, 1958 g, 62 egg and 2728 g for ASM, BWSM, WFE, EN90D, EM90D, EN120D and EM120D, for egg partial recording traits were 16 day, 411 g, 18 egg, 784 g, 13.5 egg and 593 g for PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively. **Hassan (2008)** reported that the mean were 165, 166 and 161 day for ASM, 1468, 1264 and 1477 g for BWSM, 38, 36 and 35 g, for WFE, 44, 37 and 55 egg for EN90D, 2005, 1606 and 2325 g EM90D, 28, 28.5 and 15.8 day for PF10E, 411, 389 and 374 g for EMF10E, 22, 17 and 25 egg for EN2DW, 1035, 808 and 1134 g for EM2DW, 20, 16 and 22 egg for EN1WM and 952, 705 and 1006 g for EM1WM in MN, MT and their crosses, respectively. **El-Attrouny *et al.* (2019)** cited that the overall means of ASM, BWSM, WFE, EN90D, EM90D, EN120D and EM120D were 161 day, 1704 g, 30 g, 69 egg, 2800 g, 81.4 egg and 3843 g, respectively in Benha chickens.

The coefficients of variation (CV %) were 8, 11, 9 in ASM, BWSM and WFE, and were 39, 42, 41 and 44% in EN90D, EM90D, EN120D and EM120, respectively. For egg partial recording CV% were 42, 5, 42, 45, 42 and 43% in PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM. **Yousefi *et al.* (2013)** reported that percentages of variation in ASM, BWSM and EN90D were 9.6, 11.2 and 4.8%, respectively. **Jobin (2013)** found that the percentages of 6.7 and 38.9% in ASM and EN90D of Red Rhode Island chickens. **El-Attrouny *et al.* (2019)** reported variation percentages of variation 3, 13.2, 7.5, 5, 4, 7.9 and 5.6% in ASM, BWSM, WFE, EN90D, EM90D, EN120D and EM120D, respectively.

The heritabilities of sexual maturity traits were moderate, being 0.23 for ASM, and 0.69 for BWSM. While estimates were low for egg production traits, being 0.08, 0.07, 0.07, 0.04 and 0.05 for WFE, EN90D, EM90D, EN120D and EM120D, respectively (Table 3). These estimates agreed with most estimates of the Egyptian studies **(Shaalan *et al*., 2012; Abou El_Ghar and Debes, 2013; Younis *et al*., 2014; Abdel A'al, 2016, El-Attrouny, 2017).**

For partial egg recording h^2 were 0.15, 0.17, 0.05, 0.05, 0.04 and 0.04 for PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively. **Hassan (2008)** reported nearly similar estimates for PF10E, EMF10E, EN2DW, EM2DW (0.139, 0.156, 0.084 and 0.095, respectively), but estimates for EN1WM and EM1WM (0.115 and 0.133) were higher than the present study.

Table 3. Actual means, standard deviation (SD), and coefficients of variation (CV %) for sexual maturity, egg production and partial egg recording traits in chickens.

Trait	Symbol	No	Mean	SD	CV%	h^2±SE
Sexual maturity traits:						
Age at sexual maturity (days)	ASM	747	154	11	8	0.23±0.07
Body weight at sexual maturity (g)	BWSM	747	1420	161	11	0.69±0.09
Weight of the first egg (g)	WFE	747	39.38	3.25	9	0.08±0.06
Egg production traits:						
Egg number during the first 90-days of laying (egg)	EN90D	712	45	17	39	0.07±0.06
Egg mass during the first 90-days of laying (g)	EM90D	712	1957	816	42	0.07±0.06
Egg number during the first 120-days of laying (egg)	EN120D	710	61	25	41	0.04±0.03
Egg mass during the first 120-days of laying (g)	EM120D	710	2727	1195	44	0.05±0.05
Partial egg recording:						
Period in which first ten eggs were laid (days)	PF10E	708	16	6.7	42	0.15±0.07
Egg mass for first ten eggs (g)	EMF10E	708	411	22.5	5	0.17±0.10
Egg number for two days per week (egg)	EN2DW	707	18	7.5	42	0.05±0.05
Egg mass for two days per week (g)	EM2DW	707	784	351	45	0.05±0.05
Egg number for one week per month (egg)	EN1WM	708	13.5	5.6	42	0.04±0.03
Egg mass for one week per month (g)	EM1WM	708	593	255	43	0.04±0.03

Genetic groups comparisons:

The generalized least square means (GLM) presented in Table (4) showed that ASM in MN breed was slightly earlier (157 days) than in MT breed (158 days), these results are in agreement with **Hassan (2008)** who reported 165.56 days in Mandarah and 166.2 days in Matrouh strain. The differences between simple cross MN×MT and its reciprocal MT×MN were insignificant for ASM, BWSM and WFE. Comparing the three–way cross, differences between IN×(½MN½MT) cross and SM×(½MT½MN) cross were insignificant for ASM, the crossbred IN×(½MN½MT) had significantly heavier BWSM (1626 g) than SM×(½MT½MN) cross (1381 g). When comparing between purebreds and crossbreds, the three-way crossbreds were found to start laying at an earlier ASM average 150 days; earlier 5days than the simple cross MN×MT and its reciprocal MT×MN and 8 days than the purebreds, and significantly had the heaviest BWSM (averaged

1510 g) than the purebreds (averaged 1323 g). It indicates that ASM and BWSM in chickens could be improved by crossing. The findings of the present study are in agreement with **Iraqi (2008), El-Attrouny (2011)** and **El-Tahawy (2020).** They reported that, the crossbreds reached earlier ASM than purebreds. **Iraqi (2008)** reported 1047, 1027, 1045 and 1051 for BWSM in MN, MT, MNxMT and MTxMN and **El-Attrouny (2011)** reported 1566, 1465, 1825 g in Golden Montazah, White Leghorn and their cross. Means of WFE in the simple crossbreds (averaged 38 g) were intermediate between the two purebreds. These results were in agreement with **Nawar** and **Abdou (1999).** While **El-Attrouny (2011)** who cited that means of WFE in the crossbreds (averaged 28 g) were slightly heavier than the two foundations (averaged 27 g). Means of WFE in three-way cross averaged 39 g were higher than the simple crossbreds.

The GLM in MN breed were slightly higher EN90D and EN120D (46.3 and 65 vs. 44.9 and 62 eggs) and consequently recorded the heaviest EM90D and EM120D (2039 and 2893vs. 1951 and 2727 g) compared to MT. **Hassan (2008)** cited that purebred of MN breed had the highest EN90D (44.3 vs. 36.9 eggs) and consequently the heaviest EM90D (2005 vs. 1606 g) compared to MT breed. In crossbreds, the differences between the simple cross MN×MT and its reciprocal MT×MN for EN90D, EN120D, EM90D and EM120D were insignificant. Comparing purebreds with crossbreds, the three-way cross had the highest EN90D and EN120D (averaged 49 and 67 eggs) than the purebreds (averaged 45 and 63 eggs) and heavier EM90D and EM120D (averaged 2259 and 2961 g) than the purebreds (averaged 2495 and 2810 g), respectively., i. e. crosses usually yield higher egg number during the first 90 and 120 days than the purebreds. **Khalil *et al.* (2004), El-Attrouny (2011)** and **Soliman *et al.* (2020)** cited that crossbreds produced higher egg number and heavier egg mass than the two foundations.

Table 4. Generalized least-square means (GLM) and their standard errors (SE) for sexual maturity and egg production traits in different genetic groups.

	Genetic group			
Trait^{+}	GLM	SE	GLM	SE
Parental strains:	**MN**		**MT**	
ASM (day)	157^{a}	1.3	158^{a}	1.2
BWSM (g)	1318^{b}	7.1	1327^{b}	8.1
WFE (g)	37.1^{a}	0.2	40.3^{a}	0.3
EN90D (egg)	46.3^{a}	1.1	44.9^{a}	0.98
EM90D (g)	2039^{a}	46.8	1950^{a}	42
EN120D (egg)	64.6^{a}	1.6	61.6^{a}	1.4
EM120D (g)	2893^{a}	70.2	2727^{a}	63
Two-way crosses:	**MN×MT**		**MT×MN**	
ASM (day)	154^{a}	0.7	156^{a}	0.7
BWSM (g)	1504^{ab}	13.8	1527^{ab}	12.2
WFE (g)	37.8^{a}	0.4	37.8^{a}	0.4
EN90D (egg)	47.7^{a}	1.9	47.1^{a}	1.6
EM90D (g)	2161^{a}	81	2100^{a}	70
EN120D	66.6^{a}	2.4	65.7^{a}	2.7
EM120D (g)	2940^{a}	106	2750^{a}	121
Three-way crosses:	**IN×(½MN×½MT)**		**SM×(½MT×½MN)**	
ASM (day)	149^{a}	1.2	150^{a}	1.4
BWSM (g)	1626^{a}	12.5	1381^{b}	14.7
WFE (g)	38.5^{a}	0.4	40.2^{a}	0.5
EN90D (egg)	48.7^{a}	1.6	48.3^{a}	1.9
EM90D (g)	2254^{a}	72	2264^{a}	85
EN120D (egg)	67.3^{a}	2.5	67.1^{a}	2.9
EM120D (g)	2962^{a}	108	2960^{a}	128

+ Traits as defined in table (3), means with same letters within the six genetic groups for each trait are not significantly different ($P<0.05$).

The GLM for partial egg recording (table 5) showed that MN pullets laid first 10 eggs in 15.7 days vs. 15.8 days for MT strain and have heavier EMF10E (421 g) than MT strain (419 g), higher EN2DW, EM2DW, EN1WM and EM1WM (18.4 eggs 822 g, 13.8 eggs and 618 g) than MT pullets (17.9 eggs, 813 g, 12.4 eggs and 598 g), respectively.

Table 5. Generalized least-square means (GLM) and their standard errors (SE) for partial egg recording traits in different genetic groups.

	Genetic group			
Trait$^+$	GLM	SE	GLM	SE
Parental strains:	**MN**		**MT**	
PF10E (day)	15.7^a	0.5	15.8^a	0.5
EMF10E (g)	421^a	1.45	419^a	1.6
EN2DW (egg)	18.4^c	0.48	17.9^c	0.4
EM2DW (g)	822^c	21.28	813^c	19.1
EN1WM (egg)	13.83^a	0.40	12.43^a	0.4
EM1WM (g)	617.75^a	17.48	593.25^a	15.6
Two-way crosses:	**MN×MT**		**MT×MN**	
PF10E (day)	13^a	0.9	12^a	0.8
EMF10E (g)	399^a	2.7	397^a	2.4
EN2DW (egg)	23.7^b	0.8	22.7^b	0.7
EM2DW (g)	959^b	36.9	881^c	32.55
EN1WM (egg)	14.9^a	0.7	14.4^a	0.6
EM1WM (g)	623^a	30.3	620^a	26.7
Three-way crosses:	**IN×(½MN×½MT)**		**SM×(½MT×½MN)**	
PF10E (day)	12.5^a	0.7	12.5^a	0.9
EMF10E (g)	404^a	2.4	414^a	2.9
EN2DW (egg)	26^a	0.7	25.1^a	0.8
EM2DW (g)	1163^a	32.8	1085^a	38.7
EN1WM (egg)	15.7^a	0.6	15.3^a	0.7
EM1WM (g)	668^a	26.9	640^a	31.8

+ Traits as defined in table (3), means with same letters within the six genetic groups within each trait are not significantly different ($P<0.05$).

Predicted breeding values (PBV):

Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for sexual maturity, egg production and partial egg recording traits are presented in Tables (6, 7 and 8). For purebred birds, the ranges in PBV of MT birds were slightly higher than that for MN birds. **Hassan (2008)** reported that the ranges in PBV for egg traits in MT chickens were higher than those in MN. The ranges in MN and MT being 15.5 and 14.6 days for ASM, 267.6 and 415.4 g for BWSM, 1.3 and 1.4 g for WFE, 5.2 and 6.5 egg for EN90D, 218 and 258 g for EM90D, 5.7 and 6.5 egg for EN120D, 286 and 306 g for EM120D, 5.8 and 6.9 for PF10E, 19.8 and 24.2 for EMF10E, 2.0 and 1.9 for EN2DW, 99.9 and 88.4 for EM2DW, 1.0 and 1.1 for EN1WM and 46.8 and 45.8 for EM1WM, respectively (Table 6). The high estimates of PBV in MT strain indicated that improvement of sexual maturity and egg production traits in this strain could be achieved through selection compared to MN strain. **El-Attrouny *et al.* (2019)** reported that the ranges in BLUP for most egg production traits were moderate to high.

For two-way crossbred birds, the ranges in PBV recorded by ½MT½MN were nearly similar to those ranges recorded by ½MN½MT (Table 7). The ranges in ½MN½MT and ½MT½MN being 10 and 19 day for ASM, 178 and 187 g for BWSM, 1.2 and 1.6 g for WFE, 4.7 and 3.8 egg for EN90D, 185 and 149 g for EM90D, 4.4 and 4.4 egg for EN120D, 199 and 198 g for EM120D, 5.3 and 10.6 for PF10E, 10.4 and 12.8 for EMF10E, 1.5 and 1.4 for EN2DW, 66.6 and 62.5 for EM2DW, 1.2 and 0.9 for EN1WM and 48.4 and 34.3, respectively. PBV of birds of three-way crossbreds presented in Table (8) showed that the cross fathered by SM cocks and mothered by ½MT½MN had higher ranges in PBV for sexual maturity and egg production traits than those cross fathered by IN cocks and mothered by ½MN½MT. The ranges in ½IN¼MN¼MT and ½SM¼MT¼MN being 13 and 11 day for ASM, 276 and 463 g for BWSM, 1.5 and 1.6 g for WFE, 5.6 and 6.3 egg for EN90D, 239 and 276 g for EM90D, 5.3 and 5.9 egg for EN120D, 258 and 286 g for EM120D, 3.6 and 2.2 for PF10E, 23.7 and 120.5 for EMF10E, 1.5 and 1.7 for EN2DW, 81.4 and 81.8 for EM2DW, 0.9 and 0.9 for EN1WM and 42.9 and 43.0 for EM1WM, respectively.

Table 6. Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for sexual maturity, egg production and partial egg recording traits in MN and MT parental generation.

Trait$^+$	Minimum PBV			Maximum PBV			range in PBV
MN:	PBV	SE	r_A	PBV	SE	r_A	
Sexual maturity traits:							
ASM (day)	-5.8	3.8	0.62	9.6	3.8	0.61	15.5
BWSM (g)	-133.1	47.8	0.85	134.5	50.1	0.84	267.6
WFE (g)	-0.6	0.8	0.39	0.6	0.8	0.41	1.3
Egg production traits:							
EN90D (egg)	-2.0	3.6	0.32	3.1	3.6	0.31	5.2
EM90D (g)	-92.9	154.4	0.32	125.3	151.8	0.36	218.3
EN120D (egg)	-2.4	4.5	0.27	3.3	4.4	0.35	5.6
EM120D (g)	-125.1	205.5	0.28	161.9	199.9	0.36	286.9
Partial egg recording:							
PF10E (day)	-1.4	2.0	0.62	4.4	2.3	0.43	5.8
EMF10E (g)	-9.2	7.8	0.46	10.6	7.4	0.53	19.8
EN2DW (egg)	-0.9	1.4	0.28	1.1	1.3	0.44	2.0
EM2DW (g)	-44.2	62.7	0.29	55.7	58.3	0.45	99.9
EN1WM (egg)	-0.4	0.9	0.24	0.6	0.9	0.31	1.0
EM1WM (g)	-20.6	43.1	0.24	26.1	42.2	0.31	46.8
MT:	PBV	SE	r_A	PBV	SE	r_A	range in PBV
Sexual maturity traits:							
ASM (day)	-5.0	4.2	0.51	9.6	3.8	0.61	14.6
BWSM (g)	-168.0	48.5	0.85	247.5	48.6	0.85	415.5
WFE (g)	-0.8	0.8	0.43	0.6	0.9	0.28	1.4
Egg production traits:							
EN90D (egg)	-2.6	3.7	0.30	3.9	3.5	0.40	6.5
EM90D (g)	-100.2	155.8	0.29	158.2	149.7	0.39	258.4
EN120D (egg)	-2.7	4.5	0.22	3.8	4.4	0.34	6.5
EM120D (g)	-133.6	208.4	0.23	172.6	201.1	0.34	306.2
Partial egg recording:							
PF10E (day)	-1.9	2.2	0.51	4.9	2.2	0.5	6.9
EMF10E (g)	-8.0	7.5	0.52	16.1	7.9	0.44	24.2
EN2DW (egg)	-0.8	1.4	0.25	1.1	1.4	0.34	1.9
EM2DW (g)	-35.6	63.2	0.26	52.9	61.3	0.35	88.4
EN1WM (egg)	-0.5	0.9	0.21	0.6	0.9	0.29	1.1
EM1WM (g)	-20.5	43.3	0.21	25.3	42.4	0.3	45.8

$^+$ Traits as defined in table (3).

Accuracies of PBV were high and ranged from 0.59 to 0.85 for sexual maturity traits, from 0.22 to 0.40 for egg production traits and from 0.21 to 0.62 for partial egg recording traits (Tables 6, 7 and 8) these results were higher than the ranges reported by **Hassan (2008)** (from 0.48 to 0.63) and **El-Attrouny *et al.* (2019)** (form 0.49 to 0.63) for sexual maturity traits**.**

Crossbreeding effects:

Direct additive effects (G^I):

The estimable generalized least square solutions in Table 9 indicated that the effects of G^I on all sexual maturity egg production, and partial egg recording traits were highly significant ($p \leq 0.01$) and in favour of MN strain, being -4.0% for ASM, 9.1% for BWSM, 0.8% for WFE, 5.4% for EN90D, 4.4% for EM90D, 0.4% for EN120D and 0.3% for EM120D, -11.09% for PF10E, 1.2% for EMF10E, 0.4% for EN2DW, 0.1% for EM2DW, 1.4% for EN1WM and 1.9% for EM1WM, i.e. sexual maturity and egg production traits of local chickens in Egypt could be improved by crossbreeding. This trend was confirmed by **Iraqi (2008)** and **El-Attrouny (2011).** Negative estimates of G^I for ASM and PF10E indicated that MN-sired hens reported earlier ASM by -4.0%, and the period of first ten eggs was decreased by crossing, PF10E is a good indicator for hens which characterized by high rate of laying in the early stages of production. **Khalil *et al.* (2004)** and **Iraqi *et al.* (2007)** found that the effects of G^I were significant and ranged from -1.9 to -16.2% for ASM ($P<0.05$ and $P<0.01$). **El-Tahawy (2020)** in crossing of local chicken strain Sinai with Alexandria reported that the estimate of G^I was in favour of Alexandria for ASM (5.0 day) and EN90D and EM90D (-19.62 egg and -725.29 g), respectively.

Table 7. Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for sexual maturity, egg production and partial egg recording traits in two-way crosses.

Trait$^+$	Minimum PBV			Maximum PBV			range in PBV
½MN½MT	PBV	SE	r_A	PBV	SE	r_A	
Sexual maturity traits:							
ASM (day)	-3.6	3.9	0.59	6.1	3.8	0.61	9.6
BWSM (g)	-106.7	50.5	0.83	71.6	52.9	0.82	178.4
WFE (g)	-0.6	0.8	0.42	0.7	0.8	0.33	1.2
Egg production traits:							
EN90D (egg)	-2.1	3.6	0.36	2.7	3.6	0.35	4.6
EM90D (g)	-83.0	152.0	0.36	102.4	152.8	0.35	185.4
EN120D (egg)	-2.1	4.5	0.28	2.4	4.4	0.30	4.4
EM120D (g)	-90.9	204.9	0.29	107.6	203.8	0.31	198.5
Partial egg recording:							
PF10E (day)	-1.4	2.3	0.47	3.9	2.3	0.47	5.3
EMF10E (g)	-5.2	7.4	0.54	5.2	7.6	0.50	10.4
EN2DW (egg)	-0.7	1.4	0.29	0.8	1.4	0.30	1.5
EM2DW (g)	-29.4	62.5	0.29	37.2	62.2	0.31	66.6
EN1WM (egg)	-0.5	0.9	0.24	0.6	0.9	0.26	1.2
EM1WM (g)	-21.8	43	0.25	27.1	42.8	0.26	48.8
½MT½MN	PBV	SE	r_A	PBV	SE	r_A	range in PBV
Sexual maturity traits:							
ASM (day)	-3.3	3.8	0.61	15.5	3.9	0.58	18.8
BWSM (g)	-48.6	85.0	0.37	137.9	49.0	0.85	186.5
WFE (g)	-0.8	0.8	0.37	0.8	0.8	0.36	1.6
Egg production traits:							
EN90D (egg)	-1.6	3.6	0.35	2.2	3.5	0.40	3.8
EM90D (g)	-61.9	152.7	0.35	86.8	152.2	0.36	148.8
EN120D (egg)	-1.7	4.5	0.32	2.7	4.5	0.31	4.4
EM120D (g)	-75.7	202.2	0.33	122.3	203.1	0.32	197.9
Partial egg recording:							
PF10E (day)	-2.5	2.2	0.52	8.1	2.3	0.47	10.6
EMF10E (g)	-6.9	7.4	0.55	5.9	7.6	0.51	12.8
EN2DW (egg)	-0.7	1.4	0.32	0.8	1.4	0.31	1.4
EM2DW (g)	-29.0	61.7	0.33	33.5	61.9	0.32	62.5
EN1WM (egg)	-0.4	0.9	0.26	0.5	0.9	0.27	0.9
EM1WM (g)	-14.2	42.8	0.26	20.1	42.7	0.27	34.3

$^+$ Traits as defined in table (3).

Table 8. Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for sexual maturity, egg production and partial egg recording traits in three-way crosses.

Trait$^+$	Minimum			Maximum			range in PBV
½IN¼MN¼MT	PBV	SE	r_A	PBV	SE	r_A	
Sexual maturity traits:							
ASM (day)	-5.3	3.9	0.58	7.6	4.2	0.53	12.9
BWSM (g)	-145.2	49.6	0.84	130.3	50.7	0.83	275.6
WFE (g)	-0.6	0.8	0.39	0.8	0.8	0.32	1.5
Egg production traits:							
EN90D (egg)	-3.1	3.7	0.29	2.5	3.6	0.35	5.6
EM90D (g)	-141.4	156.1	0.29	97.2	153.0	0.34	238.6
EN120D (egg)	-3.2	4.5	0.24	2.1	4.5	0.29	5.3
EM120D (g)	-164.1	207.3	0.25	93.5	200.2	0.36	257.6
Partial egg recording:							
PF10E (day)	-0.9	2.2	0.51	2.7	2.3	0.42	3.6
EMF10E (g)	-13.7	7.5	0.52	9.9	7.7	0.47	23.7
EN2DW (egg)	-0.9	1.4	0.25	0.6	1.4	0.33	1.5
EM2DW (g)	-46.9	63.3	0.25	34.4	62.3	0.31	81.4
EN1WM (egg)	-0.5	0.9	0.24	0.5	0.9	0.25	0.9
EM1WM (g)	-22.6	43.1	0.24	20.3	42.9	0.26	42.9
½SM¼MT¼MN	PBV	SE	r_A	PBV	SE	r_A	range in PBV
Sexual maturity traits:							
ASM (day)	-5.1	3.9	0.57	6.1	4.1	0.53	11.1
BWSM (g)	-175.5	50.9	0.83	287.9	51.3	0.83	463.4
WFE (g)	-0.9	0.8	0.36	0.7	0.8	0.37	1.6
Egg production traits:							
EN90D (egg)	-3.9	3.6	0.32	2.3	3.6	0.34	6.3
EM90D (g)	-174.2	154.6	0.32	101.5	151.5	0.37	275.7
EN120D (egg)	-3.7	4.5	0.27	2.1	4.5	0.29	5.9
EM120D (g)	-185.39	205.74	0.28	100.50	202.24	0.33	285.89
Partial egg recording:							
PF10E (day)	-0.7	2.3	0.44	1.5	2.3	0.48	2.2
EMF10E (g)	-11.3	7.6	0.51	10.2	7.4	0.54	120.5
EN2DW (egg)	-1.1	1.4	0.27	0.7	1.4	0.3	1.7
EM2DW (g)	-51.9	62.8	0.28	29.8	62.3	0.31	81.8
EN1WM (egg)	-0.5	0.9	0.23	0.5	0.9	0.25	0.9
EM1WM (g)	-22.7	43.1	0.23	20.3	42.9	0.26	43.0

$^+$ Traits as defined in table (3).

Maternal effects (G^M):

The generalized least square solutions of G^M and their percentages for sexual maturity, egg production and partial egg recording traits given in Table 9 indicated that most of the solutions were low to moderate and were mostly non-significantly in favour of MT breed. The percentages of G^M were 2.9, 8.6, -3.8, -5.8, -6.8, -2.3 and -3.3% for ASM, BWSM, WFE, EN90D, EM90D, EN120D and EM120D, respectively and were -10.8, 1.8, 1.9, 3.0, -2.8 and -2.4% for PF10E, EMF10E, EN2DW EM2DW, EN1WM and EM1WM, respectively. **Hassan (2008)** from crossing the same breeds reported estimates of G^M 0.41, 4.25, -0.57, -4.65, -3.86, -3.50 and -0.10% for ASM, BWSM, WFE, EN90D, EM90D, EN210D and EM210D, respectively. On the contrary, **Khalil *et al.* (2004)** found that percentages of G^M were significant ($p \leq 0.01$) for ASM (-1.9%), EN90D (36.4%) and annual egg production (26.5%), in crossing White Leghorn and Baladi Saudi chickens. **Iraqi *et al.* (2007)** found that highly significant effects ($p \leq 0.01$) of maternal ability on ASM and total egg production in Dandarawi, BWSM in Rhode Island Red and EN90D in Fayoumi breed in 4x4 diallel mating experiment in Egypt. **El-Tahawy (2020)** when crossed Sinai with Alexandria chickens reported highly significant ($p \leq 0.0001$) estimate of G^M effects on ASM, EN90D and EM90D (10.6, 12.4 and 535, respectively).

Table 9. Generalized least square solutions for direct additive effects ($G^I=G^I_{MN}-G^I_{MT}$), maternal effects ($G^M=G^M_{MN}-G^M_{MT}$) and their standard errors (SE) and percentages for sexual maturity, egg production and partial egg recording traits.

Trait$^+$	No of hens	G^I solution (units)	SE	G^I as %$^+$	G^M solution (units)	SE	G^M as %$^+$
Sexual maturity traits:							
ASM (day)	747	-6.24**	0.04	-4.0	4.56*	0.08	2.9
BWSM (g)	747	120.41**	0.45	9.1	113.98**	0.86	8.6
WFE (g)	747	0.31^{ns}	0.01	0.8	-1.47*	0.03	-3.8
Egg production traits:							
EN90D (egg)	712	2.45**	0.06	5.4	-2.66^{ns}	0.14	-5.8
EM90D (g)	712	87.98**	2.45	4.4	-135.92^{ns}	5.07	-6.8
EN120D (egg)	710	0.23**	0.09	0.4	-1.46^{ns}	0.17	-2.3
EM120D (g)	710	0.71**	3.97	0.3	-92.51^{ns}	7.61	-3.3
Partial egg recording:							
PF10E (day)	708	-1.75**	0.03	-11.1	-1.71^{ns}	0.06	-10.8
EMF10E (g)	708	5.06*	0.09	1.2	7.56^{ns}	0.18	1.8
EN2DW (egg)	707	0.07**	0.03	0.4	0.36^{ns}	0.05	1.9
EM2DW (g)	707	0.81**	1.21	0.1	24.80^{ns}	2.31	3.0
EN1WM (egg)	708	0.18**	0.02	1.4	-0.38^{ns}	0.04	-2.8
EM1WM (g)	708	11.64**	0.99	1.9	-1.71^{ns}	0.06	-10.8

$^+$ Traits as defined in table (3), $^+$Percentage computed as [Estimate of G^M or G^I in units /(MN+MT)/2]x100 ; ns= non-significant; *=P≤0.05 and **=P≤0.01.

Direct heterotic effects (H^I):

The estimable generalized least square solutions of H^I were highly significant (Table 10) for all traits. The negative percentage of H^I for ASM and PF10E indicates that crossing MN and MT chickens gave a decrease in age of the hen at first egg and the period of first ten eggs was decreased. This negative estimate of H^I for ASM agreed with **Khalil *et al*. (2004); Iraqi *et al*. (2007)** and **Hassan (2008).** On the other hand, the percentages of H^I for BWSM, EN90D, EM90D, EN120D and EM120D were positive; being 28.5, 29.3, 28.8, 24.9 and 19.7%, respectively. These estimates indicated that crossing MN with MT was associated with existence of positive and high percentages of heterotic effects on all traits of BWSM and egg production. **Iraqi *et al.* (2007), Hassan (2008), El-Attrouny (2011), El-Tahawy (2020)** and **Soliman *et al.* (2020)** reported that crossing improve egg production and egg weight and mass in hybrids compared to the parental strains**.**

Maternal heterosis (H^M):

The estimable generalized least square solutions of H^M and their percentages indicated that most of these estimates were highly significant except ASM, BWSM and WFE were non-significant (Table 10). The percentages of H^M were -2.7, 1.2, 0.03, 7.8, 8.2, 7.9, and 8.1% for ASM, BWSM, WFE, EN90D, EM90D, EN120D, EM120D, respectively, reflecting the importance and magnitude of maternal heterosis effects on egg number during the first 90 and 120-days of production. **El-Attrouny (2011)** cited that the percentages of H^M were -0.6, -0.9, 2.4, 10.8, 10.6, 8.3 and 9.1% for ASM, BWSM, WFE, EN90D, EM90D, EN120D, EM120D, RL90D and RL120D, respectively. **Khalil *et al*. (2004)** found that the percentages of maternal heterosis were negative and highly significant (-16.4%) for age at sexual maturity, but positive and highly significant (19.1 and 12.3%) for egg number at 90 days and annual egg production when crossing Baladi Saudi with White Leghorn chickens in Saudi Arabia . Most effects of H^M on the studied partial recording traits were mostly highly significant, PF10E indicating that crossbred hens were superior in parental MT and MN strains, PF10E (1.6 days) and EN2DW (1.3 eggs). The superiority indicates that the rate of laying for hens-mothered by crossbred dams was increased. In general, estimates of H^M on most partial recording traits in this study were highly significant and in favor of hens-mothered by crossbred dams.

Table 10: Generalized least square solutions and percentages for direct heterotic effects ($H^I = H^I_{MN} - H^I_{MT}$), maternal heterosis ($H^M$**)** effects and their standard errors (SE) for sexual maturity, egg production and partial egg recording traits.

Trait$^+$	No of hens	H^I solution (units)	SE	H^I as %$^+$	H^M solution (units)	SE	H^M as %
Sexual maturity traits:							
ASM (day)	747	-5.98**	0.07	-3.8	-4.30**	0.04	-2.6
BWSM (g)	747	376.78**	0.76	28.5	16.39^{ns}	0.43	1.2
WFE (g)	747	-1.79**	0.02	-4.6	0.01^{ns}	0.01	0.03
Egg production traits:							
EN90D (egg)	712	13.36**	0.10	29.3	3.57**	0.06	7.8
EM90D (g)	712	494.91**	4.48	28.8	162.85**	2.56	8.2
EN120D (egg)	710	15.72**	0.15	24.9	4.96**	0.09	7.8
EM120D (g)	710	554.65**	6.72	19.7	227.46**	3.84	8.1
Partial egg recording:							
PF10E (day)	708	-5.71**	0.05	-36.1	-1.67*	0.03	-10.5
EMF10E (g)	708	-13.34**	0.15	-3.2	0.71^{ns}	0.09	0.2
EN2DW (egg)	707	3.18**	0.05	17.4	1.31**	0.03	7.2
EM2DW (g)	707	146.88**	2.04	17.9	6.49^{ns}	1.17	0.7
EN1WM (egg)	708	1.40**	0.04	10.6	0.42**	0.02	3.2
EM1WM (g)	708	53.42**	1.68	8.8	-1.67*	0.03	-10.5

$^+$ Traits as defined in table (3),$^+$Percentage computed as [Estimate of H^I in units/(MN+MT)/2]x100; ns= non-significant; **=P≤0.01.

Superiority of three-way cross over two-way cross:

The expected superiority of the three-way cross over the two-way cross computed from the following equation (**Notter, 1987**):

Superiority = ½ [(½IN (¼MN¼MT) + (½SM (¼MT¼MN) – (½MN½MT) + (½MT½MN)].

Percentages of Superiority in Table 11 were -3.6% for ASM, -0.8% for BWSM, 4.2% for WFE, 2.3% for EN90D, 6.0% for EM90D, 1.7% for EN120D, 4.1% for EM120D, 0.0% for PF10E, 2.8% for EMF10E, 10.3% for EN2DW, 22.2% for EM2DW, 6.1% for EN1WM and 5.2% for EM1WM, respectively. These results indicate that three-way crosses reached ASM earlier than two-way crosses by 3.6% days, EN90D and EN120D were higher in three-way crosses by 2.3% and 1.7% than two-way crosses and EM90D and EM120D were increase by 6.0% and 4.1% in three-way crosses.

Table 11. Superiority in sexual maturity, egg production and partial egg recording traits of three-way cross over two-way cross in chickens.

Trait$^+$	Mean of two- way cross (g)	Mean of three- way cross (g)	Superiority estimate(g)	Superiority %
Sexual maturity traits:				
ASM (day)	155	149.5	-5.5	-3.6
BWSM (g)	1515.5	1503.5	-12	-0.8
WFE (g)	37.8	39.4	1.6	4.2
Egg production traits:				
EN90D (egg)	47.4	48.5	1.1	2.3
EM90D (g)	2130.5	2259	128.5	6
EN120D (egg)	66.2	67.2	1.1	1.7
EM120D (g)	2845	2961	116	4.1
Partial egg recording:				
PF10E (day)	12.5	12.5	0	0
EMF10E (g)	398	409	11	2.8
EN2DW (egg)	23.2	25.6	2.4	10.3
EM2DW (g)	920	1124	204	22.2
EN1WM (egg)	14.7	15.5	0.9	6.1
EM1WM (g)	621.5	654	32.5	5.2

$^+$ Traits as defined in table (3)

Conclusions

- Based on direct and maternal effects, Mandarah strain (MN) could be used as a sire and Matrouh (MT) as a dam to improve sexual maturity, egg production and partial egg recording traits.
- Crossing between MN and MT are associated with existence of high percentage of heterotic effects of individual and maternal heterosis on most the studied traits of sexual maturity, egg production and partial egg recording traits.
- Based on comparison between two-way crosses and three-way crosses, three-way crosses were superior to two-way crosses, this may be due to considerable maternal heterosis obtained.

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التقييم الوراثي لصفات النضج الجنسي وانتاج البيض في تجربة خلط تشتمل علي أربعة سلالات من الدجاج

أجريت تجربة خلط بمعهد بحوث الانتاج الحيواني بالتعاون مع جامعة بنها بمصر لدة ثلاثة أعوام بدأت 2013 حتي 2016. تم استخدام أربعة سلالات مستنبطه من الدجاج المحلى: مطروح، مندره، انشاص و المنتزه الفضي. تم الاختيار العشوائي لعدد 34 ديك و 230 دجاجة من سلالة المندرة وعدد 32 ديك و 194 دجاجة من سلالة المطروح من اجمالي 250 ديك و600 دجاجة لانتاج النسل النقي والخليط، في الجيل الثاني، تم التلقيح الصناعي للاناث الخليطه (½ مندره × ½ مطروح)بسائل منوي من ديوك انشاص بينما الاناث الخليطه (½ مطروح × ½ مندره) تم تلقيحها من ديوك المنتزه الفضي لانتاج الخلطان الثلاثية ½ إنشاصx ¼ مندره x ¼ مطروح و ½ منتزه فضىx ¼ مطروح x ¼ مندره. تم استخدام نموذج الحيوان وحيد الصفه لتقدير المكافئ الوراثي والقيم التربوية المتوقعه. تم استخدام طريقة المربعات الصغري المعممه في تقدير الأثر الوراثى التجمعي المباشر والأمي و قوة الخلط المباشرة والأمية. كانت المتوسط العام لكل المجاميع الوراثية 154 يوم، 1420 جم، 39.38 جم, 45 بيضة، 1957 جم، 61 بيضة، 2727 جم، 16 يوم، 411 جم، 18 بيضة، 784 جم، 13.5 بيضة و593 جم لصفات العمر والوزن عند النضج الجنسي، وزن أول بيضه، عدد وكتلة البيض خلال اول 90 يوم و عدد وكتلة البيض خلال اول 120 يوم انتاج، مدة أول عشر بيضات، كتلة أول عشر بيضات، عدد وكتلة البيض لمدة يومين من كل أسبوع وعدد وكتلة البيض لمدة أسبوع من كل شهر، علي التوالي. كانت تقديرات المكافئ الوراثى متوسطة لصفات العمر والوزن عند النضج الجنسي (0.23 و 0.69) بينما كانت منخفضة لصفات انتاج البيض والتسجيل الجزئي للبيض. كانت تقديرات المدى للقيمة التربوية المتوقعة لسلالة المطرح أعلي قليلا من سلالة المندرة وكان الخليط الثلاثي (½ منتزه فضىx ¼ مطروح x ¼ مندره) هو الأعلي لكل الصفات عن الخليط الثلاثي (½ إنشاصx ¼ مندره x ¼ مطروح). كانت تقديرات الأثر الوراثي التجمعي عالية المعنوية لجميع الصفات لصالح سلالة المندره. تقديرات الأثر الوراثي الأمي كانت معنوية لصفات النضج الجنسي وغير معنوية لصفات انتاج البيض والتسجيل الجزئي. كانت تقديرات قوة الخلط المباشرة (-3.8، 28.5، -4.6، 29.3، 28.8، 24.9، 19.7، -36.1، -3.2، 17.4، 17.9، 10.6 و8.8%) والأمية (-2.6، 1.2، 0.03، 7.8, 8.2، 7.8، 8.1، -10.5، 0.2، 7.2، 0.7، 3.2 و3.3%) عالية المعنوية لمعظم الصفات لكل من العمر الوزن عند النضج الجنسي، عدد وكتلة البيض خلال اول 90 يوم و عدد وكتلة البيض خلال اول 120 يوم انتاج، مدة وكتلة أول عشر بيضات، عدد وكتلة البيض خلال يومين من كل أسبوع وعدد وكتلة البيض خلال أسبوع من كل شهر، علي التوالي.