



GENETIC EVALUATION FOR EGG PRODUCTION TRAITS IN CROSSBREEDING EXPERIMENT OF SOME LOCAL STRAINS OF CHICKENS

By

Heba Ahmed Hassan Ahmed

B.Sc. Agricultural Sciences
(Poultry Production) 2000

Cairo University

M.Sc. Agricultural Sciences
(Poultry Breeding and Genetics) 2009
Benha University

**Submitted in Partial Fulfillment of the
Requirements for the Degree of**

Ph.D. Degree

in

POULTRY BREEDING and GENETICS

to

the

Department of Animal Production
Faculty of Agriculture at Moshtohor

Benha University

Egypt

2021

LIST OF CONTENTS

Title	Page No.
1. INTRODUCTION.....	1
2. REVIEW OF LITERATURE.....	3
2.1 Growth traits.....	3
2.1.1 Heritability (h^2).....	4
2.1.1.1 Body weight	4
2.1.1.2 Daily gain (DG).....	7
2.1.2 Predicted breeding values (PBV).....	9
2.1.3 Crossbreeding effect.....	11
2.1.3.1 Direct additive genetic effect (G^d).....	11
2.1.3.1.1 Body weight.....	11
2.1.3.1.2 Daily gain (DG).....	13
2.1.3.2 Maternal effect (G^M).....	14
2.1.3.2.1 Body weight.....	14
2.1.3.2.2 Daily gain (DG).....	16
2.1.3.3. Estimates of direct heterosis (H^d).....	18
2.1.3.3.1 Body weight.....	18
2.1.3.3.2 Daily gain (DG).....	21
2.1.3.4 Maternal heterosis (H^M).....	23
2.1.3.4.1 Body weight.....	23
2.1.3.4.2 Daily gain (DG).....	24
2.2 Egg production traits.....	24
2.2.1 Heritability (h^2).....	24
2.2.1.1 Sexual maturity traits.....	24
2.2.1.2 Egg production traits.....	27
2.2.1.3 Partial egg recording traits.....	30

2.2.1.4 Clutch size and pause periods traits.....	31
2.2.2 Predicted breeding values (PBV).....	32
2.2.3 Crossbreeding effect.....	35
2.2.3.1 Direct additive genetic effect (G^I).....	35
2.2.3.1.1 Sexual maturity traits.....	35
2.2.3.1.2 Egg production traits.....	36
2.2.3.1.3 Partial egg recording traits.....	37
2.2.3.1.4 Clutch size and pause periods traits	38
2.2.3.2 Maternal effect (G^M).....	39
2.2.3.2.1 Sexual maturity traits.....	39
2.2.3.2.2 Egg production traits.....	39
2.2.3.2.3 Partial egg recording traits.....	40
2.2.3.2.4 Clutch size and pause periods traits	41
2.2.3.3. Estimates of Direct Heterosis (H^I).....	41
2.2.3.3.1 Sexual maturity traits.....	41
2.2.3.3.2 Egg production traits.....	43
2.2.3.3.3 Partial egg recording traits.....	46
2.2.3.3.4 Clutch size and pause periods traits	46
2.2.3.4 Maternal heterosis (H^M).....	48
2.2.3.4.1 Sexual maturity traits.....	48
2.2.3.4.2 Egg production traits.....	48
2.2.3.4.3 Partial egg recording traits.....	48
2.2.3.4.4 Clutch size and pause periods traits	49
3. MATERIALS AND METHODS.....	50
3.1 Crossbreeding experiment performed.....	50
3.2 Strains used.....	51
3.3 Breeding plan used.....	51
3.4 Management.....	53
3.5 Studied traits.....	54
3.5.1 Growth traits.....	54
3.5.2 Egg production traits.....	54

3.6 Animal models used.....	55
3.7 Estimates of breeding values.....	56
3.8 Statistical models for estimating crossbreeding genetic effects.....	57
4. RESULTS AND DISCUSSION.....	59
4.1 Growth traits.....	59
4.1.1 Overall means and variations.....	59
4.1.2 Heritabilities.....	61
4.1.2.1 Body weight.....	61
4.1.2.2 Daily gain (DG).....	62
4.1.3 Predicted breeding values (PBV).....	62
4.1.3.1 Body weight.....	62
4.1.3.2 Daily gain (DG).....	66
4.1.4 Genetic groups comparisons.....	68
4.1.4.1 Body weight.....	68
4.1.4.2 Daily gain (DG).....	68
4.1.5 Crossbreeding effects.....	70
4.1.5.1 Direct additive effects (G^I).....	70
4.1.5.1.1 Body weight.....	70
4.1.5.1.2 Daily gain (DG).....	70
4.1.5.2 Maternal effects (G^M).....	71
4.1.5.2.1 Body weight.....	71
4.1.5.2.2 Daily gain (DG).....	72
4.1.5.3 Direct heterotic effects (H^I).....	72
4.1.5.3.1 Body weight.....	72
4.1.5.3.2 Daily gain (DG).....	74
4.1.5.4 Maternal heterosis (H^M).....	74
4.1.5.4.1 Body weight.....	74
4.1.5.4.2 Daily gain (DG).....	75
4.1.6 Contrasts between three and two-way crosses...	75
4.2 Egg production traits.....	76
4.2.1 Overall means and variations.....	76
4.2.2 Heritabilities.....	80

4.2.3 Predicted breeding values (PBV).....	80
4.2.4 Genetic groups comparisons.....	91
4.2.5 Crossbreeding effects.....	99
4.2.5.1 Direct additive effects (G^I).....	99
4.2.5.2 Maternal effects (G^M).....	102
4.2.5.3 Direct heterotic effects (H^I).....	104
4.2.5.4 Maternal heterosis (H^M).....	107
4.2.6 Contrasts between three and two-way crosses	108
5. SUMMARY.....	111
6. CONCLUSION.....	119
7. REFERENCES.....	121
ARABIC SUMMARY.....	-

LIST OF TABLES

Table No.	Title	Page No.
1	Estimates of heritability for body weight at different ages reviewed from the Egyptian studies.....	5
2	Estimates of heritability for daily gain at different age intervalls reviewed from the Egyptian studies.....	8
3	Percentages of direct additive effects (G^I %) for daily weight gains in chickens as cited in the Egyptian literature.....	14
4	Percentages of maternal additive effects (G^M %) for body weights in chickens as cited in the Egyptian literature.....	15
5	Percentages of maternal additive effects (G^M %) for daily weight gains in chickens as cited in the Egyptian literature....	17
6	Percentages of heterosis (H^I %) for body weights in chickens as cited in the Egyptian literature.....	20
7	Percentages of heterosis (H^I %) for daily weight gains in chickens as cited in the Egyptian literature.....	22
8	Reviewed estimates of heritability (h^2) for ASM as cited in the Egyptian and non-Egyptian studies.....	25
9	Reviewed estimates of heritability (h^2) for BWSM as cited in the Egyptian and non-Egyptian studies.....	26
10	Reviewed estimates of heritability (h^2) for egg number (EN90D) and egg mass (EM90D) during the 90 days as cited in the Egyptian and non-Egyptian studies.....	27
11	Reviewed estimates of heritability (h^2) for total egg number (TEN) and total egg mass (TEM) as cited in the Egyptian and non-Egyptian studies.....	28

12	Reviewed percentages of heterosis (H^I %) for ASM in the Egyptian and non-Egyptian studies.....	42
13	Reviewed percentages of heterosis (H^I %) for BWSM in the Egyptian and non-Egyptian studies.....	43
14	Reviewed percentages of heterosis (H^I %) for EN90D and EM90D in the Egyptian and non-Egyptian studies.....	44
15	Reviewed percentage of heterosis (H^I %) for TEN and TEM in the Egyptian and non-Egyptian studies.....	45
16	Numbers of sires, dams, and chicks used in different genetic groups.....	53
17	Traits and their symbols of egg production collected on purebred and crossbred groups.....	54
18	Genetic groups of chicks with their sires and dams and coefficients of the matrix relating genetic group means of chicks with crossbreeding parameters.....	58
19	Actual means, standard deviation (SD), coefficients of variation (CV %) and heritability for body weight and daily gain traits of chicks (g) at different ages in the present study.....	60
20	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for body weights and daily gain traits in MN and MT parental generation.....	63
21	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for body weights and daily gain traits in two-way crosses	65
22	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for body weights and daily gain traits in three-way crosses	66

23	Generalized least-square means (GLM) and their standard errors (SE) for growth traits (g) in chicks at different ages as affected by genetic group.....	69
24	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 growth traits of chicks (g).....	71
25	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 growth traits of chicks (g).....	73
26	Estimates of the contrasts between three and two-way crosses \pm standard errors (SE) for growth traits (g) in chicks.....	76
27	Actual means, standard deviations (SD), coefficients of variation (CV %) and heritability for sexual maturity, egg production and partial egg recording traits.....	77
28	Actual means, standard deviations (SD), coefficients of variation (CV %) and heritability for clutch size and pause periods traits.....	79
29	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.....	82
30	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.....	83
31	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.....	85

32	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for clutch size traits in MN and MT parental generation	86
33	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for clutch size traits in two-way crosses.....	87
34	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for clutch size traits in three-way crosses.....	88
35	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for pause periods traits in MN and MT.....	89
36	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for pause periods traits in two-way crosses.....	90
37	Minimum, maximum and ranges of predicted breeding values (PBV), their standard errors (SE) and accuracy of predictions (r_A) for pause periods traits in three-way crosses.....	90
38	Generalized least-square means (GLM) and their standard errors (SE) for sexual maturity and egg production traits in different genetic groups...	93
39	Generalized least-square means (GLM) and their standard errors (SE) for partial egg recording traits in different genetic groups.....	95
40	Generalized Least-square means and their standard errors (SE) for clutch size traits in different genetic groups.....	97
41	Generalized Least-Square Means (GLM) and their standard errors (SE) for pause periods traits in different genetic groups.....	98
42	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)	100

	and percentages for sexual maturity, egg production and partial egg recording traits.....	
43	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 clutch size and pause periods traits.....	101
44	Generalized least square solutions and percentages for direct heterotic effects ($H^I = H^I_{MN} - H^I_{MT}$), maternal heterosis (HM) effects and their standard errors (SE) for sexual maturity, egg production and partial egg recording traits.....	105
45	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 clutch size and pause periods traits.....	106
46	Estimates of the contrasts between three and two-way crosses \pm standard errors (SE) for sexual maturity, egg production and partial egg recording traits.....	109
47	Estimates of the contrasts between three and two-way crosses \pm standard errors (SE) for clutch size traits.....	110

LIST OF FIGURES

Figure No.	Title	Page No.
1	System of mating used in the present study.....	50

5. SUMMARY

A crossbreeding experiment was carried out using four synthesized strains of chickens involving Matrouh (MT), Mandarah (MN), Inshas (IN) and Silver Montazah (SM). 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, Egypt. The main objectives of the present study were to estimate genetic parameters (additive genetic variance, heritability and predicted breeding values) and crossbreeding effects (i.e. direct additive effect, maternal additive effect, direct heterosis and maternal heterosis), as well as to evaluate the superiority of three-way crosses versus two-way crosses. A total number 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 cocks and 600 pullets to produce purebreds of MT and MN and first generation (F1) of crossbreds ($\frac{1}{2}MN\frac{1}{2}MT$ and $\frac{1}{2}MT\frac{1}{2}MN$). In second generation of crossbreds (F2), the crossbred hens of $\frac{1}{2}MN\frac{1}{2}MT$ were artificially inseminated from Inshas strain (IN), while the crossbred hens of $\frac{1}{2}MT\frac{1}{2}MN$ were artificially inseminated from cocks of Silver Montazah strain (SM) to produce three-way crossbreds ($\frac{1}{2}IN\frac{1}{4}MN\frac{1}{4}MT$ and $\frac{1}{2}SM\frac{1}{4}MT\frac{1}{4}MN$).

The studied traits were: (1) Growth traits: (body weight at 0, 4, 8, 12 and 16 weeks of age and daily gains during the intervals of 0-4, 4-8, 8-12 and 12-16 weeks); (2) Sexual maturity traits: age (ASM) and body weight (BWSM) at sexual maturity and weight of the first egg (WFE); (3) Egg production traits: egg number (EN90D), egg mass (EM90D) during the first 90-days and egg number (EN120D), egg mass (EM120D) during the first 120-days of laying and (4) partial egg recording traits such as period (in days) in which first ten eggs were laid (PF10E), egg mass for first ten eggs (EMF10E), egg number

(EN2DW) and egg mass (EM2DW) for two days per week, egg number (EN1WM) and egg mass (EM1WM) for one week per month, as well as clutch size (CS90D) and pause periods (PP90D) during 90 days and (CS120D) and (PP120D) during 120 days. The methods of single trait animal model and CBE software program were used.

Results of this study could be summarized as follows:

For growth traits:

- Heritability estimates were 0.57, 0.26, 0.24, 0.22, and 0.25 for BW0, BW4, BW8, BW12, BW16, respectively, and 0.26, 0.16, 0.13 and 0.08 for DG0-4, DG4-8, DG8-12 and DG12-16, respectively
- The ranges of predicted breeding values (PBV) for body weight and daily gains in MN strain were slightly higher than that in MT strain. For simple crossbreds, ranges in PBV recorded by $\frac{1}{2}MN\frac{1}{2}MT$ were slightly higher than those ranges recorded by $\frac{1}{2}MT\frac{1}{2}MN$. For three-way crosses, the cross fathered by IN cocks and mothered by $\frac{1}{2}MN\frac{1}{2}MT$ had higher ranges in PBV for body weights than those cross fathered by SM cocks and mothered by $\frac{1}{2}MT\frac{1}{2}MN$.
- The generalized least square means (GLM) of growth and daily gains showed superiority of MN strain over MT chickens. The GLM for body weights at 0, 4, 8, 12 and 16 weeks of age were 31.2, 208.1, 440.4, 754.3 and 1005.7g in MN and 33.2, 206.5, 430.7, 725.9 and 989 g in MT, respectively. The differences between simple cross (MN \times MT) and its reciprocal (MT \times MN) were insignificant for body weights and daily gains, while, the differences between $\frac{1}{2}IN\frac{1}{4}MN\frac{1}{4}MT$ and $\frac{1}{2}SM\frac{1}{4}MT\frac{1}{4}MN$ crosses were significant for only traits of BW0, BW8, BW12, BW16 and DG0-4.

- The GLM solutions of the direct additive effects (G^I) for body weights and daily gains were highly significant ($P \leq 0.01$) and in favour of MT strain, being 4.0, -62.1, -38.5, -20.2 and -27.2% for BW0, BW4, BW8, BW12 and BW16, respectively and -74.6, -12.7, -9.3 and -37.8% for DG0-4, DG4-8, DG8-12 and DG12-16, respectively.
- The GLM solutions of the maternal additive effect (G^M) for body weights and daily gains in this study were highly significant ($P \leq 0.01$) and in favour of MN strain, being -10.2, 70.5, 49.1, 29.7 and 29.9% for BW0, BW4, BW8, BW12 and BW16, respectively, and 83.7, 17.7, 13.8 and 26.4% for DG0-4, DG4-8, DG8-12 and DG12-16, respectively. Results showed that effects of G^M on body weights at early ages were higher than those at later ones.
- The GLM solutions of direct heterosis (H^I) were highly significant ($P \leq 0.01$) for all growth traits, the percentages of H^I were -4.9, 53.0, 25.7, 12.3, 23.0, 64.0, 27.7, 29.1 and 49.8% for BW0, BW4, BW8, BW12, BW16, DG0-4, DG4-8, DG8-12 and DG12-16, respectively.
- Most estimates of the maternal heterosis (H^M) for body weights and daily gains were highly significant ($P \leq 0.01$). The percentages of H^M were 0.9, 15.9, 11.3, 8.1 and 10.6% for BW0, BW4, BW8, BW12 and BW16, respectively, and 21.8, 7.2, 5.8 and 6.5% for DG0-4, DG4-8, DG8-12 and DG12-16, respectively.

Egg production and partial egg recording traits:

- The heritabilities of sexual maturity traits were moderate, being 0.23 for ASM, and high (0.69) for BWSM. While the estimates of heretability 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.

- The ranges in predicted breeding values (PBV) for MT strain were slightly higher than those for MN strain ranging from 1.4 to 416 for sexual maturity traits, 6.5 to 306 for egg production traits and 1.1 to 88.4 for partial egg recording traits.
- The ranges in PBV recorded by $\frac{1}{2}\text{MN}\frac{1}{2}\text{MT}$ were slightly higher than those ranges recorded by $\frac{1}{2}\text{MT}\frac{1}{2}\text{MN}$. The cross fathered by IN cocks and mothered by $\frac{1}{2}\text{MN}\frac{1}{2}\text{MT}$ had higher ranges in PBV for sexual maturity and egg production traits than those cross fathered by SM cocks and mothered by $\frac{1}{2}\text{MT}\frac{1}{2}\text{MN}$.
- The GLM in MN strain was slightly earlier in ASM (157 days) than MT strain (158 days). The differences between simple cross of $\text{MN}\times\text{MT}$ and its reciprocal $\text{MT}\times\text{MN}$ were insignificant for ASM, BWSM and WFE. The differences between $\frac{1}{2}\text{IN}\frac{1}{4}\text{MN}\frac{1}{4}\text{MT}$ and $\frac{1}{2}\text{SM}\frac{1}{4}\text{MT}\frac{1}{4}\text{MN}$ crosses were insignificant for ASM. The crossbred of $\frac{1}{2}\text{SM}\frac{1}{4}\text{MT}\frac{1}{4}\text{MN}$ had significantly heavier BWSM (1626 g) than $\frac{1}{2}\text{IN}\frac{1}{4}\text{MN}\frac{1}{4}\text{MT}$ cross (1381 g).
- The three-way crossbreds were found to start laying at an earlier ASM by 5 days than the F1 crosses ($\frac{1}{2}\text{MN}\frac{1}{2}\text{MT}$ and its reciprocal $\frac{1}{2}\text{MT}\frac{1}{2}\text{MN}$), as well as by 8 days than the two foundations. The three-way crosses were recorded the heaviest BWSM ($P\leq 0.01$).
- The GLM in MN strain were slightly higher in EN90D and EN120D compared to MT strain and consequently recorded the heaviest EM90D and EM120D, respectively.
- For partial egg recording, estimates of GLM showed that MN pullets laid the first 10 eggs in 15.7 days vs. 15.8 days for MT strain and has insignificantly heavier EMF10E (421 g) than MT strain (419 g). Also, MN pullets recorded egg number and egg

mass for two days per week and for one week per month higher than those of MT pullets.

- In crossbreds, $\frac{1}{2}MT\frac{1}{2}MN$ cross have shorter period in which first 10 eggs were laid than $\frac{1}{2}MN\frac{1}{2}MT$ cross. In addition, the $\frac{1}{2}MN\frac{1}{2}MT$ cross hens recorded egg number and egg mass for two days per week and for one week per month higher than those of $\frac{1}{2}MT\frac{1}{2}MN$ cross hens.
- In three-way crosses, means of PF10E is the same for $\frac{1}{2}IN\frac{1}{4}MN\frac{1}{4}MT$ and $\frac{1}{2}SM\frac{1}{4}MT\frac{1}{4}MN$ crosses. The cross of $\frac{1}{2}IN\frac{1}{4}MN\frac{1}{4}MT$ has slightly higher EN2DW and EN1WM and heavier EM2DW and EM1WM than $\frac{1}{2}SM\frac{1}{4}MT\frac{1}{4}MN$ cross hens.
- Clutch size which contains one and three eggs was the highest in purebreds compared to in crossbreds, average of clutch size that contains more than five eggs was higher in three-way cross than those in both simple cross and purebreds.
- Three-way cross have the higher number of pause that equal one day than those in both simple crossbreds and purebreds, while purebreds have slightly higher number of pause that equal more than five days than simple crossbreds and three-way cross.
- The generalized least square solutions of the direct additive effects (G^I) on all traits of sexual maturity, egg production and partial egg recording were highly significant ($P \leq 0.01$) and in favour of MN strain, being -4.0, 9.1, 0.8, 5.4, 4.4, 3.6, 2.5, -11.1, 1.2, 3.9, 0.1, 6.3 and 1.9% for ASM, BWSM, WFE, EN90D, EM90D, EN120D, EM120D, PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively.
- Effects of G^I on clutch size were in favour of MT strain except for clutch contains more than five eggs. The effect of G^I was associated with a decrease in the pause periods for more than five days in favour of MT strain.

- Most of solutions for maternal additive effect (G^M) for traits of sexual maturity, egg production and partial egg recording were non-significant and ranged from low to moderate in favour of MT strain relative to MN strain being 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 -10.8, 1.8, 1.9, 3.0, -2.8 and -2.4% for PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively.
- The G^M estimates for clutch size and pause periods were in favor of pullets mothered by MT. The percentages of G^M ranged from -12.5% to 35.9% for clutch size, -28.5 to 17.6% for pause periods during the first 90 days, -40.2% to 39.4% for clutch size and -32.2% to 25.6% for pause periods during the first 120-days of egg production.
- The generalized least square solutions of H^I were highly significant for all egg production traits. The percentages of H^I were -3.8, 28.5, 29.3, 28.8, 24.9, 19.7, 17.4, 17.9, 10.6 and 8.8% for ASM, BWSM, EN90D, EM90D, EN120D, EM120D, EN2DW, EM2DW, EN1WM and EM1WM, respectively.
- The estimable solutions of H^I and their percentages for clutch size traits were negative and significant for clutches containing one and three eggs (-13.1 and -6.6%) during the first 90 days and (-16.5 and -23.9%) during the period of 120-days of egg production, while they were positive and significant for clutches containing more than five eggs (14.2% during first 90 days and 57.4% during 120-days).
- The percentages of H^I were positive and highly significant for pauses periods of one day (21.4 and 38.4%) during first 90 days and 120-days of egg production, respectively, while they were negative and highly significant for pause periods of more than five days (-20.95 and -34.38%), respectively.

- Most of the generalized least square solutions of H^M were highly significant for egg production traits except for only BWSM and WFE. The percentages of H^M were -2.6, 1.2, 0.03, 7.8, 8.2, 7.8 and 8.1% for ASM, BWSM, WFE, EN90D, EM90D, EN120D and EM120D, respectively.
- Estimates of H^M on most partial recording traits were highly significant and in favor of hens-mothered by crossbred dams. The percentages of H^M were -10.5, 0.2, 7.2, 0.7, 3.2 and -10.5% for PF10E, EMF10E, EN2DW, EM2DW, EN1WM and EM1WM, respectively
- The estimates of H^M for clutch size traits were negative and significant for clutches containing one egg (-11.2 and -15.5%) during first 90 days and 120-days of egg production, respectively, while they were positive for clutches containing five eggs (24.0 and 29.4%), respectively.
- Estimates of H^M were positive and significant for pause periods of one day during the first 90 days (17.3%) and during the period of 120-days of egg production (31.8%), while they were negative for pause periods for five days and for more than five days (-22.7 and -5.7%) during the first 90 days, respectively, (-21.7 and -6.9%) during the period of 120-days of egg production.
- Finally, from this study it is recommended that: applying genetic selection at early ages may give rapid improvement in growth of local strains, this may encourage the poultry breeders to use it to shorten the generation intervals and consequently save money, time and effort.
- Based on the superiority of the three-way versus two-way crosses for all the studied traits, one can recommend that the Animal Production Research Institution (APRI) can continue in

production of three-way crosses to improve growth and egg production traits of local chickens.