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EFFECT of SHORT-TERM DIVERGENT SELECTION for BODY WEIGHT AT 4 Week OF AGE IN JAPANESE QUAIL UNDER NORTH-SINAI CONDITIONS

A- EFFECT ON BODY WEIGHT AT 4 WK OF AGE

Basma A. Yousha [1*]; M.A. Abdel Ghaffar[1]; A.M. Ali[1] and H.M. Sabri[2]

1. Dept. of Animal and Poultry Prod., Fac. Environ. Agric. Sci., Arish Univ, Egypt.

2. Dept. of Animal Prod, Fac. Agric, Suez Canal Univ, Ismailia, Egypt.

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ABSTRACT

The base population of the evaluated Japanese quail was derived from a randomly mated flock. This flock was used for subsequent divergent body weight selection at 4 weeks of age to produce the next three generations (G1, G2, and G3). The result investigational birds during the period from November 2016 to November 2017 were produced and raised at the experimental farm, Department of Animal and Poultry Production, Faculty of Environmental Agricultural Sciences, Arish University, Al-Arish, North Sinai, Egypt. Individual selection for body weight at 4 wk of age was applied. The upmost 2/3 ranked birds were considered the high body weight line (HL), while the lowest 1/3 ranked ones were considered the low body weight line (LL). At 5 wk of age, the selected birds were transferred to cages (1 male and 2 females assigned at random from the same selection category along with avoiding sib mating). The same trend of body weight selection intensity was applied at each generation within each line. The used experimental diet was a corn-soybean growing diet in a mash form with approximately 23% crude protein and 2850 kcal ME/kg. Feed and water were offered ad libitum. The results indicated that, the interaction between body-weight and sex was significant on most evaluated body weights. Furthermore, after three generations of that divergent selection, the magnitude of response to selection showed that means of the third generation surpassed the base population by 15.25% and -22.22% for High Line and Low Line; respectively. Also, the third generation high females surpassed the high males and the difference between them was 8.76%. The response to selection for HL, LL and for divergent body weight at 4 wk were 26.33, -38.13, and 64.46, respectively. However, the low selected line had the highest realized heritability (h^2) value (0.64) compared with moderate values in high selected line (0.34 and 0.47). While the ESD / SD ratios showed higher values for HL than LL. The ratio values for LL were very close to unity an indication that natural selection did not influence selection for low 4-wk body weight.

INTRODUCTION

Japanese quail is considered as an ideal laboratory bird for its rapid growth, early sexual maturity, short generation interval and relatively high egg production (**Padgett and Ivey, 1959, Wilson *et al.*, 1961, Reese and Reese, 1962**).

Selection is an important tool for changing gene frequencies for better fit individuals for one or more particular breeding purpose(s). **Falconer and Mackay (1996)** stated that artificial selection produces its changes of gene frequency by separating the adult individuals of parent generation into two groups, the selected and the discarded that differ in gene frequencies.

*** Corresponding author: E-mail address:** basmaeby@gmail.com

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Natural selection produces its effect through differences in fertility (i.e. longevity & fertility among the parents or viability among their progeny).

In this respect, selection response is generally denoted as an important genetic parameter to improve the economic traits and produce desirable traits qualities in domestic animals. Because the relationships among these economic traits are divergent: direct or indirect as well as genetic or non-genetic, the balance between them needs to be taken into account in a selection experiment (**Peebles and Marks, 1991**). Short-term selection experiments are excellent for checking the theoretical predictions made from estimates of genetic parameters in the base population, for testing for nonlinearity of direct and correlated responses to different selection intensities and directions, for comparing rates of response in alternate breeding schemes, and for studying of genotype by environment interactions (Reddy, 1996). However, short-term selection cannot provide information on the long-term effects of selection, which is more relevant to commercial breeding operations.

Nevertheless, Marks and Lepore (1968) and Marks (1978) reported positive selection responses for high 4-wk body weight in Japanese quail. Selection for low body weight appears as effective, in Japanese quail, as that for high body weight (**Marks, 1990**). Selection for low body weight is as important as selection for high body weight, and moreover, these breeding procedures are also interesting because selection for both directions may contribute to elucidation of evolutionary mechanisms responsible for the change in body weight and size (**Suda and Okamoto, 2003**). The divergent selection can be used when the researchers are interested in producing two lines selected in opposite directions, and also to avoid the low accuracy of measuring the response resulting from using the control line as unselected line because the use of control necessitates a reduction in population size of the selected line, quadruples the sampling variance of the response measured as a deviation from control and so doubles the standard error (**Falconer and Mackay, 1996**), so the divergent selection can be used to improve the accuracy of measuring the response where each selected line acts as a control line for the other and the response is measured as the divergence between the two lines.

This work has been carried out to investigate the quails' bidirectional individual selection response either direct to body weight 4 wk of age on body weights, in addition to estimate the realistic effective selection differential.

MATERIALS AND METHODS

Experimental birds were produced and raised at the experimental farm, Department of Animal and Poultry Production, Faculty of Environmental Agricultural Sciences, Arish University, El-Arish, North Sinai, Egypt. A base population constituted of 500 Japanese quail individuals were used for subsequent divergent 4 wk of age body-weight-selection to produce the succeeding three generations (G1, G2, and G3). Eggs were collected daily and marked according to their families. Healthy hatched chicks were leg banded. All through the experimental period; feeds and water were allowed *ad libitum*, diet was in a mash form (diet with 23% and 20% crude protein, 2800 kcal ME/kg and 2850 kcal ME/kg for growing and layer diet, respectively).

Selection and Mating Methods

Individual selection for divergent 4 wk of age body weight was carried out. Birds were measured individually. In each type, the upmost 2/3 ranked birds were considered the high body weight line (HL), while the lowest 1/3 ranked ones were considered the low body weight line (LL). At 5 wk of age, the selected birds were transferred to cages (1 male and 2 female) which assigned at random from the same category avoiding sib mating. The same peculiar trend for body weight selection was applied to each line within each successive generation.

Studied Traits and Statistical Analysis

Individual body weight (g) was recorded at hatch, 2, 4, 6 and 8 wk of age. Data for each generation were analyzed separately using the general linear model procedure (PROC GLM) of SAS software package (SAS, 2004). Data were categorized into body weight. Significant between lines, sexes and generations means were applied by Duncan's multiple range test (**Duncan, 1955**).

Data of body weights were analyzed within each generation using Least Squares ANOVA applying the following model:

$$Y_{ijk} = \mu + T_i + S_j + T*S_{(ij)} + e_{ijk}$$

Where:

Y_{ijk} = Individual observation on the bird.

μ = the overall mean for the trait under consideration;

T_i = the fixed effect of the i^{th} selection type (two levels; high and low body weight)

S_j = the fixed effect of the j^{th} sex (two levels; male, and female).

$T*S_{(ij)}$ = the fixed effect of the interaction between the i^{th} selection type and the j^{th} sex.

e_{ijk} = random residual error assumed to be normally and independently distributed with zero mean and common variance equals unity.

Realized heritability (h^2) of the selected traits was obtained by dividing the cumulative response (R) by the cumulative selection differentials (SD) across the generations (**Falconer, 1989**).

Response to selection (R) was obtained by subtracting the mean of offspring of the selected parents from the mean of selected parents.

Effective selection differential was defined by Falconer and Mackay (1996) as the weighted mean superiority of the selected parents, the weights being the relative contribution of progeny from which the response is evaluated. Thus it was calculated as follows:

$$S_e = \frac{\sum [K(X - \bar{X})]}{N}$$

Where:

S_e= effective selection differential.

K= the number of offspring for each parent.

X= the value of each pair of selected parent.

$\bar{X}$ = the mean value of all parent generation.

N= the total number of the offspring.

The effective selection differential (SD) was calculated for each pair of parent within generation within selected group (HL or LL).

RESULTS AND DISCUSSION

Body Weight (BW)

Data in Table 1 presented the analysis of variance for 4-wk body weight of the base population. There was insignificant difference in 4-wk BW between males and females (Table 2). And two groups (G) were selected (high body weight H and low body weight L) from the base population according to their 4-wk BW to be used as parent stocks for the first generation. Significant group by sex (G X S) interactions were observed at all studied ages (Table 3) this might be partially hormonal mediated affected by approaching/reaching sexual maturity around these ages. The significant interaction may indicate dissimilarity of the magnitude of the difference between the two sexes within each group and/or dissimilarity of the magnitude of the difference between the two groups (H and L) within each sex (Table 4 and Figs. 1 and 2). Although it is known that in Japanese quail

Table 1. Least squares analysis of variance of body weight (g) for the base population

Source of variance	df.	BW4	
		SS	Prob.
Sex (S)	1	37.40	0.731
Error	391	123961.96	

Table 2. Least square means±SE of factors affecting body weight (g) the base population

Traits		N	BW4		
			Mean	±	SE
Sex	**Female**	215	173.41	±	1.21
	Male	178	174.03	±	1.33

Table 3. Least squares analysis of variance of body weight (g) for the parent stock at 4, 6 and 8 wk of age

Source of variance	df.	BW4		df.	BW6		BW8	
		SS	Prob.		SS	Prob.	SS	Prob.
Group (G)	**1**	79377.06	<.0001	1	142705.98	<.0001	233286.81	<.0001
Sex (S)	**1**	1291.89	0.0018	1	1900.52	0.005	4412.09	0.0012
G x S interaction	**1**	1397.38	0.0012	1	1450.47	0.015	3663.87	0.003
Error	**136**	17338.91		136	32377.05		54466.02	

BW4, BW6 **and** BW8= **Body weight at 4, 6 and 8 wk of age.**

Table 4. Least square means ±SE of factors affecting body weight (g) for the parent stock at 4, 6 and 8 wk of age

Traits				N	BW4			BW6			BW8		
					Mean	±	SE	Mean	±	SE	Mean	±	SE
Overall means	Group (G)	High		93	198.87	±	1.24	259.63	±	1.70	312.25	±	2.20
		Low		47	145.57	±	1.74	188.17	±	2.37	220.88	±	3.08
	Sex (S)	Female		93	168.82	±	1.24	219.77	±	1.70	260.28	±	2.20
		Male		47	175.62	±	1.74	228.02	±	2.37	272.85	±	3.08
Interaction Means	G x S interaction	High	Female	62	191.94	±	1.43[b]	251.90	±	1.96 [b]	300.24	±	2.54[b]
			Male	31	205.81	±	2.03[a]	267.35	±	2.77 [a]	324.26	±	3.59[a]
		Low	Female	31	145.71	±	2.03	187.65	±	2.77	220.32	±	3.59
			Male	16	145.44	±	2.82	188.69	±	3.86	221.44	±	5.00

BW4, BW6 and BW8 = Body weight at 4, 6 and 8 wk of age.
For the interaction means within column: any two means ± SE (female and male) within group are significantly different (P≤ 0.01)

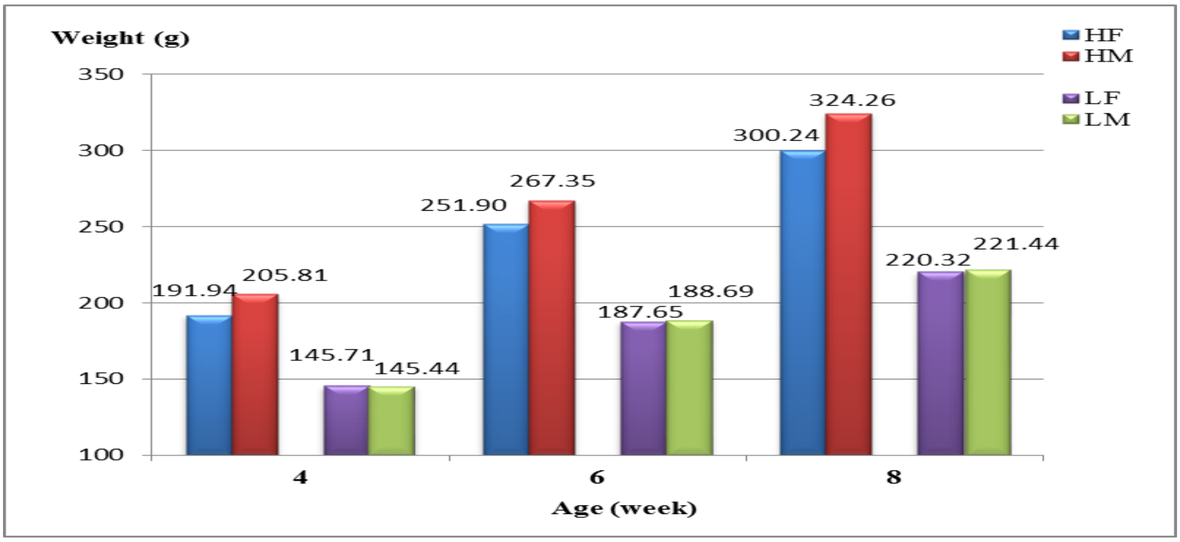

Fig. 1. Differences between sexes in body weight within group.

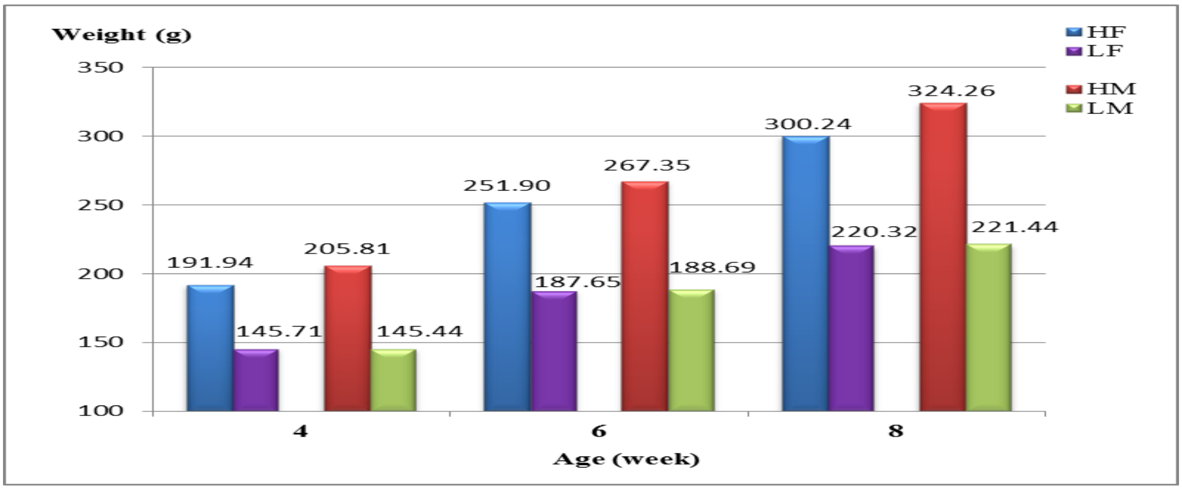

Fig. 2. Differences between groups in body weights within sex

females are slightly heavier than males (**Anthony *et al.*, 1986; Soltan *et al.*, 1987; Caron *et al.*, 1990; Moritsu *et al.*, 1997; Abd El-Fattah *et al.*, 2006; Bahie El-Deen *et al.*, 2009; Farahat *et al.* 2010**), males were significantly heavier than females in HG (Tables 3, 4 and Fig. 1), this may be due to the fact that smaller number of males were selected compared to females and this causes an increase in the intensity of the selection for males. However, the differences were not significant in Low Group (LG) between the two sexes at all studied ages. Highly significant differences were found between the two groups within sex (Table 4). These findings were expected since the difference in body weight was the criteria for groping. However the magnitude of the difference was wider for males (60.37, 78.66 and 102.82 g) than females (46.23, 64.25 and 79.92 g) for 4, 6 and 8 wk of age, respectively (Fig. 2).

First generation lines (high body weight line, HL and low body weight line, LL) were produced from the parents selected -according to their 4-wk BW- from the base population. The interaction of line by sex (L

X S) revealed insignificant effects at all studied ages (Table 5). These findings were indications of the similarity of the differences between lines within each sex as well as the similarity of the differences between sexes within each line (Table 6). In Tables 5 and 6, line effects were highly significant at all studied ages (P≤ 0.0001). These results revealed selection response for divergent selection for BW. These results of divergent selection herein agreed with those shown by **Nestor and Bacon (1982), Darden and Marks (1988), Moritsu *et al.* (1997) and Taskin *et al.* (2017)** who reported that high BW selected line was heavier than low BW selected line. The results reported by **Marks (1975 and 1993), Soltan *et al.* (1987), Bahie El-Deen (1991), Praharaj *et al.* (1992), Omran (1993), Hassan (1994), Helal (1994), Tawefeek (1995), Debes (2004), Badawy (2008) and Sheida and Keyomars (2014)** in their studies of selection for the high BW observed relative superiority of the selected line over control population.

Significant difference were found between the BW of the two sexes at hatch and 4 wk of age (P≤ 0.018; P≤ 0.005) where females were heavier than males (Table 5). The significant differences in BW at 4 wk of age can be explained as a result of developing female gonads as birds approached sexual maturity (Table 6). The superiority of females' BW over males at 4 wk of age were reported by **Anthony *et al.* (1986), Soltan *et al.* (1987), Caron *et al.* (1990), Okamoto *et al.* (1989), Omran (1993), Moritsu *et al.* (1997), Debes (2004), Badawy (2008), Farahat *et al.* (2010) and Taskin *et al.* (2017)**. On the other hand, **Bahie El-Deen (1991)** reported that the momentum of females in BW observed at 6 wk of age. Previous results of sexual dimorphism revealed that the beginning of significance appearance recorded at 4 wk of age parallel with the virtually and almost completion of the development of sex organs which is regulated by hormonal effect. **Collins and Abplanalp (1968) and Sefton and Siegel (1974)** reported that the females after 4 wk tend to grow faster and yield larger muscles and more abdominal fat than their contemporary males.

Two groups of birds (one of each line) were selected to present the parents of the second generation. Line by sex interactions on BW were insignificant at all studied ages, but the difference between the two groups was high significance (P≤ 0.0001) at all studied ages (Tables 7 and 8). Several investigators reported that females of Japanese quails were highly significantly heavier than males at 4, 6 and 8 wk of age. However, data in Table 7 showed that females were heavier at 4 wk (P<0.024) and 8 wk (P< 0.049) of age, while insignificant difference was found at 6 wk of age (Table 8).

Second generation lines (high body weight line, (HL) and low body weight line, (LL)) were produced from the parents selected -according to their 4-wk BW from the first generation. Significant line by sex (L X S) interactions were observed at BW0 and BW4; P≤0.049 and P≤ 0.020 (Table 9). The significant interaction indicated dissimilarity of the magnitude of the difference between the two sexes within each line as well as dissimilarity of the magnitude of the differences between the two lines (HL and LL) within each sex (Table 10 and Figs. 3 and 4). Results in Table 9 revealed that the heaviest BW was for HL females at all studied ages. These results were in agreement with **Anthony *et al.* (1986)** who reported that HL females were found to be heavier than males during the period from 1 to 19 days of age. The insignificant difference between the two sexes in LL was in general in agreement with **Nestor and Bacon (1982)** who showed that the differences in body weight between sexes at 4 wk of age were larger in high body weight line and smaller in the low body weight line.

Table 5. Least squares analysis of variance of body weight (g) for the first generation at hatch, 2 and 4 wk of age

Source of variance	df.	BW0		BW2		BW4	
		SS	Prob.	SS	Prob.	SS	Prob.
Line (L)	**1**	**176.23**	<.0001	56708.97	<.0001	551834.07	<.0001
Sex (S)	**1**	**4.15**	0.018	335.97	0.171	3092.01	0.005
L x S interaction	**1**	**0.0001**	0.990	1.30	0.932	109.86	0.592
Error	**924**	685.47		165351.35		353567.81	

Table 6. Least square means ±SE of factors affecting body weight (g) for the first generation at hatch, 2 and 4 wk of age

Traits				N	BW0	N	BW2	N	BW4
					Mean ± SE		Mean ± SE		Mean ± SE
Overall means	**Line (L)**	**High**		681	8.81 ± 0.03[a]	650	90.36 ± 0.53[a]	635	197.80 ± 0.78[a]
		Low		341	7.84 ± 0.05[b]	317	72.99 ± 0.82[b]	293	143.63 ± 1.20[b]
	Sex (S)	**Female**		516	8.40 ± 0.04[a]	516	82.35 ± 0.61	516	172.74 ± 0.89[a]
		Male		412	8.25 ± 0.05[b]	412	81.01 ± 0.76	412	168.69 ± 1.11[b]
Interaction Means	**L x S interaction**	**High**	**Female**	326	8.89 ± 0.05	326	90.99 ± 0.74	326	200.21 ± 1.08
			Male	309	8.74 ± 0.05	309	89.73 ± 0.76	309	195.39 ± 1.11
		Low	**Female**	190	7.92 ± 0.06	190	73.70 ± 0.97	190	145.27 ± 1.42
			Male	103	7.77 ± 0.08	103	72.28 ± 1.32	103	141.98 ± 1.93

BW0, BW2 and BW4 = Body weight at hatch, 2 and 4 wk of age.

For the main effects within column: any two means ± SE within line or within sex with different superscripts are significantly different between ($P \leq 0.05$) and ($P \leq 0.0001$).

Table 7. Least squares analysis of variance of body weight (g) for selected parents for the second generation at 4, 6 and 8 wk of age

Source of variance	df.	BW4		df.	BW6		df.	BW8	
		SS	Prob.		SS	Prob.		SS	Prob.
Line (L)	**1**	517409.35	<.0001	1	509386.74	<.0001	1	720915.52	<.0001
Sex (S)	**1**	886.25	0.024	1	1126.43	0.200	1	4073.27	0.049
L x S interaction	**1**	9.94	0.810	1	23.68	0.852	1	468.11	0.503
Error	**274**	46873.39		264	180203.37		258	268000.65	

Table 8. Least square means ±SE of factors affecting body weight (g) for selected parents for the second generation at 4, 6 and 8 wk of age

Traits			N	BW4 Mean ± SE	N	BW6 Mean ± SE	N	BW8 Mean ± SE
Overall means	Line (L)	High	185	222.68 ± 1.02[a]	180	275.90 ± 2.07[a]	176	319.90 ± 2.57[a]
		Low	93	126.24 ± 1.20[b]	88	177.24 ± 2.96[b]	86	201.70 ± 3.68[b]
	Sex (S)	Female	184	176.45 ± 1.02[a]	179	228.89 ± 2.08	174	265.24 ± 2.60[a]
		Male	94	172.46 ± 1.42[b]	89	224.25 ± 2.95	88	256.35 ± 3.65[b]
Interaction Means	L x S interaction	High Female	123	224.46 ± 1.18	120	277.88 ± 2.39	117	325.85 ± 2.98
		High Male	62	220.89 ± 1.66	60	273.92 ± 3.37	59	313.95 ± 4.20
		Low Female	61	128.44 ± 1.67	59	179.90 ± 3.40	57	204.63 ± 4.27
		Low Male	32	124.03 ± 2.31	29	174.59 ± 4.85	29	198.76 ± 5.98

BW4, BW6 and BW8= Body weight at 4, 6 and 8 wk of age.
For the main effects within column: any two means ± SE within line or within sex with different superscripts are significantly different between (P≤ 0.05) and (P≤ 0.0001).

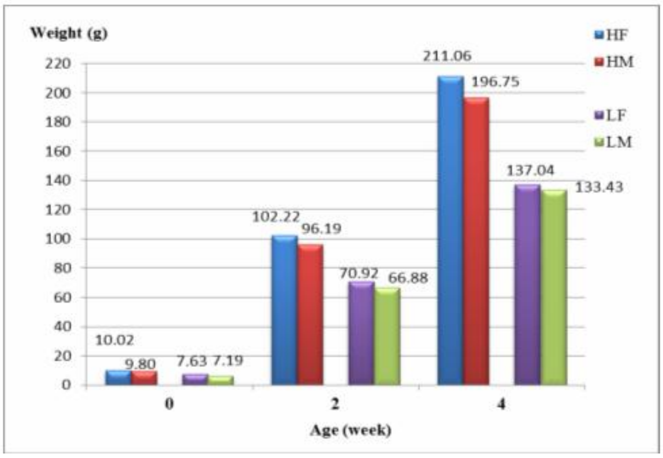

Fig. 3. Differences between sexes in body weight within line in 2nd generation

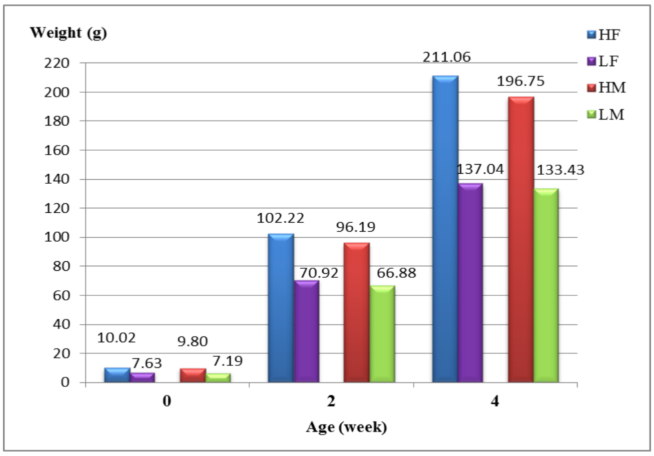

Fig. 4. Differences between lines in body weights within sex in 2nd generation

Line effects were highly significant at all studied ages (P≤ 0.0001) as represented in Table 9 and Fig. 3. These results were expected after two generations of divergent selection for BW. Highly significant differences were found between the two lines within sex (Table 10). These findings were expected since the difference in body weight was the criteria for selection. The magnitude of the differences for females were (2.39, 31.0 and 74.02 g) and for males (2.61, 29.31 and 63.32 g) for 4, 6 and 8 wk of age, respectively (Table 10 and Fig. 4). Females were significantly heavier than males in HL only at hatch and 4 wk and in the two lines (HL and LL) at 4 wk of age.

Parents for the third generation were selected for each line (HL and LL) according to their body weights. Line by sex interactions on BW were insignificant at all studied ages (Table 11). Data in Table 11 revealed that the difference between the two groups was high significance (P≤ 0.0001) at all studied ages. Also, the differences between sexes were observed in 4 wk of age (P<0.049) only (Table 12).

Third generation lines (high body weight line, HL and low body weight line, LL) were produced from the parents selected - according to their 4-wk BW- from the second generation. Significant line by sex (L X S) interactions were observed at BW4 (Table 13). Results in Table 14 revealed that the heaviest BW was for HL females at all studied ages. Line effects had high significance (P≤ 0.0001) at all studied ages (Table 13). These results were expected after three generations of divergent selection for BW. Significant difference was found between the BW of the two sexes at all studied ages, where females were heavier than males (Tables 13 and 14 and Fig. 5).

Two groups of birds (one of each line) were selected to present the parents. Line by sex interactions on BW were insignificant at all studied ages (Table 15). Data in Table 15 revealed that the difference between the two groups was high significance (P≤ 0.0001) at all studied ages (Table 16). Data in Table (15) showed that the sex effect observed in 4wk of age (P<0.0001) only. While the females had a heavier weight at all studied ages than males (Table 16).

Response to Selection (R) and Realized Heritability (h^2)

The results in Table 14 and Fig. 6 showed the response of selection after 3 generations of divergent selection in body weight at 4 wk. The third generation surpassed the base population by 15.25% and -22.22% for HL and LL, respectively. Also, the third generation high females surpassed the high males and the difference between them was 8.76% (=18.57 - 9.81). The superiority of females' BW over males at 4 wk of age were reported by **Anthony *et al.* (1986), Soltan *et al.* (1987), Caron *et al.* (1990), Okamoto *et al.* (1989), Omran (1993), Moritsu *et al.* (1997), Debes (2004), Badawy (2008), Farahat *et al.* (2010) and Taskin *et al.* (2017)**. The superiority of females over males may be due to that female quails had higher growth performance than males at the same age stages; which can be hormonally mediated and ascribed to the development of females' sex organs and accumulation of reservoirs for facing of the later sexual activities (**Badawy, 2008; Badawy *et al.*, 2010**).

The response to selection (R) depends on many factors including selection intensity (i), selection accuracy and genetic variation in the base population and these factors cause different selection responses in different populations according to their genetic background (**Sheida and Keyomars, 2014**).

Data in Table 15 represented the response to selection for HL, LL and divergence for body weight at 4 wk were 26.33, -38.13, and 64.46, respectively. However, the low selected line had the highest realized heritability (h^2) value (0.64) compared with moderate values in high selected line and divergence (0.34 and 0.47, respectively).

Table 9. Least squares analysis of variance of body weight (g) for the second generation at hatch, 2 and 4 wk of age

Source of variance	df.	BW0		BW2		BW4	
		SS	Prob.	SS	Prob.	SS	Prob.
Line (L)	**1**	721.13	<.0001	105792.37	<.0001	543169.53	<.0001
Sex (S)	**1**	12.41	<.0001	2918.37	0.0002	9249.52	0.0001
L x S interaction	**1**	1.55	0.049	113.87	0.466	3297.65	0.020
Error	**537**	213.00		114829.35		326330.07	

Table 10. Least square means ±SE of factors affecting body weight (g) for the second generation at hatch, 2 and 4 wk of age

Traits				N	BW0	N	BW2	N	BW4
					Mean ± SE		Mean ± SE		Mean ± SE
Overall means	**Line (L)**	**High**		409	9.91 ± 0.03	390	99.20 ± 0.78^{a}	370	203.90 ± 1.31
		Low		213	7.41 ± 0.05	195	68.90 ± 1.12^{b}	186	135.23 ± 1.89
	Sex (S)	**Female**		311	8.82 ± 0.04	311	86.57 ± 0.86^{a}	311	174.05 ± 1.45
		Male		230	8.50 ± 0.05	230	81.53 ± 1.06^{b}	230	165.09 ± 1.78
Interaction Means	**L x S interaction**	**High**	**Female**	197	10.02 ± 0.04^{a}	197	102.22 ± 1.04	197	211.06 ± 1.76^{a}
			Male	162	9.80 ± 0.05^{b}	162	96.19 ± 1.15	162	196.75 ± 1.94^{b}
		Low	**Female**	114	7.63 ± 0.06^{a}	114	70.92 ± 1.37	114	137.04 ± 2.31
			Male	68	7.19 ± 0.08^{b}	68	66.88 ± 1.77	68	133.43 ± 2.99

BW0, BW2 and BW4 = Body weight at hatch, 2 and 4 wk of age.
For the main effects within column: any two means ± SE within line or within sex with different superscripts are significantly different (P≤ 0.0001).
For the interaction means within column: any two means ± SE (female and male) within line are significantly different (P≤ 0.05).

Table 11. Least squares analysis of variance of body weight (g) for selected parents for the third generation at 4, 6 and 8 wk of age

Source of variance	df.	BW4		df.	BW6		df.	BW8	
		SS	Prob.		SS	Prob.		SS	Prob.
Line (L)	1	629874.67	<.0001	1	664032.79	<.0001	1	856081.82	<.0001
Sex (S)	1	881.08	0.049	1	1174.40	0.268	1	290.64	0.648
L x S interaction	1	260.50	0.284	1	67.13	0.791	1	8.43	0.938
Error	276	62444.83		264	251280.10		256	362337.53	

Table 12. Least square means ±SE of factors affecting body weight (g) for selected parents for the third generation at 4, 6 and 8 wk of age

Traits			N	BW4 Mean ± SE	N	BW6 Mean ± SE	N	BW8 Mean ± SE
Overall means	Line (L)	High	186	226.58 ± 1.17^{a}	176	280.59 ± 2.44^{a}	174	326.24 ± 2.98^{a}
		Low	94	120.42 ± 1.64^{b}	92	169.94 ± 3.40^{b}	90	199.18 ± 4.17^{b}
	Sex (S)	Female	186	175.49 ± 1.17^{a}	176	227.59 ± 2.443	174	263.88 ± 2.98
		Male	94	171.52 ± 1.64^{b}	92	222.94 ± 3.402	90	261.54 ± 4.17
Interaction Means	L x S interaction	High Female	124	229.65 ± 1.35	115	283.47 ± 2.88	114	327.22 ± 3.50
		High Male	62	223.52 ± 1.91	61	277.70 ± 3.95	60	325.27 ± 4.82
		Low Female	62	121.33 ± 1.91	61	171.71 ± 3.95	60	200.55 ± 4.82
		Low Male	32	119.51 ± 2.66	31	168.17 ± 5.54	30	197.81 ± 6.82

BW4, BW6 and BW8= Body weight at 4, 6 and 8 wk of age.

For the main effects within column: any two means ± SE within line or within sex with different superscripts are significantly different between ($P \leq 0.05$) and ($P \leq 0.0001$).

Table 13. Least squares analysis of variance of body weight (g) for the third generation at hatch, 2 and 4 wk of age

Source of variance	df.	BW0 SS	BW0 Prob.	BW2 SS	BW2 Prob.	BW4 SS	BW4 Prob.
Line (L)	1	1077.84	<.0001	125487.49	<.0001	720620.26	<.0001
Sex (S)	1	3.32	0.043	2222.03	0.005	15907.44	<.0001
L x S interaction	1	0.62	0.380	956.96	0.065	4222.68	0.027
Error	836	675.50		234031.26		717441.98	

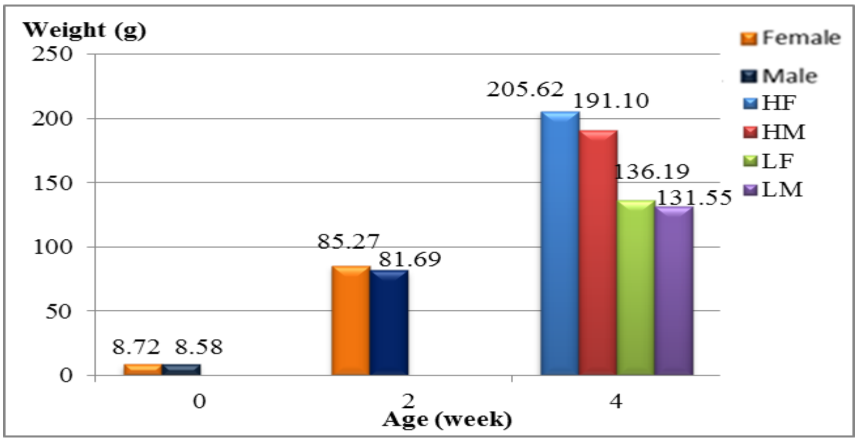

Fig. 5. Sex effect on body weights of 3rd generation

Table 14. The effect of selection after 3 generations of divergent selection on live body weight at 4 wk

Traits			Base pop.	1st gen.	2nd gen.	3rd gen.	Superiority (%)
Line (L)	High		172.11	197.8	203.90	198.36	15.25
	Low		172.11	143.63	135.23	133.87	-22.22
L x S interaction	High	Female	173.41	200.21	211.06	205.62	18.57
		Male	174.03	195.39	196.75	191.1	9.81
	Low	Female	173.41	145.27	137.04	136.19	-21.46
		Male	174.03	141.98	133.43	131.55	-24.41

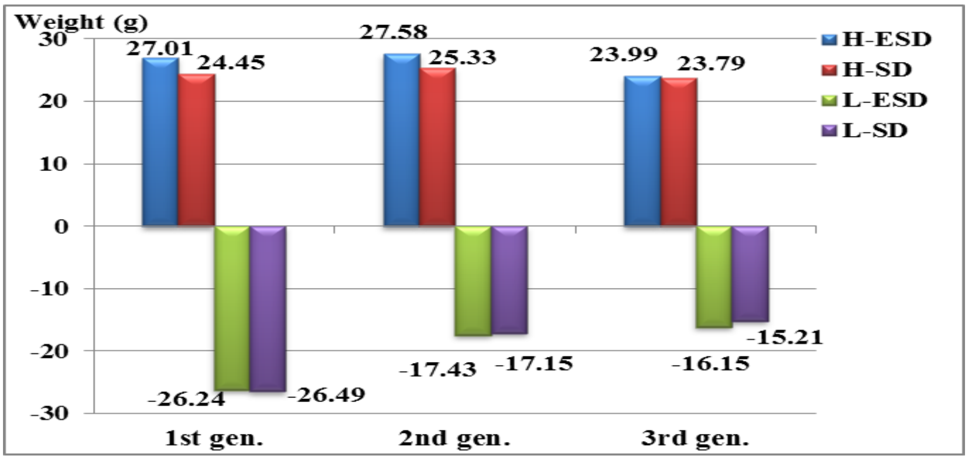

Fig. 12. Selection differential (SD) and effective selection differential (ESD) in HL and LL

Table 15. Selection response (R) and realized heritability (h^2) for HL and LL and divergence for the studied Japanese quail populations

Population	H Line			L Line			Divergence	
	(M)	ESD	ΣS	(M)	ESD	ΣS	R	ΣS
Base population	172.11	0.00	0.00	172.11	0.00	0.00	0.00	0.00
1st gen.	197.94	27.01	27.01	144.11	-26.24	-26.24	53.83	53.25
2nd gen.	203.81	27.58	54.59	135.92	-17.43	-43.67	67.89	98.26
3rd gen.	198.44	23.99	78.58	133.98	-16.15	-59.82	64.46	138.40
	Total R = 26.33			Total R = -38.13			R = 64.46	
	Realized h^2 = 0.34			Realized h^2 = 0.64			Realized h^2 = 0.47	

M = Population Mean; ESD= Effective Selection differential; Σ S= Total ESD; R= Response to selection (Mean of selected parents – Mean of offspring of the selected parents), and Realized h^2= R / SD.

Selection Differential (SD) and Effective Selection Differential (ESD)

The magnitude of the selection differential (SD) depends on two factors, the proportion of the population included among the selected group and the phenotypic standard deviation of the character (**Falconer and Mackay, 1996**). The SD increases with the decrease in the proportion of the selected group and the increase of phenotypic standard deviation of the character.

The SD and ESD as well as the ratio between the ESD and SD for 4-wk BW are presented in Table 16 and Fig. 12 for the studied populations and for the two lines (HL and LL) of these generations.

The ESD/SD ratios showed higher values for HL than LL (Table 16). The ratio values for LL were very close to unity an indication that natural selection did not influence selection for low 4-wk body weight.

Brah *et al*. (2001), Aggrey *et al.* (2003), Balcıoğlu *et al.* (2005) and Fadhil and Hassan (2018) recorded a significant superiority of HL of body weight compared with LL, also there were asymmetry in selection response value in the two lines HL and LL.

Falconer and Mackay (1996) stated that one of the divergent selection features is the asymmetry in selection response between high body weight and low body weight lines which may be a result of unequal selection differential, or may be the natural selection assist the artificial selection response in one direction and suppressed the response in the other direction.

Table 16. Selection differential (SD) and effective selection differential (ESD) for 4-wk BW of the studied Japanese quail populations

Population	Population Mean (M)	Selected Means (P)	Selection differential (SD)	Effective Selection differential(ESD)	ESD/ SD
			H Line		
Base population	172.11	196.56			
1st gen.	197.94	223.27	24.45	27.01	1.10
2nd gen.	203.81	227.60	25.33	27.58	1.09
3rd gen.	198.44		23.79	23.99	1.01
			L Line		
Base population	172.11	145.62			
1st gen.	144.11	126.96	-26.49	-26.24	0.99
2nd gen.	135.92	120.71	-17.15	-17.43	1.02
3rd gen.	133.98		-15.21	-16.15	1.06

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الملخص العربي

تأثير الانتخاب المتباين قصير المدى لوزن الجسم عند عمر 4 أسابيع في السمان الياباني تحت ظروف شمال سيناء أ. التأثير على وزن الجسم عند عمر 4 أسابيع

بسمة عبدالناصر يوشع[1]، محمود أحمد عبد الغفار[1]، أحمد محمد علي[1]، هاني محمد صبري[2]

1. قسم الانتاج الحيواني والداجني، كلية العلوم الزراعية البيئية، جامعة العريش، مصر.
2. قسم الانتاج الحيواني والداجني، كلية الزراعة، جامعة قناة السويس، مصر.

تم الحصول على جيل الآباء للسمان الياباني من قطيع عشوائي التزاوج حيث تم استخدام هذا القطيع للانتخاب في اتجاهين لوزن الجسم عند عمر 4 أسابيع لإنتاج الأجيال الثلاثة التالية (G1 و G2 و G3)، تم إنتاج وتربية الطيور الناتجة خلال الفترة من نوفمبر 2016 إلى نوفمبر 2017 في المزرعة التجريبية، قسم الإنتاج الحيواني والداجني، كلية العلوم الزراعية البيئية، جامعة العريش، العريش، شمال سيناء، مصر، تم إجراء الانتخاب عن طريق قياس الطيور بشكل فردي لوزن الجسم عند عمر 4 أسابيع و تقسيم الطيور حيث أن 3/2 الطيور تمثل خط وزن الجسم المرتفع (High line HL)، بينما كانت 3/1 الطيور تمثل خط وزن الجسم المنخفض (Low line LL)، وفي عمر 5 أسابيع، تم نقل الطيور المنتخبة إلى أقفاص (بنسبة 1 ذكر و2 أنثى تم تعيينهما عشوائياً من نفس فئة الاختيار مع تجنب تزاوج الأشقاء)، وتم تطبيق نفس الاتجاه من الانتخاب على كل جيل في كل خط، غُذِيت جميع الطيور النامية على عليقة موحدة بشكل حر بها نسبة بروتين خام 23% و 2800 كيلو كالوري/كجم وكانت عليقة البياض تحتوي على 20% من البروتين الخام و2850 كالوري/كجم، أشارت النتائج إلى أن التداخل بين وزن الجسم والجنس أظهر تأثيرًا معنويًا كبيرًا على معظم أوزان الجسم، علاوة على ذلك، بعد ثلاثة أجيال من هذا الانتخاب المتباين، فقد أظهرت النتائج استجابة الانتخاب حيث تفوق الجيل الثالث عن جيل الآباء بنسبة 15.25% و -22.22% للخط العالي والمنخفض على التوالي، أيضا، تفوقت إناث الجيل الثالث المنتخبة لوزن الجسم العالي عن الذكور المنتخبة لنفس الخط وكان الفرق بينهم 8.76%، وقدرت الاستجابة للانتخاب للخطين العالي والمنخفض والفرق بين الخطين لوزن الجسم عند عمر 4 أسابيع بقيمة 26.33 و -38.13 و 64.46 على التوالي، بينما كان للخط المنتخب لوزن الجسم المنخفض قيمة عليا في المكافئ الوراثي بقيمة 0.64 بالمقارنة مع القيم المعتدلة في الخط العالي والفرق بين الخطين (0.34 و0.47)، بينما أظهرت النسبة بين الفارق الانتخابي الفعال والفارق الانتخابي أعلى القيم للخطين العالي والمنخفض لوزن الجسم، وكانت قيم النسبة للخط المنخفض قريبة جدا من الواحد الصحيح مما يدل على أن الانتخاب الطبيعي لم يؤثر على الانتخاب لوزن الجسم المنخفض لوزن الجسم عند 4 أسابيع.

الكلمات الإسترشادية: السمان الياباني، الانتخاب، المتباين، الانتخاب الفعال، الاستجابة، الفارق الانتخابي.

المحكمــــــون:

1- **أ.د. عـــادل إبـراهيــم عطيــــــة** أستاذ تغذية الدواجن، قسم الدواجن، كلية الزراعة، جامعة الزقازيق، مصر.
2- **أ.د. إسماعيل السيد إسماعيل عطية** أستاذ فسيولوجي الدواجن، قسم الدواجن، كلية الزراعة، جامعة الزقازيق، مصر.