

Productive, reproductive performance and biochemical parameters of short-term divergently selected Japanese quail lines and their reciprocal crosses

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Abstract The current study investigated the effect of short-term selection for four week body weight (BW) on performance of divergent lines of Japanese quail and their crosses. The mean of BW at hatching time, one, two, three and four week old and BW at sexual maturity time, age at sexual maturity, number of eggs (from 50 to 100 days old), mean of egg weight, percentage of fertility and hatchability in each group (two lines and their crosses) were compared to explore the maternal and heterosis effects. The results indicated that there were significant difference between two lines for all the measured productive and reproductive traits ($P < 0.01$). But the heterosis effects were not significant in all traits except age at sexual maturity, egg number, percentage of fertility and hatchability ($P < 0.01$). Also, the reciprocal effect (maternal effect) reported to be significant for all measured traits except for the BW at four-week old in males and females, BW at sexual maturity and egg weight in females ($P < 0.01$). Moreover, the heterosis and reciprocal effects did not significantly differ in biochemical constituents of plasma ($P < 0.01$). In addition, the difference between two parental lines was not significant in all biochemical constituents of plasma but triglyceride and high-density lipoprotein (HDL). These constituents were markedly in high weight line located higher than low weight line ($P < 0.01$).

Keywords: heterosis, Japanese quail, productive traits, reciprocal cross, reproductive traits

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Introduction

The Japanese quail belonging to the order *Galiformes*, family *Phasianidae*, genus *Coturnix* and sp. *Japonica* (Turkmut et al., 1999), that is the smallest avian species farmed for meat and egg production. A laboratory research established that body weight (BW) of Japanese quail quickly responded to selection (Vali, 2009). Numerous selection experiments on live body weight have been carried out and were completely successful in increasing or decreasing body weight (Syed Hussein et al., 1995; Aggrey and Marks, 2003).

Furthermore, egg production is a complex metric trait showing many variations during the period pullet production. The study of egg production and its related traits such as age at sexual maturity, weight of quail at sexual maturity, egg weight, hatchability and fertility were the parameters attracted to several researchers who found that there were wide variations in these traits between different strains and lines of quails (Moritsu et al., 1997; Aboul Seod et al., 2008).

Beside, plasma triglyceride was used as an index of very-low density lipoprotein (VLDL) level, which was

the primary source of yolk lipid. Also, the cholesterol was the main precursor for synthesis of steroid hormones. Thus, the measurement of blood parameters has been important for analyzing the reproductive characters in poultries. Chemical blood parameters during laying period could be influenced by many factors such as laying rate and age of hens (Hassan, 2010). Little information is available on plasma constituents during the laying periods of females Japanese quail.

Successful breeding of plants and animals is a continuous process of elimination and searching. Breeders manipulate genetic variation to change populations in a way that attempt to optimize favorite phenotypes. Heritable effects influencing quantitative traits may be attributed to additive and non-additive genetic variation. Specially, heterosis has become a routine tool for poultry breeders to produce progeny that exhibits more desirable phenotypes than their parental populations. Theoretically, the magnitude of heterosis is inversely related to the degree of genetic resemblance between parental populations and is expected to be proportional to

the degree of heterozygosity of the crosses (Willham and Pollak, 1985); thus heterosis is a result of non-additive genetic effects and may be viewed as overall fitness as well as expression of a specific trait.

Heterosis is measured by crossing populations to produce an F1 generation, which is compared to the parental populations. It may reflect specific or general combining ability and is not permanent because of recombination, among other factors; in subsequent generations. Heterosis for BW was observed in chickens when there were small differences in BW between the parental lines (Yalcin et al., 2000) and when there were large differences between the parental lines used in the cross (Liu et al., 1993). Heterosis is usually greater for reproductive traits than for growth traits; these traits are influenced by maternal and dietary effects, and may vary with regard to complex traits (Gram and Pirchner, 2001). Lamont and Deeb (2001) reported that heterosis for BW was dependent to age as well.

The purpose of the present study was to measure heterosis (non-additive genetic variation) and reciprocal effects (sex-linked or maternal effects) in some of the productive and reproductive traits for reciprocal crosses of the short-term divergently selected for 4-wk BW lines in Japanese quail. Because the information about the biochemical parameters of blood in the divergently selected lines in Japanese quail has been still limited, an additional objective was to assess the variation magnitude in blood metabolic constituents in two lines and reciprocal crosses.

Materials and methods

Population structure and animal management

The experimental work of this study was carried out at the Poultry Research Station, Animal Science Department, University of Tehran from September 2009 to April 2010. The used groups in this experiment were high weight and low weight lines (HH, LL) with 90 and 80 birds, respectively. The HH and LL lines had undergone 7 generations of phenotypic selection for BW at 28 days old. For 8th generation, matings made between HH and LL lines using age- contemporary parents provided reciprocal F1 chicks in two hatches. Hereafter, progeny type is denoted by showing the sire line firstly and then the dam line (e.g., the HL is the HH sire mated to an LL dam). Thus, the two mating combinations are HL and LH. The lines were maintained using a paired mating system.

Chicks in 7th and 8th generations were leg-tagged with a numbered plastic plate which was pitched by nip. The chicks from each group were placed on pen with similar

environmental conditions. They were reared in artificially lighted housing for 24 hours per day from hatching till two week old and environmental temperature declined from 38 to 25°C during these two weeks. Afterwards, the lighting was gradually reduced to 16 hours per day in the third and fourth week and environmental temperature was fixed on 24°C. Vaccination was not carried out during the breeding period for birds. Also feed and water were available *ad libitum* and the birds fed a standard commercial food containing 20% CP and 2,650 kcal/kg ME.

On day 28, females were moved into single cages in a light-proof room with a 16L: 8D photoperiod and environmental temperature was fixed on 24°C. Feed and water were available *ad libitum* and the birds were provided with a standard commercial food containing 26% CP and 2,900 kcal/kg ME.

There were between 23 and 135 studied birds in the four groups (HH, LL, LH and HL) during two generations. The fertility, hatchability, as well as BW (weekly up to four week old and at laying first egg), the age in which the first egg laid, the number of eggs, the egg weights laid between the age of 50 and 100 days were recorded (in 8th generation for HL and LH groups and in 7th generation for HH and LL lines).

Blood samples were randomly collected from 40 female birds (10 birds of each genetic group) at the 60 day old and analyzed for the estimation of biochemical parameters viz. glucose, triglyceride, cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL) and albumin. Reaching this purpose, 5 ml of blood was drawn from the brachial vein into dry clean centrifuge tubes containing EDTA (Ethylene diaminetetra acetic acid) in the morning and immediately centrifuged at 3000 rpm for 15 mins. To separate serum. Serum samples were stored at -20°C until chemical analysis. Samples were analyzed at the Medical Research Institute.

Statistical analysis

Data were analyzed by analysis of variance with group, sex and hatch number as sources of variation. Orthogonal contrasts (SAS Institute, 2000) were applied for separating lines or reciprocal crosses. Separate contrasts were made for each set of line crosses. The specific contrasts that were utilized include the contrast of the two parental lines (additive genetic effect), the contrast of averages of the reciprocal crosses with the average of the two parental lines (heterotic effect), and the contrast of the two reciprocal crosses (sex-linked or maternal effects). These contrasts were analyzed using Duncan Multiple range test of PROC GLM of SAS (2000) software 9.2. Heterosis was expressed as the percentage deviation of the mean of the reciprocal crosses from the

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Table 1. Descriptive statistics for the weight at 28 days of age for the high and low BW lines

		N ²	Mean(g)	s.d. ³	Min	Max	
BW4 ¹	HH	Female	45	175.62a	15.8	153	207
	(7 th generation)	Male	45	166.37b	10.2	149	198
	LL	Female	40	139.59c	12.8	115	167
	(7 th generation)	Male	40	135.55d	13.2	115	163

¹BW4: body weight at 4 weeks of age.

²N: number of birds

³s.d.: standard deviation

a,b,c,d Means within each column with different superscript are significantly different ($P < 0.01$)

mean of the parental lines.

Results and discussion

Productive and reproductive traits

In our study, the BW of females were higher than males at four week old within HH and LL lines ($P < 0.01$) (Table 1). Other researchers reported (Anthony et al., 1996; Sato et al., 1989; Shokoochand et al., 2007) a significant differences among sexes at five weeks old and the older quails. Mortisu et al. (1997) and Minvielle et al. (2007) reported that sex had significant effect for BW at four week old. The reason is that their sexual maturity begins between the three and four week old and development of sex organs will be started in the four week old females (Syed Hussein et al., 1995). In the current study, a significant difference of BW between sexes was observed at four week old quails. There was a significant difference in BW of four week old quails, inter and intra lines (Table 1). The HH line had higher BW than the LL line (with 7-generation selection) which was supported by other reports (Sato et al., 1989; Minvielle et al., 2007; Shokoochand et al., 2007).

The HH and LL lines differed in BW of the male and female at hatching time, one, two, three and four weeks

of age (Table 2) and at sexual maturity in the females (Table 3) ($P < 0.01$). The sexual maturity age and egg production were differently greater for the LL than the HH in the females ($P < 0.01$). The egg weight, percentage of fertility and hatchability in the HH line were greater than in those of the LL line ($P < 0.01$). Significant positive heterosis was observed in egg production, percentage of fertility and hatchability ($P < 0.01$). Significant negative heterosis for the sexual maturity age in the females was observed in the LH and HL crosses ($P < 0.01$). No significant heterosis was discerned for BW at hatching time, one, two, three and four weeks of age in both sexes and for BW at sexual maturity in the females ($P < 0.01$). Also, it was not significant for egg weight ($P < 0.01$). Reciprocal effects were significant for all traits in the males and females except for BW at 28 days of age in both sexes and BW at the sexual maturity time and egg number in the females ($P < 0.01$).

In this study, heterosis was low and not significant for BW traits because heritability for these traits was high (Toelle et al., 1991; Minvielle and Oguz, 2002). Marks (1993) showed significant reciprocal effects in cross between long-term selected low weight and high weight lines and their reciprocal crosses and negative heterosis

Table 2. Productive parameters of lines divergently selected for high and low BW and their reciprocal crosses

sex	N	HH		LL		HL		LH		P ¹	H ¹	R ¹	H% ²
		N	(7 th generation)	N	(7 th generation)	N	(8 th generation)	N	(8 th generation)				
Male	hatch BW (g)	45	9.48±1.08	40	8.82±0.69	11	7.51±0.36	43	9.93±1.02	**	NS	**	-4.69
	7 days of age (g)	45	23.77±5.77	40	18.63±1.39	11	18.47±3.03	43	23.23±4.09	**	NS	**	-5.23
	14 days of age (g)	45	64.14±8.03	40	57.14±6.56	11	55.65±40.63	43	63.53±9.57	**	NS	**	-1.46
	21 days of age (g)	45	105.03±6.25	40	95.25±10.14	11	99.09±15.33	43	103.48±18.06	**	NS	**	1.14
	28 days of age (g)	45	166.37±10.29	40	135.55±13.16	11	152.00±18.01	43	158.53±23.11	**	NS	NS	2.85
Female	hatch BW (g)	45	9.52±1.10	40	8.65±0.62	12	7.81±0.62	88	9.79±1.04	**	NS	**	-3.08
	7 days of age (g)	45	24.38±5.96	40	19.02±2.19	12	18.13±4.02	88	24.30±3.85	**	NS	**	-2.23
	14 days of age (g)	45	65.66±8.33	40	57.71±6.93	12	57.48±12.06	88	65.11±8.88	**	NS	**	-0.06
	21 days of age (g)	45	107.60±9.49	40	99.02±10.21	12	100.49±17.00	88	108.32±13.95	**	NS	**	1.05
	28 days of age (g)	45	175.62±15.35	40	139.59±12.84	12	158.70±24.94	88	161.92±20.41	**	NS	NS	1.71

¹Orthogonal contrasts. P = HH-LL; H = (HL + LH) - (HH + LL); R = (HL - LH).

²H%: heterosis percent

** : significant effect within each row ($P < 0.01$)

NS: not significant effect within each row ($P < 0.01$)

in six of eight comparisons. The results were attributed to greater progress being made in selection for low BW line than for selection for high BW line (Marks, 1993). Moritsu et al. (1997) revealed negative heterosis in cross between long-term selected low weight and high weight lines for four and eight week age BWs, but selection response in the high weight line was greater than that of the low weight line. The large negative heterosis indicated the possibility of major genes in the populations that reduced BW (Minvielle et al., 2007). Gerken et al. (1988) showed that in diallel crosses among two random bred control lines and a selected line in long-term selection for large body size, the heterosis was not significant for BW from 25 through 49 days old. Piao et al. (2004) reported that the heterosis for BW of females was observed at four and six weeks old, but it was not significant at later ages in males and females (at 10 and 15 weeks old). Vali (2009) also estimated percent of the heterosis for BW at 1-63 days old which was positive at 1, 14, 21, 28, 49, 56 and 63 days old, but negative at other ages.

The reciprocal effects were significant for BW in HH and LL crosses at all ages except for four week old in the males and females, indicating the presence of maternal effects which was supported by other reports in long-term selection as well (Sato et al., 1989; O et al., 2004).

The egg production traits such as egg number, egg weight and BW at sexual maturity time were affected by the sexual maturity age in chickens and quails (El-Bodgady et al., 1993; Camci et al., 2002). In the present study, the LL line had lower BW at sexual maturity age, egg weight, percentage of fertility and hatchability than the HH line and crossbred quails, but they attained sexual maturity earlier.

At sexual maturity age is generally determined by the age that the first egg laid, and is considered as one of the

important factors determining the overall profitability of the flocks. The sexual maturity age varied from breed to breed or among strains, and occurred at a certain age and BW. A sex linked gene and an autosomal one was ascertained by Greenwood and Blyth (1951) to be involved in the inheritance of sexual maturity in poultry. This character is additionally influenced by many environmental factors such as temperature, nutrition, lighting intensity, etc. Moreover, the modern poultry industry had succeeded in reducing the age of first egg placed in layers at up to 20 weeks (Moreng and Avens 1984), which has been economically important. However, this must be precisely considered, because it may lead to vaginal prolapsed disorder, and, hence, increase mortality within the flock.

The heterosis for sexual maturity age was significant and negative ($P < 0.01$). Chahil et al. (1975) reported that both general and specific combining ability were important for age at 25, 50, 75, and 100% lay in a 3*3 diallel crosses of two random-bred control lines and a growth-selected line. In addition, the line of dam effect was significant and, indicated maternal effects. Gerken et al. (1988) observed negative heterosis (5.5%) for age at 50% production with evidence of sex-influenced and sex-linked effects.

The results of the present study implied significant difference in the egg number among different body size of quails during the entire experimental period ($P < 0.01$). The maximum egg number was recorded in two reciprocal crosses and the low body weight line (Table 3). Similar findings have also been observed (North and Bell, 1990; Ipek and Sahan, 2004) in poultry birds. On the contrary some workers indicated that egg production was affected by breed, body size, food, season and breeder age (North and Bell, 1990; Ipek and Sahan, 2004). The higher growth-selected strain of broiler breeder had the poorest egg production of all other strain-

Table 3. Reproductive parameters of lines divergently selected for high and low BW and their reciprocal crosses

sex	N	HH (7 th generation)	N	LL (7 th generation)	N	HL (8 th generation)	N	LH (8 th generation)	P ¹	H ¹	R ¹	H% ²
									**	NS	NS	3.27
									**	**	**	-4.94
Female									**	**	NS	11.69
									**	NS	**	3.41
									**	**	**	17.97
									**	**	**	18.9

¹Orthogonal contrasts. P = HH-LL; H = (HL + LH) - (HH + LL); R = (HL - LH).

²H%: heterosis percent

** : significant effect within each row ($P < 0.01$)

NS: not significant effect within each row ($P < 0.01$)

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ns (Wolanski et al., 2007). These findings were in quite agreement with those of Nestor and Bacon (1982) showed that egg production was decreased in heavy quails and was increased in low body weight in strains of Japanese quail. The findings have been similarly proved in selected strains of broiler breeders (Wolanski et al., 2007) and in quails (Aboul-Hassan, 2001). In this study, the low egg production in heavy quails in comparison to small quails could be due to less number of mature ovarian follicles in heavy quails.

The heterosis effect for egg number was remarkable ($P < 0.01$). Published heritability was estimated for egg production of Japanese quail for various periods of time range from 0.09 to 0.51 with an un weighted average of 0.25 (Strong et al., 1978; Sato et al., 1980). Nestor et al. (1983) selected lines of Japanese quail for increased or decrease 120-d egg production. The realized heritability of egg production in the high and low lines was 0.06 and 0.35, respectively, based on five generations of selection. Even with moderate heritability estimates, heterosis for egg production ranged from 22 to 46% in the various crosses. Sato et al. (1989) manifested a heterosis of 32% for egg production in reciprocal crosses of two highly inbred lines. The heterosis effect for egg number in this study was lower than previous researches that may be to due short-term selection for parental lines.

The results of current study demonstrated significant difference in the mean egg weight in quails of two lines ($P < 0.01$). The maximum and minimum mean egg weights were recorded in the high weight line and low weight birds, respectively (Table 3). The comparable outcomes were reported by Leeson et al. (1997) in which it was presented that the egg weight was directly associated with the BW and age of the breeder. These are also in quite conformity with those of Kirikci et al. (2007) who made obvious that heavy eggs were obtained from the heavy birds and the light eggs were produced by the low eight birds. It has further been indicat-

ed that a positive correlation exists between body weight and egg weight (Hassan, 2011).

With reference to contribution of male on the egg weight, no detectable effect of male on the egg weight of their mates has been observed (Moss and Watson 1999). Altan et al. (1998) stated that selection of quails for live body weight influenced egg weight due to increase in size of ova produced in the ovaries of females. However, significant differences were found in percentage of Fertility and hatchability between the two lines ($P > 0.01$). Similarly, Ipek and Sahan (2004) observed that the breeder pairs that had the heaviest BW displayed higher fertility rates. Medium and heavy groups had higher H/TE % compared to the light group being 87.99 and 85.18 vs 78.32, respectively. Also, Coban et al. (2008) found that increasing the parent BW of Japanese quail caused to elevate the hatchability.

The fertility observed in the eggs of reciprocal crosses was significantly higher than those of two parental lines. Since the egg hatchability of the reciprocal cross was higher than that of the HH or LL, it showed some heterosis ($P < 0.01$). There are many reports on fertility and hatchability of crossbred populations (Suda and Okamoto, 2003; Piao, et al., 2004). According to their results, there is heterosis for the percentage of egg fertility when the dam of the cross comes from the line with higher fertility.

Plasma biochemical constituents

The levels of blood glucose, albumin and lipid constituents in the parental generation and their crosses were shown in Table 4. The glucose, cholesterol, LDL (low density lipoprotein) and albumin levels for the HH and LL lines were insignificantly differed from each other ($P < 0.01$). But the triglyceride and HDL (high density lipoprotein) level in the HH line was significantly higher than LL line ($P < 0.01$). Nevertheless, the reciprocal and heterosis effects were not significant for any of

Table 4. Plasma Biochemical constituents' parameters of lines divergently selected for high and low BW and their reciprocal crosses

sex		HH		LL		HL		LH		P ¹	H ¹	R ¹	H% ²
		N	(7 th generation)	N	(7 th generation)	N	(8 th generation)	N	(8 th generation)				
Females	Glucose (mg/dl)	10	320.8±0.88	10	327.60±0.23	10	324.40±0.18	10	326.27±0.10	NS	NS	NS	2.27
	Triglycerid (mg/dl)	10	95.45±0.62	10	87.40±0.91	10	91.11±0.70	10	96.11±0.70	**	NS	NS	4.37
	cholesterol (mg/dl)	10	226.32±0.74	10	221.53±0.61	10	230.36±0.91	10	224.90±0.73	NS	NS	NS	7.41
	HDL (mg/dl)	10	166.20±0.21	10	155.65±0.79	10	166.80±0.74	10	159.22±0.91	**	NS	NS	4.17
	LDL (mg/dl)	10	41.51±0.76	10	45.13±0.41	10	48.50±0.21	10	43.18±0.84	NS	NS	NS	5.04
	Albumine (g/dl)	10	1.18±0.41	10	1.25±0.11	10	1.23±0.59	10	1.22±0.62	NS	NS	NS	0.02

¹Orthogonal contrasts. P = HH-LL; H = (HL + LH) - (HH + LL); R = (HL - LH).

²H%: heterosis percent

** : significant effect within each row ($P < 0.01$)

NS: not significant effect within each row ($P < 0.01$)

the blood's factors in females ($P < 0.01$).

The biochemical values in the two lines and reciprocal crosses were shown in Table 4. The higher triglyceride concentrations related to high weight line and relatively lower concentration in low weight line was attributable to an increased lipogenic activity of liver stimulated by the endogenous estrogens resulting from selective breeding (North and Bell, 1990). Hassan (2011) presented that medium and heavy groups significantly had higher plasma TG than the light group. The results were shown that high weight line was higher than low weight line in the HDL value. Hammad et al. (1998) reported that the plasma HDL value of high weight quails was significantly higher than low weight quails.

However, the heterosis and reciprocal effects for biochemical constituents of plasma in Japanese quail have not been studied so far. In this study heterosis and reciprocal effects were not significant for any of the studied factors.

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بررسی عملکرد تولیدی، تولیدمثلی و ترکیبات بیوشیمیایی لاینهای بلدرچین انتخاب شده در کوتاه مدت و گروههای حاصل از تلاقی های متقابل بین آنها

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چکیده تحقیق حاضر به منظور بررسی اثر انتخاب کوتاه مدت برای وزن در سن ۴ هفتگی، بر روی عملکرد لاینهای انتخاب شده و تلاقی های آنها در بلدرچین ژاپنی صورت گرفته است. میانگین اوزان تولد در زمان تولد، یک، دو، سه و چهار هفتگی از سن و همچنین صفات وزن در زمان بلوغ جنسی، سن در زمان بلوغ جنسی، تعداد تخم گذاشته شده (از ۵۰ تا ۱۰۰ روزگی)، مینگین وزن تخم، درصد باروری و تولد در هر گروه (دو لاین و تلاقی هایشان) جهت بررسی اثرات هتروزیس و مادری مورد مقایسه قرار گرفتند. نتایج حاصل دلالت بر این داشت که تفاوت معنی داری بین دو لاین در همه صفات تولیدی و تولیدمثلی اندازه گیری شده وجود داشت ($P < 0.01$). همچنین اثر جابجایی (اثر مادری) برای همه صفات اندازه گیری شده بجز برای صفات وزن ۴ هفتگی در نرها و ماده ها، وزن در زمان بلوغ جنسی و وزن تخم در ماده ها معنی دار بود ($P < 0.01$). علاوه بر این اثرات هتروزیس و جابجایی تفاوت معنی داری برای ترکیبات بیوشیمیایی پلاسما نداشتند ($P < 0.01$). همچنین، تفاوت بین دو لاین والدی در تمام ترکیبات بیوشیمیایی پلاسما بجز تری گلیسرید و لیپوپروتئین با چگالی بالا (HDL) معنی دار نبود، این دو ترکیب در لاین سنگین وزن نسبت به لاین سبک وزن به طور معنی داری بالاتر بودند ($P < 0.01$).