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Original article

Impact of family-based selection on growth performance and immune response of Japanese quail

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Abstract

The present study was aimed to evaluate the growth performance and immune response of three genetic lines of Japanese quails. These lines i.e., selected for 4-week body-weight group (WBS), selected for egg number (EBS), and random-bred control (RBC), were selected for three consecutive generations from a base population of 1125 quails. In total, 2700 four-week-old quails from three selected groups were slaughtered in total of four generations (G0 to G3). Effects of selection and generations as well as their interactions were assessed for growth performance and immune response by applying a two-way analysis of variance. Significant means were compared with Duncan's Multiple Range Test. The statistical analysis showed a significant effect of selection and generations on most of the growth and immune response parameters. WBS in G3 presented significantly higher values of body weight, weight gain, and FCR than RBC and EBS. FCR was better in WBS during G3 than those of EBS and RBC. However, Livability% was highest in RBC while the lowest was noted in G3 of WBS line. Thymus% and spleen% were higher in EBS as compared to RBC and WBS. RBC presented a better B/S ratio and ND titer than those of EBS and WBS. The decreasing trend of ND titer in both lines of WBS and EBS as compared to RBC suggested a decrease in New Castle disease resistance in progressive generations of selection. It was concluded that selection for body weight and egg number has a positive impact on respective traits but negatively affects the immunity in later generations.

Key words: weight base selection, egg base selection, growth performance, immune response

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Introduction

In Pakistan, chicken is the main source of meat and eggs which provide a proteinaceous diet to the population. Efforts are being made to add other species as well as improving the available avian genetic resources to fulfill the daily demand for animal-origin protein. Among these species, the Japanese quail seems to be the best candidate as an alternative to chicken because of its short life span, early maturity (Jatoi et al. 2013, Ghayas et al. 2017). The genetic potential could be enhanced in animals by using selective breeding as a tool (Hussain 2014). In any breeding program, bodyweight is a trait of economic importance because of its positive relationship with other growth and carcass traits (Caron et al. 1990). Bodyweight could be enhanced by the improved environment, mating system, and the selection of cross-breeding (Parks 1971). Indigenous breeds of chicken have shown improvement in growth when subjected to selective breeding (Bhatti and Sahota 1994). Japanese quails selected for higher 3-week body weight showed higher growth (Hussain et al. 2014). In another study, higher body weight and body weight gain were observed in pedigreed birds and mass-selected birds for the trait of 4th-week body weight as compared to random breed control (Ahmad et al. 2018). Khaldari et al. (2010) during selection for 4^{th}-week body weight in Japanese quails recorded an increase in body weight with progressive generations. Similarly, an increase in body weight was also observed by Akram et al. (2012) during G1 as compared to G0 of Japanese quails selected for higher 4th-week bodyweight mass selection procedure. However, selection for growth had been reported to be negatively associated with other related traits such as immune response (Van der Most et al. 2011) and egg production (Durmus et al. 2017). Ignorance of other traits negatively correlated with body weight has also resulted in sudden death (Havenstein et al. 1994), leg weakness (Paxton et al. 2013), skeletomuscular disorders (Paxton et al. 2010), and impaired immunity (Rauw 2012). Poor productive performance has been observed in avian species selected for higher growth rate, which typically reflects itself through a decline in egg number and hatching eggs because of an increase in eggs with the double yolk and soft shells (Nester and Bacon 1982). To mitigate the effects of selection for growth on productive performance, there is a need to develop a complementary selection group or genetic line for higher egg numbers.

Such a situation calls for very carefully designed and well-executed breeding programs. Selection in different lines for a specific set of traits and then crossing these lines after certain generations seems to be an ideal strategy. The present study is an effort to explore the consequences of selection for higher body weight and selection for higher egg numbers on the growth performance and immune response in Japanese quails.

Materials and Methods

Experimental site

The present experiment was conducted at Avian Research and Training Centre (ARTC), the University of Veterinary and Animal Sciences (UVAS), Lahore, Pakistan.

Ethics

The care and use of birds were by the laws and regulation of Pakistan and was approved by a committee of Ethical Handling of Experimental Birds (No. DR/495), University of Veterinary and Animal Sciences (UVAS), Lahore, Pakistan.

Experimental groups

The current study was conducted on three experimental groups. The first group consisted of the birds subjected to selection for body weight (WBS). The second group consisted of quails selected for egg number (EBS). The third group consisted of non-selected random-bred (RBC) Japanese quails. Each group of selection strategy had 75 families with a 1:4 male to female ratio.

Selection protocol

Initially, 3000 day old chicks (DOC) of Japanese quail were obtained from the hatchery of ARTC and were subjected to rearing for 4 weeks. From the 5^{th} week, 900 females and 225 male birds were randomly selected as base population (G0) and divided into three groups based on different selection procedures i.e., weight-based selected (WBS), egg number-base selected (EBS), and random-bred control (RBC). The base population (G0) of each group comprised 75 families containing 300 females and 75 males where each family consisted of one male and four females.

In WBS, total, 2050 chicks were obtained from the G0 population and their growth performance was assessed until the 4th week of age. Only those families fulfilling the criteria (Average bodyweight + 0.5 Standard Deviation) were selected for next-generation (G1). Similar to WBS, 2050 chicks from the G0 population of the EBS line were obtained and grown until egg production started. All the female quails were equally divided into 225 families with a ratio of 1 male: 4 females. Egg production records of these families were maintained till the end of the 12th week of age. At the end of the 12th week, out of 225 families, only those families were selected which fulfill the criteria (Average Egg Number + 0.5 Standard deviation) as G1. RBC was maintained without practicing selection. Among selected families, the same selection process was adopted in the second (G2) and third (G3) generation.

Housing and management

Birds were maintained in customized Ventury Welders battery cages for quail rearing and breeding. Eggs were tagged and collected according to the particular family identification numbers. For hatching, eggs were placed in an automatic multi-stage incubator (Victoria, Italy). After hatching, the chicks were placed in customized battery cages already placed in well-ventilated octagonal shape quail sheds with 33×12×9 ft dimension. An uninterrupted supply of water was ensured with the help of nipple drinkers. A broiler starter ration (CP= 24% and ME= 2900 kcal/kg) was provided to broiler quails up to 5 weeks and a breeder ration (CP= 19.5% and ME= 2900 kcal/kg) was offered from 6th to 12th week of age.

Parameters evaluated

Growth performance

A measured amount of feed (g) was offered on daily basis. After 24 hours, feed refusal was recorded from each family using a weighing balance (Gromy International Co, China) having the least count of 0.01 grams. Bodyweight (g) was measured throughout the experimental period on weekly basis with the help of a digital weighing balance. Bodyweight values were used to calculate weight gain (g) by subtracting the initial weight from the recent on weekly basis. The weekly feed conversion ratio was calculated by dividing the total feed intake (g) by the total weight gain (g). Mortality in each family was recorded and later was converted into weekly and cumulative data and subsequently used to calculate the overall livability by subtracting the mortality figures from the total number of chicks placed in each experimental unit.

Immune response

From the progeny of each selected group, 225 birds (3birds/family/generation) were selected for assessing immunity development. Blood (3ml) from the individual bird was collected in a vacutainer and subsequently was centrifuged at 4000 revolutions per minute for 10 minutes. This act separated the serum that was collected in the Eppendorf tube. The serum was stored at -4°C for two days and thereafter analyzed for antibody titer against Newcastle disease virus through Haemagglutination assay (Kapczynski et al. 2013). The birds were later slaughtered and their immune organs (thymus, spleen, and bursa) were weighed (mg).

Statistical analysis

Collected data were analyzed with the two-way ANOVA technique using the General Linear Model procedure with the help of the Statistical Analysis System (SAS, version 9.1). Significant treatment means were separated through Duncan's Multiple Range Test.

Results

Growth performance

Feed intake of Japanese quails differs significantly ($p<0.0001$) among genetic lines and generations and interaction with higher feed intake in the WBS line as compared to RBC and EBS lines (Table 1). The highest feed intake was observed in G3 while the minimal one was observed in G0 (Table 1). WBS in G3 presented the highest feed intake while the lowest was in RBC during G2 (Table 2).

In terms of different genetic lines, significant differences ($p<0.0001$) were observed regarding body weight and weight gain, WBS showed higher body weight and weight gain followed by RBC and EBS (Table 1). Regarding Generation, the progressive increase was observed, G3 showed highest BW and WG followed by G2 and G1 while lowest in G0 (Table 1). As far as the interaction is concerned, the genetic lines and generations interacted well for BW and WG ($p<0.0001$). Higher values of BW and WG were observed in WBS × G3 while the lowest value was noted in G3 of the EBS line (Table 2).

There was a significant difference ($p<0.0001$) in the FCR of genetic lines. Significantly better FCR was noted in WBS followed by RBC and EBS. However, FCR was comparable among the birds of different generations (Table 1). Genetic lines and generations interacted very well for FCR. The birds from the WBS line during G3 presented better FCR as compared to birds of EBS × G3.

There was a significant effect of genetic lines on the livability of broiler quails ($p<0.0001$). Higher livability was noted in RBC than those of EBS and WBS (Table 1). Livability differs significantly in generations with the highest values noted in G0 as compared to and G2 whiles the lowest livability was observed in G3 (Table 1). As far as interaction is concerned, significant variations were noted with higher livability in RBC during G0 and the lowest livability was noted in G3 of WBS birds (Table 2).

Table 1. Effect of family-based selection for improved body weight and egg production on Broiler Production Performance at 4th Week.[1]

Traits	Lines			P-value	Generation				P-value
	WBS	EBS	RBC		G0	G1	G2	G3	
FI	452.70±2.49^{a}	421.83±0.79^{b}	422.05±1.10^{b}	<.0001	423.41±0.99^{d}	430.23±1.47^{c}	433.97±2.84^{b}	441.17±3.82^{a}	<.0001
BW	192.65±1.77^{a}	168.66±1.04^{c}	174.43±1.52^{b}	<.0001	174.23±1.79^{c}	177.46±1.4^{bc}	179.83±2.12^{ab}	182.81±2.85^{a}	0.0002
WG	183.79±1.74^{a}	160.37±1.03^{c}	166.16±1.51^{b}	<.0001	165.96±1.78^{c}	169.02±1.4^{bc}	171.26±2.07^{ab}	174.19±2.80^{a}	0.0003
FCR	2.47±0.02^{c}	2.64±0.02^{a}	2.56±0.02^{b}	<.0001	2.57±0.03	2.55±0.02	2.55±0.02	2.55±0.03	0.9030
Liv %	87.90±0.25^{c}	88.72±0.25^{b}	89.93±0.24^{a}	<.0001	89.88±0.27^{a}	89.24±0.25^{a}	88.20±0.32^{b}	88.09±0.31^{b}	<.0001

$^{a-c}$ Means in a row with no common superscript differ significantly at $p \leq 0.05$.
[1] Values are least-square mean ± standard error.
WBS = Body weight Base Selection; EBS = Egg Production Base Selection; RBC = Random-Bred Control; G0 = Generation Zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; DOC = Day Old Chick; FI = Feed Intake; BW = Body Weight; WG = Weight Gain; FCR = Feed Conversion Ratio; Liv = Livability.

Table 2. Interaction effects (Lines × Generation) on Broiler Production Performance at 4th Week.[1]

Traits	WBS				EBS				RBC				P-value
	G0	G1	G2	G3	G0	G1	G2	G3	G0	G1	G2	G3	
FI	423.48 ±1.58^{de}	443.75 ±1.30^{c}	462.77 ±1.18^{b}	480.81 ±1.12^{a}	422.94 ±1.86^{de}	422.11 ±1.20^{de}	420.74 ±1.64^{de}	421.50 ±1.64^{de}	423.80 ±1.78^{de}	424.83 ±1.50^{d}	418.38 ±2.27^{e}	421.19 ±2.84^{de}	<.0001
BW	174.27 ±3.51^{de}	187.85 ±1.00^{c}	198.15 ±0.95^{b}	210.35 ±0.92^{a}	173.90 ±3.44^{de}	169.17 ±1.33^{def}	167.18 ±1.07^{ef}	164.41 ±0.85^{f}	174.54 ±2.38^{de}	175.36 ±2.88^{d}	174.16 ±3.46^{de}	173.68 ±3.50^{de}	<.0001
WG	166.00 ±3.49^{de}	179.03 ±1.00^{c}	189.02 ±0.99^{b}	201.10 ±0.95^{a}	165.62 ±3.42^{de}	160.91 ±1.31^{def}	158.84 ±1.04^{ef}	156.12 ±0.87^{f}	166.27 ±2.38^{de}	167.11 ±2.89^{d}	165.91 ±3.41^{de}	165.35 ±3.47^{de}	<.0001
FCR	2.57 ±0.06^{bc}	2.48 ±0.02^{cd}	2.45 ±0.01^{cd}	2.39 ±0.01^{d}	2.57 ±0.05^{bc}	2.63 ±0.02^{ab}	2.65 ±0.02^{ab}	2.70 ±0.02^{a}	2.56 ±0.04^{bc}	2.56 ±0.05^{bc}	2.54 ±0.05^{bc}	2.57 ±0.06^{bc}	0.0124
Liv %	89.76 ±0.30^{a}	88.61 ±0.38^{ab}	86.80 ±0.54^{cd}	86.43 ±0.35^{d}	89.81 ±0.56^{a}	89.17 ±0.42^{ab}	88.01 0.40^{bc}	87.87 ±0.49^{bc}	90.05 ±0.53^{a}	89.93 ±0.46^{a}	89.79 ±0.49^{a}	89.95 ±0.49^{a}	<.0001

$^{a-c}$ Means in a row with no common superscript differ significantly at $p \leq 0.05$.
[1] Values are least-square mean ± standard error.
WBS = Body weight Base Selection; EBS = Egg Production Base Selection; RBC = Random-Bred Control; G0 = Generation Zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; DOC = Day Old Chick; FI= Feed Intake; BW = Body Weight; WG = Weight Gain; FCR = Feed Conversion Ratio; Liv= Livability.

Immune response

In terms of different genetic lines, a significant difference ($p<0.0001$) was observed regarding Thymus %. Higher thymus % was noted in EBS than those of RBC and WBS (Table 3). Regarding Generation, thymus % differs significantly ($p<0.0001$) with higher values observed in G1 as compared to G0 and G2 while the lowest thymus % was noted in birds of G3 (Table 3). The interaction between lines and generations, significant differences were observed regarding thymus %, quails of EBS during G1 showed highest thymus % while the lowest value was recorded in WBS × G3 (Table 4). Spleen % was significantly affected by genetic lines. Higher spleen % was noted in RBC followed by EBS and WBS. However, spleen% was comparable among the birds of different generations ($p>0.05$) (Table 3) and no interaction was observed between genetic lines and generations (Table 4). Bursa% was non-significant among the birds of genetic lines as well as generations (Table 3). However, the interaction between lines and generations differs significantly with the highest values observed in birds of RBC×G0 and WBS×G0 while the lowest bursa % was noted in WBS×G3 (Table 4).

In terms of different genetic lines, a significant difference ($p=0.0073$) was observed regarding B/S Ratio. B/S ratio was better in RBC as compared to EBS and WBS. However, the B/S ratio was comparable among the birds of different generations ($p>0.05$) (Table 3) and no interaction was observed between genetic lines and generations (Table 4). ND titer was significantly affected by different genetic lines ($p<0.0001$). Significantly higher values were noted in bird's term of RBC line as compared to EBS and WBS lines (Table 3). Significant differences ($p<0.0001$) were also noted regarding generations with better ND titer in G0 followed by G1, G2, and G3 (Table 3). As far as interaction is concerned, significant variations were noted with higher ND titer

Table 3. Effect of family-based selection for improved body weight and egg production on Immunity at 4th Week.[1]

Traits	Lines			P-value	Generation				P-value
	WBS	EBS	RBC		G0	G1	G2	G3	
Thymus %	0.35 ± 0.01^{c}	0.47 ± 0.02^{a}	0.42 ± 0.02^{b}	<.0001	0.42 ± 0.02^{b}	0.48 ± 0.02^{a}	0.38 ± 0.02^{b}	0.38 ± 0.02^{b}	<.0001
Spleen %	0.09 ± 0.01^{b}	0.12 ± 0.01^{a}	0.13 ± 0.01^{a}	0.0160	0.12±0.01	0.11±0.01	0.11±0.01	0.10±0.01	0.5704
Bursa %	0.12±0.00	0.12±0.00	0.13±0.00	0.0870	0.13±0.01	0.12±0.01	0.12±0.01	0.12±0.01	0.0799
B/S Ratio	1.65 ± 0.08^{a}	1.40 ± 0.07^{b}	1.36 ± 0.06^{b}	0.0073	1.36±0.06	1.44±0.08	1.52±0.09	1.55±0.10	0.3784
ND Titer	4.34 ± 0.06^{c}	4.65 ± 0.07^{b}	5.11 ± 0.06^{a}	<.0001	5.18 ± 0.06^{a}	4.63 ± 0.06^{b}	4.55 ± 0.08^{b}	4.44 ± 0.09^{b}	<.0001

[a-c] Means in a row with no common superscript differ significantly at $p\leq0.05$.
[1] Values are least-square mean ± standard error.
WBS = Body weight Base Selection; EBS = Egg Production Base Selection; RBC = Random-Bred Control; G0 = Generation Zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; B/S Ratio = Bursa/Spleen Ratio; ND Titer = Antibodies Titer against New castle disease virus vaccine.

Table 4. Interaction effects (Lines × Generation) on Lymphoid Organs and antibody titer at 4th Week.[1]

Traits	WBS				EBS				RBC				P-value
	G0	G1	G2	G3	G0	G1	G2	G3	G0	G1	G2	G3	
Thymus %	0.42 ± 0.03^{b}	0.37 ± 0.03^{bcd}	0.31 ± 0.02^{cd}	0.30 ± 0.02^{d}	0.41 ± 0.03^{bc}	0.66 ± 0.05^{a}	0.40 ± 0.03^{bc}	0.40 ± 0.03^{bc}	0.42 ± 0.03^{b}	0.42 ± 0.03^{b}	0.42 ± 0.03^{b}	0.42 ± 0.03^{b}	<.0001
Spleen %	0.12 ±0.02	0.10 ±0.02	0.08 ±0.01	0.06 ±0.01	0.11 ±0.02	0.12 ±0.02	0.12 ±0.02	0.11 ±0.02	0.12 ±0.02	0.12 ±0.02	0.14 ±0.03	0.12 ±0.02	0.1442
Bursa %	0.14 ± 0.01^{a}	0.11 ± 0.01^{ab}	0.12 ± 0.01^{ab}	0.10 ± 0.01^{b}	0.12 ± 0.01^{ab}	0.13 ± 0.01^{a}	0.13 ± 0.01^{a}	0.13 ± 0.01^{a}	0.14 ± 0.01^{a}	0.12 ± 0.01^{ab}	0.14 ± 0.01^{a}	0.13 ± 0.01^{a}	0.0235
B/S Ratio	1.36 ± 0.08^{b}	1.59 ± 0.18^{ab}	1.81 ± 0.17^{ab}	1.84 ± 0.21^{a}	1.37 ± 0.12^{b}	1.38 ± 0.13^{b}	1.41 ± 0.14^{ab}	1.44 ± 0.14^{ab}	1.36 ± 0.08^{b}	1.35 ± 0.12^{b}	1.35 ± 0.13^{b}	1.36 ± 0.14^{b}	0.0984
ND Titer	5.15 ± 0.10^{ab}	4.35 ± 0.11^{de}	4.08 ± 0.10^{ef}	3.80 ± 0.10^{f}	5.13 ± 0.11^{ab}	4.65 ± 0.08^{cd}	4.50 ± 0.14^{d}	4.33 ± 0.17^{de}	5.28 ± 0.11^{a}	4.90 ± 0.10^{bc}	5.08 ± 0.10^{ab}	5.15 ± 0.10^{ab}	<.0001

[a-c] Means in a row with no common superscript differ significantly at $p\leq0.05$.
[1] Values are least-square mean ± standard error.
WBS = Body weight Base Selection; EBS = Egg Production Base Selection; RBC = Random-Bred Control; G0 = Generation Zero; G1 = Generation 1; G2 = Generation 2; G3 = Generation 3; B/S Ratio = Bursa/Spleen Ratio; ND Titer = Antibodies Titer against New castle disease virus vaccine.

in RBC during G0 and the lowest ND titer was noted in G3 of WBS birds (Table 4).

Discussion

Growth performance

In this experiment, there was an increasing trend of feed intake with advancement in generations of weight base selected line. Higher feed intake was noted in the BWS line in G3 while RBC in G2 presented the lowest feed intake. This increase in feed intake of WBS×G3 is attributed to the increased demand for nutrients for increased body weight and rapid growth in progressive generations. Higher fed intake was also observed in selected groups than in non-selected birds by Khaldari et al. (2010). Similarly, Ahmad et al. (2018) noted higher feed intake in pedigreed birds selected for higher body weight rather than random-bred control. Narinc and Aksoy (2012) observed higher feed intake in mass-selected Japanese quail for higher weight than birds of the control group. Hussain et al. (2013) also reported differences among generations and selection groups with the highest feed intake in G2 of selected birds and lowest in birds G0 of the selected and random control group.

WBS line exhibited the highest body weight and weight gain followed by RBC and EBS lines. Among different generations, birds from G3 had higher body weight and weight gain as compared to G2, G1, and G0. There were significant interactions between the selection line and generations. WBS birds presented the highest weight gain while the EBS line presents decreasing tendency in progressive generations as compared to RBC, which may be due to the response to the intensive selection to increase the productive potential in both lines. WBS showed better weight gain due to better utilization of feed. Earlier studies are in agreement with the current findings who reported the higher body weight in selected lines of Japanese quail (Ahmad et al. 2018). Similarly, in another study on Japanese quail higher weight gain was observed in lines selected for high body weight (Antony et al. 1986, Khaldari et al. 2010). Among different generations, progressive increase of body weight and gain was reported in earlier studies with response to selection for higher body weight (Mohammed et al. 2006, Hussain et al. 2013).

In the present study, significant differences were noted in FCR among genetic lines. WBS line showed better FCR followed by RBC and EBS lines. However, FCR was comparable among the birds of different generations. As far as the interaction between genetic lines and generations is concerned, results were significant. Quails from WBS interacted well and exhibited better FCR in progressive generations followed by RBC and EBS groups. It might be due to the intensive selection for desired characteristics of higher body weight and egg production resulted in feed intake adjustment concerning change in body weight in progressive generations. Similarl findings were observed by Khaldari et al. (2010) who reported better FCR in three generations of Japanese quail selected for higher body weight. This could resulted from lower maintenance cost and fat depositions in birds with a higher growth rate for particular body weight that resulted in better FCR (Pym 1990). In another study, Hussain et al. (2013) also endorsed the same results in pedigree-based selected birds selected for higher three-week body weight as compared to mass-selected and random control groups. The present study is also in agreement with the result of Ahmad et al. (2018).

Livability differs significantly among genetic lines and generations with better livability in the RBC line followed by EBS and WBS lines. G0 presented the highest livability as compared to G1, G2 while it was lowest in G3. Interaction among genetic lines and generations also showed significant differences with decreasing tendency in WBS as compared to EBS and RBC in progressive generations. This decrease in the livability of the WBS line might be due to the negative relation of increasing body weight with immunity. This is contradictory to the findings of Hussain et al. (2013) who reported the lower mortality in pedigreed birds selected for three-week body weight in the second generation as compared to mass selection and control group, who argued that the selection of superior genes of better production through intensive selection results in increased livability. However, Ahmad et al. (2018) observed no significant difference in cumulative mortalityamong the birds selected for higher 4-week bodyweight and random control group.

Immune response

Like mammals, the role of the thymus in poultry is to induce cellular immunity in the form of T-cells also known as T-lymphocytes. In the present experiment relative weight of the thymus differed among different lines as well as between generations. Thymus% showed an increasing trend in the EBS line as compared to the WBS line in which thymus% decrease with progressive generation. The interaction between lines and generations revealed higher thymus% in Japanese quails of EBS during G1 while it was lowest in WBS in G3. Similarly, Bayyari et al. (1997) observed the difference between heavy and lightweight individually in relative thymus weight in turkey. This is contradictory to the findings of Faisal et al. (2008) and Cheema et al. (2003) who reported that the relative weight of the thymus is not influenced by genetic lines in Japanese quail and chicken.

Spleen also plays an important part in the immune system by producing plasma cells which consist of lymphocytes, monocytes, and antibody-producing cells. Spleen% differs among genetic lines. Higher spleen% was noted in RBC followed by EBS and WBS. However, spleen% was comparable among the birds of a different generation. This is in agreement with Faisal et al. (2008) who observed the influence of selection in Japanese quail for heavy and low weight lines on the relative weight of spleen. A similar finding was observed by El-Bayomi et al. (2014) who reported the higher relative weight of spleen in the line selected for increased body weight than those of control and low weight lines of Japanese quails. Similarly, in turkey Bayyari et al. (1997) and Li et al. (2001) also show the difference of relative weight of spleen among different lines (heavy and lightweight). However, in chicken Cheema et al. (2003) suggested no difference for the relative weight of the spleen among different lines.

Bursa of Fabricius control development and proliferation of B-lymphocytes during growth. Therefore, the weight of the Bursa indicates the difference in the humoral immune response. However, Bursa% difference was non-significant among the birds of genetic lines as well as generations. Similar findings were reported by Kankova et al. (2019) who reported no differences among low weight gain line (LG) and High weight gain line (HG) regarding the relative weight of Bursa of Fabricius in Japanese quail. Similarly, in chicken Cheema et al. (2003) also suggest no line and age differences in the relative weight of bursa among commercial broiler chicken and random breed control line. This is contradictory to the findings of Faisal et al. (2008) who reported the differences in the relative weight of bursa among heavy and low lines in Japanese quail. This is in agreement with Bayyari et al. (1997) and Li et al. (2001) who illustrate differences in the relative weight of bursa among different lines (heavy and lightweight) and age groups of turkey.

In terms of different genetic lines, the B/S ratio differs significantly with a better B/S ratio in the RBC line as compared to EBS and WBS lines. However, the B/S ratio was comparable among the birds of different generations and no interaction was observed between genetic lines and generations. Similarly, Bayyari et al. (1997) reported lower values of B/S ratio in low weight and higher egg-producing lines as compared to heavy lines in turkey.

For the estimation of humoral immune response evaluation of plasma antibody concentrations is more reliable than the weight of lymphoid organs. ND titer differs significantly among genetic lines and generations with higher titer values in the RBC line followed by EBS and WBS lines. G0 presented the highest ND titer as compared to G1, G2 while it was lowest in G3. Interaction among genetic lines and generations also showed significant differences with decreasing tendency in WBS as compared to EBS and RBC in progressive generations. This decrease in ND titer of the WBS line might be due to the negative relation of increasing body weight with immunity. These findings are in harmony with the findings of El-Nagar et al. (2016) who reported decreasing antibody titer against ND vaccine in respective 3 generations of Japanese quails selected for higher 4^{th}-week bodyweight resulting in lower resistance to Newcastle disease. Similarly, in another study (Kankova et al. 2019) lower concentration of plasma antibodies was observed in higher weight gain (HG) lines as compared to low weight gain (LG) lines of Japanese quail. Koenen et al. (2002) also observed weaker long-term IgG response in broiler chickens as compared to layer types. However, contradictory to previous findings Faisal et al. (2008) observed higher antibody titter in heavy weight Japanese quail than those of low weight lines against NDV.

Conclusions

It is concluded that selection for bodyweight has a positive impact on the growth performance of Japanese quails. But the selection for body weight and egg number both compromise the livability of the flock possibly due to a decrease in the immunity levels. It is therefore recommended that selection for higher body weight should be accompanied by selection for immune response at least after G1 and G2 in case of selection for egg number.

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