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Baylan, M

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■Author(s)

Baylan M¹

¹ Cukurova Universitesi - Animal Science
Cukurova University Agricultural Faculty
Department of Animal Science, Adana/
TURKEY Adana 01330 Turkey

■Mail Address

Corresponding author e-mail address
Mikail Baylan
Cukurova Universitesi - Animal Science
Cukurova University Agricultural Faculty
Department of Animal Science, Adana/
TURKEY Adana 01330 Turkey
Tel: +90 506 4079879
Email: mikailbaylan@gmail.com

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ABSTRACT

This experiment was conducted to investigate the effects of different selection methods of parent lines on the body weight of Japanese quails. For this purpose, line M₅₅ was subjected to individual selection for body weight at 5 weeks of age, while a reciprocal recurrent selection method was applied to lines R₃₃ and S₅₅. Selection lasted two generations. Body weight changes, age and weight at sexual maturity, egg weight, and egg production were investigated in the parent generations as well as in the selection lines. Body weight at 5 weeks of age of the parents of the M₅₅, R₃₃ and S₅₅ lines were 299.0, 285.3, and 280.4 g in the first generation, and 314.8, 316.6, and 306.8±3.11 g in the second generation, respectively. The first generation of the M₅₅, R₃₃, and S₅₅ lines presented egg production rates of 73.4, 77.6, and 75.8%, respectively, and egg weights of 12.7, 11.9, and 12.1g, respectively. The second generation of the M₅₅, R₃₃, and S₅₅ lines presented egg production rates of 74.6, 77.8, and 78.3%, and egg weights of 12.72, 12.59, and 12.56 g, respectively. Both egg production and egg weights were significantly different between the first and the second generations ($p>0.05$). As a result, despite significant increase in body weight of the selection lines, no significant differences in egg production or egg weight were determined among generations. However, reciprocal selection lines of both generations presented higher egg yield than the individual selected line.

INTRODUCTION

Japanese quails are commercially produced mainly for meat in Europe and for eggs in Japan, and are often bred as dual-purpose poultry in other Asian countries (Minvielle, 1998; Kayang *et al.*, 2004; Maiorano *et al.*, 2012). Recently, quail meat has begun to attract the consumers, but most producers find it difficult to obtain superior quality parents. For this purpose, especially for the production of fast-growing birds, researchers have been working on Japanese quail parent strains with high growth potential.

Selection has an important role for the genetic improvement of livestock. Individual selection, in particular, is essential in experiments for selection for body weight (BW) in poultry, and the high heritability of body weight provides major benefits (Hussein *et al.*, 2014). Many researchers have reported that the heritability of BW in Japanese quails is moderate to high (Darden & Marks, 1988; Marks, 1989; Kocak *et al.*, 1995; Marks, 1996; Baylan *et al.*, 2009a; Sari *et al.*, 2011; Narinc & Aksoy, 2014; Kaye *et al.*, 2016). Selection experiments applying different selection methods in different environments have been performed, but most involved individual selection and used BW at 3, 4, and 5 weeks of age as the criterion.



Experiments using selection methods have also been carried out to evaluate heterosis. Reciprocal recurrent selection, which involves two types of selection in favor of additive and nonadditive genetic variation, is an important breeding method to obtain heterosis and stable genetic lines. First developed by Comstock *et al.* (1949), this method enables the selection and combination of preferred capable lines. That is to say, reciprocal recurrent selection designed to increase the genetic distance between lines should eventually achieve maximum heterosis. This is even more so in the negative correlation between body weight and egg production. This situation should be considered in the development of quail parent lines (Kocak *et al.*, 1995; Minvielle *et al.*, 1999; Yahaya *et al.*, 2009). It is reported that the long-term selection for body weight in quails has resulted in a decrease in egg production and an increase in egg weight. Usually, a significant increase in egg production causes a decrease in egg weight. This is applicable for quails as well, and it is an important measure for selection for body weight (Marks, 1996; Alkan *et al.*, 2010; Silva *et al.* 2013).

This study investigated the change in egg production and egg weight in genotypes bred for body weight. These two characteristics that guide the development of the maternal and paternal lines of the quail flock being worked on would be effective in the consideration as selection measures.

MATERIALS AND METHODS

The quail lines used were M_{55} , R_{33} and S_{55} . These lines were developed previously by selection for BW in the Department of Animal Science Quail Research Unit, Agricultural Faculty at Cukurova University, Adana, Turkey. Details regarding the establishment of these lines can be found in Baylan (2003). Briefly, M_{55} was obtained after nine generations of individual selection for body weight at 5 weeks of age (5-wk BW). Lines R_{33} and S_{55} were obtained following three generations of individual selection for body weight at 3 and 5 weeks of age, respectively, followed by three generations of reciprocal recurrent selection.

In this study, line M_{55} was subjected to individual selection for 5-wk BW, while reciprocal recurrent selection was applied to lines R_{33} and S_{55} . Selection lasted for two generations.

In the M_{55} line individual selection was applied for 70 parents from the quail population based on the sex ratio (3♀: 1♂) per generation. Eighty males and female pullets were obtained from each generation from

lines R_{33} and S_{55} and these parents were transferred to individual cages in order to perform reciprocal crosses (80 pair-matings of $R_{33}S_{55}$ and pair-matings of $S_{55}R_{33}$) at the end of 5 weeks of age. One male and one female were kept together in individual cages (15×25×20 cm). At week 8 of egg laying, hatching was initiated and the obtained offspring were wing-tagged and raised for five weeks. Depending on the performance of hybrid offspring in week 5, the best male and female individuals (1:3 ratio; 9:27) were selected to determine the R_{33} and S_{55} parents.

After the parents were determined in all lines, at the inbreeding stage, the productivity levels of the mothers (age and weight at sexual maturity, egg production, egg weight) were compared.

During the study, the parents were fed a caged chicken egg laying feed with 15% crude protein and 2650 kcal ME/kg. Feed and water were supplied *ad libitum*, and a lighting schedule of 16 hours light and 8 hours of darkness was applied.

In the study of all parent groups, beginning on the date of initial laying, the eggs laid were collected daily. Egg weight was determined weekly on the same day of the week for 18 weeks for each generation. All weights were measured to 0.1-g precision.

Data were analyzed by one-way analysis of variance procedure of the SPSS software. Significant differences among means were ranked by Duncan's Multiple Range Test (Windows version of SPSS, release 10.01).

RESULTS AND DISCUSSION

Five-week body weights of the parents of M_{55} , R_{33} and S_{55} lines were determined as 299.0, 285.3, and 280.4 g for the first generation; 314.8, 316.6, and 306.8±3.11 g for the second generation (Tables 1 and 2). The body weight differences among lines in the first and the second generation were statistically significant ($p<0.05$). Higher body weight was obtained in the second generation compared with the first generation. These results are consistent with Baylan *et al.* (2009a), who obtained for the M_{55} , R_{33} and S_{55} lines 5-wk BW of 282.9, 284.8, and 279.5 g for the first generation, and 284.6, 285.5, and 284.3 g for the second generation, respectively. Those researchers reported that the 5-wk BW differences among lines were statistically significant in the first generation ($p<0.05$), and reported that, at the end of the second generation, 5-wk BW increased in 11.1, 26.6, and 25.3 g compared with the initial generations of the M_{55} , R_{33} and S_{55} lines, respectively. Baylan *et al.* (2009b) also



reported that, among individual lines, the percentage deviation of 5-wk BW was 2.19 and 6.29% in the first and second generation, respectively.

The egg production and 5-wk BW values of female individuals of the first and second generations of the selection lines are given in Tables 1 and 2. In both generations, selection lines were housed in the laying cages at 5 weeks of age. Egg production, starting in week 6, was calculated as quail-day average by dividing the number of eggs by the number of surviving hens, and expressed in as a weekly percentage (%) and cumulative egg production during 18 weeks of evaluation for both generations.

Age at sexual maturity was reached at 38, 45.1, and 46.8 days in the first generation and 38, 46.3 and 46.6 days in the second generation of the M_{55} , R_{33} , and S_{55} lines, respectively. Body weights at sexual maturity were

317.9, 333.5, and 337.9 g in the first generation and 331.8, 358.2, and 352.3 g in the second generation of the M_{55} , R_{33} , and S_{55} lines, respectively. Daikwo et al. (2014) reported that the mean body weight at first egg was 145.68 g and mean age at first egg was 47.01 days. The body weight at first egg obtained in the present study was higher than that reported by Daikwo et al. (2014), but mean age at first egg was similar.

Average egg production at 20 weeks in the first generation of the M_{55} , R_{33} and S_{55} lines was 73.4, 77.6, and 75.8%, and 74.6, 77.8, and 78.3% in the second generation, respectively.

Egg production per quail of the first generation (18 weeks) of the M_{55} , R_{33} and S_{55} lines was 93.2, 96.6, and 94.7 eggs, respectively, and in the second generation (18 weeks) 94.3, 96.5 and 97.3, respectively.

Table 1 – Body weight at 5 weeks of age and egg production values of the first generation of Japanese quails according to selection line (*)

Parameters	Individual selection line	Reciprocal selection lines	
	M_{55}	R_{33}	S_{55}
5-wk body weight (g)	299.0 \pm 3.03 ^a	285.3 \pm 3.01 ^b	280.4 \pm 2.80 ^b
Age at sexual maturity (d)	38.0	45.1	46.8
Body weight at sexual maturity (g)	317.9 \pm 2.58	333.5 \pm 3.16	337.9 \pm 3.63
Egg production in 20 weeks (n)	93.2	96.6	94.7
Egg production (%)	73.4 \pm 3.32 ^b	77.6 \pm 4.34 ^a	75.8 \pm 4.65 ^a
Egg weight week 1 (g)	10.2 \pm 0.71	9.2 \pm 0.50	9.6 \pm 0.80
Egg weight week 15 (g)	13.3 \pm 0.16 ^a	12.54 \pm 0.13 ^b	12.5 \pm 0.14 ^b
Average egg weight (g)	12.7 \pm 0.06 ^a	11.9 \pm 0.04 ^c	12.1 \pm 0.04 ^b

(*) Significant differences ($p < 0.05$) among the overall means of the selection lines are indicated by different letters (a,b,c).

Table 2 – Body weight at 5 weeks of age and egg production values of the second generation of Japanese quails according to selection line (*)

Parameters	Individual selection line	Reciprocal selection lines	
	M_{55}	R_{33}	S_{55}
5-wk body weight (g)	314.8 \pm 2.90 ^a	316.6 \pm 4.14 ^a	306.8 \pm 3.11 ^b
Age at sexual maturity (d)	38	46.3	46.6
Body weight at sexual maturity (g)	331.8 \pm 2.07	358.2 \pm 2.92	352.7 \pm 3.16
Egg production in 20 weeks (n)	94.3	96.5	97.3
Egg production (%)	74.6 \pm 5.58 ^b	77.8 \pm 4.47 ^a	78.3 \pm 4.43 ^a
Egg weight week 1 (g)	9.7 \pm 0.57	9.3 \pm 0.48	10.8 \pm 0.57
Egg weight week 15 (g)	12.8 \pm 0.19 ^b	13.4 \pm 0.13 ^a	13.5 \pm 0.15 ^{ab}
Average egg weight (g)	12.7 \pm 0.07	12.5 \pm 0.05	12.5 \pm 0.05

(*) Significant differences ($p < 0.05$) among the overall means of the selection lines are indicated by different letters (a,b).

As demonstrated both in Tables 1 and 2 and these values and in Figures 1 and 2, the egg production of the selection lines did not change between generations; however, in both generations, the cross selection lines (R_{33} , S_{55}) presented higher egg production values compared to the individual selection line (M_{55}).

In a study on the long-term selection for 4-week body weight in Japanese quails, Marks (1979) reported average egg production in all generations of 75.8% in the selected group and 81.1% in the control group, and emphasized that selection based on body weight causes a reduction in egg production. Anthony et al.



(1996) also reported that correlated responses over 30 generations of divergent selection for 4-wk BW in Japanese quails indicate that selection had negative effects on fitness traits, including egg number. Durmus *et al.* (2017) observed that selection for high body weight in Japanese quails led to a reduction in egg production by 13.5%.

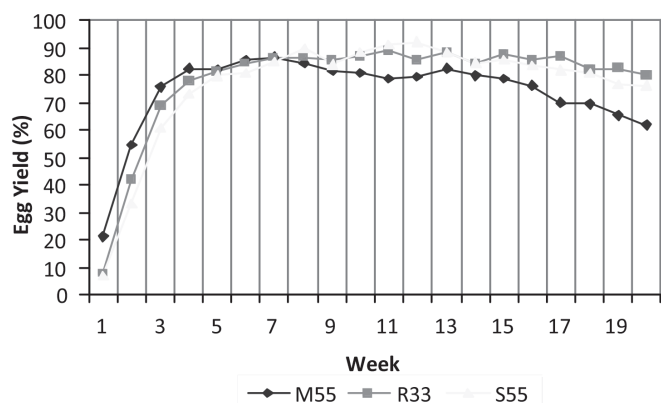


Figure 1 – Weekly egg production of the first generation of the selection lines

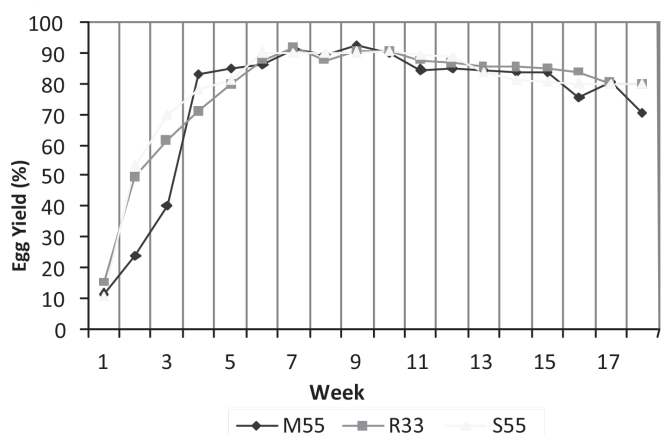


Figure 2 – Weekly egg production of the second generation of the selection line

Testik *et al.* (1993) observed that in Japanese quails with different origins, lower egg production was obtained in the selected for body weight. Those researchers reported the 300-d egg production of 165.8 and 160.7 eggs in the Aegean-sourced control and selected groups, respectively, and 164.3 and 159.3 eggs in the Ankara-sourced control and selected groups, respectively.

On the other hand, Okan & Uluocak (1992) reported that the 15-wk quail-day egg production varied between 51.2-77.9%, and Nacar and Uluocak (1995) also observed egg production variability in females of different age groups, with the highest production peak over a 21-week period of 77.9%. All these values are much lower than those obtained with all

the lines evaluated in the present study. Nacar *et al.* (1997), selecting Japanese quails for heavy and light 5-wk BW, recorded 17-wk quail-coop egg production of 95.93 eggs in the heavy group, with a percentage egg production of 80.6%, and peak egg production in week 13 of 89.7%. On the other hand, Inal *et al.* (1996) reported the egg production in the selected group between days 80-95 as 67.33-84.58 %, which is close to the values recorded in the present study during the same time period. Baylan (2003) obtained in the same lines (M₅₅, R₃₃ and S₅₅) 23-week egg production averages of 75.3, 78.5, and 80.4 eggs, respectively. These values are slightly higher than those obtained in the present study, and may be a negative result from the selection for body weight. Kocak *et al.* (1995) recorded the 25-week egg production as 83.97%, Canogullari *et al.* (2010), 12-week egg production between 87.74- 92.49%, and Canogullari *et al.* (2016) reported 8-week egg production between 90.57 and 92.35% in Japanese quails. These values are higher than those obtained in the present study.

From 6 weeks of age, when the selection lines started laying, all eggs were weighed at 0.1-g precision once weekly. As shown in Figures 3 and 4, egg weight increased with age in both generations of both selection lines. In general, for the first generation, the M₅₅ line laid heavier eggs in all weeks compared with the other lines, including when the egg weight average was calculated for the 18-week production period. For the second generation, egg weight difference was significant only in weeks 8, 15 and 18, and the Egg weight in the 18-week average was not significant.

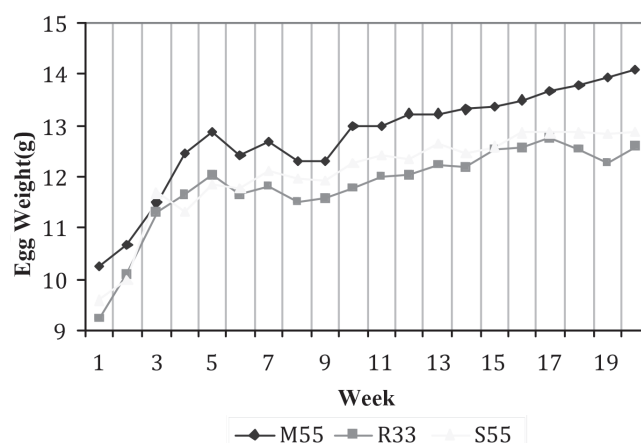


Figure 3 – Weekly egg weight of the 1st generation of the selection lines

The egg weights of the 1st generation determined for M₅₅, R₃₃ and S₅₅ lines in week 1 of lay were, in that order, 10.2, 9.2 and 9.6 g, and in week 15 were, in the same order, 13.3, 12.54 and 12.5 g, while the 20-



week average was calculated as 12.7, 11.9, and 12.1 g, respectively.

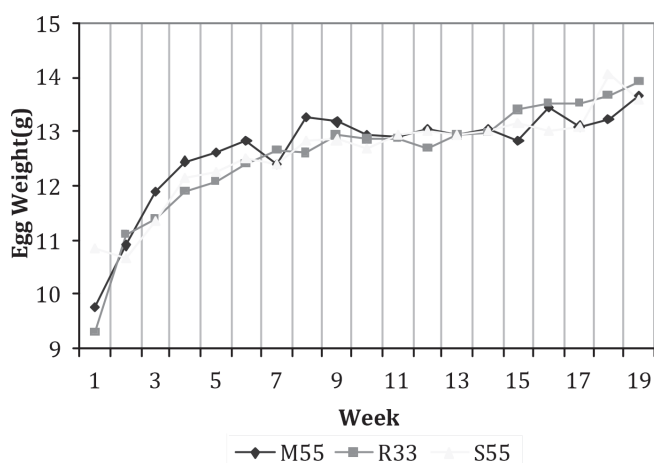


Figure 4 – Weekly egg weight of the 2nd generation of the selection lines

For the second generation, the egg weights of the M_{55} , R_{33} and S_{55} lines were determined as 9.7, 9.3, and 10.8 g in week 1, as 12.8, 13.4, and 13.5 g in week 15; and the average egg weights calculated for the 18-week production period were 12.7, 12.5, and 12.5 g. The egg weights of selection lines did not change much between generations. Baylan (2003) reported average egg weights over 23 weeks for M_{55} , R_{33} and S_{55} lines as 13.0, 13.3, and 12.8 g, respectively. Working with Japanese quails, many researchers reported that egg weight increased as a result of selection for body weight (Woodard *et al.*, 1973; Marks, 1976; Marks, 1979; Moritsu *et al.*, 1997; Alkan *et al.*, 2008). During their selection study of Japanese quails for high body weight in two different environments, Darden and Marks (1988) recorded increases of 1.4 and 1.3 g in egg weight after 11 generations. In the selection study for high body weight in week 4, under complete and split feeding conditions, Marks (1991) reported egg weights of 8.3 and 7.5 g in light lines and 11.7 and 10.8 g in heavy lines, respectively.

Testik *et al.* (1993) observed that in groups where selection for live weight was applied, egg weight increased, reporting egg weights of 13.0 and 12.8 g in selection groups of Aegean and Ankara origin. Inal *et al.* (1996) obtained egg weights between 12.01-13.23 g in their study on five generations selected for 5-wk body weight, and Alkan *et al.* (2013) obtained 12.22 g egg weight in a line selected for high body weight for 11 generations. Baylan (1998) reported average egg weights over 25 weeks of 13.0, 13.0 and 13.0 g in lines selected was applied for body weight at different ages (3, 4, and 5 weeks of age) in the first generation; while for the 2nd generation, 17-week average egg weights

of 11.9, 12.4 and 12.4 were obtained. Those authors suggested that the decrease in egg weight in the second generation might be related to environmental conditions. The results of the current experiment are consistent with those findings.

The egg weights obtained in the present study are higher than those reported by many researchers. Thomas and Ahuja (1988) reported 18-week egg weight at the end of two long-term selections for high body weight as 11.4 and 10.8 g. Ariturk *et al.* (1980) reported the 90-day egg weights between 10.83 and 10.60 g. Nacar *et al.* (1997), in their selection study for light and heavy 5-wk body weight observed heavier egg weights in the group selected for heavy BW, with 17-wk egg weight of 11.8 g in the heavy group and 11.6 g in the light group. In a similar study, Nacar (1998) obtained 16-wk egg weight of 11.9 in the heavy group, and 11.8 g in the light group. Alkan *et al.* (2008), in their study of selection in the heavy and light live weight, reported egg weights of 9.16 g in the light group and 11.26 g in the heavy group. All these reported Japanese quail egg weight values are lower than those calculated for all three selection lines in the present study.

CONCLUSION

This study applied different selection methods and evaluated egg production parameters in the parents and at the end of two generations of selection. While 5-wk body weight values were higher in the second generation, no significant differences between generations in egg production levels was determined. However, in both generations, cross-selection lines presented higher egg production compared with the individual selection line. Continuing the selection of the aforementioned lines may be important, especially with regards to body weight. Selecting for carcass traits, in addition to body weight, in the development of paternal lines, while selecting for egg production and egg weight, together body weight, in the maternal lines is recommended.

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