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Research Article
An Evaluation of Selection Data of Barred Rock-1 and Rhode Island Red-1 Pure Line Laying Hens at the Poultry Research Institute of Ankara

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Abstract
Background and Objective: In Turkey, study on egg-laying hens has been performed by Republic of Turkey, Ministry of Food, Agriculture and Livestock, Poultry Research Institute which was established in 1930. Many genetic selection projects have been successfully completed at the Institute. The project mentioned in this study has been conducted since 1995 with six brown and five white layer pure lines. The aim of this study was to evaluate the selection data of two brown egg shell layer pure lines between the years 2005 and 2014. **Methodology:** Data on age and body weight at first egg, egg number and egg weight upto 43 weeks age were collected from 12,904 Barred Rock-1 and 11,821 Rhode Island Red-1 pure lines for 10 years. Data were analyzed by Multiple Trait Derivative Free Restricted Maximum Likelihood. **Results:** Estimated heritabilities were 0.46 and 0.40 for age at first egg, 0.49 and 0.43 for body weight at first egg, 0.36 and 0.33 for egg number, 0.55 and 0.50 for egg weight in Barred Rock-1 and Rhode Island Red-1 lines, respectively. Genetic correlations were 0.45 and -0.33 between age at first egg and body weight at first egg, 0.22 and -0.35 between age at first egg and egg number, -0.34 and -0.23 between age at first egg and egg weight, -0.49 and -0.38 between body weight at first egg and egg number, 0.17 and 0.26 between body weight at first egg and egg weight, -0.15 and -0.23 between egg number and egg weight in BAR-1 and RIR-1 lines, respectively. Means of 43 weeks egg production traits between two lines were statistically significant ($p \leq 0.05$). **Conclusion:** As a result of implementing the selection while, egg number was increasing, age at first egg and body weight at first egg were decreasing and egg weight was remaining almost at the same level.

Key words: Egg production, selection, heritability, genetic correlation, laying hens

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In modern laying hen breeding studies as mentioned in this study requires knowledge of genetic parameters such as heritability, correlations and variances for the traits concerned[1]. Producing hybrid laying hen process which starts at the pure-line level and proceeds through the multiplication process to grandparents and then to parent stock for hybrids. As the gene flow proceeds, specific mating is used to produce the male and female lines that are ultimately crossed to produce the final commercial product[2]. In animal breeding, heritabilities and genetic correlations are important objectives for the breeding value predictions[3]. According to one of the previous study egg number showed low to moderate heritabilities in Barred Plymouth Rock and Rhode Island Red ranging from 0.09-0.16. Estimated heritabilities were moderate to high for egg weight, age at first egg and body weight at first egg in both lines[4]. This study findings were generally agreed with results of Wolc *et al.*[4]. Breeding genetics studies can be risky, time-consuming, expensive and often require long-term planning so, few companies control most of the world's meat and egg breeder market[5]. In this study, poultry and selection studies are very important for developing countries.

The aim of this study was to evaluate selection studies for improving egg production traits of RIR-1 and BAR-1 pure lines between the years 2005 and 2014.

MATERIALS AND METHODS

Birds: The animal material part of the study was formed within two pure lines at PRI (Ankara, Turkey). The data were obtained between 2005 and 2014. With regards to the selection criteria, superior birds (450 hens and 50 cocks) were selected from the base populations; 50 families were formed (9 hens were artificially inseminated with the semen from 1 male). Eggs obtained from these full-pedigree families were then incubated. Chicks were hatched, vent sexed, pedigreed, wing banded and vaccinated against diseases according to the Institute's Vaccination Programme. Chicks were raised until 16 weeks of age under standard conditions in a chick-raising barn upto 16 weeks of age. When the pullets reached 16 weeks of age, they were randomly distributed into individual cages with conventional compact-type tree floor cages. Feed, prepared in accordance with commercial feed standards of Turkey was supplied *ad libitum*.

Characteristic data collection: Egg production traits were defined as follows.

- **Age at first egg (AFE):** The difference between the date a hen laid its first egg and the date, it came out of its incubation was recorded as the sexual maturity age
- **Body weight at first egg (BWFE):** Each hen was weighed on the day it laid its first egg and this weight was recorded as the sexual maturity weight
- **Egg number (EN):** The number of eggs that a hen laid until 43 weeks of age
- **Egg weight (EW):** Average egg weight of each hen's eggs recorded by weighing three sequential eggs at 28th, 32nd and 36th weeks

Statistical analysis: During the study, variance and co-variance components in two lines were estimated using restricted maximum likelihood (REML).

The following statistical model was used:

$$Y_{irxn} = \mu+s_i+d_r\ (s_i)+b_x+e_{irxn}$$

where, Y_{irxn} is the record of the nth progeny of the rth female mated to ith male in the xth year, μ is the common mean, s_i is the effect of the ith male (i is subscript for male), d_r (s_i) is the fixed effect of the rth female which is mated to the ith male (r is subscript for female), b_x is the fixed effect of the year (x is subscript for year) and e_{irxn} is the random error and e's assumed N (0, θ^2).

Progeny of next generations was selected using index selection according to the following formula:

$$I = P_1h^2{}_1w_{1+}P_2h^2{}_2w_2+\dots\dots\dots+P_nh^2{}_nw_n$$

where, I was the selection index, P_i was the phenotype of individual traits, h^2 was the heritability coefficients of the traits and w_i was the economic weight of trait i by Hazel[6] and Hazel and Lush[7]. The selection index program was used to calculate the selection index[8]. The means of traits were compared using Tukey's test at the 5% probability level[9].Variance components and genetic parameters were estimated with an animal model using the MTDFREML suite of software programs[10]. The MTDFREML includes the MTDFNRM, MTDFPREP and MTDFRUN computer programs.

The MTDFNRM firstly calculates the inverse of the relationship matrix to be used in the mixed model equations and utilises rules of Henderson[11] to calculate the inverse of the relationship matrix directly from a list of birds and their parents, secondly, it provides an individual identification for matching phenotypic records to individuals, thirdly, it calculates inbreeding coefficient sand and fourthly, it calculates the logarithm of the determinant of the relationship matrix needed to calculate the logarithm of the likelihood function.

The MTDFPREP prepares coefficients for the mixed model equations based on the statistical model for single and multiple trait analyses.

The MTDFRUN solves the mixed model equations and finds variance component estimates that maximise the restricted likelihood given the phenotypic data[12].

RESULTS

The mean egg production traits of the two pure lines are shown in the tables and figures. Cumulative descriptive statistics of the traits in 24,725 individuals are shown in Table 1.

Means of 43 weeks egg production traits among lines were statistically significant ($p \leq 0.05$). It was important that the pullets should have attained sufficient body weight by the time they laid their first eggs. The BAR-1 pullets with low body weight began laying earlier than similar sized RIR-1 pullets. However, the RIR-1 hens produced not only more but also heavier eggs than BAR-1 during the 10-year study period ($p \leq 0.05$).

The AFE showed variable trends in both lines during the 10-year period (Fig. 1). The RIR-1 matured 5 days earlier in 2014 than 2005, but BAR-1 matured 1 day later. Generally, BAR-1 began laying earlier than RIR-1 in this study.

The mean BWFE of lines showed a slight decreasing tendency (Fig. 2) however, fluctuations were observed during the 10 years. The difference between the two lines reached a maximum value of 96.95 g in 2008 with a gradual decrease of this gap to around 1 g in 2013 but 28 g in 2014.

From 2005-2014, the trend in ENs in the two pure lines generally showed a perceptible upward trend, except in 2006, 2008 and 2011 years (Fig. 3). The almost two more eggs in RIR-1 than BAR-1 difference remained constant until the end of the study period; the difference between the two lines was highest in 2006 and 2011 years with four eggs more in BAR-1 than that of RIR-1.

The EW was generally not stable in the two lines over the 10 years (Fig. 4). The RIR-1 line reached the highest average EW value in 2011. Selection pressure for EW in RIR-1 increased because it was the sire line. The EW of the lines showed parallel changes during the study however, it was always higher in RIR-1 than in BAR-1.

Table 1: Cumulative descriptive statistics of BAR-1 and RIR-1 pure lines

Lines	NO	*AFE	**BWFE	***EN	****EW
BAR-1	12904	150.09 ± 0.08^{b}	1710.43 ± 1.28^{b}	131.10 ± 0.11^{a}	55.52 ± 0.03^{b}
RIR-1	11821	154.56 ± 0.11^{a}	1756.86 ± 1.59^{a}	127.12 ± 0.14^{b}	59.40 ± 0.03^{a}

[a,b,c]Column means with different superscripts differ significantly at $p<0.05$, *AFE: Age at first egg, **BWFE: Body weight at first egg, ***EN: Egg number and ****EW: Egg weight

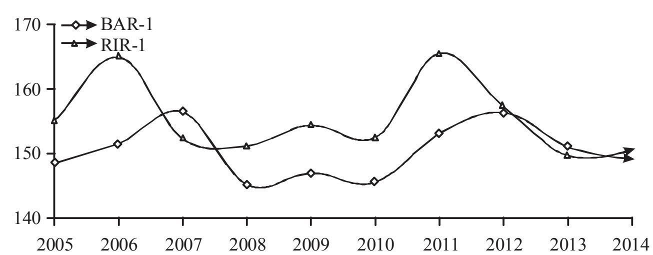

Fig. 1: Age at first egg (AFE) trends in BAR-1 and RIR-1 lines

Fig. 2: Body weight at first egg (BWFE) trends in BAR-1 and RIR-1 lines

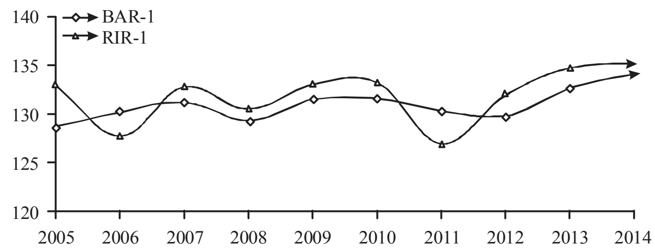

Fig. 3: Egg number (EN) trends in BAR-1 and RIR-1 lines

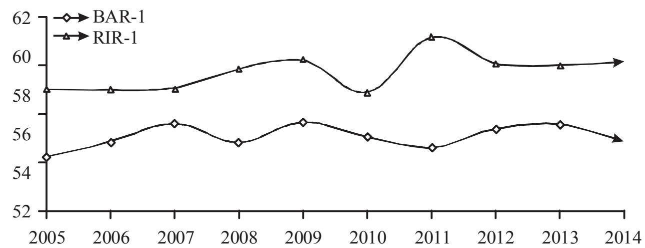

Fig. 4: Egg weight (EW) trends in BAR-1 and RIR-1 lines

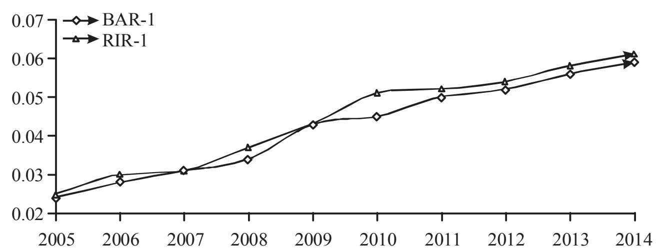

Fig. 5: Breeding coefficients (BC) trends in BAR-1 and RIR-1 lines

Table 2: Coefficients of genetic correlations between egg production traits

Genetic correlations	BAR-1	RIR-1
AFE-BWFE	0.55±0.023	-0.33±0.047
AFE-EN	0.22±0.043	-0.35±0.045
AFE-EW	-0.34±0.033	-0.23±0.044
BWFE-EN	-0.49±0.025	-0.38±0.014
BWFE-EW	0.17±0.036	0.26±0.043
EN-EW	-0.15±0.034	-0.23±0.046

AFE: Age at first egg, BWFE: Body weight at firt egg, EN: Egg number and EW: Egg weight

Table 3: Heritability of egg production traits in BAR-1 and RIR-1 lines

Genetic correlations	BAR-1	RIR-1
AFE	0.46±0.02	0.40±0.03
BWFE	0.49±0.02	0.43±0.01
EN	0.36±0.01	0.33±0.02
EW	0.55±0.03	0.50±0.02

AFE: Age at first egg, BWFE: Body weight at firt egg, EN: Egg number and EW: Egg weight

Genetic correlations between traits were estimated in RIR-1 and BAR-1 pure-line populations (Table 2).

The genetic correlation between AFE and BWFE and AFE and EN was positive in BAR-1 but negative in RIR-1. The BWFE and EN in RIR-1 was more negative than that of BAR-1. Although, the EW of eggs produced by a hen varied throughout the 43 weeks period, EW was negatively correlated with AFE and EN but positively with BWFE. The genetic correlation of two populations between EW and EN was negative (a small value). The estimated genetic correlations in this study showed that selection to improve one trait would be associated with disadvantageous changes in other traits. The estimated heritabilities (range 0.36-0.55 in BAR-1 and 0.33-0.50 in RIR-1lines) are shown in Table 3.

Heritabilities for egg production traits were generally moderate or high. Average inbreeding coefficients in BAR-1 and RIR-1 were 0.039 and 0.042, respectively (Fig. 5).

The inbreeding rates increased gradually during the study. Due to measures aimed at preventing mating between related birds, the inbreeding ratio was generally low. The average inbreeding per generation was 0.042±0.003 in BAR-1

Table 4: Mean coefficient of variation for egg production traits of two pure lines

	AFE		BWFE		EN		EW	
Years	BAR-1	RIR-1	BAR-1	RIR-1	BAR-1	RIR-1	BAR-1	RIR-1
2005	6.51	6.08	9.26	8.2	9.11	10.96	6.08	6.44
2006	10.03	7.78	9.59	8.46	11.76	12.51	5.70	5.90
2007	5.34	6.78	8.73	8.36	6.61	8.78	6.31	6.64
2008	5.51	6.78	7.57	7.95	11.38	11.59	5.46	6.76
2009	2.99	5.71	7.35	8.06	7.09	7.89	5.75	6.47
2010	3.59	6.87	7.49	9.18	7.13	11.93	5.03	6.39
2011	6.84	7.48	5.82	8.77	9.04	9.87	5.72	6.02
2012	5.96	4.58	6.74	5.16	8.80	8.03	6.00	6.87
2013	2.72	8.03	4.87	15.95	8.37	17.67	6.34	6.55
2014	5.77	6.20	7.79	7.82	9.77	7.75	5.82	5.94

AFE: Age at first egg, BWFE: Body weight at firt egg, EN: Egg number and EW: Egg weight

and 0.044 ± 0.004 in RIR1. The increase in inbreeding per generation was higher in RIR-1 than BAR-1. Egg production traits in this study were not highly variable and had a typical coefficient of variation of approximately 6-8% (Table 4).

The use of the coefficient of variation could potentially allow for a different evaluation for traits in laying hens. The highest phenotypic variation was related to EN with a CV percentage of 17.67 in RIR-1 while, the lowest phenotypic variation was related to AFE with a CV percentage of 2.72 in BAR-1. Over the entire selection period, there was little change in the coefficient of variation of the different traits in the lines.

DISCUSSION

The selection programme at PRI was performed simultaneously on four traits; the greater the number of traits, the smaller the improvement in each single trait[13]. The PRI's main breeding goals were increasing the EN, maintaining EW, decreasing body weight and gradually reducing sexual maturity. Selection for improving egg production traits in two pure lines did not always produce consistent results at PRI between 2005 and 2014.

One of the main challenges was that fact that selection for high egg production would result in small eggs; in addition, decreasing BWFE tended to decrease EW. On the other hand, high adult body weight negatively affected egg production and increased feed consumption. The development of a suitable selection index was not an easy task considering the weak and strong points of lines. Therefore, the index required changes as the line improved or degenerated in certain traits. Henderson and Quaas[14] and Quaas[15] reported that selection was usually exercised on several traits. Thus, to avoid selection bias, it is common in animal breeding to perform a multivariate mixed model analysis. There were consequences of selection for high production.

Chicken breeders were cognisant of the fact that selection for changes in one trait may not be independent of changes in other traits. Indeed, these changes could have consequences that could be positive or negative[16].

The use of genetically selected sire and dam lines enhances the performance of terminal crossbreeding systems. At the end of the tenth generation of selection, inbreeding coefficients in BAR-1 and RIR-1 lines were 0.059 and 0.061, respectively. The rate of mean inbred reached 0.048 and 0.039 in the lines in a similar study by Savas *et al.*[17] over 10 generations. Sewalem *et al.*[18] reported that White Leghorn lines and the prediction average increment of percentage inbreeding coefficient per generation were 0.015 and 0.011 in EN and EW, respectively. It was concluded that heritability and selection pressure have great importance in the improvement of egg production traits.

Egg and body weight traits with high heritability are easily passed from parent to offspring. In contrast, the EN trait with low heritability would take more generations to produce the same amount of genetic progress or it needs more selection pressure than other traits.

The results of this study generally agree with those of Zhang *et al.*[19], Wolc *et al.*[4], Kamali *et al.*[20], Sreenivas *et al.*[21] and Wei and Werf[22]. They reported heritabilities between 0.13 and 0.46 for EN, 0.46 and 0.67 for EW, 0.39 and 0.49 for BWFE and 0.32 and 0.55 for AFE. Kumar *et al.*[23] estimated heritability for AFE, BW, EN and EW as 0.42, 0.39, 0.25 and 0.28, respectively, the results (except EW) agree with the heritability of this study prediction.

The estimated heritability values for EW in this study were generally within the range of values reported in previous studies, although Ahrabi[24] estimated that the heritability of EW in Isfahan native fowl (0.36 and 0.46) was lower than the results of the present. Friars *et al.*[25] suggested that selection was not affected by heritability for as many as 10 generations of a selection experiment. Rath *et al.*[26] estimated that heritability of EW from the sire+dam and sire were 0.360 ± 0.131 and 0.443 ± 0.160, respectively.

In this study, EW was not considered in selecting dam lines as sire lines and just enough emphasis was placed on this trait to prevent its further decline. In RIR-1, selection was directed at improving EW as well as EN. The changes that have taken place in the selected strains are illustrated in Fig. 4, it can be observed that EW of RIR-1 was 4 g heavier than that of BAR-1. The genetic relationship between economically important traits and their trends were investigated in the selected populations during the study.

CONCLUSION

The heritabilities in the two lines were inclose values or with little differences during the period of selection study and the estimated heritabilities were generally moderate or high. The results of this study showed that selection of the laying hens according to four egg production traits was achieving improvement. After the obtained results were evaluated, it was concluded that it would be useful to continue the selection study.

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