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Developments in the performance of brown egg layer parental stocks for superior hybrid

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Abstract: This study examines the effect of grandparent, parent, and hybrid brown chickens, selected from 3 generations of pure lines, on hybrid egg-laying performance. The study was conducted at the Poultry Research Station of Ankara. In the first stage, 4 grandparent lines were derived from 2 pure line base populations. Grandparent lines included 2 male lines (low body weight and high egg weight) and 2 female lines (low body weight and high egg production). In the second stage, grandparent male and female lines were reciprocally crossed to produce 4 parent lines. In the third stage, male and female parental lines were crossed to produce 4 hybrid lines. The average age at first egg of grandparents, parents, and hybrids was 147.68, 154.46, and 157.53 days, respectively; body weight was 1662.95, 1699.19, and 1684.24 g, respectively; average number of eggs was 128.10 (43 weeks), 241.84 (64 weeks), and 303.89 (72 weeks), respectively; and egg weight was 57.46 (43 weeks), 58.28 (64 weeks), and 68.89 g (72 weeks), respectively. As a result, this study produced 4 parent lines with good combining ability for hybrids.

Key words: Laying hen, female line, male line, hybrid material, genetic correlations

1. Introduction

In Turkey, genetic research on egg laying has been carried out by the Poultry Research Station (PRS) since 1930. The traditional breeding programs of the PRS apply traits such as age at first egg (AFE), body weight at first egg (BWFE), egg number (EN), egg weight (EW), and egg quality to the improvement of parent lines and the production of layer hybrids. The PRS is currently preserving and developing its genetic resources. There has been a dramatic reduction in the number of poultry genetic companies around the world, which has resulted in the reduction of genetic potential, gene pools, and genetic variability (1). Field performance is based on selection decisions used by companies active in breeding across the world (2). Poultry breeders must consider many economically important traits. Food consumption, which has a positive correlation with body weight, is an important cost in the production of eggs. It is difficult to apply sufficient selection pressure on key traits in egg-laying stock (3). The aim of this study is to increase egg numbers and egg weight and decrease body weight, thus reducing food consumption.

2. Materials and methods

2.1. Animals and experimental design

The base populations were formed from 2 brown eggshell pure lines, Rhode Island Red and Barred Rock, which were part of a selection and crossbreeding study by the PRS. These lines have been selected for egg production traits since 1995. Flock structure constituted an average of 200 cocks and 1500 hens per line, and 30% were selected as parents of the next generations (1995 to 2006). Both pure lines were formed from 50 families that consisted of 1 male and 9 females (9 hens were artificially inseminated with the semen of 1 male). Fifty-four females and 6 males were selected as grandparents for each characteristic. This study used 4 grandparents with low body weight from Rhode Island Red (GP1), high egg weight from Rhode Island Red (GP2), high egg production from Barred Rock (GP3), and low body weight from Barred Rock (GP4). Four parent combinations were established as GP1 × GP2, GP3 × GP4, GP2 × GP1, and GP4 × GP3. These combinations were abbreviated as P1, P2, P3, and P4, respectively, and their hybrid combinations were produced. Hybrid combinations were abbreviated as indicated below:

H1: P1 × P2, H2: P3 × P4, H3: P3 × P2, H4: P1 × P4.

The study was performed in compact-type, 3-floor individual battery cages. The size of each cage was 50 × 30 × 59 cm (width × length × height). Cage floor area was 0.15 m^2 per hen. Feed and water were provided ad libitum during the experiment. Light was provided for 15 h daily during laying period. The study used 2464 grandparent

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hens and 243 cocks (first generation GP: 672 hens and 60 cocks; second generation GP: 740 hens and 85 cocks; third generation GP: 1052 hens and 98 cocks), 624 parent hens and 35 cocks, and 1203 hybrid hens.

2.2. Defined traits

Egg number, mortality, and cracked and broken eggs were recorded daily on a card that included the wing number of each hen. All the eggs were numbered and weighed. One weighed egg from each hen was used to determine egg quality characteristics at weighing time. Eggs were broken onto a flat glass surface for internal quality and shell quality analysis. These processes were completed within 24 h of egg collection. Twenty hens were selected randomly from each group and were weighed on scheduled days between 28 and 64 weeks of age. Feed consumption was also recorded.

Age at first egg (AFE): Defined as the age of the hen on the day of the first egg.

Body weight at first egg (BWFE): The weight of the chickens on the day of their first egg as measured using a 20-g precision scale.

Egg number (EN): The number of eggs laid at 43 weeks for grandparents, 64 weeks for parents, and 72 weeks for hybrids.

Hatching egg rate (HER): All defective eggs (i.e. eggs with cracks, double yolks, and shell-less eggs) were eliminated, and only intact eggs were regarded as hatching. HER was calculated using the formula egg number placed in incubator / total egg number.

Cracked and broken eggs rate (CBER): CBER was calculated using the formula cracked and broken egg number / total egg number.

Egg weight (EW): When eggs were collected on weighing days, wing numbers were written individually on the egg by pencil. The numbered eggs were transported to the laboratory for weighing. Three successive eggs laid on the 28th, 32nd, and 36th weeks were weighed and their mean weight was calculated. The mean weight for grandparent and parent genotypes was determined at 64 weeks, and for hybrids at 72 weeks (3 successive eggs were weighed every 4 weeks).

Egg mass (EM): EM was calculated by multiplying egg weight by egg number.

Egg shape index (ESI): ESI was measured by standard mechanical egg shape index tool that measures the index value automatically, using the formula ESI = (W / L) × 100, where L is length and W is width of egg.

Egg shell breaking strength (ESBS): ESBS was measured with a Newton-type Futura resistance meter.

Egg shell thickness (EST): After manually removing shell membranes, eggshell thickness (without inner and outer shell membranes) was measured according to 3 different values (upper and lower ends and middle) using a FUTURE digital micrometer. The average thickness value of the egg described eggshell thickness.

Albumen height (AH): Albumen height was determined by FUTURA albumen height measuring systems.

Haugh unit (HU): HU was calculated using the formula $HU = 100 \log (H + 7.57 - 1.7W^{0.37})$, in which HU is Haugh unit, H is albumen height (mm), and W is egg weight (g).

Feed consumption (FC): At 16 weeks of age, 20 birds were randomly selected from the parent and hybrid groups for assessment of feed consumption. The mean feed consumption was calculated by subtracting the feed remaining in the feeders from the amount of feed added to the feeders.

Feed conversion ratio (FCR): The ratio of the weight of feed eaten by a bird to the weight of its egg production. Mean feed consumption of the groups was calculated.

Grandparents: AFE, BWFE, EN, EW, heritability, genetic correlation, and phenotypic correlation were measured.

Parents: AFE, BWFE, EN, EW, HER, FC, BW at 28 and 32 weeks, and ESI at 24 and 60 weeks were measured.

Hybrids: AFE, BWFE, EN, EW, FC, cracked and broken egg rate, and egg quality characteristics were measured.

2.3. Model and data analysis

Variance components for grandparents were calculated using an animal model:

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

where Y_{irxn} is the record of the *n*th progeny of the *r*th female mated to the *i*th male in the *x*th year, μ is the common mean, s_i is the effect of the *i*th male (i = subscript for male), $d_r(s_i)$ is the fixed effect of the *r*th female, which is mated to the *i*th male (r = subscript for female), b_x is the fixed effect of the year (x = subscript for year), e_{irxn} is the random error, and e is assumed as $N(0, \theta^2)$.

Computations were performed using the Multiple Trait Restricted Maximum Likelihood package programs (4).

One-way ANOVA was used to determine the differences between grandparent, parent, and hybrid groups. When a significant difference was found, a post hoc Duncan's multiple comparison test was conducted. Statistical significance was determined at $P \leq 0.05$ (5).

3. Results

3.1. Grandparents

A mean of performance characteristics for grandparents is presented in Table 1.

In order to observe the selected groups, heritability and genetic and phenotypic correlations between traits were estimated for 3 generations of grandparents (Table 2).

AFE and BWFE were significantly different ($P < 0.05$) between the observed lines. Body weight at first egg was significantly ($P < 0.05$) higher in lines GP2 and GP4

Table 1. The performance characteristics of grandparents during 43-week laying period.

	n	AFE (days)	BWFE (g)	EN (number)	EW (g)
GP1	283	147.61[b] ± 0.26	1504.93[c] ± 7.50	127.01[b] ± 0.96	53.03[d] ± 0.17
GP2	298	146.48[c] ± 0.28	1736.98[a] ± 6.69	135.54[a] ± 0.75	55.40[c] ± 0.16
GP3	268	150.90[a] ± 0.44	1687.33[b] ± 7.99	125.81[b] ± 0.87	58.59[b] ± 0.22
GP4	203	146.91[bc] ± 0.41	1756.71[a] ± 9.12	127.06[b] ± 1.06	62.14[a] ± 0.22
P	-	<0.0001	<0.0001	<0.0001	<0.0001

[a–d]Means within columns with different letters are significantly different ($P < 0.05$).

compared to lines GP3 and GP1. Line GP2 produced significantly ($P < 0.05$) more eggs than the other lines. EW was higher in line GP4 than in other examined lines (Table 1).

In line GP1, BWFE positively correlated with EW, but there were negative genetic correlations between other traits. In line GP2, although AFE positively correlated with EN, there were negative genetic correlations between other traits. BWFE negatively correlated with EN and EW negatively correlated with other traits in line GP3. As shown in Table 2, AFE and egg production had lower degrees of heritability than other characteristics. Except for AFE and EW, there were positive genetic correlations between traits. EW negatively correlated with AFE, BWFE, and EN in line GP4. Estimated heritability of egg production traits in GP1 was generally higher than in the other grandparent groups. The highest heritability was estimated for BWFE (0.65). According to this estimation, BWFE can be easily reduced.

Heritability of AFE was 0.34, 0.18, 0.19, and 0.21 in lines GP1, GP2, GP3, and GP4, respectively. BWFE heritability

Table 2. Estimated heritability, genetic, and phenotypic correlations of grandparents.

	Traits	AFE (days)	BWFE (g)	EN (number)	EW (g)
GP1	AFE (days)	**0.34 ± 0.07**	−0.02 ± 0.01	−0.26* ± 0.00	0.18* ± 0.01
	BWFE (g)	−0.08 ± 0.15	**0.65 ± 0.07**	0.14* ± 0.06	0.16* ± 0.03
	EN (number)	−0.58* ± 0.12	−0.82* ± 0.05	**0.60 ± 0.07**	−0.27* ± 0.00
	EW (g)	−0.04 ± 0.17	0.48* ± 0.11	−0.26* ± 0.14	**0.48 ± 0.08**
GP2	AFE (days)	**0.18 ± 0.07**	0.09 ± 0.17	0.06 ± 0.04	0.02 ± 0.08
	BWFE (g)	−0.33* ± 0.25	**0.35 ± 0.08**	−0.11 ± 0.17	−0.05 ± 0.05
	EN (number)	0.30* ± 0.25	−0.96* ± 0.02	**0.35 ± 0.08**	0.01 ± 0.04
	EW (g)	−0.04 ± 0.26	−0.06 ± 0.20	−0.29* ± 0.19	**0.41 ± 0.09**
GP3	AFE (days)	**0.19 ± 0.06**	0.09 ± 0.06	−0.05 ± 0.00	−0.07 ± 0.03
	BWFE (g)	0.41* ± 0.18	**0.48 ± 0.08**	−0.27* ± 0.00	0.37* ± 0.00
	EN (number)	0.03 ± 0.25	−0.73* ± 0.12	**0.20 ± 0.06**	−0.06 ± 0.04
	EW (g)	−0.05 ± 0.22	0.11 ± 0.18	0.29* ± 0.20	**0.35 ± 0.08**
GP4	AFE (days)	**0.21 ± 0.07**	−0.02 ± 0.03	−0.02 ± 0.01	−0.08 ± 0.05
	BWFE (g)	0.17* ± 0.18	**0.62 ± 0.08**	−0.02 ± 0.04	0.34* ± 0.00
	EN (number)	0.32* ± 0.26	0.47* ± 0.18	**0.17 ± 0.07**	−0.16* ± 0.04
	EW (g)	−0.29* ± 0.19	0.53* ± 0.09	0.67* ± 0.13	**0.67 ± 0.07**

Heritabilities are given on the diagonal with bold, genetic correlations below diagonal, phenotypic correlations above diagonal.
*P-values for correlation coefficients significantly different ($P < 0.05$).

in lines GP1, GP2, GP3, and GP4 was estimated as 0.65, 0.35, 0.48, and 0.62, respectively. Heritability of BWFE was within the same order of magnitude in lines GP4 and GP1. EN values of heritability in lines GP4 and GP3 were lower than in lines GP1 and GP2 (0.17, 0.20, 0.60, and 0.35, respectively). Heritability of EW was higher in line GP4 (0.67) than in lines GP1, GP3, and GP2 (0.48, 0.35, and 0.41, respectively). Heritability in line GP4 showed significant differences according to egg production characteristics.

3.2. Parents

Hatching egg rate (HER) ranged from 83.61% to 86.41%. Feed consumption in P3 was significantly lower than in P1, P2, and P4. There were no significant differences in feed consumption between P1, P2, and P4 (Table 3).

EW of P3 was significantly higher than that of P1, P2, and P4. There were no significant differences in EW between P1 and P2. Egg production was significantly lower for P3 than for P1, P2, and P4 at 64 weeks (Table 3). BWFE and AFE were statistically significant ($P < 0.05$) for the examined lines. Body weight at first egg in line P3 was significantly ($P < 0.05$) higher than body weight at first egg in other lines.

A statistically significant ($P < 0.05$) difference in body weight between parent lines occurred at 32 weeks (Table 4). Egg shape index of P1 and P2 lines at 24 weeks was significantly different from egg shape index of P3 and P4 lines. The index of line P2 was varied at 60 weeks, as was the case with the other lines. Egg shape index in hens was lower at 60 weeks compared to 24 weeks (Table 4). The value was lower for older hens, and the shape of the eggs was becoming rounder.

3.3. Hybrids

H1 had higher EN than other hybrids with 310 eggs in 72 weeks. EW of H3 and H4 was significantly higher than in H1 and H2. Feed consumption was significantly higher for H4 than for other hybrid genotypes. The mean FCR per gram value in H1, H2, H3, and H4 was 1.97, 2.07, 2.11, and 2.25, respectively. Data analysis showed that hybrid genotypes H2, H3, and H4 were significantly less efficient in feed conversion compared to genotype H1. Mean FCR value between groups H2 and H3 was not significantly different ($P > 0.05$). The rate of cracked and broken eggs was higher in H3 and H4 than in H1 and H2 hybrid genotypes. The rate of cracked and broken eggs increased with increasing EW (Table 5).

Table 3. Egg production traits, hatching egg rate, and feed consumption of parents during 64-week-old laying period.

	AFE (days)	BWFE (g)	EN (number)		HER (%)	FC (kg feed/bird)
P1	142.71^{c} ± 0.65	1589.50^{b} ± 7.85	242.83^{a} ± 2.04	55.44^{c} ± 0.31	86.41	42,770^{a}
P2	149.46^{b} ± 0.73	1606.57^{b} ± 7.62	245.58^{a} ± 1.61	56.15^{c} ± 0.25	86.12	41,125^{ab}
P3	155.22^{a} ± 0.85	1656.72^{a} ± 8.45	233.19^{b} ± 3.09	61.86^{a} ± 0.30	83.05	40,467^{b}
P4	149.87^{b} ± 0.88	1592.90^{b} ± 7.53	245.74^{a} ± 2.96	59.72^{b} ± 0.28	83.61	42,112^{a}
P	<0.0001	<0.0001	0.001	<0.0001	-	0.003

$^{a–c}$Means within columns with different letters are significantly different ($P < 0.05$).

Table 4. Average body weight at 28 weeks of age and 32 weeks of age and egg shape index at 24 weeks and 60 weeks of parents.

	n	BW (g)		ESI (%)	
		28 weeks old	32 weeks old	28 weeks old	32 weeks old
P1	156	1688.14 ± 26.37	1750.09^{b} ± 23.41	78.43^{c} ± 0.14	77.45^{a} ± 0.19
P2	155	1695.06 ± 20.88	1748.73^{ab} ± 17.72	78.28^{c} ± 0.20	76.69^{b} ± 0.18
P3	156	1771.03 ± 33.94	1836.88^{a} ± 30.19	79.84^{b} ± 0.17	76.60^{b} ± 0.19
P4	157	1731.98 ± 34.40	1797.21^{ab} ± 41.26	80.46^{a} ± 0.15	76.47^{b} ± 0.18
P	-	0.097	0.046	<0.0001	0.002

$^{a–c}$Means within columns with different letters are significantly different ($P < 0.05$).

Table 5. Egg production, egg weight, feed consumption, feed conservation ratio, and cracked and broken egg rate of hybrids during 72-week laying period.

	EN (per hen)	EW (g)	EM (g e/b)	FC (g f/b)	FCR (f/e)	CBER (%)
H1	310.51^{a} ± 0.77	63.64^{c}	19,762.17	39,049.74^{d}	1.97^{c}	1.78
H2	304.58^{b} ± 0.67	65.05^{b}	19,807.72	41,174.97^{c}	2.07^{b}	2.13
H3	304.14^{b} ± 0.72	66.71^{a}	20,287.80	42,812.99^{b}	2.11^{b}	2.41
H4	296.40^{c} ± 0.68	66.29^{a}	19,650.34	44,401.26^{a}	2.25^{a}	2.25
P	<0.0001	<0.0001	-	<0.0001	0.002	-

$^{a–d}$Means within columns with different letters are significantly different (P < 0.05).
f: feed, b: bird, e: egg.

Average egg quality characteristics of egg shape index, shell thickness, shell strength, albumen height, and Haugh unit values were studied for the first period (weeks 24–40) and second period (weeks 41–72) to determine how egg production traits changed with chicken age. Hen age generally affected egg quality negatively. While shell thickness, shell strength, albumen height, and Haugh units decreased, egg shape index increased during the second period. Average values of external and internal quality traits of hybrid genotypes are presented in Table 6.

4. Discussion

The results of this research were generally consistent with findings presented in the literature on the performance of laying hens. Several hybrid program variations were utilized in the development and selection of commercial poultry stocks (6). Genetic improvement of poultry was based on 2 alternative approaches: crossbreeding and selection. A feature that was found to improve laying hen performance was reduced body weight (7). The success of this project depended on the availability of 4 grandparent lines with good combining ability to provide heterosis. Selection of BW, EW, and EN in grandparent lines resulted in significant changes in parents and hybrids. During the project feed efficiency was improved by decreasing hen weight and increasing egg mass. Aktan et al. (8) studied hybrid chickens produced from the same pure lines used in this project. At 72 weeks they recorded a live weight of 2066.90 g, egg production of 305.10 eggs/hen, EW of 69.30 g, 18–72 weeks average food intake per chicken

Table 6. Egg quality characteristics of hybrids at 24 weeks and 64 weeks of age

		ESI (%)	EST (mm)	ESBS (kg/cm^2)	AH (mm)	HU
1st per (24–40 weeks)	H1	76.17^{b} ± 0.25	0.43^{a} ± 0.00	4.14^{a} ± 0.10	6.33^{b} ± 0.14	78.34^{b} ± 1.09
	H2	78.06^{a} ± 0.25	0.41^{c} ± 0.00	3.51^{b} ± 0.12	7.08^{a} ± 0.13	82.72^{a} ± 0.89
	H3	76.23^{b} ± 0.27	0.42^{b} ± 0.00	3.87^{a} ± 0.09	7.01^{a} ± 0.09	82.50^{a} ± 0.59
	H4	76.50^{b} ± 0.26	0.41^{c} ± 0.00	2.99^{c} ± 0.06	7.09^{a} ± 0.14	82.75^{a} ± 0.94
	P	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
2nd per (41–72 weeks)	H1	75.72^{b} ± 0.28	0.36^{a} ± 0.003	3.82^{a} ± 0.10	5.80^{b} ± 0.10	72.68^{b} ± 0.84
	H2	77.49^{a} ± 0.25	0.34^{bc} ± 0.00	3.75^{ab} ± 0.11	6.46^{a} ± 0.13	77.21^{a} ± 1.03
	H3	75.60^{b} ± 0.28	0.35^{b} ± 0.00	3.45^{c} ± 0.10	6.43^{a} ± 0.08	77.16^{a} ± 0.62
	H4	75.77^{b} ± 0.20	0.34^{c} ± 0.00	3.49^{bc} ± 0.05	6.71^{a} ± 0.10	78.54^{a} ± 0.79
	P	<0.0001	<0.0001	0.017	<0.0001	<0.0001

$^{a–c}$Means within columns with different letters are significantly different (P < 0.05).

of 119.79 g, and feed conversion ratio of 2.28 (kg feed/kg egg). Akbaş et al. (9) researched brown layer hybrids. They reported an average eggshell thickness of 0.38 mm, eggshell strength of 2.96 kg/cm^2, albumen height of 6.93 mm, and Haugh unit of 81.55. Zhang et al. (10) recorded heritability of albumen height, albumen weight, eggshell color, eggshell index, eggshell strength, eggshell thickness, eggshell weight, EW, Haugh units, and yolk weight in brown egg dwarf hens. These were reported as 0.51, 0.59, 0.46, 0.40, 0.24, 0.34, 0.64, 0.63, 0.41, and 0.45, respectively. This research observed negative genetic correlations between EW and EN in GP1 and GP2 lines, but positive genetic correlations between these traits in GP3 and GP4 lines. Breeding companies have been breeding and selecting closed pure line populations for decades, and started to hybridize commercial poultry in the 1940s. Icken et al. (11) reported that all breeding plans for commercial egg laying stocks have one major common objective: to increase the genetic potential of a laying hen population in order to produce a maximum number of marketable eggs at minimum cost. Within lines, there was a separation between male and female chickens, which were crossed to produce commercial hybrids. The primary selection goal for both lines was the improvement of feed efficiency and the achievement of economic gain. Selection indexes generally included a large number of characteristics, which formed the basis of the breeding program. In the overall selection index, each characteristic was assessed in relation to the breeding goal. A higher number of characteristics in the selected lines causes less performance quality for each laying hen. Therefore, the lines should be developed with specific characteristics. Under the conditions of the current study, sire lines can be developed in terms of high EW, low body weight, dam lines, high egg production, and low body weight. In the present study, the desired characteristics were brought together in the hybrid lines without reducing the external and internal egg quality.

As a result of this project, it was found that developed genotypes are quite a valuable material for Turkey. To improve egg production performance, the selection and production process of these genotypes should continue. Two planned projects that produced animals from these genotypes were successfully carried out. It is concluded that dispersing these genotypes would be more appropriate for Atak-S chickens than using commercial breeding firms. The results of this project can reduce dependency on international stock production and can contribute to the economy by selling the obtained genotypes to national and international egg production companies.

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