Genetic parameters of egg quality traits in two strains of Japanese quails

B. Punya Kumari*, B. Ramesh Gupta and M. Gnana Prakash

Sri Venkateswara Veterinary University,
Tirupati-517 502, India.
Received: 15-11-2014 Accepted: 09-06-2015 DOI: 10.18805/ijar.10710

ABSTRACT
Present study was carried out to estimate the genetic and phenotypic parameters among external, internal egg quality traits and quality indices in Black and Brown Japanese quails. A total of 1218 eggs collected consecutively for three days at 16 weeks of age from 202 Black and 204 Brown Japanese quails were utilized in the present study to record the data on external and internal egg quality traits. The overall least squares means for EW, EL, EWD, SW, ST, AL, AWD, AH, AW, YD, YH, YW, YFC, SI, AI, YI and HUS were 13.63 g, 33.85 mm, 26.76 mm, 1.14 g, 0.21 mm, 42.63 mm, 33.45 mm, 5.04 mm, 7.95 g, 24.53 mm, 11.43 mm, 4.53 g, 5.66, 79.18, 0.13, 0.47 and 60.09, respectively. Majority of the heritability estimates for egg quality traits were within the range of moderate to high and suggested the existence of sizeable genetic variability for exploitation by appropriate selection procedure.

Key words: Egg quality traits, Genetic parameters, Heritability, Japanese quails.

INTRODUCTION
Japanese quails (Coturnix coturnix japonica), the tiny farmed avian species gaining more importance as commercial egg and meat producer. The average age at first egg in Japanese quail is 6-8 weeks and quails can lay up to 280 to 300 eggs in their first year of lay. Quality of eggs had great influence on breeding and marketing of eggs since the external egg quality traits have direct effect not only on hatchability and development of chicks, but also related with the number of salable eggs. Even though, several publications (Chaudhary et al., 1999; Dhaliwal et al., 2003 and Kui and Seker 2004) reported the means for external egg quality traits and phenotypic parameters among them in Japanese quails, but the literature on genetic parameters viz., heritability, genetic, phenotypic and environmental correlations among external, internal egg quality traits and quality indices is scanty and limited. Hence, the present investigation was undertaken to study the effects of strain, generation and hatch on external, internal egg quality traits and quality indices and also to estimate phenotypic and genetic variation among all the egg quality traits under study in Black and Brown Japanese quails.

MATERIALS AND METHODS
The study was conducted on 100 Black and 102 Brown Japanese quails belonging to 6th and 102 Black and 102 Brown Japanese quails belonging to 7th generations maintained during the years 2006 to 2007 at Poultry Experimental Station, College of Veterinary Science, Rajendranagar. Total of 1218 eggs were collected in three sequential days from total of 406 Black and Brown female Japanese quails at 16 weeks of age and utilized for the measurement of external egg quality traits viz., egg weight (EW), egg width (EWD), egg length (EL), shell weight (SW), shell thickness (ST) and internal egg quality traits (albumen weight (AW), albumen length (AL), albumen width (AWD), albumen height (AH), yolk weight (YW), yolk diameter (YD), yolk height (YH) and yolk fan colour (YF). Based on the data collected on various egg quality traits, egg quality indices viz., shape index, Albumen index (Heiman and Carver, 1936) and Yolk index ((Funk, 1948) were computed. The weight of each egg was recorded with electronic digital balance to the accuracy of 0.01 g. The longer and wider diameter of the egg was measured using Vernier calipers with an accuracy of 0.01 mm. The eggs were then broken on a perfectly leveled glass plate. The length and width of the thick albumen spread on the glass plate were measured at the longest point by vernier calipers and expressed as percentages. The transformation of

*Corresponding author’s e-mail: punya67@yahoo.co.in.
percentage data (egg quality traits) in to arc-sin values was undertaken wherever the percentages ranged from near zero to 30% and from 70% to 100% (Snedecor and Cochran, 1967). The data generated on egg quality traits was subjected to least squares analysis (Harvey, 1979) to study the effects of strain, generation and hatch and the data adjusted for generation and hatch effects was utilized for estimation of genetic parameters (Becker, 1985).

**RESULTS AND DISCUSSION**

The results of least squares analysis of variance of egg quality traits of Japanese quails revealed that strain, generation and hatch had a significant influence not only on egg quality indices but also on percentages of albumen and yolk, EW, EWD, SW, AL, AH, YD, YH and YF.

The least square means for various egg quality traits according to the strains, generations and hatches are shown in Table 1. The overall least squares means for EW, EL, EWD, SW, ST, AL, AWD, AH, AW, YD, YH, YW, YFC, SI, AL, YI and HUS were 13.63 g, 33.85 mm, 26.76 mm, 1.14 g, 0.21 mm, 42.63 mm, 33.45 mm, 5.04 mm, 7.95 g, 24.53 mm, 11.43 mm, 4.53 g, 5.66, 79.18, 0.13, 0.47 and 60.09, respectively. The albumen, yolk and shell weights constituted 58.30, 33.28 and 8.41 per cent of the egg weight, respectively.

The overall least squares means obtained in this study for EW (13.63 g), EL (33.85 mm), EWD (26.76 mm), SW (1.14 g) and ST (0.21 mm), internal egg quality traits and quality indices were within the range of means reported by Chaudhary et al. (1999), Nazilugul et al., 2001 and Sezer (2007), where as Dhaliwal et al. (2003) reported the lower mean percentages for albumen, yolk and shell than those in the present study. The means higher than those in the present investigation were observed by Tiwari (1976), Sreenivasaiah (1977) and Altinel et al. (1996).

The eggs of Brown Japanese quails were found to be slightly heavier (13.74 g) and wider (26.90 mm) than those of Black Japanese quails (13.51 g and 26.62 mm). Brown Japanese quails recorded significantly higher means for SW (1.16 g), AL (43.68 mm), YD (24.69 mm), YFC (5.78), SI (79.49) and SP (8.47) than Black Japanese quails, while Black Japanese quails were superior with significantly higher means for AH (5.16 mm), AI (0.14), HUS (61.78) and YP (33.56).

Generation had significant effect (P<0.01) on AWD, AH, YF, AI, YI, HUS, AP and YP. Chicks of generation 7 recorded significantly (P<0.01) higher means for AWD (33.89 mm), YFC (5.72) and YP (33.51), while, the females of generation 6 recorded higher means for other traits. The dams in the present study were selected based on individual selection for high 4-week body weight up to 5 generations, but in generations 6 and 7, the dams were selected based on their body weight at 4 weeks of age, AFE and EP up to 16 weeks of age, which resulted in selection of birds with mediocre body weights but better in their AFE and egg production, that has resulted in eggs with lower means in generations 6 and 7 compared to earlier generations.

Significant (P<0.01) effect of hatch was noticed on majority of egg quality traits. The hens of hatch 7 produced

| Table 1: Least squares means of egg quality traits of Japanese quails |
|------------------------|----------------|----------------|----------------|----------------|----------------|
| Trait                  | Overall (n=406) | Black (n=202) | Brown (n=204) | Generation 6 (n=202) | Generation 7 (n=204) |
|                        | Mean   | SE   | Mean   | SE   | Mean   | SE   | Mean   | SE   | Mean   | SE   |
| Egg weight (g)         | 13.63  | 0.06 | 13.51  | 0.08 | 13.74  | 0.07 | 13.63  | 0.08 | 13.63  | 0.07 |
| Egg length (mm)        | 33.85  | 0.07 | 33.81  | 0.09 | 33.89  | 0.09 | 33.79  | 0.10 | 33.91  | 0.08 |
| Egg width (cm)         | 26.76  | 0.04 | 26.62  | 0.05 | 26.90  | 0.05 | 26.76  | 0.06 | 26.77  | 0.05 |
| Shell weight (g)       | 1.14   | 0.00 | 1.13   | 0.01 | 1.16   | 0.01 | 1.15   | 0.01 | 1.14   | 0.01 |
| Shell thickness (mm)   | 0.21   | 0.00 | 0.21   | 0.00 | 0.22   | 0.00 | 0.21   | 0.00 | 0.21   | 0.00 |
| Albumen length (mm)    | 42.63  | 0.14 | 41.58  | 0.20 | 43.68  | 0.19 | 42.68  | 0.22 | 42.59  | 0.19 |
| Albumen width (mm)     | 33.45  | 0.11 | 33.55  | 0.15 | 33.36  | 0.14 | 33.02  | 0.16 | 33.89  | 0.14 |
| Albumen height (mm)    | 5.04   | 0.03 | 5.16   | 0.04 | 4.92   | 0.04 | 5.27   | 0.04 | 4.80   | 0.04 |
| Albumen weight (g)     | 7.95   | 0.04 | 7.85   | 0.05 | 8.05   | 0.05 | 7.98   | 0.06 | 7.91   | 0.05 |
| Yolk diameter (mm)     | 24.53  | 0.05 | 24.38  | 0.07 | 24.69  | 0.07 | 24.46  | 0.08 | 24.61  | 0.07 |
| Yolk height (mm)       | 11.43  | 0.03 | 11.43  | 0.04 | 11.43  | 0.04 | 11.49  | 0.04 | 11.17  | 0.04 |
| Yolk weight (g)        | 4.53   | 0.02 | 4.54   | 0.03 | 4.53   | 0.03 | 4.50   | 0.04 | 4.57   | 0.03 |
| Yolk fan               | 5.66   | 0.03 | 5.53   | 0.04 | 5.78   | 0.04 | 5.60   | 0.05 | 5.72   | 0.04 |
| Shape index            | 79.18  | 0.14 | 78.86  | 0.19 | 79.49  | 0.19 | 79.33  | 0.21 | 79.02  | 0.18 |
| Albumen index          | 0.13   | 0.01 | 0.14   | 0.00 | 0.13   | 0.00 | 0.14   | 0.00 | 0.13   | 0.00 |
| Yolk index             | 0.47   | 0.01 | 0.47   | 0.00 | 0.46   | 0.00 | 0.48   | 0.00 | 0.45   | 0.00 |
| Haugh unit score       | 60.09  | 0.35 | 61.78  | 0.48 | 58.41  | 0.47 | 63.21  | 0.53 | 56.97  | 0.45 |
| Percentage Albumen     | 58.30  | 0.12 | 58.07  | 0.16 | 58.54  | 0.16 | 58.55  | 0.18 | 58.06  | 0.15 |
| Percentage yolk        | 33.28  | 0.12 | 33.56  | 0.16 | 32.99  | 0.16 | 33.04  | 0.18 | 33.51  | 0.16 |
| Percentage shell       | 8.41   | 0.00 | 8.36   | 0.00 | 8.47   | 0.00 | 8.41   | 0.00 | 8.42   | 0.00 |

Means followed by the same superscript(s) do not differ significantly (P<0.05) Contd.,
<table>
<thead>
<tr>
<th>Trait</th>
<th>Hatch 1 (n=69) SE</th>
<th>Hatch 2 (n=64) SE</th>
<th>Hatch 3 (n=66) SE</th>
<th>Hatch 4 (n=49) SE</th>
<th>Hatch 5 (n=59) SE</th>
<th>Hatch 6 (n=54) SE</th>
<th>Hatch 7 (n=66) SE</th>
<th>Hatch 8 (n=22) SE</th>
<th>Hatch 9 (n=20) SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell thickness (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.62±0.12</td>
<td>13.42±0.16</td>
<td>13.58±0.13</td>
<td>13.54±0.15</td>
<td>13.58±0.09</td>
<td>13.37±0.09</td>
<td>13.55±0.09</td>
<td>13.67±0.12</td>
<td>13.58±0.12</td>
</tr>
<tr>
<td>Albumen weight (g)</td>
<td>33.83±0.14</td>
<td>33.68±0.12</td>
<td>33.70±0.09</td>
<td>33.31±0.10</td>
<td>33.70±0.09</td>
<td>33.68±0.09</td>
<td>33.70±0.09</td>
<td>33.68±0.09</td>
<td>33.70±0.09</td>
</tr>
<tr>
<td>Yolk diameter (mm)</td>
<td>26.79±0.09</td>
<td>26.67±0.09</td>
<td>26.67±0.09</td>
<td>26.72±0.09</td>
<td>26.67±0.09</td>
<td>26.67±0.09</td>
<td>26.67±0.09</td>
<td>26.67±0.09</td>
<td>26.67±0.09</td>
</tr>
<tr>
<td>Yolk weight (g)</td>
<td>1.14±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
<td>1.12±0.01</td>
</tr>
<tr>
<td>Albumen index</td>
<td>42.55±0.32</td>
<td>42.12±0.21</td>
<td>42.76±0.03</td>
<td>42.96±0.03</td>
<td>42.12±0.21</td>
<td>42.76±0.03</td>
<td>42.96±0.03</td>
<td>42.12±0.21</td>
<td>42.76±0.03</td>
</tr>
<tr>
<td>Yolk index</td>
<td>33.29±0.24</td>
<td>33.18±0.20</td>
<td>33.46±0.28</td>
<td>34.06±0.24</td>
<td>33.18±0.20</td>
<td>33.46±0.28</td>
<td>34.06±0.24</td>
<td>33.18±0.20</td>
<td>33.46±0.28</td>
</tr>
<tr>
<td>SP</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
<td>7.88±0.06</td>
</tr>
<tr>
<td>YH</td>
<td>24.69±0.12</td>
<td>24.28±0.16</td>
<td>24.57±0.12</td>
<td>24.57±0.12</td>
<td>24.57±0.12</td>
<td>24.57±0.12</td>
<td>24.57±0.12</td>
<td>24.57±0.12</td>
<td>24.57±0.12</td>
</tr>
<tr>
<td>YW</td>
<td>4.63±0.05</td>
<td>4.48±0.07</td>
<td>4.55±0.07</td>
<td>4.55±0.07</td>
<td>4.55±0.07</td>
<td>4.55±0.07</td>
<td>4.55±0.07</td>
<td>4.55±0.07</td>
<td>4.55±0.07</td>
</tr>
<tr>
<td>AP</td>
<td>52.28±0.31</td>
<td>79.31±0.39</td>
<td>79.35±0.31</td>
<td>79.45±0.27</td>
<td>79.31±0.39</td>
<td>79.35±0.31</td>
<td>79.45±0.27</td>
<td>79.31±0.39</td>
<td>79.35±0.31</td>
</tr>
<tr>
<td>YP</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
</tr>
<tr>
<td>HUS</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
<td>34.17±0.14</td>
</tr>
<tr>
<td>Percentage Albumen</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
<td>34.10±0.04</td>
</tr>
<tr>
<td>Percentage Yolk</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
<td>8.40±0.00</td>
</tr>
<tr>
<td>Percentage Shell</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
<td>9.83±0.00</td>
</tr>
</tbody>
</table>

Mean followed by the same superscript(s) do not differ significantly (P<0.05).

Heritability estimates for external egg quality traits in Brown Japanese quails varied from 0.06 to 0.38; while the estimates for internal egg quality traits ranged from 0.13 to 0.65. The heritability estimates for SI, AI, YI and HUS were 0.17, 0.03, 0.52, 0.86, 0.77 and 0.05 (low to high), respectively (Table 2).

Heritability estimates for external egg quality traits in Brown Japanese quails were within the range of moderate to high and suggested the existence of sizeable genetic variability for exploitation by appropriate selection procedure.

**Correlations:** The genetic, phenotypic and environmental correlations of EW with other external egg quality traits (EL, EWD, SW and ST) varied from -0.09 to 0.95, 0.01 to 0.87 and 0.17 to 0.85, respectively, in Black strain (Table 2). The genetic correlation of EW with EWD was 0.61 in Brown strain, whereas the phenotypic correlations were found to be positive but varied from low to high (0.10 to 0.84) in magnitude. The environmental correlations varied from 0.58.
Table 2: Estimates of genetic parameters among egg quality traits in Black Japanese quails

<table>
<thead>
<tr>
<th></th>
<th>EW</th>
<th>EL</th>
<th>EWD</th>
<th>SW</th>
<th>SI</th>
<th>AL</th>
<th>AWD</th>
<th>AW</th>
<th>YD</th>
<th>YH</th>
<th>YW</th>
<th>YF</th>
<th>SI</th>
<th>AI</th>
<th>YI</th>
<th>AP</th>
<th>YP</th>
<th>SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>EW</td>
<td>0.26</td>
<td>0.79</td>
<td>$</td>
<td>0.95</td>
<td>$</td>
<td>0.94</td>
<td>0.88</td>
<td>0.79</td>
<td>0.61</td>
<td>$</td>
<td>0.37</td>
<td>0.80</td>
<td>-0.55</td>
<td>$</td>
<td>0.26</td>
<td>-0.25</td>
<td>-0.17</td>
<td></td>
</tr>
<tr>
<td>EL</td>
<td>0.83</td>
<td>0.24</td>
<td>0.73</td>
<td>0.95</td>
<td>-0.11</td>
<td>0.85</td>
<td>0.43</td>
<td>0.87</td>
<td>0.60</td>
<td>$</td>
<td>0.18</td>
<td>$</td>
<td>-0.59</td>
<td>-0.82</td>
<td>-0.97</td>
<td>0.30</td>
<td>-0.33</td>
<td>0.34</td>
</tr>
<tr>
<td>EWD</td>
<td>0.87</td>
<td>0.57</td>
<td>0.32</td>
<td>0.66</td>
<td>0.08</td>
<td>0.95</td>
<td>0.78</td>
<td>0.95</td>
<td>0.58</td>
<td>$</td>
<td>0.22</td>
<td>0.13</td>
<td>0.12</td>
<td>0.47</td>
<td>-0.94</td>
<td>0.46</td>
<td>-0.41</td>
<td>$</td>
</tr>
<tr>
<td>SW</td>
<td>0.07</td>
<td>0.11</td>
<td>0.03</td>
<td>0.30</td>
<td>0.39</td>
<td>0.47</td>
<td>0.44</td>
<td>0.87</td>
<td>0.80</td>
<td>-0.75</td>
<td>0.46</td>
<td>$</td>
<td>-0.62</td>
<td>-0.97</td>
<td>-0.92</td>
<td>0.10</td>
<td>-0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>ST</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.41</td>
<td>0.07</td>
<td>-0.44</td>
<td>$</td>
<td>0.11</td>
<td>0.81</td>
<td>0.26</td>
<td>-0.44</td>
<td>0.26</td>
<td>$</td>
<td>0.71</td>
<td>0.35</td>
<td>-0.41</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>$</td>
<td>$</td>
<td>0.48</td>
<td>0.35</td>
<td>0.87</td>
<td>0.51</td>
<td>0.67</td>
<td>0.83</td>
<td>0.88</td>
<td>-0.32</td>
<td>0.58</td>
<td>$</td>
<td>-0.08</td>
<td>0.85</td>
<td>0.07</td>
<td>0.01</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>AWD</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>0.31</td>
<td>0.10</td>
<td>0.69</td>
<td>0.17</td>
<td>0.82</td>
<td>0.67</td>
<td>$</td>
<td>0.50</td>
<td>0.88</td>
<td>0.28</td>
<td>-0.11</td>
<td>$</td>
<td>0.09</td>
<td>-0.03</td>
<td>$</td>
</tr>
<tr>
<td>AW</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>0.61</td>
<td>0.13</td>
<td>0.53</td>
<td>0.61</td>
<td>0.44</td>
<td>0.07</td>
<td>$</td>
<td>-4.28</td>
<td>0.17</td>
<td>0.11</td>
<td>0.26</td>
<td>-0.67</td>
<td>0.79</td>
<td>-0.79</td>
<td>-0.37</td>
</tr>
<tr>
<td>YD</td>
<td>0.67</td>
<td>0.62</td>
<td>0.58</td>
<td>0.02</td>
<td>0.01</td>
<td>0.38</td>
<td>0.40</td>
<td>0.87</td>
<td>0.38</td>
<td>-0.24</td>
<td>0.84</td>
<td>$</td>
<td>-0.12</td>
<td>$</td>
<td>-0.80</td>
<td>-0.51</td>
<td>0.49</td>
<td>0.58</td>
</tr>
<tr>
<td>YH</td>
<td>0.34</td>
<td>0.25</td>
<td>0.34</td>
<td>0.01</td>
<td>0.05</td>
<td>0.19</td>
<td>0.15</td>
<td>0.41</td>
<td>0.17</td>
<td>0.16</td>
<td>-6.64</td>
<td>-0.02</td>
<td>0.29</td>
<td>-0.47</td>
<td>0.76</td>
<td>-0.26</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>YW</td>
<td>0.39</td>
<td>0.65</td>
<td>0.59</td>
<td>0.34</td>
<td>0.08</td>
<td>0.50</td>
<td>0.53</td>
<td>0.22</td>
<td>0.81</td>
<td>0.21</td>
<td>0.41</td>
<td>0.88</td>
<td>0.03</td>
<td>$</td>
<td>-0.85</td>
<td>-0.80</td>
<td>0.81</td>
<td>0.25</td>
</tr>
<tr>
<td>YF</td>
<td>-0.25</td>
<td>-0.10</td>
<td>-0.09</td>
<td>-0.10</td>
<td>-0.88</td>
<td>$</td>
<td>-0.07</td>
<td>0.37</td>
<td>0.03</td>
<td>0.01</td>
<td>0.02</td>
<td>0.12</td>
<td>$</td>
<td>$</td>
<td>-0.85</td>
<td>-0.58</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>SI</td>
<td>$</td>
<td>$</td>
<td>0.15</td>
<td>-0.11</td>
<td>0.01</td>
<td>$</td>
<td>-0.17</td>
<td>0.41</td>
<td>0.02</td>
<td>-4.16</td>
<td>0.07</td>
<td>0.17</td>
<td>$</td>
<td>0.23</td>
<td>0.06</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.08</td>
<td>-0.08</td>
<td>0.11</td>
<td>-0.92</td>
<td>0.15</td>
<td>0.01</td>
<td>0.01</td>
<td>0.17</td>
<td>-0.10</td>
<td>0.13</td>
<td>0.03</td>
<td>$</td>
<td>0.89</td>
<td>-0.84</td>
<td></td>
</tr>
<tr>
<td>YI</td>
<td>-0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.05</td>
<td>0.14</td>
<td>-0.30</td>
<td>$</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.17</td>
<td>0.18</td>
<td>0.20</td>
<td>0.52</td>
<td>0.16</td>
<td>-0.20</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>$</td>
<td>0.55</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>0.33</td>
<td>$</td>
<td>$</td>
<td>-0.20</td>
<td>0.11</td>
<td>0.16</td>
<td>0.33</td>
<td>0.86</td>
<td>-1.00</td>
<td></td>
</tr>
<tr>
<td>YP</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>-4.43</td>
<td>$</td>
<td>$</td>
<td>-0.38</td>
<td>-0.38</td>
<td>$</td>
<td>0.29</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>-0.24</td>
<td>-0.12</td>
<td>$</td>
<td>0.41</td>
<td>-0.32</td>
<td>$</td>
<td>0.26</td>
<td>0.14</td>
<td>0.06</td>
<td>0.57</td>
<td>-0.23</td>
<td>0.66</td>
<td>0.09</td>
<td>-0.34</td>
<td>-0.06</td>
<td>-0.79</td>
<td>(0.91)</td>
<td></td>
</tr>
</tbody>
</table>

Diagonal – heritability, above the diagonal – genetic correlations and below the diagonal – phenotypic and environmental (figures in parenthesis) correlations
$ - Beyond biological limits
to 0.86 among various egg quality traits in Brown Japanese quails (Table 3).

The positive genetic association with moderate to high (0.37 to 0.96) magnitude was noticed for EW with internal egg quality traits (AL, AWD, AH, AW, YD, YW and YFC) in both Black and Brown strains, while the phenotypic correlations ranged from -0.25 to 0.67. Majority of environmental correlations were high in magnitude and positive in direction, with an exception for albumen height and yolk fan colour in Brown Japanese quails and for yolk fan color in Black strain.

Medium to high genetic correlations observed for EW with egg quality indices (SI, AI, YI, AP, YP and SP) in Black (-0.55 to 0.26) and Brown (-1.00 to 0.73) strains, whereas, the phenotypic association was inconsistent in direction with low to medium range (-0.24 to 0.01) among the strains. The environmental correlations ranged from -0.56 to 0.34 in Black and -0.52 to 0.16 in Brown strain. The genetic correlations of EL with other external, internal egg quality traits and quality indices ranged from low to high (-0.11 to 0.95) in Black Japanese quails and medium to high (0.36 to 0.94) in Brown Japanese quails, whereas, low to high (0.01 to 0.57) correlations with inconsistency in direction were observed at phenotypic level in both the strains.

Low to high genetic correlation coefficients were observed for EWD with external and internal quality traits as well as the quality indices (SI, AI, YI, AP) in Black (-0.94 to 0.95) and Brown (-0.56 to 0.68) strain. The phenotypic association was low to medium in magnitude (-0.14 to 0.59) with positive direction in Black (Table 2) and with both directions in Brown Japanese quails (Table 3). The environmental correlations varied from -0.34 to 0.85 among the strains.

Genetic association of SW with other egg quality traits ranged from low to high both Black (-0.97 to 0.80) and Brown (-0.20 to 0.93) Japanese quails. Similar trend was observed for phenotypic and environmental correlations in the present study for the above combination of the traits. Genetic and phenotypic correlations of ST with other egg quality traits ranged from -0.77 to 0.98 and -0.18 to 0.13. Similarly, the genetic and phenotypic association of AL, AWD and AH with the other egg quality traits ranged from low to high.

The genetic, phenotypic and environmental correlations of AW with other egg quality traits ranged from -0.79 to 0.79, -0.41 to 0.41 and -0.48 to 0.92 in Black Japanese quails and from -0.37 to 0.61, -0.18 to 0.39 and -0.15 to 0.38 in Brown Japanese quails.

The genetic, phenotypic and environmental correlations of YD with other egg quality traits were low to high in magnitude with inconsistency in direction both in Black (-0.24 to 0.84, -0.05 to 0.81 and -0.67 to 0.78) and Brown (-0.69 to 0.45, -0.77 to 0.06 -0.55 to 0.13) strains. The estimates varied from low to high (-0.64 to 0.88) on genetic scale among the strains for YH with other quality traits, while the phenotypic association was low to medium (0.01 to 0.33) in magnitude in Black and low in Brown (0.01 to 0.15) strains. The estimates were low in magnitude for YW with other quality traits at phenotypic level (-0.16 to 0.02) and low to high (-0.85 to 0.88) on genetic scale in Black strain. The genetic, phenotypic and environmental correlations of Yolk fan colour with other quality indices in Black Japanese quails varied from -0.85 to 0.45, -0.20 to 0.17 and -0.14 to 0.34, respectively, whereas the correlations in the same order for Brown Japanese quails were -0.75 to 0.53, -0.11 to 0.12 and -0.30 to 0.90.

The genetic, phenotypic and environmental correlations of SI with other quality indices varied from low to medium in Black (0.06 to 0.23, 0.11 to 0.18 and -0.01 to 0.24) and Brown (-0.42 to 0.46, 0.09 to 0.19 and -0.04 to 0.20) Japanese quails. The genetic, phenotypic and environmental correlations of AI with other quality indices ranged from -0.84 to 0.89, -0.16 to 0.20 and -0.06 to 0.11 in Black Japanese quails, whereas in Brown Japanese quails the corresponding estimates were medium, medium to high and low in magnitude (0.50 to 0.77, 0.23 to 0.87 and 0.03). In Black Japanese quails the genetic, phenotypic and environmental correlations of YI with other quality indices varied from -0.20 to 0.68, -0.38 to 0.33 and -0.79 to 0.89, respectively, while the phenotypic and environmental correlations of yolk index with Haugh unit score in Brown Japanese quails were 0.26 and 0.10 respectively.

The phenotypic correlations of AP with YP and SP in Black Japanese quails were -0.98 and 0.03, respectively and the corresponding estimates of genetic correlations were -1.00 and -0.45. The magnitude and direction of genetic and phenotypic correlations observed in the present study were in conformity with the findings of Kondaiah et al. (1983), Praharaj et al. (1989), Dhaliwal et al. (2003) and Kui and Seker (2004). The positive correlation of egg weight with shell weight on genetic and phenotypic scale noticed in the present study was in accordance with the findings of earlier reports (Choi et al., 1983; Poyraz, 1989 and Kui and Seker, 2004). The association between EW with its external and internal components observed in the present investigation revealed variation in the genetic, phenotypic and environmental correlations among the Black and Brown strains and all most all internal and external quality traits varied depending on egg weight. Baumgartner et al. (2003) and Sezer (2007) also revealed high positive genetic and phenotypic association of egg weight with its components.

Further, results of the present study revealed that almost all the egg quality traits (external and internal) were associated themselves positively in direction but low to high in
Table 3: Estimates of genetic parameters among egg quality traits in Brown Japanese quails

<table>
<thead>
<tr>
<th></th>
<th>EW</th>
<th>EL</th>
<th>EWD</th>
<th>SW</th>
<th>ST</th>
<th>AL</th>
<th>AWD</th>
<th>AH</th>
<th>AW</th>
<th>YD</th>
<th>YH</th>
<th>YF</th>
<th>SI</th>
<th>AI</th>
<th>YI</th>
<th>HUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EW</td>
<td>0.10</td>
<td>$</td>
<td>0.61</td>
<td>$</td>
<td>$</td>
<td>0.91</td>
<td>0.46</td>
<td>0.96</td>
<td>$</td>
<td>0.44</td>
<td>$</td>
<td>0.37</td>
<td>0.73</td>
<td>-1.00</td>
<td>-0.45</td>
<td>0.28</td>
</tr>
<tr>
<td>EL</td>
<td>0.70</td>
<td>0.38</td>
<td>0.53</td>
<td>0.46</td>
<td>$</td>
<td>0.72</td>
<td>0.52</td>
<td>0.41</td>
<td>$</td>
<td>0.71</td>
<td>$</td>
<td>0.36</td>
<td>0.94</td>
<td>-0.92</td>
<td>-0.48</td>
<td>0.01</td>
</tr>
<tr>
<td>EWD</td>
<td>0.84</td>
<td>0.34</td>
<td>0.06</td>
<td>$</td>
<td>$</td>
<td>0.08</td>
<td>-0.40</td>
<td>0.38</td>
<td>0.68</td>
<td>0.31</td>
<td>$</td>
<td>0.27</td>
<td>-0.56</td>
<td>-0.15</td>
<td>-0.23</td>
<td>0.39</td>
</tr>
<tr>
<td>SW</td>
<td>0.10</td>
<td>0.08</td>
<td>0.02</td>
<td>$</td>
<td>0.34</td>
<td>-0.20</td>
<td>0.25</td>
<td>-0.01</td>
<td>0.93</td>
<td>$</td>
<td>0.81</td>
<td>$</td>
<td>0.55</td>
<td>0.27</td>
<td>0.26</td>
<td>0.23</td>
</tr>
<tr>
<td>ST</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.28</td>
<td>0.35</td>
<td>-0.68</td>
<td>-0.77</td>
<td>0.20</td>
<td>$</td>
<td>$</td>
<td>0.01</td>
<td>0.25</td>
<td>0.47</td>
<td>0.98</td>
<td>0.38</td>
<td>$</td>
</tr>
<tr>
<td>AL</td>
<td>$</td>
<td>$</td>
<td>0.41</td>
<td>0.49</td>
<td>0.09</td>
<td>0.56</td>
<td>0.79</td>
<td>0.01</td>
<td>0.85</td>
<td>0.22</td>
<td>$</td>
<td>0.40</td>
<td>0.45</td>
<td>-0.80</td>
<td>-0.74</td>
<td>0.30</td>
</tr>
<tr>
<td>AWD</td>
<td>$</td>
<td>$</td>
<td>0.62</td>
<td>0.70</td>
<td>0.73</td>
<td>0.58</td>
<td>0.01</td>
<td>0.44</td>
<td>0.09</td>
<td>0.71</td>
<td>0.65</td>
<td>-0.41</td>
<td>0.33</td>
<td>-0.13</td>
<td>0.07</td>
<td>0.68</td>
</tr>
<tr>
<td>AH</td>
<td>(-0.11)(-0.21)(0.02)(-0.37)(-0.8)(-0.23)(0.08)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AW</td>
<td>$</td>
<td>$</td>
<td>0.56</td>
<td>0.09</td>
<td>0.53</td>
<td>0.50</td>
<td>0.13</td>
<td>0.13</td>
<td>0.61</td>
<td>0.38</td>
<td>$</td>
<td>0.35</td>
<td>$</td>
<td>-0.37</td>
<td>0.20</td>
<td>$</td>
</tr>
<tr>
<td>YD</td>
<td>0.55</td>
<td>0.44</td>
<td>0.53</td>
<td>0.05</td>
<td>0.48</td>
<td>0.43</td>
<td>0.49</td>
<td>-0.14</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YH</td>
<td>0.45</td>
<td>0.20</td>
<td>0.44</td>
<td>0.01</td>
<td>0.03</td>
<td>0.12</td>
<td>0.19</td>
<td>0.26</td>
<td>0.32</td>
<td>0.06</td>
<td>0.28</td>
<td>-0.31</td>
<td>0.65</td>
<td>0.88</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>YF</td>
<td>-0.04</td>
<td>-0.10</td>
<td>0.07</td>
<td>-0.06</td>
<td>-0.15</td>
<td>0.97</td>
<td>0.07</td>
<td>-0.14</td>
<td>-0.04</td>
<td>0.01</td>
<td>0.01</td>
<td>0.46</td>
<td>$</td>
<td>-0.75</td>
<td>0.53</td>
<td>$</td>
</tr>
<tr>
<td>SI</td>
<td>-0.23</td>
<td>$</td>
<td>0.33</td>
<td>0.08</td>
<td>0.03</td>
<td>-0.01</td>
<td>0.06</td>
<td>0.09</td>
<td>-0.77</td>
<td>0.15</td>
<td>0.12</td>
<td>0.26</td>
<td>0.46</td>
<td>0.16</td>
<td>-0.42</td>
<td></td>
</tr>
<tr>
<td>AI</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.27</td>
<td>0.01</td>
<td>-0.15</td>
<td>0.30</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.01</td>
<td>$</td>
<td>0.01</td>
<td>-0.11</td>
<td>0.16</td>
<td>0.59</td>
<td>0.50</td>
<td>0.77</td>
</tr>
<tr>
<td>YI</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.20</td>
<td>0.03</td>
<td>-0.04</td>
<td>0.00</td>
<td>-0.23</td>
<td>0.23</td>
<td>0.01</td>
<td>$</td>
<td>0.01</td>
<td>0.01</td>
<td>0.19</td>
<td>0.23</td>
<td>0.31</td>
<td>$</td>
</tr>
<tr>
<td>HUS</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>0.09</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Diagonal – heritability, above the diagonal – genetic correlations and below the diagonal – phenotypic and environmental (figures in parenthesis) correlations

$ - Beyond biological limits
magnitude. Majority of the traits studied were secondary and dependent on the major trait of the egg weight. Hence, any selection programme aimed to alter egg weight would modify the associated traits due to correlated response to selection.

REFERENCES
Harvey, W. R. (1979). Least Squares Analysis of Data with Unequal Sub-class Numbers. USDA,