Influence of Selection for Increased Body Weight, Egg Production, and Shank Width on the Length of the Incubation Period of Turkeys

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ABSTRACT An experiment was designed to study the influence of selection for increased 16-wk BW (F line), egg production (E line), and shank width (FL line) in turkeys on length of the incubation period and to estimate the influence of adult BW (BW50) and egg weight on the incubation period. The base populations for the F, FL, and E lines were randombred control (RBC)2, F, and RBC1, respectively. An additional RBC (RBC3) was also included in the study.

The experimental turkey lines differed in length of the incubation period in all trials, indicating genetic differences exist. The E line, in general, had a longer incubation period than the RBC1 line, due to an increase in the time required for external pipping. The FL line had a longer period of incubation than the F line. Differences in the length of the incubation period between the F and RBC2 lines were inconsistent. The F line had a shorter incubation period than the RBC2 line in Trial 1, whereas there was no difference between lines in Trial 2. In Trial 3, the comparison of the F and RBC2 lines was influenced by treatment of the eggs prior to setting. When the eggs were held at room temperature for 29 h prior to setting, the F line had a longer incubation period than the RBC2 line, whereas when the eggs were set directly from the egg cooler, there was no line difference. The line differences in length of the incubation period could not be explained by line differences in egg weight based on a comparison of line means for these traits. Within lines, the regression of length of the incubation period on egg weight was positive and significantly different from zero in three of the six lines. Overall regression of hatching time on egg weight and BW50 was positive for egg weight and negative for BW50. However, only 4% of the variation in the length of the incubation period could be explained by variation in egg weight and BW50. Within lines, the regression coefficient of length of the incubation period on BW50 was not significantly different from zero but the sign was negative in five of six lines.

(Key words: turkey, incubation period, egg weight, body weight, genetic differences)

INTRODUCTION

The length of incubation period may be influenced by a number of factors including inheritance, egg weight, and holding time of the eggs. In chickens, the unweighted average for heritability estimates of length of the incubation period was 0.29 (Crittenden and Bohren, 1961; Becker et al., 1966; MacLaury and Insko, 1969; Abdou and Ayoub, 1975; Palomares-Hilton and Bohren, 1981). MacLaury and Insko (1968) reported differences between the White Plymouth Rock and New Hampshire breeds in length of the incubation period. Incubation periods were greater in lines of chickens selected for increased BW than those selected for decreased BW (Hassan and Nordskog, 1971; Dunnington et al., 1992; McNabb et al., 1993). Fast- and slow-hatching lines of chickens have been developed by divergent selection (Smith and Bohren, 1975; Palomares-Hilton and Bohren, 1981). Selection for a shorter incubation period was associated with smaller egg weight (Smith and Bohren, 1975; Bohren, 1978a) and larger BW at hatching through 6 wk of age (Vasquez and Bohren, 1978).

Literature reports concerning the relationship between egg weight and length of the incubation period are inconsistent. In chickens, Crittenden and Bohren (1961) reported that the genetic correlation between these two variables was 0.55 based on variation among sires and

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Abbreviation Key: BW50 = BW when the hens first achieved 50% production; E = subline of RBC1 selected for increased egg production; F = subline of RBC2 selected for increased 16-wk BW; FL = subline of F selected for increased shank width; RBC1, RBC2, RBC3 = randombred control populations.
pose of the present study was to evaluate the in
domestic control population developed in 1956, 1966,
0.20 based on variation among dams. Henderson (1950)
found that the phenotypic correlation coefficient between
egg weight and length of the incubation period varied
from 0.05 to 0.21 in various genetic groups with an aver-
age of 0.18. Bohren et al. (1961) found that the phenotypic
correlation coefficient between egg weight and hatching
time was 0.30 based on dam means but was not significant
based on individual eggs. A correlation coefficient of 0.11
was observed between these variables by Suarez et al.
(1996). In turkeys, Olsen (1942) found that the length of the incubation
period in Beltsville Small Whites was 637.6,
639.8, and 641.6 h, respectively, in eggs weighing 70 to
80, 80 to 90, and 90 to 100 g. Cherms (1969) found no
association between egg weight and length of the incubation
period in turkey eggs.

Increased holding time of eggs generally leads to in-
creased length of the incubation period in chickens (Boh-
ren et al., 1961; Crittenden and Bohren, 1961; Abdou and
Ayoub, 1975; Bohren, 1978b). In turkeys, Kosin (1950)
and Cherms (1969) reported that an increased incubation
period was associated with longer holding periods for the
eggs, but Olsen (1942) found no difference in incubation
period between eggs held 1 to 8 d vs. 9 to 16 d.

Genetic increases in BW (F line) and shank width (FL
line) of turkeys was associated with increased egg weight
and reduced hatch of fertile eggs relative to a correspond-
ing randombred control (RBC2) (Nestor and Noble, 1995; Nestor et al., 1996). In the same studies, genetic increases
in egg production (E line) resulted in decreased egg
weight with no change in hatchability relative to the cor-
responding randombred control (RBC1). Unpublished
data (K. E. Nestor) indicated that selected lines and their
randombred controls plus an additional randombred con-
trol (RBC3) differed in the length of the incubation period.
Based on these data, setting times of the lines were varied
to synchronize hatching. The large-bodied lines (F, FL,
and RBC3) were set 24 h prior to the small-bodied E line,
and the medium-bodied lines (RBC1 and RBC2) were set
15 h prior to the small-bodied E line. Under these
conditions in which setting time and line were con-
founded, Noble (1996) found that the length of the incubation
period was longer for the E line (651 h) than for the
RBC1 line (638 h), and the other lines were ranked FL
(653 h) > F (649 h) > RBC2 (647 h) > RBC3 (642 h); there
did not appear to be a relationship on a line basis between
egg weight and length of the incubation period. The pur-
pose of the present study was to evaluate the influence
of selection for increased BW, shank width, and egg pro-
duction on length of the incubation period and to study
the association of incubation period, egg weight, and
adult BW.

**MATERIALS AND METHODS**

Six experimental turkey lines were used in the present

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Robbins Incubator Co., PO Box 899, Denver, CO 80201 (out of
business).
**Trial 2**

The hens in this trial were from the same generations of selection listed previously for Trial 1, but only the E, RBC1, F, and RBC2 lines were observed. Eggs were collected during the 6th to 14th wk of production. After weighing, the eggs were set in Jamesway 252 incubators that operated at 37.5 ± 0.1 C and 50.5% RH. The eggs were turned 12 times per day. At the conclusion of 576 h of incubation, the eggs were sorted by line and transferred to hatching baskets of 24 eggs each. For hatching, the machines operated at 36.9 C. RH was 50.5% RH.

From 616 to 696 h of incubation, eggs were observed at 4-h intervals for stage of development as well as for hatching. The door of the hatcher was opened, and a basket of 24 eggs was removed, checked, and returned to the hatchery. Three stages of development were classified using a candling light, and the time each stage was attained was calculated. The stages observed were pre-pipping, pipping, and hatching (Christensen et al., 1982). The data were analyzed by ANOVA with line being the only variable tested, and the error term was based on individual eggs or poult. Means were separated using Duncan’s multiple-range test. Three identical independent replicates were used in Trial 2.

**Trial 3**

The E, F, FL, RBC1, RBC2, and RBC3 lines were used. Lines E, F, and FL were in the 39th, 34th, and 22nd generations of selection, respectively. Average egg weight was obtained by group-weighing the eggs from each hen biweekly throughout a 12-wk hatching period. Eggs for the study of the length of the incubation period were collected from hens in their 16th wk of lay. Eggs from each line were divided into two groups. One group of eggs was removed from the egg cooler 29 h before setting and was allowed to remain at room temperature (Treatment 1). The second group of eggs was removed from the egg cooler and was set immediately in the incubator (Treatment 2). Eggs in Treatments 1 and 2 were placed in the incubator at the same time. The eggs were set in an incubator (Model H-5-W®) maintained at 37.5 C and 60% RH. The eggs were turned 12 times per day. The eggs were transferred to a hatcher (Model I-UNIT®) at 564 h of incubation. The hatcher was maintained at 36.9 C, and RH was increased from 60 to 80% over a 2-d period. Hatching time was checked at 12-h intervals by the method used in Trial 1.

Egg weight was analyzed for the effect of line using variation among hens as the error term. Two statistical analyses were run on the incubation period data. Unfortunately, the tray containing FL-line eggs for Treatment 1 was dropped, and many of the eggs were broken. In one analysis, data for the FL line were excluded, and the data were analyzed for the effects of line, treatment, and their interaction. Separate analyses were run for each treatment including all of the available data. The error term on all analyses of incubation period was the individual poult.

**RESULTS**

**Trial 1**

Lines differed in the length of the incubation period, egg weight, and BW50 (Table 1). Week of production had no significant effect on the length of the incubation period. The length of the incubation period in the E line was longer than the RBC1 line even though egg weight was greater in the RBC1 line than in the E line (87.5 vs. 68.4 g). The FL line had a longer incubation period than the F line even though egg weights were similar in the two lines. In this trial, the F line had a shorter incubation period than the RBC2 line even though egg weight was greater in the F line than in the RBC2 line.

The linear regression coefficient of length of the incubation period on egg weight was positive and significant within three (E, FL, and RBC3) of the six lines (Table 1). Within lines, there was no significant linear regression coefficient of length of the incubation period on BW50. The overall equation based on the data of all lines that described the relationships among length of the incubation period, BW50, and egg weight was

\[
\text{length of the incubation period} = 635.4 \text{ h} \\
+ 0.17 \text{ h/g egg weight} - 0.62 \text{ h/kg BW50.}
\]

The regression coefficients for both egg weight and BW50 were different from zero \((P \leq 0.0001)\), but the coefficient of determination for the model was only 4%.

**Trial 2**

The length of the incubation period, but not the times required to attain internal and external pipping stages of development, differed among lines with the E line requiring the longest time with no difference among the RBC1, RBC2, and F lines (Table 2). The E line also had the smallest eggs. Even though the length of the incubation period did not differ among the RBC1, RBC2, and F lines, egg weight varied greatly among lines.

The data indicated that the additional incubation time for the E line embryos to hatch is spent between external pipping and hatching (Table 3). Times to attain internal and external pipping did not differ between the lines, but the time from the initiation of external pipping was extended by nearly 15 h for the E line compared with the remaining three lines in Trial 2.

**Trial 3**

Lines differed in length of the incubation within both treatments (Table 4). When the data for the FL line were

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3Jamesway Incubator Co., 756 Bishop Street, Cambridge, ON Canada N2E 1B3.
4Natureform Hatchery Systems, Jacksonville, FL 32202.
TABLE 1. The influence of selection for increased BW, egg production, and shank width in turkeys on egg weight, body weight at 50% production (BW50), length of the incubation period, and multiple regression coefficients of length of the incubation period on egg weight and BW50 by line in Trial 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>E</th>
<th>RBC1</th>
<th>RBC2</th>
<th>FL</th>
<th>RBC3</th>
<th>F</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg weight, g</td>
<td>68.4</td>
<td>87.5</td>
<td>90.0</td>
<td>98.2</td>
<td>96.0</td>
<td>98.8</td>
<td>0.680</td>
</tr>
<tr>
<td>BW50, kg</td>
<td>6.5</td>
<td>8.1</td>
<td>9.5</td>
<td>14.0</td>
<td>14.3</td>
<td>17.4</td>
<td>0.092</td>
</tr>
<tr>
<td>Incubation period, h</td>
<td>644</td>
<td>641</td>
<td>645</td>
<td>652</td>
<td>637</td>
<td>640</td>
<td>0.771</td>
</tr>
<tr>
<td>Regression coefficients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incubation period on egg weight, h/g</td>
<td>0.31*</td>
<td>-0.13</td>
<td>0.09</td>
<td>0.42**</td>
<td>0.43**</td>
<td>-0.02</td>
<td></td>
</tr>
<tr>
<td>Incubation period on BW50, h/kg</td>
<td>-1.54</td>
<td>-0.04</td>
<td>-0.83</td>
<td>1.41</td>
<td>-0.54</td>
<td>-0.37</td>
<td></td>
</tr>
</tbody>
</table>

*Means within a row with no common superscript are different (P ≤ 0.05).
1E = subline of RBC1 selected for increased egg production; RBC1 = randombred control line developed in 1956; RBC2 = randombred control line developed in 1966; RBC3 = randombred control line developed in 1986; FL = subline of F selected for increased shank width.

excluded from the analysis, there was an interaction between egg treatment and line in length of the incubation period primarily because there was no difference between treatments for the F line, whereas the length of the incubation period was longer in Treatment 2 within the RBC1, E, RBC2, and RBC3 lines. Egg treatment had an effect on the line comparisons for length of the incubation period. In Treatment 1, the E and F lines had a longer incubation period than their corresponding randombred controls, but there was no line difference in these comparisons for Treatment 2. The FL line had the longest incubation time in Treatment 2. There appeared to be little relationship between line means for egg weight and length of the incubation period for either egg treatment.

DISCUSSION

The question arises as to the effect of repeated opening of the hatcher door on hatching time. This question cannot be answered in the present study, but Bohren et al. (1961) found that when using chicken eggs that repeated opening of the hatcher had no effect on hatching even at 2-h intervals. In the present study, unhatched eggs were placed in contact with each other after removing hatched poults in order to synchronize hatching time (Pani et al., 1969).

Selection for increased egg production in the E line increased the length of the incubation period in three of four comparisons in the present study and in a study by Noble (1996), even though egg weight was greatly reduced in the E line. The length of the incubation period was longer in the FL line than in the F line in Trials 1 and 3, even though egg weight of the two lines did not differ greatly. Similar results were observed by Noble (1996). The effect of selection for increased 16-wk BW on length of the incubation period in the F line was inconsistent in the three trials. In Trial 1, the length of the incubation period was shorter (5 h) in the F line relative to the RBC2 line even though the average egg weight was 8.8 g larger in the F line. Eggs were 8.5 g larger in the F line than in the RBC2 line in Trial 2, but the length of the incubation period was similar for the two lines. By Trial 3, the line difference in egg weight had increased to 10.4 g. When the eggs were held for 29 h at room temperature (Treatment 1), the length of the incubation period was 5 h longer in the F line than in the RBC2 line. When the eggs were set immediately out of the egg cooler (Treatment 2), the incubation period was 5 h (P ≥ 0.05) shorter in the F

TABLE 2. Time required to attain the internal piping, external piping, and hatching stages by line in Trial 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>E</th>
<th>RBC1</th>
<th>RBC2</th>
<th>F</th>
<th>RBC2</th>
<th>Mean ± SEM</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of poults</td>
<td>486</td>
<td>380</td>
<td>258</td>
<td>396</td>
<td></td>
<td></td>
<td>0.0001</td>
</tr>
<tr>
<td>Egg weight, g</td>
<td>64.4</td>
<td>80.2</td>
<td>86.3</td>
<td>77.8</td>
<td>77.2</td>
<td>± .05</td>
<td>10.4</td>
</tr>
<tr>
<td>Stage of development, h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal piping</td>
<td>622</td>
<td>621</td>
<td>622</td>
<td>622</td>
<td>622</td>
<td>± 1</td>
<td>NS</td>
</tr>
<tr>
<td>External piping</td>
<td>626</td>
<td>627</td>
<td>625</td>
<td>626</td>
<td>626</td>
<td>± 1</td>
<td>NS</td>
</tr>
<tr>
<td>Hatching</td>
<td>665</td>
<td>643</td>
<td>643</td>
<td>641</td>
<td>648</td>
<td>± 1</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*Means within a row with no common superscript are significantly different (P ≤ 0.05).
1E = subline of RBC1 selected for increased egg production; RBC1 = randombred control line developed in 1956; RBC2 = randombred control line developed in 1966; E = subline of RBC1 selected for increased egg production; and F = subline of RBC2 selected for increased 16-wk BW.
line than in the RBC2 line. Noble (1996) did not observe a difference in length of the incubation period between the F and RBC2 lines in the 29th generation of selection in the F line. The reasons for the inconsistent results in length of the incubation period for the comparison of the F and RBC2 lines is unknown. The results of Trial 3 suggest that egg treatment prior to setting had a major influence on this line comparison.

The line differences in length of the incubation period indicate that there is genetic variation in this trait in the turkey as has been observed in chickens (Crittenden and Bohren, 1961; Becker et al., 1966; MacLaury and Insko, 1968, 1969; Abdou and Ayoub, 1975; Palomares-Hilton and Bohren, 1981). Differences in length of the incubation period among lines in the present study could not be explained by line differences in egg weight, although egg weight and length of the incubation period were positively associated in three of the six lines. The inconsistency in the relationship between length of the incubation period and egg weight has previously been observed in chickens and turkeys. The genetic correlation coefficient between these two variables in chickens was 0.20 and 0.55, based on the dam and sire components of variance, respectively (Crittenden and Bohren, 1961). Henderson (1950) found that the phenotypic correlation coefficient between egg weight and length of the incubation period in chickens varied from 0.05 to 0.21 in various genetic groups. Based on dam means, Bohren et al. (1961) reported a phenotypic correlation coefficient of 0.30 between egg weight and length of the incubation period, but based on individual eggs, the correlation coefficient was not significantly different from zero. In turkeys, Olsen (1942) reported that egg weight and length of the incubation period were positively associated, but no association of these traits was reported by Cherms (1969).

Selection for increased BW during the growing period of chickens (Anthony et al., 1989) and of turkeys (Bray, 1965; Anthony et al., 1991b) alters growth rate throughout life, including embryonic development as early as 16 d of incubation in chickens (Anthony et al., 1989) and 18 d of incubation in turkeys (Bray, 1965). Over all lines in Trial 1, there was a significant negative regression coefficient length of the incubation period on BW50, indicating that as growth rate increased, as measured by adult BW, the length of the incubation period decreased. Within lines, the regression coefficient of length of the incubation period on BW50 was not significant for any line, although the sign of the coefficient was negative in five of six lines.

In summary, length of the incubation period differed among experimental lines of turkeys, and the line differences could not be explained by line differences in egg weight. Embryos from the E line, in general, had one of

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### TABLE 3. Time spent during the internal pipping and external pipping stages of development by line in Trial 2

<table>
<thead>
<tr>
<th>Stage of development</th>
<th>Line1</th>
<th>Line2</th>
<th>Mean ± SEM</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E</td>
<td>RBC1</td>
<td>F</td>
<td>RBC2</td>
</tr>
<tr>
<td>Internal pipping</td>
<td>8.5</td>
<td>10.6</td>
<td>11.3</td>
<td>10.9</td>
</tr>
<tr>
<td>External pipping</td>
<td>30.0*</td>
<td>15.5b</td>
<td>18.3b</td>
<td>16.7b</td>
</tr>
</tbody>
</table>

*Means within a row with no common superscript are different (P ≤ 0.05).

1RBC1 = randombred control line developed in 1956; RBC2 = randombred control line developed in 1966; E = subline of RBC1 selected for increased egg production; and F = subline of RBC2 selected for increased 16-wk BW.

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### TABLE 4. The effect of selection for increased BW, egg production, and shank width in turkeys on egg weight and length of the incubation period when the eggs were left at room temperature for 27 h prior to setting (Treatment 1) or set immediately after removal from the egg cooler (Treatment 2)

<table>
<thead>
<tr>
<th>Line1</th>
<th>Egg weight</th>
<th>Poults</th>
<th>Incubation period</th>
<th>Poults</th>
<th>Incubation period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>no.</td>
<td>h</td>
<td>no.</td>
<td>h</td>
</tr>
<tr>
<td>RBC1</td>
<td>87.6c</td>
<td>43</td>
<td>637c</td>
<td>44</td>
<td>650b</td>
</tr>
<tr>
<td>E</td>
<td>66.0a</td>
<td>179</td>
<td>643b</td>
<td>177</td>
<td>649b</td>
</tr>
<tr>
<td>RBC2</td>
<td>86.9b</td>
<td>68</td>
<td>643b</td>
<td>67</td>
<td>652b</td>
</tr>
<tr>
<td>F</td>
<td>97.3a</td>
<td>43</td>
<td>648b</td>
<td>58</td>
<td>647b</td>
</tr>
<tr>
<td>FL</td>
<td>94.4b</td>
<td>—</td>
<td>—</td>
<td>46</td>
<td>662b</td>
</tr>
<tr>
<td>RBC3</td>
<td>94.5b</td>
<td>60</td>
<td>642b</td>
<td>56</td>
<td>650b</td>
</tr>
<tr>
<td>SEM</td>
<td>0.332</td>
<td>0.314</td>
<td>0.375</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Means within a column with no common superscript are different (P ≤ 0.05).

1RBC1 = randombred control line developed in 1956; RBC2 = randombred control line developed in 1966; RBC3 = randombred control line developed in 1986; E = subline of RBC1 selected for increased egg production; F = subline of RBC2 selected for increased 16-wk BW; and FL = subline of F selected for increased shank width.

2Tray containing eggs was dropped.
the longer incubation periods but attained internal and external pipping at the same time as the RBC1, RBC2, and F lines. The longer incubation periods of E-line embryos were accounted for by increased time spent breaking the shell. Growth rate over all lines, as indicated by BW50, was associated negatively with hatching time, but no significant relationship was observed within lines.

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