Fearfulness and Performance Related Traits in Selected Lines of Japanese Quail (*Coturnix japonica*)

F. Minvielle,* A. D. Mills,+ J. M. Faure,+ J. L. Monvoisin,* and D. Gourichon‡

*Laboratoire de Génétique Factorielle, INRA, 78352 Jouy-en-Josas, France; †Station de Recherches Avicoles, INRA, 37380 Nouzilly, France; and ‡Unité Expérimentale de Génétique Avicole, 37380 Nouzilly, France

**ABSTRACT** Fearfulness and economic traits were studied in three lines of Japanese quail. Two of the lines were of the same genetic origin and were subjected to divergent selection for the duration of tonic immobility (TI), a measure of fearfulness. Birds were selected for long (LTI) or short (STI) duration of TI. The third line (DD) was of a different genetic origin and had been selected for early egg production. Fear, growth, residual feed intake, and measures of egg composition and production varied among lines. The distribution of TI in Line DD was closer to that from Line STI. Residual feed intake and shell content were lowest in the DD line. The DD birds laid more broken eggs than quail of the other lines. The STI line birds had higher BW and laid more, but smaller, eggs than LTI line birds. Eggs laid by LTI line birds had higher albumen content, but lower percentage shell, than those laid by STI line birds. When all traits were considered together, there was an overall tendency for STI line birds to outperform LTI birds with DD line birds showing intermediate performance. This finding supports the notion that there is a relationship between fearfulness and productivity. However, the skewed distribution of TI precluded estimation of correlation with production traits in the LTI and STI lines. No significant relationships among fear and production-related traits were found in the DD line, which contradicts the notion that fearfulness and production are related.

(Key words: egg production, growth, fearfulness, tonic immobility, Japanese quail)


**INTRODUCTION**

The development of commercial poultry lines has been largely based on selection for traits related to economic performance. That such selection has had secondary effects on behavior has been extensively documented (reviewed by Siegel and Dunnington, 1990). Also, selection on yolk precursor has been related to fearfulness and mortality in Japanese quail (Ely et al., 1998). However, the reverse effect, the influence of selection for behavioral traits on economic performance, has not been extensively studied. Such information is of considerable importance if behavioral traits are to be included in commercial poultry selection programs. One candidate trait for incorporation into such selection programs is fearfulness. Extreme or inappropriate expression of fear related behavior is thought to have negative effects on productivity and welfare in the domestic fowl *Gallus domesticus* (Jones and Hocking 1999). If this is the case reduction of fearfulness levels ought to improve not only the birds’ economic performance but also the extent to which they are able to adapt to, or cope with environmental restrictions imposed by an intensive husbandry system (Faure and Mills 1998).

Fear can be assessed by duration of the tonic immobility reaction (TI) as a measure (Gallup, 1979; Jones, 1986). Tonic immobility is a variable period of immobility induced by manual restraint. A long duration of TI is thought to be indicative of high levels of fearfulness, and a short duration is indicative of low levels of fearfulness (reviewed by Jones 1986). Genetic variation in TI has been demonstrated (Gallup 1974; Benhoff and Siegel, 1976); Mills and Faure (1991) have developed lines of Japanese quail that show long (LTI) or short (STI) duration of TI. That these lines differ in underlying fearfulness has been demonstrated under a wide range of experimental conditions (reviewed by Faure and Mills 1998). In the present study, the effect of selection for fearfulness on various aspects of the birds’ economic performance was evaluated. The hypothesis was that selection for low levels of fearfulness would have beneficial effects on the expression of production-related traits. Be-

---

**Abbreviation Key:** AFE = age at first egg; BT = body temperature; BWG = BW gain during the feed trial; CL = clutch length; DD = line selected for early egg production; ELR = egg laying rate; EM = egg mass during the feed trial; EN = egg number; EW = average egg weight; FI = feed intake; LTI = line selected for long duration of tonic immobility; NI = number of inductions; RFI = residual feed intake; STI = line selected for short duration of tonic immobility; TI = duration of tonic immobility.
behavior, BW, feed intake, and aspects of egg production were studied in the STI and LTI lines of Japanese quail to test this hypothesis. To provide a basis for this comparison, behavior and performance in a third line of quail (DD) were also measured. The DD line has not been selected for behavioral traits and was originally selected for economic performance as measured by early egg production (Minvielle et al., 1999, 2000b).

MATeRIALS AND METHODS

Line Histories

**LTI and STI Lines.** Mills and Faure (1991) give a complete description of the selection procedures used to develop the LTI and STI lines. Briefly, birds of two commercial strains where reciprocally crossed so as to constitute a common base line population for the two selected lines. The LTI line was selected for high TI, whereas the STI line was selected for low TI. The duration of TI was measured when the chicks were 9 to 10 d of age. It was defined as the length of time during which an unrestrained chick remained immobile after 10 s of manual restraint. The number of times a chick had to be restrained (NI) before TI was induced was also measured. However, there was no direct selection for NI. For practical reasons the maximum number of inductions allowed to induce TI was limited to five, and TI was limited to 300 s. If TI could not be induced after five attempts the bird was deemed to be unsusceptible and given scores of NI = 5 and TI = 0. If the bird failed to right itself after 300 s, it was given scores of NI between 1 and 5, and TI = 300. By the 18th generation of selection, the mean (± SD) value for TI was 215.6 ± 92 s in the LTI line and 9.3 ± 12 s in the STI line.

**DD Line.** Birds of the DD line were of a different genetic origin to that of the LTI and STI lines (Minvielle et al., 2000a). They had originally been subjected to directional (upward) selection for early egg production in a study of the evolution of heterosis under artificial selection (Minvielle et al., 1999, 2000b). Selection of the DD line was carried out over 13 generations and was relaxed thereafter.

**Numbers of Birds Used.** The number of DD LTI, and STI chicks hatched were 183, 183, and 189, respectively. The values of NI and TI were obtained for all chicks. Then males were eliminated (see husbandry below), and all the other traits were measured on 72, 72, and 69 females of Lines STI, LTI, and DD, respectively. During the egg-laying test, 8, 9, and 5 quail, respectively, died in the three lines from various causes. The numbers of birds available for the various measures are given in the tables.

Husbandry

Incubation, hatching of eggs and rearing of chicks and adults were carried out at the Unité Expérimentale de Génétique Avicole Nouzilly, France. The chicks were hatched in a single lot. Eggs of all lines were incubated and hatched together. In the hatchery, chicks of the various lines and families were prevented from intermingling by solid partitions placed between families in the hatching trays. Chicks were wing-tagged at hatching. They were then placed, all lines together, in group cages for 10 d. Temperature in the group cages was maintained at 35 to 37 C. They were then transferred down to other group cages of the same two batteries. Temperature in these cages was maintained at 30 C. Sexing was carried out at 3 wk of age on the basis of plumage color pattern. Males were eliminated and females moved further down to group cages that were maintained at 25 C. When the birds were 5 wk of age they were transferred to individual cages of a four-tier egg laying battery located in an adult quail husbandry unit. The birds remained in these individual cages until the end of the experiment. Temperature was maintained at 22 C. Artificial lighting was provided for 14 h/d.

During the experiment, the birds were fed on two diets. Initially they received a mash starter diet (2,901 kcal ME / kg, 11.5% moisture, 7% ash, 27% total protein, 8% fat, and 4% crude fiber). They were then fed a commercial layer diet (2,709 kcal ME / kg, 11.5% moisture, 12% ash, 20% total protein, 4% fat, and 4% crude fiber). Food and water were available ad libitum.

**Experimental Birds**

**Parent Stock and Mating Systems.** The breeding population of the LTI and STI lines comprised 20 males and 40 females selected from about 200 birds per line for each generation. The parents of the birds used in the present study were of the 18th generation of divergent selection for TI. Each male was mated to two females, and full- and half-sib matings were prohibited. At the start of egg collection the parents of the LTI and STI birds were 4 mo old. The DD birds were the progeny of breeders from the 22nd generation of that line. At that stage, the breeding population of the DD line comprised 25 males and 25 females randomly chosen from about 150 birds. Each male was mated to one female, and there was no full-sib mating. At the start of egg collection, the DD parental birds were 8 mo old.

**Traits**

**TI.** When chicks (males and females) were 9 to 10 d old they were subjected to the TI test (Mills and Faure, 1991). Values for NI and TI were measured on a total of 555 females.

**Body Weight and Temperature.** Body weight was measured in female quail at 35, 162, 231, 253, and 333 d of age. Rectal measure of body temperature (BT) was taken at 162 and 253 d of age.

**Egg Production and Quality.** Individual egg production (EN) was recorded daily until the birds were 315 d of age. Age at first egg (AFE) and average clutch length (CL), defined as the mean number of consecutive days with an oviposition, were obtained for each bird. Two birds that failed to lay were removed from the experiment. When the birds were approximately 19 wk of age, eggs
were collected over a 5-d period. Three normal eggs laid on 3 consecutive d were used to measure average egg weight (EW) and egg composition (shell, yolk, and albumen) for each bird.

**Feeding Trial and Associated Measures.** At 231 d of age, a 3-wk feeding trial was started on a subset (34 or 35 birds per line) of the laying females. The EN recorded during the feed trial and EW were used to estimate egg mass (EM). Average BW and BW gain during the trial (BWG) were measured, and residual feed intake (RFI) was estimated from FI, EM, BW, and BWG.

**Statistical Analyses**

Traits expressed as percentages were transformed to angles by arcsine transformation (Snedecor and Cochran, 1980). Raw data for measures of fearfulness (NI and TI) were standardized and expressed as standard deviations from the mean (NIs and TIs, respectively) for within-line correlation analyses. Box-Cox transformations (Besbes et al., 1993) with parameters of 3.5, 3.5, and 4 were applied to EN at 17, 29, and 45 wk of age, respectively. Two-factor (line and family) nested ANOVA was used to analyze fear-related traits, EN, egg composition, BT, and feed trial traits.

Growth was studied using the nonlinear regression monomolecular model described by France et al. (1996). The following three-parameter equation was used: 
\[ BW = A - B \exp(-kt); \]
where 
\[ t = \text{age in weeks} \]
\[ A = \text{asymptotic BW in grams} \]
\[ B = \text{range of BW from initial BW (BW was set to 9 g for } t = 0) \text{ to asymptotic BW, and } k = \text{relative rate of growth.} \]

Egg laying rate (ELR) was analyzed by nonlinear regression using the modified compartmental model described by Yang et al. (1989). The equation used was 
\[ \%ELR = \frac{a \exp(-bt)}{1 + \exp(-c(t-d))}; \]
where 
\[ t = \text{number of weeks in the laying test from the age of 35 d onward (} t = 0) \]
\[ a = \text{scale parameter, } b = \text{rate of decrease in egg laying, } 1/c = \text{indicator of the variance in sexual maturity, and } d = \text{mean number of weeks in the test before sexual maturity was reached.} \]

Values of RFI were the residuals of the multiple regression of individual of feed intake (FI) on BW\(^{0.75}\), BWG, and EM fitted (R\(^2 = 0.64\)) to data for the three lines. The equation used to calculate RFI was 
\[ \text{RFI} = 23.1 + 7.83 \text{ BW}^{0.75} + 3.01 \text{ BWG} + 0.514 \text{ EM.} \]

**RESULTS**

**Fearfulness**

Line DD was significantly different (P < 0.001) from the LTI and STI lines for TI and NI (Table 1). However, the distribution of TI in that line was closer to that from Line STI (Figure 1). Figure 2 presents the distribution of NI for the three lines. There was no difference between sexes in NI and TI (data not shown).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Line(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DD</td>
</tr>
<tr>
<td>Tonic immobility, s</td>
<td>39(^b) ± 38</td>
</tr>
<tr>
<td>Number of inductions</td>
<td>2.4(^b) ± 1.5</td>
</tr>
</tbody>
</table>

\(^a\)Values within rows with no common superscript are different (P \leq 0.05).

\(^b\)DD = early egg production line, n = 183; STI = low fear line, n = 189; LTI = high fear line, n = 183.

--

**TABLE 1. Measures of fearfulness (least squares mean ± SD) in the DD, STI, and LTI Japanese quail lines**

**FIGURE 1. Distribution of the duration of tonic immobility in lines of quail selected for early egg production (DD) and short (STI) or long (LTI) tonic immobility.**

**FIGURE 2. Distribution of the number of inductions required to induce tonic immobility in lines of quail selected for early egg production (DD) and short (STI) or long (LTI) tonic immobility.**
Growth

Growth rate was similar in the three lines, but the three lines reached different values of asymptotic BW (P < 0.05), which was 15 and 6% higher in STI than in DD and LTI, respectively (Table 2). Mean BW obtained between the ages of 33 and 36 wk was different in the three lines (P < 0.05), and it was intermediate in Line DD (Table 6).

Egg Production

The STI birds started laying 3.6 d earlier, had clutches which lasted 1.5 d longer, and laid consistently more eggs through 17, 29, and 45 wk of age (P < 0.05) than LTI birds (Table 3). Performances of DD quail were intermediate to those of the STI and LTI birds but were not significantly different from STI, except for broken eggs (P < 0.05). The DD line birds also laid more broken eggs than the LTI line birds (P < 0.05). Parameters of the egg-laying rate are given in Table 4. The rate of decrease of egg laying was smaller (P < 0.05) in STI than in DD and LTI. Other parameters of the egg-laying curve did not differ among the three lines.

TABLE 3. Egg production (least squares mean ± SD) in the DD, STI, and LTI Japanese quail lines

<table>
<thead>
<tr>
<th>Trait2</th>
<th>Line1</th>
<th>DD</th>
<th>STI</th>
<th>LTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at first egg, d</td>
<td>50.0± 5.8</td>
<td>48.6± 6.5</td>
<td>52.2± 5.8</td>
<td></td>
</tr>
<tr>
<td>Egg number at 17 wk of age</td>
<td>21.3± 10.0</td>
<td>22.8± 8.8</td>
<td>16.8± 8.1</td>
<td></td>
</tr>
<tr>
<td>Egg number at 29 wk of age</td>
<td>43.3± 18.3</td>
<td>46.6± 12.5</td>
<td>34.9± 14.8</td>
<td></td>
</tr>
<tr>
<td>Egg number at 45 wk of age</td>
<td>88.2± 48.9</td>
<td>99.6± 33.7</td>
<td>69.5± 36.4</td>
<td></td>
</tr>
<tr>
<td>Clutch length, d</td>
<td>8.6± 3.9</td>
<td>9.0± 4.1</td>
<td>7.5± 2.9</td>
<td></td>
</tr>
<tr>
<td>Soft-shell eggs, %</td>
<td>2.2± 8.2</td>
<td>1.4± 3.8</td>
<td>0.8± 1.0</td>
<td></td>
</tr>
<tr>
<td>Double yolk eggs</td>
<td>0.5± 1.2</td>
<td>0.4± 0.7</td>
<td>0.6± 0.9</td>
<td></td>
</tr>
<tr>
<td>Broken eggs, %</td>
<td>2.3± 3.8</td>
<td>1.0± 6.3</td>
<td>0.5± 0.7</td>
<td></td>
</tr>
</tbody>
</table>

a,bValues within rows with no common superscript are different (P < 0.05).

TABLE 4. Parameters (± SE) and R² of the egg laying rate (ELR) curve for the DD, STI, and LTI Japanese quail lines as described by the modified compartmental model, a exp (−bt)/(1+exp(−ct−d))

<table>
<thead>
<tr>
<th>Parameter2</th>
<th>Line1</th>
<th>DD</th>
<th>STI</th>
<th>LTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>100.1± 3.8</td>
<td>95.4± 2.0</td>
<td>93.8± 2.9</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>0.00915± 0.00147</td>
<td>0.00369± 0.00081</td>
<td>0.00738± 0.00118</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>0.858± 0.214</td>
<td>0.975± 0.201</td>
<td>1.181± 0.603</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>4.187± 0.1883</td>
<td>3.858± 0.0981</td>
<td>4.285± 0.1938</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.89</td>
<td>0.96</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>

a,bValues within rows with no common superscript are different (P < 0.05).

Egg Quality

Egg composition was different in the three lines (Table 5). Egg weight was higher for LTI, it was intermediate for DD, and it was lower for STI (P < 0.05). Yolk weight was 0.2 g less (P < 0.05) in eggs from STI than in eggs laid by birds of the DD and LTI lines. Shell weight was about 10% lower (P < 0.05) in Line DD than in the other two lines. Eggs of DD had the highest yolk content (P < 0.05) and the lowest shell content (P < 0.05). The ratio of yolk to albumen was lowest (P < 0.05) in LTI, and albumen content was least (P < 0.05) in STI.

Feeding Trial

Egg production (number and weight) was similar in the three lines during the 3-wk feed trial (Table 6). The FI and BW were, respectively, 11 and 10% lower (P < 0.05) in Line DD, which had also the lowest BT (P < 0.05). The RFI was lowest in Line DD (P < 0.05), and the difference was approximately 5% of average FI. Adding BT as an independent variable into the multiple regression of FI did not improve R², and the coefficient of regression of FI on BT was not significant (data not shown).

TABLE 5. Egg composition (least squares mean ± SD) at 20 wk of age in the the DD, STI, and LTI Japanese quail lines

<table>
<thead>
<tr>
<th>Trait1</th>
<th>Line1</th>
<th>DD</th>
<th>STI</th>
<th>LTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg weight, g</td>
<td>11.0± 0.8</td>
<td>10.6± 0.9</td>
<td>11.5± 1.1</td>
<td></td>
</tr>
<tr>
<td>Yolk weight, g</td>
<td>3.6± 0.3</td>
<td>3.4± 0.4</td>
<td>3.6± 0.5</td>
<td></td>
</tr>
<tr>
<td>Shell weight, g</td>
<td>0.82± 0.06</td>
<td>0.91± 0.09</td>
<td>0.89± 0.10</td>
<td></td>
</tr>
<tr>
<td>Ratio yolk/albumen, %</td>
<td>54.5± 4.1</td>
<td>54.0± 5.6</td>
<td>52.0± 5.0</td>
<td></td>
</tr>
<tr>
<td>Yolk content, %</td>
<td>32.6± 1.6</td>
<td>31.3± 2.1</td>
<td>31.5± 2.0</td>
<td></td>
</tr>
<tr>
<td>Albumen content, %</td>
<td>60.0± 1.6</td>
<td>59.4± 2.1</td>
<td>60.8± 1.9</td>
<td></td>
</tr>
<tr>
<td>Shell content, %</td>
<td>7.4± 0.4</td>
<td>8.6± 0.6</td>
<td>7.7± 0.7</td>
<td></td>
</tr>
</tbody>
</table>

a,bValues within rows with no common superscript are different (P < 0.05).
TABLE 6. Performances (least squares mean ± SD) of females from the the DD, STI, and LTI Japanese quail lines during the 3-wk feeding trial started at 33 wk of age

<table>
<thead>
<tr>
<th>Trait</th>
<th>Line1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DD</td>
</tr>
<tr>
<td>BW, g</td>
<td>221.1* ± 20.5</td>
</tr>
<tr>
<td>BW gain (BWG), g</td>
<td>−5.5β ± 9.1</td>
</tr>
<tr>
<td>Egg number</td>
<td>17.6β ± 3.3</td>
</tr>
<tr>
<td>Egg weight, g</td>
<td>10.8β ± 0.7</td>
</tr>
<tr>
<td>Egg mass (EM), g</td>
<td>190.4β ± 38.0</td>
</tr>
<tr>
<td>FI, g</td>
<td>532.8β ± 58.4</td>
</tr>
<tr>
<td>Body temperature, C</td>
<td>41.3β ± 0.30</td>
</tr>
<tr>
<td>RFI, g</td>
<td>−19.9β ± 34.3</td>
</tr>
</tbody>
</table>

a,bValues within rows with no common superscript are different (P ≤ 0.05).

DD = early egg production line, n = 35; STI = low fear line, n = 35; LTI = high fear line, n = 34; FI = feed intake; RFI = residual FI.

The absence of sex difference for NI and TI observed in this work confirmed previous report by Mills and Faure (1986). The distributions of TI and NI appeared to be less skewed in Line DD, which had a different origin and had not been the subject of conscious selection for fear-related traits (Minvielle et al., 1999, 2000a).

Growth Traits

Comparisons of mature BW and of growth curves complemented previous studies of the STI and LTI lines. Mills et al. (1994) reported that there were differences in BW between the lines even in the early generations of the selection experiment. Similarly, Trognon (1998) reported a significant difference in BW between the two lines as early as 15 d of age. In a study of quail lines selected for high or low 4-wk BW, it also appeared that fear (high TI) and growth were negatively related (Jones et al., 1997). Within-line associations between TI and growth traits, however, were not measured in those lines. In the present work, Line DD had not been selected for BW or for TI (Minvielle et al., 1999), and BW of Line DD birds was intermediate to those of the LTI and STI lines. Also, Line DD exhibited variation for TI. However, correlations between measures of fear-related traits and BW were not significant in Line DD. It is possible, therefore, that the existence of a covariation between productivity and TI suggested by Jones and Hocking (1999) is limited to highly divergent experimental lines.

Egg Traits

Egg production was consistently better in STI and DD than in the high fear line LTI. Birds of the low fear STI

TABLE 7. Correlations between traits related to egg production in the the DD, STI, and LTI Japanese quail lines

| Variable                        | Line1  |
|                                 |        |
|                                 | DD     | STI    | LTI    |
| Egg number at 17 wk of age      | −0.64*** | 0.42*** | −0.79*** | 0.30*  | −0.76*** | 0.55*** |
| Egg number at 29 wk of age      | −0.47*** | 0.61*** | −0.65*** | 0.45*** | −0.47*** | 0.73*** |
| Egg number at 45 wk of age      | −0.36*** | 0.65*** | −0.45*** | 0.57*** | −0.25*** | 0.85*** |

a,bValues within rows with no common superscript are different (P ≤ 0.05).

DD = early egg production line, n = 64; STI = low fear line, n = 64; LTI = high fear line, n = 63.

AFE = age at first egg; CL = clutch length; egg number after Box-Cox transformation with parameter 3.5, 3.5, and 4 for production at 17, 29, and 45 wk of age, respectively.

*P < 0.05; ***P < 0.001.

Correlations

Correlations between (raw or standardized) measures of fearfulness and production traits could only be estimated in females of Line DD because distributions of fear-related variables (NI and TI) were highly skewed in Lines STI and LTI, with only few observations falling outside of the mode (Figures 1 and 2). No significant correlation was obtained between fear and production traits in Line DD (data not shown). All correlations between zootechnical traits were obtained within each of the three lines. The BT was not correlated with any other trait.

The correlation between BW at 35 d and EN after 1 mo of the egg-laying test was 0.42 and 0.34 (P < 0.01), respectively, for DD and LTI, and it was not significant (r = 0.16; P = 0.2) in STI. Similarly, the correlation between BW at 35 d and AFE was only significant (P < 0.05) in Lines DD (r = −0.36) and LTI (r = −0.25). There was a highly (P < 0.001) significant correlation between BW at 35 d and EW in the STI and LTI lines (r = 0.48 and 0.51), but this correlation was not significant in Line DD (r = 0.20; P = 0.13). Correlations among egg production-related traits are shown in Table 7, and all correlations were significant (P < 0.05 to P < 0.001). In all lines, the correlation between AFE and EN was negative and decreased as the number of weeks in test increased. Conversely, CL and EN were positively related, and the correlation between the two variables increased with the number of weeks in test.

DISCUSSION

Fearfulness Traits

Distributions of TI and NI measured on 189 LTI and 183 STI chicks indicated that the birds used in the present study were representative samples of the divergent lines selected on TI (Mills and Faure, 1991; Faure and Mills, 1998). The absence of sex difference for NI and TI observed in this work confirmed previous report by Mills and Faure (1986). The distributions of TI and NI appeared to be less skewed in Line DD, which had a different origin and had not been the subject of conscious selection for fear-related traits (Minvielle et al., 1999, 2000a).
line had the highest laying persistency. Working with laying hens, Hemsworth and Barnett (1989) reported that the level of fear of humans might be associated negatively with productivity, but the present work appears to be the first to address directly the existence of a link between fear and egg production. Because no correlations between fear and production characters were found in the DD line, the positive aspects of egg production observed in the STI line might be line specific or fortuitous.

The present study confirmed the observation of Mills et al. (1994) that LTI birds laid heavier eggs than STI quail. Egg composition differed markedly between the three lines. The different origin of Line DD (Minvielle et al., 2000a) may account for some of these differences. However, it is not clear how divergent selection for TI could have affected albumen and shell contents in lines STI and LTI, which were of the same origin. The origin of Line DD (Minvielle et al., 2000a) may account for some of these differences. However, it is not clear how divergent selection for TI could have affected albumen and shell contents in lines STI and LTI, which were of the same origin. The origin of Line DD, which had been previously selected for egg production (Minvielle et al., 1999) suggest that, at least in this line, these traits are related to one another in the absence of stress.

Feed Efficiency

Selection for TI did not influence feed use by laying quail of the LTI and STI lines; FI and RFI (as well as BT) were similar in the two divergent lines. On the other hand, DD line birds, which had lower RFI and BT than STI and LTI line birds but produced the same EM, used feed more efficiently in the production of eggs.

In conclusion, although divergent selection for TI appeared to be associated with higher BW, higher egg production and lower EW in the less fearful Line STI, the lack of significant correlation between fearfulness traits and production traits in Line DD, unselected on behavior, indicated that these associations need to be further analyzed within populations.

ACKNOWLEDGMENTS

The technical assistance of C. Moussu (Nouzilly), M. Marché (Nouzilly), and J. L. Chanussot (Jouy-en-Josas) is gratefully acknowledged.

REFERENCES


