SELECTION FOR BODY WEIGHT IN JAPANESE QUAIL
UNDER DIFFERENT NUTRITIONAL ENVIRONMENTS

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The type of environment under which selection should be practiced has not received a great deal of attention until rather recently. Historically, most selection studies have been practiced under optimum conditions or at least under very favorable conditions. This pattern was undoubtedly influenced by Hammond (1947) who stated, "It would appear that the character required is best selected for under environmental conditions which favor its fullest expression, and that once developed it can also be used in other environments, provided that other characters, specially required by that new environment, are also present in the animal." Falconer (1952) was one of the first to present experimental evidence regarding the validity of Hammond's thesis and noted that it required two conditions: (1) That genes determining the expression of the character selected are mainly the same in both good and bad environments, (2) A different sort of interaction between genotype and environment is required such that the bad environment affects the superior genotypes more than the inferior.

From a practical point of view, for overall selection progress to be greater under a poor or stress environment, the heritability under the poor environment would have to be greater than under a good environment or there would have to be an increase in phenotypic variance resulting in larger selection differentials. Falconer (1952) presented evidence that clearly contradicted the more important part of Hammond's thesis. Working with mice, he demonstrated that improvement attained by selection under good conditions was not realized when the selected
strain was transferred to poor conditions and showed no evidence of any advance beyond the initial level. However, improvement of the genotype for growth under the poor environment did carry with it considerable improvement under the good environment.

This work was followed by several studies utilizing different species, Fowler and Ensminger (1960) working with swine, McNary and Bell (1962), Hardin and Bell (1967), and Yamada and Bell (1969) working with Tribolium, all investigated relative selection progress under different environments. One interesting feature of Yamada's and Bell's (1969) work was that the average response per generation in the large lines was greater in the poor environment than in the good environment.

McBride (1959) presented an extensive summary of genotype-environment interactions, while Robertson (1959 and 1963) reported on the ecological genetics of Drosophila with regard to the interdependence of genetic and environmental factors in determining the nature of quantitative variation.

The current investigation was designed primarily to study the influence of environmental manipulation on the ultimate selection limit. While many studies have involved selection under good and poor environments with subsequent testing under the opposite environment, there have been few attempts to investigate selection response in lines after switching them to a new environment. In other words, selecting under a poor environment until the selection limit is approached and then shifting to a good environment and continuing selection. The work of Yamada and Bell (1969) showing a greater response per generation under a poor environment, Falconer's work showing higher heritability under a poor environment, and the possibility of greater phenotypic variation under a
stress or poor environment may be a useful genetic tool. Instead of working with a single restriction, it was decided to utilize two predictable restrictions to formulate the stress environment in the current study. This would allow for the relaxation of a single restriction at two separate points in the overall duration of the study. Primarily from the point of managerial ease, dietary stress environments were chosen for this study. Preliminary studies indicated that crowding, limiting waterer and feeder space and temperature stresses were not consistent in producing repeatable restrictions. A low protein level of 20 percent and 0.2 percent thiouracil were selected as the two restrictions, which would result in a 25 to 30 percent restriction in four-week body weight when compared to birds receiving a normal 28 percent protein diet. These restrictions were additive in that each was responsible for approximately 1/2 of the total restriction in four-week body weight.

It is not the intent of this paper to try to convince this audience that selection should be practiced under a stress environment, but rather to present what information we have collected on this possible approach. In retrospect, there are several changes that would have been desirable in the design of this study. In view of the response of the T line to thiouracil, replicated lines would have been extremely valuable.

MATERIALS AND METHODS

The base population for this study was a control population which was established at Beltsville in 1963 (Marks, 1967). This population had a fairly diverse base with stock coming from California, Alabama, Florida, Washington State, NIH and Massachusetts. It is possible, however, that all sources except the Auburn strain could be traced back to a single California source.
Two lines were established on the basis of high body weight at four-weeks of age. One population (P) was selected on an adequate 28 percent protein diet, while the second population (T) was selected on a 20 percent protein diet containing 0.2 percent thiouracil (Marks and Lepore, 1968).

Population size has been approximately 400 straight run chicks per generation. In addition, 100 randombred controls have been raised intermingled with each of the selected populations. Immediately after hatching chicks were placed in electrically heated quail battery brooders for a four-week period. Both populations were maintained in the same room in order that temperature, humidity, light intensity and other variables would be as similar as possible among populations and generations. Two- and four-week body weights were obtained for all birds. Individual phenotypic selection was practiced within each population for four-week weight with selected breeders transferred to laying cages at five weeks of age.

After ten generations, both selected lines (P and T) and the randombred control population were transferred from the Agricultural Research Center, Beltsville, Maryland, to the Southern Regional Poultry Genetics Laboratory, Athens, Georgia. All lines were maintained for one additional generation at Beltsville after the transfer. Equipment, diets and management at Athens were as similar as possible to those at Beltsville. The only intentional change after the move was the manner of setting up matings to reproduce subsequent generations. Within each population and generation 24 males and 72 females were selected as breeders to reproduce the first ten generations. Generations 11 thru 25 were reproduced with 60 paired matings.
RESULTS AND DISCUSSION

Selection Responses

Four-week body weights of P-line and control quail for the first 25 generations are shown in Figure 1. Regression of population means on generations indicated a 3.1 g increase per generation in the P line while the regression coefficient for the controls was minus .47. Both regressions were significant at the one percent level. The response of the P line indicates continued genetic improvement and after 25 generations of selection in this environment.

Presented in Figure 2 are regression coefficients of population means on generations for four-week body weight of T line and control quail. The regression coefficient for the T line was 2.4 g while that of the control was minus .43. These data indicate T line quail are continuing to respond to selection for four-week body weight under a stress environment.

The significant (P < .01) decrease in body weights of controls under both the P and T environments was not anticipated. Since controls were reared intermingled with the selected lines, it was postulated that the reduction in the body weights of the controls could be due to their inability to compete with the larger quail for feed and water. A study was conducted, therefore, to evaluate the relative performance of controls reared intermingled with selected lines and controls reared in separate pens. Data obtained in generation 26 indicate that controls maintained in separate decks were from 9 to 15 grams heavier than their contemporaries reared intermingled with larger birds (Table 1). Since this difference was approximately the same as the decrease in body weight of controls across generations, it may partially explain the negative
regressions of control body weights.

The percent deviation of the P and T lines from their respective controls for four-week body weight is shown in Figure 3. The response patterns are similar in both populations. After 25 generations of selection, the P and T lines are approximately 130 percent larger than their respective controls. This value is slightly biased upward as a result of the negative trend in the body weights of controls.

Heritabilities for four-week body weight for generations 0-6 are shown in Table 2. Realized heritabilities were larger for the P line than for the T line. Heritability estimates by other methods of computation also appeared to be larger in the P line. Regression of offspring on mid-parent and realized heritability estimates were approximately .45 in the P line and .38 in the T line (Table 2). Heritabilities for generation 0-15 were smaller (Table 3) than estimates from earlier generations. Presented in Table 4 are heritabilities for four-week body weight for generations 0-25 for the P and T lines. It is of interest to note that these values are very similar to those for generations 0-15 indicating no apparent reduction in genetic variability during the last 10 generations of selection.

Coefficients of variation in four-week body weights for females of the P and T lines are shown in Figure 4. Values for the T line for the first 20 generations were consistently greater than comparable values in the P line, however, after generation 20 there was little difference in the coefficients of variation between the two lines.

Selection differentials (effective) for the P and T lines are presented in Figure 5. There was a tendency for these values to be larger in the T line for
the first 10 generations with little difference between the two lines for the remaining 15 generations. The larger selection differentials in the T line, although heritabilities were smaller, resulted in similar genetic gains to those of the P line during the earlier generations of this study.

Two-week body weights of P line and control quail are presented in Figure 6. Regression of mean body weights on generations yielded coefficients of 1.68 g and -.19 g in the P line and controls, respectively. Regression coefficients of population means on generations of .83 g and -.19 g were observed for the T line and controls, respectively (Figure 7). It is evident from these data that most of the improvement in four-week body weight of T-line quail occurred between two and four weeks of age.

Correlated Responses

Responses of correlated traits are based on 60 individual pairs in the P and T lines per generation after generation 10. These estimates therefore, may be slightly biased in comparison to values on the entire population. This should not make a great deal of difference, however, in comparing the relative performance of various traits in these two lines. An attempt was made to calculate correlations from data collected from initial generations. Due to the relatively small sample size, estimates and standard errors were so variable that they appeared to be of little value.

Data on correlated traits have been designed to: (1) provide a comparison of these traits in lines selected under a normal and stress environment, and (2) provide information on the trends in these traits accompanying selection for four-week body weight under two different environments.
The regressions of adult body weight (15 week) means on generations yielded (b) values of 3.6 g and 2.9 g in the P and T lines, respectively (Figure 8). Considering the P line as a zero base, the adult body weights of T line quail as a deviation from the base, were smaller in all generations. There appeared to be a trend for the T line body weights to show a greater deviation in generations 17-25.

Presented in Figure 9 are the regressions of mean egg weights on generations in the P and T lines. The regression coefficient for the P line was -.002 while a value of .06 was observed in the T line, indicating that egg weights had increased significantly (P < .01) in the T line, while decreasing in the P line. During the initial generations, egg weights in the T population were smaller than those of the P line, however, in later generations, egg weights of T line birds were approximately one gram heavier than those of P line eggs. While this difference appears small in quail, it represents a ten percent differential in egg size.

Sexual maturity in the T line (age at first egg) as a deviation from the P line is presented in Figure 10. Regressions of population means on generations were positive and significant for both populations indicating later sexual maturity accompanying selection for four-week body weight. During earlier generations, T line quail matured approximately five days later than P line quail, however, there was little difference between populations after generation 15.

A significant (P < .01) reduction in egg production was noted in the P line (b = -.59) while egg production in the T line remained constant (b = .007) as a result of selection for four-week body weight (Figure 11). Egg production during the first 15 generations was similar in both selected lines, however,
higher egg production was observed in T line quail in generations 20-25.

Fertility of T-line quail was superior to that of P-line quail in every generation except 16 (Figure 12). This advantage was 10 percent in generation 1 and 25 percent in generation 25. Regressions of population means on generations were -.16 and .17 in the P and T lines, respectively. Regressions of hatchability on generations were positive for both populations (Figure 13). While differences in hatchability of fertile eggs between the selected lines varied considerably from generation to generation, the mean values of the two lines were similar.

Evaluation under different environments

The experimental design of these trials normally included three replications for each line with 12-15 birds per replication. Birds from different lines (P, T, C) receiving the same diet within replication were reared on the same deck of quail brooders.

Mean four-week body weights of P, T and C lines (from generation 6 breeders) reared under different nutritional environments are presented in Table 5. Body weights of P population quail were greatly reduced when this line was reared on the 20 percent protein diet containing 0.2 percent thiouracil (stress environment). Body weights of T-line quail, however, were greater under the good environment (28 percent protein), than under their selected environment. These data are similar to those of Falconer and Latyszewski (1952) which indicated that animals selected under a poor environment when exposed to a good environment performed almost as well as animals selected under a good environment, while animals selected under a good environment perform poorly under a stress environment.
Mean four-week body weights for P, T and C lines (from generation 13 breeders) reared under different nutritional environments are shown in Table 6. Responses are similar to those observed in generation 6 (Table 5). P-line quail performed poorly under the stress environment while T-line quail performed extremely well under the normal 28 percent protein environment. Perhaps, the most interesting observation was that body weights of T-line quail receiving the 28 percent protein diet containing 0.2 percent thiouracil were equal or superior to body weights of T-line quail receiving the 28 percent protein diet (121 g vs. 120 g). These data indicate that T-line quail have developed an inherent ability to resist the growth depressing effect of thiouracil when fed a 28 percent protein diet.

In an attempt to determine the nature of the resistance of T-line quail to thiouracil, studies were conducted to investigate the influence of varying levels of thiouracil and the influence of different goitrogenic compounds. Mean four-week body weights for P, T and C quail receiving different levels of dietary thiouracil are presented in Figure 14. Body weights of T-line quail receiving 0.1 percent thiouracil were heavier than quail receiving the basal diet, while body weights of T-line quail receiving 0.2 percent thiouracil were similar to those receiving the basal diet. Body weights of both P and C line quail were reduced at four-weeks on the 0.1 percent thiouracil diet and to a greater degree on higher levels of thiouracil. The reductions in body weights between the 0.2 and 0.3 percent thiouracil levels were similar in all three lines. These data suggest that while T-line quail are more resistant to dietary thiouracil than P and C lines, they are not totally resistant to thiouracil above the 0.2 percent level. This would suggest that a threshold mechanism may be involved in the
Resistance of T-line quail to dietary thiouracil.

In an attempt to determine if the change in thyroid activity of T-line quail was a rather specific or a more general one, goitrogenic compounds which act by different metabolic pathways were utilized.

Four-week body weights of the P, T and C quail receiving different goitrogenic compounds are shown in Figure 15. As in previous trials, body weights of T-line quail were not reduced when fed diets containing 0.2 percent thiouracil while body weights of P- and C-line quail were depressed. Potassium thiocyanate (KSCN) at the 0.2 percent level and 2.0 percent sulfaguanidine were not effective goitrogenic agents in this study as measured by growth inhibition.

Body weights (four-week) of P, T and C quail, from generation 19 breeders receiving thiouracil and sulfaguanidine are presented in Figure 16. Thiouracil at the 0.2 percent level resulted in response patterns similar to that observed in previous trials. Four-week body weights of quail receiving 8.0 percent sulfaguanidine were similar to those of quail receiving the basal diet indicating that this compound was not producing a goitrogenic effect in quail as measured by restriction in growth rate. Mean four-week body weights of P, T and C quail lines receiving diets containing thiouracil, potassium thiocyanate, sulfadiazine and thiourea are presented in Figure 17. The response of all three lines to 0.2 percent thiouracil was similar to that of previous trials. Potassium thiocyanate at the 0.5 percent level had a slight, but definite, goitrogenic effect in reducing body weights in all three lines while sulfadiazine (2.0 percent) also resulted in a reduction of body weights in T and C line quail. Mortality of approximately 100 percent was observed for P-line birds receiving this diet.
Thiourea at the 0.2 percent level also resulted in a reduction in body weight in all three lines. The results of these studies indicate that while T-line quail are resistant to 0.2 percent thiouracil, they are not totally resistant to other goitrogenic compounds, although they are less effected by these compounds than the P and C lines. The metabolic change in thyroid activity in the T population which allows them to eliminate the adverse effect of thiouracil therefore appears to be a rather specific alteration.

The relative performance of P- and T-line quail to varying protein levels was investigated in several trials. Mean gain in body weight from one to three weeks of age of P- and T-line birds (from generation 15 breeders) are shown in Figure 18. T-line quail had superior rates of gain on the 18 and 21 percent protein diets while body weights of P-line quail were superior on the higher protein levels. A definite line by protein level interaction was present for all observation periods. In similar studies conducted in generations 6 and 7, P-line quail were superior on all levels of dietary protein. These results suggest that if genetic alterations occur in response to specific environments, they may not occur until after a number of generations of selection.

**Physiological Responses**

In an attempt to determine possible alterations in thyroid activity of T-line quail, cooperative studies with Dr. B. Howarth, Poultry Science Department, University of Georgia, were undertaken. $^{131}$I uptake values for P, T and C lines are shown in Table 7. It is apparent that 0.2 percent dietary thiouracil increased the uptake of $^{131}$I in P-line and C-line quail. Thiouracil which acts to block the iodination of tyrosine would be expected to suppress thyroxine production, which in turn could lead to an accumulation of high concentrations of inorganic iodide in the gland. This accumulation would
appear to be the reaction of C- and P-line quail in response to thiouracil as suggested by the increased uptake of $^{131}$I, whereas T-line quail, which have been shown to be tolerant to thiouracil, do not elicit a corresponding increase in $^{131}$I. This lack of response could indicate a more rapid turnover of iodine by the thyroids of T-line quail and an increased production of thyroxine or the physiologically more economical triiodothyronine (Howarth and Marks, 1973a).

Sexual maturity as measured by spermatogenic development in males is presented in Table 8. All controls (100 percent) receiving a normal diet (C-N) reached sexual maturity by 42 days of age. Sexual maturity of 100 percent of the controls receiving a thiouracil diet (C-TU) however, was not observed until 54 days of age. T-line quail receiving thiouracil (T-TU) were similar to the C-N control groups with 100 percent of the birds reaching sexual maturity as measured by spermatogenic activity at 42 days of age. These data (Howarth and Marks, 1973b) suggest that thiouracil in T-line quail does not delay sexual maturity as in the controls (C-TU) and may be related to the superior fertility of T-line quail as opposed to P-line quail (Figure 12).

In an attempt to determine if histological differences were present in the selected quail lines, thyroids were removed and prepared for histological examination. Thyroids of a T-line quail receiving thiouracil showed an invasion of the follicle with additional secretory cells while P-line thyroids were greatly enlarged but did not show a corresponding response. This increase of secretory cells in thyroids of T-line quail may result in the output of larger amounts of thyroxine which would tend to eliminate the goitrogenic effect of thiouracil in this population.
In an attempt to determine if T-line quail were more resistant to other forms of stress, a study was conducted to evaluate the tolerance of P, T and C quail lines to high temperature stress. P- and T-line quail and their respective controls were subjected to a temperature stress of 45.6°C. (114°F.) for a three-hour period. Mortality and LD-50 values for P, T and C quail are presented in Table 9. Mortality (percent) was identical for P and T quail lines while controls reared under the P environment (PC) were not significantly different from the selected lines. Controls reared under the T environment (TC) had significantly lower mortality than the other experimental groups. LD-50 values for P and T line quail were also similar while the values for controls under both environments were higher. These data suggest that LD-50 measures may be somewhat more sensitive than gross mortality data in evaluating temperature stresses. This study indicates that while T-line quail are resistant to thiouracil stress, they may not be more resistant to other stresses such as high temperatures (Marks and Huston, 1973).

Summary

Selection for increased four-week body weight was slightly more effective under a 28 percent protein diet than under a stress environment (20 percent protein plus 0.2 percent thiouracil). In the 25th generation, however, both selected lines were approximately 130 percent heavier than their respective controls. When selected lines were evaluated under reciprocal environments, body weights of P-line quail were greatly reduced, while body weights of T-line quail were greater under the 28 percent protein environment than under their selected environment.
After 12 generations of selection body weights of T-line quail exposed to a 28 percent protein diet containing 0.2 percent thiouracil were equal or superior to birds receiving a 28 percent protein diet without thiouracil. While T-line quail were found to be more resistant to all levels of thiouracil than P-line and control quail, they were not totally resistant to thiouracil above the 0.2 percent level. The T-line quail were also found to be more resistant to other goitrogenic compounds than P- and C-line quail, however, they were not totally resistant to any compound other than thiouracil. Metabolic change in thyroid activity in T-line quail which allows them to eliminate the adverse effect of thiouracil, therefore, appears due to a specific alteration.

Performance characteristics of traits other than the selected trait (four-week body weight) were generally superior in the T-line which had been selected under a stress environment.
References


Robertson, F. W., (1959). Gene-environment interaction in relation to the nutrition and growth of Drosophila. Biological Contributions, The University of Texas, Austin; Fall 1959, publ. no. 59II.

Four-week body weight of P-line and control

Fig. 1
Four-week body weight of T-line and control

Fig. 2
Generation

Percent deviation from control in P and T lines

Fig. 3
Coefficients of variation in 4-week weight (females)

Fig. 4
Selection differential (effective) for P and T lines

Fig. 5
Two-week body weight of P-line and control

Fig. 6
Regression on generations

\[ P_b = -0.002 \]
\[ T_b = 0.06** \]

Egg Weight (T - line plotted as deviation from P - line)

Fig. 9
Sexual Maturity (T - line plotted as deviation from P - line)

Fig. 10
Regression on generations

P_b = -.59**
T_b = .007

Egg Production (T - line plotted as deviation from P - line)

Fig. 11
Regression on generations

\[ P_b = -0.16 \]
\[ T_b = 0.17 \]

Fertility (T - line plotted as deviation from P - line)

Fig. 12
Hatchability (T - line plotted as deviation from P - line)

Fig. 13
Influence of varying levels of Thiouracil (S17)

Fig. 14
Influence of different goitrogens (S_{18})

Fig. 15
Fig. 16

Influence of different goitrogens (S19)

Diets

Cont.  .2% TU  8.0% Sulfa  .4% TU

4-week body weight (g.)
Influence of different goitrogens (S₂₅)

Fig. 17
Mean gain in body weight from 1 to 3 weeks of age ($S_{15}$)

Fig. 18
Table 1.
Comparison of Intermingled vs. Separate Controls

<table>
<thead>
<tr>
<th>Gen.</th>
<th>Pop.</th>
<th>4-week Body Weight</th>
<th>Intermingled</th>
<th>Separate</th>
<th>Diff.</th>
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<tr>
<td>26</td>
<td>P</td>
<td></td>
<td>76</td>
<td>85</td>
<td>9</td>
</tr>
<tr>
<td>26</td>
<td>R</td>
<td></td>
<td>58</td>
<td>73</td>
<td>15</td>
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Table 2.

Heritabilities for 4-week Body Weight (Gen. 0-6)

<table>
<thead>
<tr>
<th>Method</th>
<th>Population</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
</tr>
<tr>
<td>Realized¹</td>
<td>.52</td>
</tr>
<tr>
<td>Realized²</td>
<td>.48 ± .10</td>
</tr>
<tr>
<td>4S</td>
<td>.56 ± .08</td>
</tr>
<tr>
<td>4D</td>
<td>.63 ± .08</td>
</tr>
<tr>
<td>2b (Sire)</td>
<td>.38 ± .10</td>
</tr>
<tr>
<td>2b (Dam)</td>
<td>.29 ± .10</td>
</tr>
<tr>
<td>b (M-P)</td>
<td>.45 ± .08</td>
</tr>
</tbody>
</table>

¹Cumulative \( h^2 = R/S \); ²Regression means on S.D.
Table 3.
Heritabilities for 4-week Body Weight (Gen. O-15)

<table>
<thead>
<tr>
<th>Method</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
</tr>
<tr>
<td>Realized¹</td>
<td>.34</td>
</tr>
<tr>
<td>Realized²</td>
<td>.29 ± .04</td>
</tr>
<tr>
<td>2b (Sire)</td>
<td>.27 ± .07</td>
</tr>
<tr>
<td>2b (Dam)</td>
<td>.28 ± .08</td>
</tr>
<tr>
<td>b (M-P)</td>
<td>.27 ± .06</td>
</tr>
</tbody>
</table>

¹Cumulative (h² = R/S); ²Regression means on S.D.
<table>
<thead>
<tr>
<th>Method</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
</tr>
<tr>
<td>Realized(^1)</td>
<td>.34</td>
</tr>
<tr>
<td>Realized(^2)</td>
<td>.29 ± .02</td>
</tr>
<tr>
<td>2b (Sire)</td>
<td>.24 ± .05</td>
</tr>
<tr>
<td>2b (Dam)</td>
<td>.24 ± .06</td>
</tr>
<tr>
<td>b (M-P)</td>
<td>.27 ± .04</td>
</tr>
</tbody>
</table>

\(^1\) Cumulative \((h^2 = R/S)\); \(^2\) Regression means on S.D.
### Average of 3 Reps

\[ 10\% \text{ Threonine (Tm)} \]

<table>
<thead>
<tr>
<th>Diet</th>
<th>2% Protein</th>
<th>28% Protein + Tm</th>
<th>28% Protein + Tm + Tm</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
<td>105</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>108</td>
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<td>67</td>
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<td>84</td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>112</td>
<td>116</td>
<td></td>
</tr>
</tbody>
</table>

\[ \frac{\tilde{p}}{\tilde{q}} \]

Population

---

**Table 5.1**

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Under different nutritional environments (gen. 6)

Mean 4-week body weights of P, T, and C lines.
### Table 6.

Mean 4-week Body Weights of P, T, and C Lines

**Under Different Nutritional Environments (Gen. 13)**

<table>
<thead>
<tr>
<th>Diet</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
</tr>
<tr>
<td>28% Protein</td>
<td>126²</td>
</tr>
<tr>
<td>20% Protein + TU¹</td>
<td>71</td>
</tr>
<tr>
<td>28% Protein + TU¹</td>
<td>95</td>
</tr>
<tr>
<td>20% Protein</td>
<td>110</td>
</tr>
</tbody>
</table>

¹ 0.2% Thiouracil (TU)

²Average (g.) of 3 reps
Table 7.

$^{131}$I Uptake of P, T, and C Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>N</th>
<th>Control</th>
<th>0.2% TU</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>16</td>
<td>11.4$^1$</td>
<td>26.5</td>
</tr>
<tr>
<td>P</td>
<td>16</td>
<td>6.4</td>
<td>16.7</td>
</tr>
<tr>
<td>T</td>
<td>16</td>
<td>5.1</td>
<td>3.4</td>
</tr>
</tbody>
</table>

$^1$Mean thyrodial $^{131}$I uptake expressed as percentage of dose.
Table 8.
Sexual Maturity Based on Degree of Spermatogenic Development

<table>
<thead>
<tr>
<th>Days of age</th>
<th>C-N</th>
<th>C-TU</th>
<th>T-TU</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>80¹</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>42</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td></td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

¹Percentage of males with full spermatogenic activity
Table 9.
Mortality and LD-50 for P, T and Controls at 45.6°C.

<table>
<thead>
<tr>
<th>Population</th>
<th>P</th>
<th>FC</th>
<th>T</th>
<th>TC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality (%)</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LD-50 (min.)</td>
<td>58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>159&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Each mean value involves 5 reps with 10 birds/rep.
ALAN EMSLEY: Based on 24 males and 72 females per generation, the approximate change in inbreeding is 7/10 percent (effective population size about 70). Did you compute inbreeding to be about 17.5 percent after 25 generations?

MARKS: Since 60 pairs were set up to reproduce generations 11-25, the effective population size was less than 70. We calculated the level of inbreeding in the P and T lines to be approximately 14 percent after 25 generations of selection.

TOM SOCHA: Did you compare total body composition of the two lines? Since you are changing the protein intake by approximately 28 percent, could you also be reducing the protein content of the body?

MARKS: Yes, total body compositions of the two lines were compared in generation 4 and again in generation 15. There was essentially no difference in the body composition (moisture, fat, protein) between the P and T lines in generation 4. While differences were not significant, there was a tendency for T-line quail to have carcasses containing more protein than those of the P-line in generation 15. The T population carcasses also contained a higher percentage of total lipid and less water than P population carcasses.

PAUL MARINI: With respect to the three slides of thyroid sections, were magnifications the same for all three?

MARKS: Yes, the same magnification was used in all three slides showing histological differences in the thyroids.
DuWAYNE ENGLERT: Would the assumed influence of intermingling of the selected and control lines have increased proportionately as the increase of response over time. If so, what effect do you feel this has had on your overall response?

MARKS: I am not absolutely sure, however, I tend to believe that the decline was not proportional with time. Similar tests involving the rearing of controls both intermingled and separate in earlier generations did not show a definite effect. Therefore, it appears that most of the decline has probably occurred after generation 10. With regard to this influence on overall response, it has resulted in an upward bias of approximately 20-25 percent. Correcting for the downward trend of controls would result in deviation from controls of 110-115 percent instead of 135 percent in the P and T lines in generation 25.

DINUS M. BRIGGS: Do you feel that four-week body weight variation is being influenced by sexual maturity in the female? Would selection at two or three weeks avoid the influence of sexual maturity?

MARKS: It is possible, however, I do not feel that sexual maturity in females at four weeks is an important factor influencing variation in body weight at this age. It is my understanding from talking with individuals that have looked at variation at different ages that selection at four weeks is as good, if not better than other ages for growth rate selection in quail.

EARL LASLEY: Have you considered the possibility that a simply inherited situation is responsible for T-line response?

MARKS: Yes, the P and T lines were crossed reciprocally, however, body weights of cross progeny were intermediate to the weights of pure line progeny when tested on thiouracil and control diets.
BILL COOK: Were the correlated responses for fertility and egg weight the same when you switched environments of the lines?

MARKS: Unfortunately, we did not measure fertility and egg weights in the lines when they were evaluated under switched environments. All evaluations of the lines under different environments involved only measures of growth rate to four weeks of age.

GORDON DICKERSON: Did not your slide comparing 26 generations deviation of P-line from control, show larger P-C deviations under separate than under intermingled rearing? Also for R-C comparison, could inbreeding in control line (6%) explain negative trend in growth?

MARKS: The values in this slide were actual body weights of the controls reared intermingled with larger selected birds or in separate decks under the P and R environments and not deviations from controls. Four-week body weights of controls were larger in separate decks indicating that quail reared intermingled may have difficulty competing for feed and water. It is entirely possible that inbreeding in the control line may have been partially due to the negative trend in the control response across generations.

H. ABPLANALP: Have you tested your P-line fertility under thiouracil treatments?

MARKS: No, we have not. This is a good point and should be checked.

JAMES R. CHAMBERS: Have you examined the performance of crosses of the T and P lines to attempt to learn more about the nature of the difference between these two lines?

MARKS: Yes, the T and P lines were crossed reciprocally in generation 18, however, we were unable to uncover any interesting leads.
PETER HUNTON: Would you care to speculate whether the results of this work might be extrapolated to suggest if in the situation of feed protein shortage, meat-type poultry might, with advantage, be selected under a low protein environment?

MARKS: I hesitate to extrapolate a great deal from one species to another. These data, however, do indicate that selection over a long period of time can produce definite alterations in the response of lines to different levels of dietary protein. It is important, however, to keep in mind that these changes were not evident until after a number of generations of selection.