60 GENERATIONS SELECTION FOR AN INDEX COMBINING HIGH BODY WEIGHT AND HIGH STRESS RESISTANCE IN LABORATORY MICE

L. Bünger; U. Renne; G. Dietl
Research Institute for Biology of Farm Animals, Dummerstorf-Rostock
Dept. Population Biology and Breeding Research, Wilhelm-Stahl-Allee,
18196 Dummerstorf, Germany

SUMMARY

A modified exponential model was used to analyse the direct response of long term selection among full-sib-families (2 test-males per litter, 80 pairs per line and generation , selection proportion about 50%) in outbred laboratory mice. The selection criterion was an index combining the genetically negatively correlated traits: high body weight (BW) and high stress resistance. To quantify the stress resistance the treadmill performance (TP) was measured as the distance to exhaustion. Starting at 7545 index units (IU) in generation 0 the index came up to 118580 IU in generation 60. That is a total selection response of 4313 IU or about 57%, equivalent to 12 s_p or 21 s_g. The realised heritability for the index converted to an individual base was initially 0.33, decreasing to 0.03 at generation 60. The half live was 24 generations.
Selection response in the index line (DU-6+LB) was compared to the development of stress resistance in 3 lines, 2 were single trait selected for growth traits (body weight - line DU-6); protein amount - DU-6P) and the control (DU-Ks). Means for treadmill performance in generation 50 in lines DU-Ks, DU-6, DU-6P, DU-6+LB were estimated as 2000m (100%), 272m (14%), 441m (22%) and 2853 m (143%), respectively. Body weights were 28.7g (100%), 54.6g (190%), 49.1g (171%) and 46.1g (60%). These results demonstrate the combining possibility of high growth and high TP and the negative effects of single trait selection for growth traits on TP.

INTRODUCTION

The laboratory mouse is a valuable animal model for animal breeding studies on genetic basis and selection theory for traits such as body weight, growth rate, fertility, feed efficiency, body composition and stress resistance, because of it's short generation interval and low unit cost.
Considerable data are available on genetic architecture of postweaning body weight or growth rate and fertility traits (especially litter size), but only a few studies have involved direct selection for stress resistance or selection for a combination of these antagonistic traits.
The **first objective** of this paper was to evaluate the efficacy of long term antagonistic index selection for body weight and stress resistance. The **second objective** was to investigate the development of stress resistance as a result of single trait selection for protein amount and body weight.

MATERIALS AND METHODS

The selection experiment has been described in detail by BÜNGER et al. (1983) and BÜNGER (1987) and is briefly reviewed here in tabular form (Table 1).
The basic concept for stress resistance especially endurance fitness, the measuring method for laboratory mice using a run on a treadmill up to exhaustion (speed about 2.28 km/h) and the device were presented earlier (BÜNGER 1980,1982).
For the analyses of the data following model, proposed by HERRENDÖRFER and BÜNGER (1988) and BÜNGER and HERRENDÖRFER (1993) was used: **Y= A-(A-C) exp [(-Bx/(A-C)]** , where A = theoretical final value, B = maximal slope at x = 0, C = y-values at x = 0. Because the selection criterion for a litter was the sum of two male full-sibs the heritabilities and phenotypic variances were converted to an individual basis using: $h^2 = 2Q/ [(n-(n-1)Q]$ where : Q = Ratio 'selection response/ selection differential' and n: number of full sibs and $s_{p_i}^2 = s_{p_{fs}}^2 / (2\vartheta + 2)$

ϑ : Intra-class correlation = 0.4 ±0.14 for the index   i : individual   fs : full sib

Table 1. Experimental design

	DU-Ks	DU-6	DU-6P	DU-6+LB
length of the experiment (generations)	9 to 70	0 to 70	0 to 70	0 to 60
selection trait	----	BW 42 2♂ body weight	PR 42 2♂ protein amount	BW 42 2♂+ TP 42 2♂ index
selection procedure	full sib groups for the sum of 2 test males per litter			
litter size standardisation	to 8/9 at birth			
selection quote (%)	45.8±2	50.2±9.3	53.4±9	51.1±11
i (SD / s_p)	0.08±0.14	0.77±0.19	0.73±0.2	0.77±0.23

* **DU-Ks** = control line, built up from the same base population, corresponding to generations 8/9 , selection at random
* technical problems concerning the treadmill resulted in a temporary end of the selection in line DU-6+LB after generation 60 and in generations 10,47,48 and 57 only relaxed selection was possible
* Index in line DU-6+LB combining high body weight and high treadmill performance.
  $I = BW\ 42 * 100 + (TP\ 42 * s_{BW\ 42} * 100 / s_{TP\ 42})$
* 80 pairs per line and generation; mating age: 63 ±3days; mating ratio : 1♂ : 1♀

RESULTS AND DISCUSSION

Development of the index is presented in figure 1. Starting at 7545 index units (IU) in generation 0 the index came up to 11858 IU in generation 60. Consequently selection yielded a total response of 4313 IU or 57%, equivalent to 12 phenotypic or 21 genetic standard deviations. The realised heritability for the index converted to an individual base was initially 0.33, decreasing to 0.03 in generation 60. The half live was 24 generations.

Because the change of the index is not very descriptive, the development of body weight and of treadmill performance are separately presented in figures 2 and 3. It was not possible to measure the TP continuously in all lines and all generations. Therefore some cross sectional studies over all lines were done in generations 7,8,9,15,31, 32 to 41 and 43, including 50 to 120 males per line and generation (N_{total} = 523 to 900 per line). The data were fitted with the above described model. As a point for a more detailed line comparison generation 50 will be chosen. In this generation the body weights in lines DU-Ks, DU-6, DU-6P, DU-6+LB were 28.7g (100%), 54.6g (190%), 49.1g (171%) and 46.1g (160%). A further increase in generation 70 is obviously (figure 2). A theoretical selection limit (parameter A) in lines DU-6, DU-6P and DU-6+LB can be expected at about 63g, 52g and 47g, respectively. At this time the mean BW 42 will be increased, compared to the starting level (parameter C), by about 226%, 197% and 172%, respectively.

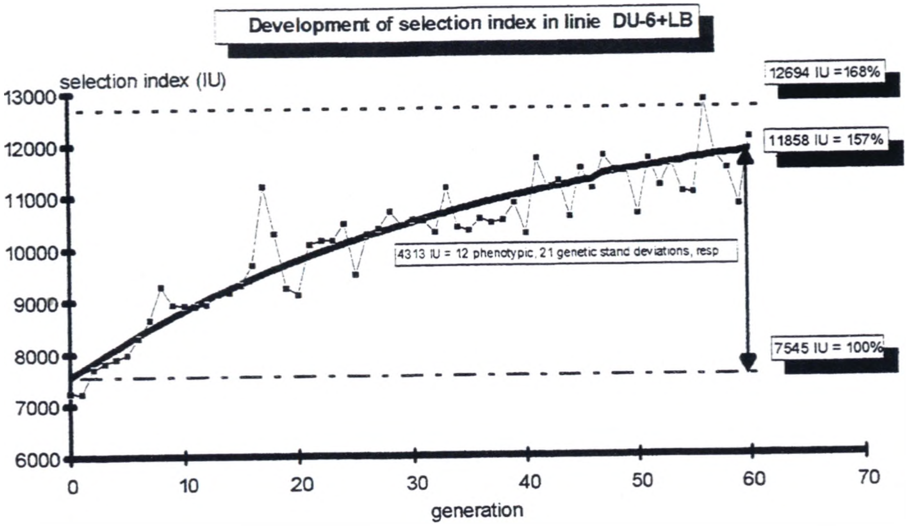
Thus can be established a high differentiation against the control line in the growth performance of the selected lines.

Single trait selection for body weight or protein amount is accompanied by a strong decrease of TP by about 34m/gen, resulting in a very low TP in generation 50 (figure 3). The mean TP in the lines DU-6 and DU-6P were only 440m (22%) and 270 m (14%), whereas the control animals are able to run 2000m (100%; almost one hour).

BÜNGER et al. (1988) gave an approximate estimation for the realised genetic correlation between TP 42 and BW 42 with r_g = - 0.66 ± 0.1. The phenotypic correlation based on 3400 animals was r_p = - 0.12 (-.15; -.09) [5%-interval of confidence]. Recently we have no estimate for the heritability of the TP 42 , but a realised value for the TP 70 is given by RENNE and BÜNGER (1993) with h^2 = 0.24 ± 0.1.

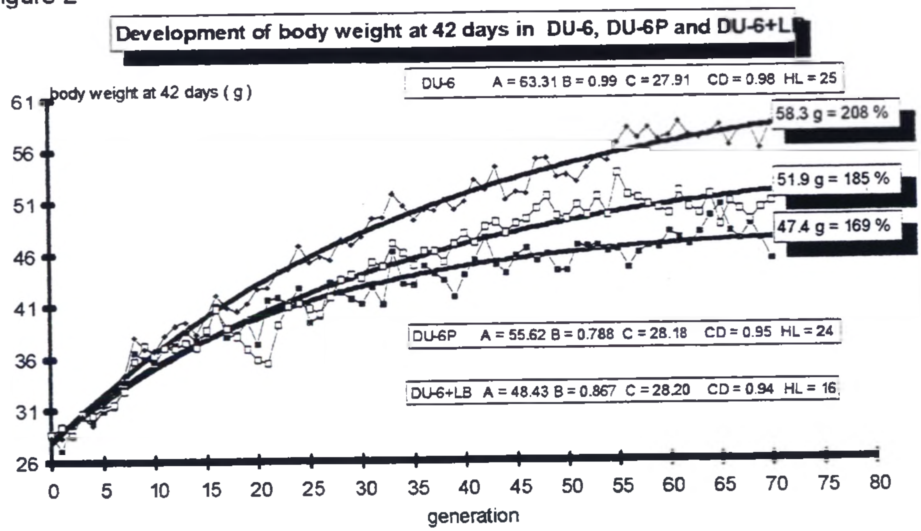
Despite of this high negative genetic correlation the results of line DU-6+LB show that a genetic combination of high growth performance and high stress resistance is possible. The body weight in this line was increased in generation 50 by about 17.4g (60%). Simultaneously the mean TP was 2853m. That is a difference to the control of 853 m (43%).

Figure 1



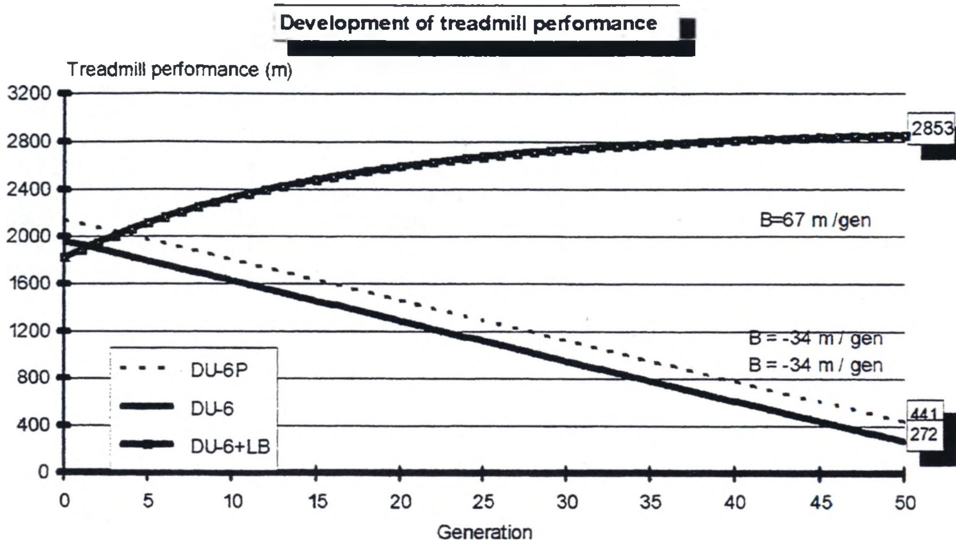
start values : heritability 0.33, phenotypic and genetic standard deviation = 350 and 202

Figure 2



Some studies in mice aimed to test the selection theory of negatively correlated traits. Often 2 traits were taken which are positively correlated, e.g. body weights at different ages (McCARTHY and BAKKER 1979)., or body weight and tail length (RUTLEDGE et al. 1973) or litter size and body

Figure 3



weight (EISEN 1978). The antagonistic index selection was then directed to combine high X-character with a low Y-Character or vice versa. Most studies demonstrated a successful combination of such traits, although the predicted and the observed response did not always agree very well. So far known only one selection study in mice was directed to a combination of stress resistance and body weight, but without success ((WENIGER et al. 1974, HORST et. al. 1975). We assume that this disagreement of result is due to methodical differences between both experiments (selection method /cross after some generations single trait selection and the method of measuring the stress resistance.

REFERENCES

BÜNGER, L. (1980) Proc. of Symp. „Leistungsfrühinformation beim Schwein", Universität Leipzig :119-138
BÜNGER, L. (1982) Arch. Tierzucht 25 : 487-495
BÜNGER, L. (1987) Genet. Probl. in der Tierzucht, 13, Res. Centre for Animal Production, Dummerstorf
BÜNGER,L. and HERRENDÖRFER,G. (1993) (in press)
BÜNGER, L., SCHÜLER, L., KUPATZ, B., RENNE, U. (1982) Arch. Tierzucht 25 : 373-385
BÜNGER, L., SCHÜLER, L., KUPATZ, B., RENNE, U. (1983) Arch. Tierzucht 26 : 281-293
BÜNGER, L., RENNE, U., HERRENDÖRFER, G. (1988) Tag.-Bericht, Akad. der Landwirtsch.Wiss. DDR.Berlin 268 : 137-156
BÜNGER,L., HERRENDÖRFER,G.; RENNE,U.(1990): Proc. 4th WCGALP XIII:321-324
BÜNGER,L.; DIETL,G.; RENNE,U.(1993) Paper, given at the 44th EAAP, Aarhus, Denmark
EISEN, E.J. (1978) Genetics 88:781-811
HORST,P.; MAJOR,F.; TAWFIK,E.S.;WOLF,M.,WENIGER,J.H.; STEINHAUF,D. (1975): J. Anim. Breed. Genet. 92 : 260-266
HERRENDÖRFER, G., BÜNGER, L. (1988) Proc. Internat. Conf. „Population Mathematics"; Schwerin;In: Probl. d. angew. Statistik, Heft 26 : 45-49; Research Centre for Animal Production, Dummerstorf-
MCCARTHY AND BAKKER,H. (1979) Theoretical and Applied Genetics 55:57-64
RUTLEDGE,J.J., EISEN,E.J. E.J., AND LEGATES,J.E. J.E.(1973) Genetics 75:709-726,
RENNE,U.; BÜNGER,L. (1993) Proc. of 1st Symp. „Populationsgenetische Grundlagen ..."; Martin-Luther-Universität, Halle
WENIGER,J.H.; HORST,P.; STEINHAUF,D.; MAJOR,F.; WOLF,M.; TAWFIK,E.S.; (1974) J.Anim.Breed.Genet. 99:265-270