POSSIBILITY OF CHANGING SHAPE OF GROWTH CURVE THROUGH BREEDING

Mögliche Veränderung der Form der Wachstumskurve durch Zucht

Sur la possibilité de modifier l'allure de la courbe de croissance au moyen de l'élevage et dressage

R. G. BEILHARZ *

INTRODUCTION

Selection of animals in one direction is usually followed by a change in the values of the population in the same direction. This fact is the basis of evolution as well as being useful to man in relation to his domestic animals.

Evolution acts on all traits, from simple colours to most complex characters such as social and mating systems, sexual dimorphism and rates of development at different stages of the life cycle (SELANDER, 1972; BOURLIERE, 1964). Breeders of livestock have usually been content with selecting only for a minute fraction of the total range of characters that evolution has altered. With rare exceptions (e. g. EISEN and HANRAHAN, 1972) we have ignored the possibility of changing one sex differently from another. Should we not set ourselves the aim of producing rapidly growing, large, lean male stock from small mature females?

We have also tended always to look at size at a particular age, or growth rate at a particular stage, as the trait to be improved. We have accepted almost as inevitable that some undesirable correlated responses in related characters will follow. For example, selection for rapid growth in some large European breeds of cattle has also resulted in an increase in birthweight to the point where birth becomes difficult. We should emulate nature and selected for the more complex trait «shape of growth curve»? Could we not devise an index based on the shape of the growth curve? For males our index should be highest when: *a*) birth weight is low, *b*) the growth rate from say the week after birth is high, and *c*) mature weight is high. For females the index can be modified at *b*) and *c*) to allow for high growth rate only to puberty followed by a sharp drop in growth so that

* School of Agriculture and Forestry, Melbourne University, Parkville, Victoria 3052, Australia.

mature size is not much larger than size at puberty. Any progress in this direction is economically useful, even if all we do is eliminate difficult calving. We should investigate the possibility of altering shape of growth curve in long-term livestock breeding programmes.

Can we find evidence for the possibility of changing shape of growth curve through breeding? In this paper data from various populations of laboratory mice are examined and heritability is estimated for bodyweight at 3, 6 and 9 weeks of age, as well as for some simple shape-of-growth curve indices based on these weights. All of the populations selected directly for individual 9-week weight responded well to selection. It will be shown that the heritability estimates of the indices were of similar magnitude to those of the weights.

Experimental methods

The methods of rearing and the mouse stocks used were described fully by Beilharz (1972). The original stock were non-inbred, albino laboratory mice from a colony used in veterinary research. Data from two randomly bred populations (A and B: generations 1-3), one unselected control population (1: 5-13) and 12 selected populations (5-13 or prior abandonment) were used to estimate heritability from parent-progeny regression coefficients. Populations A and B were each propagated by 50 pairs of mice per generation. Population 1 was propagated by 20

TABLE 1

Features of Mouse Populations

Identification	Type of nutrition	Litter Size reared	Criteria of selection	Generations included	Comments
1	Complete	Complete	Nil	5 - 13	—
A	Ditto	Restricted to 6	Ditto	1 - 3	—
B	Restricted	Ditto	Ditto	1 - 3	—
4*a*, 4*b*	Complete	Ditto	High mean cage weight at 9 weeks	5 - 9	Abandoned for lack of response to selection
5*a*, 5*b*	Ditto	Complete	Ditto	5 - 9	Ditto
7*a*, 7*b*	Ditto	Ditto	High Social Dominance Value	5 - 13	Became aggressive
2*a*, 2*b*	Ditto	Restricted to 6	High weight at 9 weeks	5 - 12	Poor reproduction after excellent response to selection
3*a*, 3*b*	Ditto	Complete	Ditto	5 - 12 (13)	Ditto
6*a*, 6*b*	Ditto	Ditto	High total litter weight at 9 weeks	5 - 13	—

pairs per generation, with each pair being replaced by 1 son and 1 daughter. The males were moved systematically to avoid inbreeding. The selected populations were all derived from the same stock as population 1 (progeny of A and B in generation 4) and each was propagated by 10 pairs per generation. The features that differentiate the populations are shown in Table 1. The first two populations were fully fed and unselected. The next seven were either not fully-fed or not selected effectively for bodyweight. The last six were effectively selected for weight at 9 weeks.

Regression of progeny on parents were calculated from data within generation and within population, but pooled over generations and replicated populations. Separate regressions were calculated from sires and from dams for each sex of progeny. The heritability estimated for each sex is the sum of the separate regression coefficients from sires and dams. This is equal to the mean of the two

TABLE 2

HERITABILITY ESTIMATES

Trait	Weight at:						Index No:							
Sex	3 *w*		6 *w*		9 *w*		1		2		3		4	
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Population:														
1	0.10	0.15	0.20	0.13	0.34	0.20	0.20	0.25	0.30	0.38	0.18	0.04	0.28	0.23
A	0.30	0.40	0.42	0.47	0.45	0.54	0.04	—	0.10	0.04	0.30	0.28	0.24	0.20
B	0.30	0.27	0.38	0.26	0.30	0.46	0.41	0.22	0.17	0.16	—	0.16	—	0.15
4*a*, 4*b*	0.20	0.23	0.34	0.25	0.32	0.30	0.05	—	—	0.12	—	0.08	—	0.20
5*a*, 5*b*	0.32	0.33	0.40	0.43	0.40	0.48	0.23	0.21	0.27	0.30	0.30	0.21	0.29	0.32
7*a*, 7*b*	0.08	0.18	0.31	0.28	0.44	0.30	0.18	0.28	0.10	0.32	—	0.19	0.01	0.29
2*a*, 2*b*	—	—	—	—	—	0.18	0.06	0.02	—	—	—	—	—	—
3*a*, 3*b*	0.02	0.03	0.16	0.14	0.54	0.49	0.10	0.08	0.08	—	—	—	—	—
6*a*	—	—	0.44	0.25	0.20	0.16	—	—	—	—	—	0.04	—	—
6*b*	0.17	—	0.21	0.22	0.15	0.18	0.06	—	0.08	—	0.06	—	0.02	—

— Indicates that sum of the regression coefficients from the two sexes of parents was O or negative.

separate estimates obtained utilising twice the regression coefficient for each sex of parents. Each single coefficient has between 210 and 750 degrees of freedom associated with it.

Heritability was estimated for weight at 3, 6 and 9 weeks and for four indices based on these weights as follows. Index 1 was the ration of 3-week to 6-week weight. Index 2 was the ratio of 3-week to 9-week weight. Index 3 was the ratio of 6-week to 9-week weight. Index 4 combined all 3 weight to express the area under the growth curve as a fraction of the rectangle defined by the sides «9 weeks» and «weight at 9 weeks» ($I\,4=[2\times Wt\,(3)+2\times Wt\,(6)+Wt\,(9)]\,/\,6\times Wt\,(9)$).

RESULTS

Table 2 presents the heritability estimates found. Table 3 shows, as an example, the average weights of males and females of populations 1 and 3^a in the generations 5 to 13 inclusive, during which selection for 9-week weight occurred in population 3^a.

Discussion

The estimates given in Table 2 for any trait vary greatly. That such variation occurs should be remembered when single estimates are used in large species such as cattle.

Full consideration of the relationship between the size of the estimates and the particular features that distinguish the populations must await a longer paper. In general the estimates for all traits are low in the 4 types of populations under effective selection for weight. As expected, there is a general tendency for heritability of weight to increase with age. In the 3 population types 1, A and 5*a*-5*b*, estimates for the indices were relatively high, comparable with those for weight at 3 or 6 weeks.

Similar trends to those shown in Table 3 for population 3*a* were present for populations 2*a*, 2*b* and 3*b*. In all 4 cases there was a very rapid response to

TABLE 3

Average weights of mice in two populations (1 and 3*a*) (gms)

Sex	Males				Females			
Weight at:	3 *w*		9 *w*		3 *w*		9 *w*	
Population	1	3*a*	1	3*a*	1	3*a*	1	3*a*
Generation:								
5	8.6	10.0	30.2	32.7	8.7	9.9	25.5	27.7
6	11.2	10.9	31.9	35.0	10.6	10.4	25.8	27.4
7	11.1	10.3	34.0	36.9	10.6	9.8	26.9	30.6
8	10.9	11.7	33.4	40.4	10.8	11.4	26.5	31.7
9	11.9	12.2	33.4	39.8	11.8	11.8	27.6	32.2
10	8.8	7.9	31.9	38.8	8.6	7.5	26.0	31.7
11	10.3	10.2	33.8	42.1	9.9	10.1	27.1	34.0
12	10.8	11.3	34.6	45.1	10.3	11.5	28.2	38.4
13	9.9	10.9 [1]	34.2	43.5 [1]	9.9	11.3 [1]	27.6	36.0 [1]

[1]) Seven individuals only in each sex. Population was abandoned in generation 13 because of poor reproduction.

selection in 9-week weight only. All 4 populations had very poor reproduction in generation 12 and were abandoned either then or in generation 13. One may conclude that, if other traits had been selected they would also have responded to selection. A question still to be answered is what rate of response to selection in a single trait remains compatible with continued high fertility.

Acknowledgements

Mrs. S. Gedge has faithfully kept accurate records in the mouse colony. The work is supported by the Australian Meat Research Committee.

SUMMARY

Several indices of shape-of-growth-curve based on weights at 3, 6 and 9 weeks of age had estimates of heritability of similar size to that of the weights themselves in several types of mouse populations. The high response to selection for 9-week weight found in those populations selected directly for it suggests that selection directly for a shape index should also result in a significant response.

ZUSAMMENFASSUNG

Da Evolution sich auf komplexe sowie auf einfache Merkmale auswirkt, dürfen auch Züchter komplexe Merkmale wie die Form der Wachstumskurve angreifen.

Heritabilität, auf Eltern-Nachkommen Regression basierend, wurde für Körpergewicht im 3-6- und 9-Wochen Alter, sowie für vier Indexe die diese Gewichte kombinieren, in 15 Mäusepopulationen geschätzt. In mehreren Populationen gleichten die Schätzwerte für die Formindexe denjenigen der Gewichte. Da in allen Populationen in welchen direkt nach Gewicht selektiert wurde, das Gewicht sich in Richtung Selektion veränderte, sollten auch Formindexe auf Selektion reagieren.

RESUME

Etant donné que l'évolution agit aussi bien sur les caractéristiques simples que sur celles complexes, les éleveurs-éducateurs devraient viser à modifier les tendances à caractère complexe, telle que l'allure de la courbe de croissance.

L'hérédité a été estimée et évaluée par régression des ascendants directs sur leur progéniture, sur la base des poids pris à l'âge de 3, 6 et 9 semaines et pour 4 indices basés sur les rapports existant entre ces poids, dans 15 populations de souris.

Dans plusieurs populations, les estimations pour les indices de l'allure étaient identiques à celles des poids.

Etant donné que les poids réagirent selon la sélection faite dans toutes les populations dans lesquelles ces poids avaient été directement sélectionnés, les indices de l'allure devraient également réagir par voie de sélection directe.

REFERENCES

BEILHARZ, R. G. (1972): Studies in Mouse Breeding. I. Description of mouse stocks in the School of Agriculture, University of Melbourne. Occ. Paper No. 1, *Anim. Prod.*, School of Agric., Univ. of Melbourne.

BOURLIERE, F. (1964): *The Natural History of Mammals.* 3rd ed. Alfred A. Knopf, New York.

EISEN, E. J., and HANRAHAN, J. P. (1972): Selection for sexual dimorphism in bodyweight of mice. *Aust. J. Biol. Sci.*, 25:1015-24.

SELANDER, R. K. (1972): *Sexual Selection and Dimorphism in Birds.* In Campbell, B. ed. *Sexual Selection and the Descent of Man.* Aldine, Chicago, pp. 180-230.