SIZE OF POPULATION REQUIRED FOR ARTIFICIAL SELECTION

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Genetic drift is an important source of variation in response to artificial directional selection. How large should a selection line be in order to reduce the effect of genetic drift to an acceptably low level?

This paper investigates two criteria that can be used to answer this question in relation to short term response to selection. The first criterion is coefficient of variation of response, and the second is chance of success, where a successful selection program is one in which the observed response is greater than a certain proportion, β, of expected response.

MODEL

Consider a selection line derived from a large base population and undergoing t discrete generations of artificial directional selection with intensity i on a quantitative character with heritability h^2 and phenotypic variance V_P. Following Hill (1971a), we assume that these parameters do not change during selection. Thus the model does not cover long term selection response. Assume initially that the population is monoecious, and that N individuals are selected as parents each generation from M individuals scored. A contemporaneous control line of the same size as the selection line also is maintained.

By drawing on recent advances in our understanding of variation of response to artificial selection, as reviewed by Hill (1977a), it can be shown that if measurement error variance is small in comparison to drift variance, the coefficient of variation of response to t generations of selection is approximately $\sqrt{2}/ih\sqrt{Nt}$, and the chance of success is approximately prob$\{Z>(\beta-1)ih\sqrt{Nt/2}\}$, where Z is a standard normal deviate.

HOW LARGE SHOULD A SELECTION LINE BE?

It follows from above that the size of population required in order to obtain a coefficient of variation of response equal to γ, is approximately $2/(\gamma ih)^2t$, while the size of population required in order to be 100α% certain of achieving at least a proportion β of expected response is approximately $2\{z_\alpha/(\beta-1)ih\}^2/t$, where z_α is the relevant tabulated value of the standard normal deviate.

Since $ih \leqslant 2$ in most selection programs, the above expressions indicate, for example, that a population size of at least 50/t is required for the coefficient of variation of response to t generations of selection to be 10%, and that a population size of at least 82/t is required for there to be a 90% chance of achieving 9/10 of the predicted response after t generations. For programs in which $ih \leqslant 1$, the minimum sizes are four times greater, being 200/t and 328/t respectively.

Similar expressions for more general models incorporating overlapping generations, two sexes, divergent selection and lack of a control have been obtained. To illustrate the answers obtained for a more practical situation involving overlapping generations and two sexes, consider a beef cattle selection program of the type discussed by Hill (1971b, 1977b), in which ih = 0.6. In order for there to be a 90% chance of achieving 9/10 of predicted response over a 10 year period, the effective population size of the herd must be approximately 220.

CONCLUSION

It must be emphasized that this paper provides no guidelines for the design of a selection program so as to maximize expected response to selection. Instead, it provides simple expressions for calculating the size of population required, once the optimum design in relation to expected response has been determined.

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THE EFFECTS OF POPULATION SIZE BOTTLENECKS ON RESPONSE TO ARTIFICIAL SELECTION

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The consequences of population size bottlenecks are of importance in animal improvement schemes when founding new breeds, or introducing breeds, strains or species into a country. The topic of this contribution is an experimental evaluation in *Drosophila melanogaster* of the effect of a single initial population size bottleneck (size n individuals) on the subsequent response to selection. The relevant theory for a single locus additive model was developed by James (1971) who predicted that the short term response to selection would be reduced to a proportion $(1 - 1/2n)$ of that in lines not subject to the bottleneck. At the limit to selection the proportionate response should lie between $(1 - 1/2n)$ and $(1 - (1 - p)^{2n-1})$, where p is the initial frequency of the allele. Forty bottlenecked selection lines (B) were founded, two each from the progeny of 20 single pair matings from the Canberra outbred population, as well as three non-bottlenecked selection lines (U) and six control lines (C). All lines were maintained using 10 pairs of parents per generation; these being the extreme high flies for abdominal bristle number from 30 pairs scored per generation in the selection lines. Selection was continued for 52 generations (G). The proportionate short term response (B/U) due to a single pair population size bottleneck of 0.69 approximated the expectation of $(1 - 1/2n) = 0.75$ (assuming sex-linked effects are absent). The final proportionate long term response (G. 49-52) was 0.72 or 0.69, depending on scale, rather close to the $(1 - 1/2n)$ proportion. Final response (G. 49-52) showed the usual large variation among replicate lines, even when those replicate lines came from the same