The Part Played by Measurement Technique in the Efficiency of Selection.

By GLENORCHY McBRIDE*

SUMMARY

THIS paper outlines the effects on heritability estimates of measurement techniques and the various conditions under which the measurements are made. Analyses are presented of the bodyweight of chickens, taken on two types of balance and on two successive days. The results indicate that reduction of weighing errors led to an increase in the heritability estimate which was of negligible importance in the present circumstances, where the heritability was high, but might be of value with lower estimates. The effect of such adjusted heritability values on estimates of genetic progress is discussed.

I. INTRODUCTION

Heritability may be defined as the fraction of the observed phenotype variation which is additively genetic. As a fraction, it is expressed as—

$$h^2 = \frac{\sigma^2_G}{\sigma^2_P} = \frac{\sigma^2_G}{\sigma^2_H + \sigma^2_E}$$

where h^2 = Heritability
σ^2_G = addititive genetic variance
σ^2_P = phenotypic variance
σ^2_H = genotypic variance
σ^2_E = environmental variance

Heritability can be measured by a number of statistical techniques which relate the likeness or reduction in variation between relatives to the percentage of genes these relatives have in common. Analysis of variance or convariance is used for the purpose of eliminating variation due to known environmental causes from the denominator of the above fraction. Some of the causes of environmental variation which can be eliminated include year-to-year and season-to-season variation. Physical control of environment is also practicable, though only to a limited extent, by maintaining animals as much as possible under uniform conditions.

The full phenotypic variance may then be written as $\sigma^2_H + \sigma^2_{RE} + \sigma^2_{KE}$ where σ^2_{RE} is the uncontrolled, unexplained, and presumably random environmental variability, and σ^2_{KE} is the variability due to known factors and, therefore, removable.

Further,. it should be realised that the heritability of a character is really the heritability of a group of measurements of that character in the population of animals studied. Since the taking of any measurement involves error, the estimate of heritability normally made is-

$$\frac{\sigma^2_G}{\sigma^2_H + \sigma^2_{RE} + \sigma^2_{EM}}$$

where σ^2_{EM} is the error variance of the measurement technique used. These errors may be small or large depending on (1) the character measured, (2) the type of measurement technique, and (3) the conditions under which the measurements are made (this includes the personal or operator errors). With some characters such as bodyweight, where good balances are available, these errors are probably slight; with others, such as milk production recording, where sampling techniques are used, the errors may be very high.

When defining a character by physical measurement, a number of techniques can frequently be used, and the criterion for choosing a technique is the measurement error variance, which should be small. When selection of breeding stock is to be based on the measurement, however, change in the heritability estimate is a more suitable criterion. For example, a sophisticated technique may give an appreciable reduction in measurement error variance, but if the heritability is high, the change in heritability may be relatively slight. If the heritability is low, however, a similar change may make the same technique highly desirable.

II. MATERIAL AND METHODS

In order to check the part played by measuring errors **in the weighing** of chickens at the University of Queensland Animal Husbandry Farm, the

*Lecturer in Animal Genetics, University of Queensland Veterinary School.

following experiment was undertaken. The birds are normally weighed on a clock-face spring balance which weighs to the nearest half-ounce. In this experiment, a batch of 256 ten-week-old Australorp chickens were weighed on two consecutive days on each of two balances, the spring balance and an accurate single-arm gram balance which weighs to the nearest half gram (weights were taken to the nearest gram). The birds were weighed on the spring balance and immediately transferred to the single-arm gram balance.

The results on each balance from the first day's weighings and the average weight for two consecutive days' weighings were analysed. A comparison can then be made of four techniques — two balances, combined with weighing on one or two days.

III. RESULTS AND DISCUSSION

(a) Influence of measurement errors on heritability estimates

The results of analyses are given in Tables I to IV.

TABLE 1

ANALYSIS OF VARIANCE OF SINGLE-DAY AND TWO-DAY WEIGHTS OF CHICKENS ON TWO TYPES OF BALANCE

SOURCE OF VARIATION		DEGREES OF FREEDOM	VARIANCE				COMPONENTS OF VARIANCE
			Gram Balance		Ounce Balance*		
			Single Day (gm)[2]	Two-Day Av. (gm)[2]	Single Day (gm)[2]	Two-Day Av. (gm)[2]	
I. MALES							
Total		128					
Between Sires	(S)	29	39,329	38,712	38,932	38,612	$4.222\ \sigma^2_S + 1.641\ \sigma^2_D + \sigma^2_I$
Between Dams within Sires	(D)	53	17,614	17,548	17,546	17,523	$1.499\ \sigma^2_D + \sigma^2_I$
Between Individuals within Dams	(I)	46	11,274	10,668	11,393	10,866	σ^2_I
II. FEMALES							
Total		126					
Between Sires	(S)	33	22,439	22,787	22,090	22,356	$3.701\ \sigma^2_S + 1.697\ \sigma^2_D + \sigma^2_I$
Between Dams	(D)	46	8,471	8,295	8,866	8,778	$1.501\ \sigma^2_D + \sigma^2_I$
Individuals	(I)	47	7,217	6,929	7,457	7,016	σ^2_I

*Measured in ounces, but converted to grams for comparison.

TABLE II

COMPONENTS OF VARIANCE
(Derived from Table 1)

	Gram Balance		Ounce Balance	
	Single Day	Two-day Av.	Single Day	Two-day Av.
I. MALES				
σ^2_S	5,002	4,859	4,104	4,846
σ^2_D	4,229	4,589	4,928	4,441
σ^2_I	11,274	10,668	11,393	10,866
II. FEMALES				
σ^2_S	3,730	3,870	3,523	3,605
σ^2_D	836	904	939	1,174
σ^2_I	7,217	6,929	7,457	7,016

$\sigma^2_S = \frac{1}{4}\sigma^2_G$

$\sigma^2_D = \frac{1}{4}\sigma^2_G$

$\sigma^2_I = \frac{1}{2}\sigma^2_G + \sigma^2_{RE} + \sigma^2_{ME}$

TABLE III

INTRA-CLASS CORRELATIONS

	MALES				FEMALES			
	Gram Balance		Ounce Balance		Gram Balance		Ounce Balance	
	Single Day	Two-Day Av.	Single Day	Two-Day Av.	Single Day	Two-Day Av.	Single Day	Two-Day Av.
r^2Sires	0.2439	0.2415	0.2413	0.2405	0.3166	0.3306	0.2956	0.3056
r^2Dams	0.2062	0.2281	0.2009	0.2204	0.0709	0.0773	0.0788	0.0995
r^2full Sibs ..	0.4502	0.4698	0.4422	0.4608	0.3875	0.4079	0.3744	0.405

TABLE IV

HERITABILITIES (FULL-SIB)

MALES				FEMALES			
Gram Balance		Ounce Balance		Gram Balance		Ounce Balance	
Single Day	Two-Day Av.	Single Day	Two-Day Av.	Single Day	Two-Day Av.	Single Day	Two-Day Av.
0.900	0.940	0.884	0.922	0.775	0.816	0.749	0.810

IV. CONCLUSIONS

1. Heritability estimates can usually be increased by the use of more accurate measurement techniques, but whether their use is justified in any particular case depends on (i) the magnitude of the heritability; (ii) the type of measurement needed for the character studied; and (iii) the conditions under which the measurements are taken.
2. The change brought about in the heritability estimate is the most suitable criterion for determining the effectiveness of a measuring technique, and the use of sophisticated techniques is probably only justified when the heritability is low.
3. The results of a trial to determine the relative effectiveness of (i) two types of balance, and (ii) the use of the average of two weighings, in changing the heritability of bodyweight in Australorp chickens, indicated that the changes produced were not important. Heritability estimates were high.
4. The use of techniques to increase the heritability by eliminating portion of the variance due to known factors in the environment is not justified unless corrections are made for these conditions when selections are being made.

DISCUSSION

Dr. FRANKLIN: If a constant nutritional environment is essential in selecting, how would you reconcile this with the two very different pictures obtained by MacDonald in New Zealand and by us here in Australia? Bodyweight gains of sires have varied widely, according to the plane of nutrition Sires which have given the poorest performance on a low plane of nutrition have in observations recorded by MacDonald given the best performance when the plane of nutrition has been raised.

ANS.: If the cattle are to be put out at 1,000 lb. at 20 months of age then one should decide what time to mate for that purpose and then select at the weight at that time.

Mr. McDONALD: Was any attempt made to control degree of fill in these birds? At Seven Hills we find that a large proportion of chickens defaecate whilst being weighed. Estimates of error after a 24-hour fast have been found to be 20-30 per cent. lower than before, the fast-control of this sort of error should make a large contribution towards increasing heritability estimates.

ANS.: The birds were without feed on the day of weighing until after they had been weighed. They did not defaecate between scales. Such a reduction in variance would certainly increase heritability.

Mr. WILLIAMS: The speaker pointed out that where the system of selection for a character depended on the level of heritability, it is important that the environmental variation in the field be not unduly greater than that operating in the original estimate of heritability. This is a problem in the application of production testing of beef cattle in Australia and is one reason why heritability must be estimated under Australian conditions.

Dr. FERGUSON: In connection with the comparison of selection of cows fed at the flat rate with those fed in proportion to production, it should be pointed out that the production levels in the latter case are more in proportion to the inherent productive capacities of the cows than in the former, due to the nature of the production response curve of cattle of different productive capacities.