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PROGENY TESTING IN SHEEP

THE INHERITANCE OF BIRTH WEIGHT, GROWTH RATE AND CANNON BONE LENGTH.

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The application of science to animal breeding requires the measurement of productivity and the measurement of its inheritance. The former can be done with relative ease; the latter, because of its nature, only with difficulty. The most accurate method is by the assessment of genotype by a study of the effects of random gene samples in a reasonably large number of offspring—a process known as progeny testing.

This paper reports some of the results of our work on the progeny testing of Southdown rams. It can be regarded only as a progress report, probably better as a slow progress report, largely due to the facts that only a portion of the immense amount of data collected is presented, that some difficulty was experienced in the statistical handling of the material, and that the more immediate demands of teaching in such an institution as ours interrupt the intense concentration that research matters require. The work was designed, first, to ascertain whether heritable differences of an appreciable magnitude can be identified by measurement of productivity and progeny testing. Second, if so, to determine the minimum number of such measurements and progeny necessary to provide a reasonably accurate system for application of the method to the present organisation of commercial animal breeding; and third, to test the accuracy with which genotype for productiviy can be assessed by other methods of selection commonly used by the breeder, such as type, pedigree and performance.

In aim, therefore, the trial differs somewhat from those usually carried out, being partly investigational and partly demonstrational. The latter may seem presumption, by inferring a prior knowledge of the nature of the results, but such an attitude is perhaps not unreasonable in view of the results of similar work previously presented to this Society.

Further, it differs in one other important respect—it involves the testing of sires by cross breeding, Southdam rams being mated to mature Corriedale flock ewes. What effect, if any, heterosis has in accentuating or concealing heritable differences between sires, is questionable. All eminent geneticists or animal breeders with whom the problem has been discussed have successfully evaded the question by saying either that the nature and cause of heterosis is not fully understood, or that it would be an interesting problem to investigate. Useful comment by this Society would be welcomed.

Whatever the effects may be, this is what is done in practice. The Southdown is a single purpose sheep, used solely for the production of early maturing, high quality fat lambs out of commercial flock ewes. Reasonably, therefore, rams are either good or bad to the extent and with the regularity that they produce good or bad crossbred progeny. This, at any rate, is the premise on which our work is based.

The single purpose nature of the breed has one advantage—that little attention need be paid to attributes other than fat lamb quality. Consequently we have been mainly concerned with the measurements of rate of growth and carcase quality and the elucidation of the causes of their variability.

General Procedure

The general procedure was separate paddock mating of each sire with comparable samples of 25 or 30 Corriedale ewes. The ewes were individually identified and divided into groups by restricted randomisation on the basis of live weight. After mating, all ewes were run together and lambed down in one mob. During pregnancy and after lambing they were weighed at suitable intervals. The lambs were weighed at birth or within 18 hours and individually identified with ear tags. They were weighed at lamb-marking, at approximately three weeks of age, and thereafter at intervals of one month. As they reached marketable weights they were selected by a fat lamb buyer, weighed and sent to the freezing works in drafts where the carcases were measured and other data collected. Two lots of ewes were slaughtered and treated in a similar fashion.

Data Collected

ON EWES

Changes in live weight throughout the year.
General conformation grading on the hoof.
Udder size grading at weaning.
Carcase measurement at slaughter (as for lambs).

ON LAMBS

Birth weight, sex, type of birth.
Rate of growth.
Carcase measurements. L.F.T.Ca.Th.G. grade, fat cover, carcase weight.
Total stomach worm count (Ostertagia).
Other features such as leg colour grading, entropion, distortion of vulva, scouring, etc.

Selection of Sires

With the object of increasing the chances of finding differences among them, the sires were selected for the greatest possible range of quality. In the first year five stud rams were compared with five medium to low grade flock rams from our own stud. The five stud rams, in addition to their complement of stud ewes, were mated each to 25 Corriedales. Most of these rams were of our own breeding, some of them being related (see Table I.).

In the second year it seemed desirable to repeat the high grade-low grade comparison, and this was done by using high and low grade **flock** rams. The low grade flock rams (4) were what might best be described as of "cull" quality—according to accepted standards, really bad types. For the purposes of this paper they were of unknown origin. The high grade rams were first-class flock rams, a sample of four from each of two well-established and reputable studs in the South Island. These were selected for the purpose of making a comparison between the stock of different studs which might be expected to differ according to the aims and methods of the individual breeder. The intention was to obtain a sample—admittedly a small one—of the average quality of flock rams presented for sale by each stud in that year. To the extent that this could be done, it would give a measure of the immediate contribution of each breeder to the fat lamb industry as a whole.

In the third year, it was decided to repeat four rams; two were retained from each of the two high grade samples of the previous year. A further four high grade flock rams were purchased from another well-established stud in Canterbury. The high-low grade trial was continued by the addition of a sample of low grade sires from a recently established stud. This provided possible comparisons among three studs; the re-testing of four sires on different ewes and the usual high-low grade test. It is worthy of note that the four rams from Stud G were half-brothers and this relationship also existed between the four rams from Stud J.

Results

In general the first year's trial proved disappointing due, mainly, to the slow rate of growth of the lambs, particularly towards the end of the season, a circumstance largely attributable to exceptional weather conditions in Canterbury. At weaning, all lambs had to be put on to fattening feed. Before this was done, however, all the lambs were drafted up into their sire groups for observation: to see if group differences of **any** kind could be detected.

A similar practice was adopted in each subsequent year and on no occasion was it possible to recognise differences of any kind—in size, conformation, condition or type—between the groups, which would even suggest that heritable differences existed amongst the range of sires tested. No stamp of superior quality marked the progeny of a 150-guinea stud sire from those of a low grade flock, and the progeny of a supposed "cull" looked as good as those of a 14-guinea flock. All were reduced or elevated to common clay with a slightly tinted skin.

Certainly, groups varied in composition with regard to sex and type of birth, factors likely to obscure real differences if they did exist. This, notwithstanding, it appeared certain, as might well have been anticipated, that if differences did exist they were small and would be difficult to identify.

The second and third years were exceptionally good from the point of view of fat lamb production and the great majority of lambs were taken fat off their mothers early in the season. One slight disadvantage to our trial work developed—too high a proportion of the ewes produced twins, in that, of the ewes that lambed, the percentages marked varied from 130 to 150%. This naturally tended to slow up the rate of development which is so important in producing lambs of the highest quality and might be responsible for reducing the size of the differences found.

Detailed Analysis of Data—Birth Weights

Since the live weight at birth provides a measure of pre-natal growth over a relatively constant period of time, in a fairly constant environment, it may be used as a reliable means of comparing rates of growth of the progeny of different sires.

It will be seen from Table II (1) that considerable seasonal variation occurs; (2) that single lambs are on the average 1-2 lb. heavier than twins; and (3) that female lambs at birth are usually ¼-¾ lb. lighter than males. All these differences are real.

Table III. shows the effects of sires on birth weight. In the first year the mean birth weights of the progney of the five stud and the five flock sires were identical, so that no sire group differences appear. Within sire groups, however, individual differences occur, the range of means per sire extending from 9 lb. to 10 lb. Analysis of variance shows that these differences are significant at the 5% level.

In the second year, analysis shows no significant variation between or within sire groups.

In the third year, however, sire differences again become apparent and real, due almost entirely to the high birth weights of all of the progeny groups of the low grade sires from Stud J. These as a group differ significantly from those of the high grade rams in Stud G. The reduced variability between sires within groups G and J is most easily explained by the half-brother relationship existing between them.

Growth Rate

Obviously, rate of growth is one of the most important factors affecting fat lamb quality. In the analysis of this measurement some statistical difficulties were encountered and it was finally decided that for the purposes of this paper the regression of weight on age would give the most reliable method of expression. These were calculated over the period of lamb-marking to the taking of the first draft, separately for each sire, for each sex and type of birth.

Table II. gives an indication of the variability caused by season, sex and type of birth. In general, as already noted, in the first year the rates of growth were low for this class of lamb. In the second and third years the rates were high and uniform.

From the weights at 100 days, calculated from the average regressions for each sex and type of birth, it will be seen that single lambs are 6 or 7 lb. heavier than twins and that males are 3 or 4 lb. heavier than females. These differences are similar to those usually observed.

Considering sire effects, it will be seen from Table IV. that over all lambs the progeny of high grade sires—in this instance the "valuable" studs—grow at the same rate as those of the low grade sires. Some variability is apparent in the sire sub-classes, obviously due to small numbers; this is ironed out in the group sub-class means. Considering the variability of the figures, the small differences between sires within groups seemed unlikely to warrant elaborate statistical analysis.

Table IV. shows the regressions for the 10 sires for which data was available in 1945-46. Again no group differences are apparent, these, indeed, being very similar. Considering individual sires, only ram No. 3 from Stud D appears to be appreciably below the mean.

In Table V., which presents that data for 1946-47, the same kind of thing is shown. Ram 3 from Stud D, one of the sires repeated from the previous year, is again appreciably below the average and appears to be the only one likely to diverge significantly since he is lower than average in all four sub-classes.

It seems highly probable, therefore, in the absence of an elaborate analysis of co-variance involving 12 sire groups, with unequal numbers in four sub-classes, at the prospect of which our statistical assistants were thoroughly appalled, but which, no doubt in due course, will be attempted, that all we have found from our growth rate studies is one bad ram.

Cannon Bone Length

In a general way, cannon bone length is believed to be related to carcase quality, this being the higher, the shorter the cannon. Further, a short, thick cannon is characteristic of the improved meat animals. Developmentally, the bones of the distal extremities of the limbs mature early. Such parts are affected by environmental influences to a lesser degree than later maturing parts. A positive correlation of some significance exists between cannon bone length and the length of the more proximal bones. The measurement is easily and accurately made. These facts imply that heritable differences in cannon measurements amongst sires, if they exist, might be easily determined and if so, they would provide a ready means of establishing differences in carcase quality.

Before considering sire effects, the influence of age at slaughter and sex may be observed. Table VI. shows that the age at slaughter is of little importance and that, as has been shown before, female cannon bones are a little shorter than male—in this instance about 2mm., which proved to be significant at the 1% level.

Table VII shows the sire effects. It will be seen that in 1945-46 there were no differences **between** sire groups, but within groups differences exist. Analysis of variance indicates that differences of about 3mm. are significant.

In 1946-47 group variation is apparent. The rams from Stud G as a group produce lambs with cannon bones significantly shorter than those of the low grade rams from Stud J. It will be remembered that the rams in each of these two groups were half-brothers.

The inference from this data is that Stud G sires leave progeny of higher carcase quality. Whether this will be substantiated when the other carcase data are analysed has yet to be determined.

Another method of measuring the intensity of inheritance—or the ratio of genetic to total variance—of cannon bone length is by the correlation between cannon lengths of dam and offspring. Using data from the 1946 trial, this correlation was found to be significant with a value of $r = 0.302$. This correlation might be expected to increase by approximately 50% in the relationship of one member of a pair of twins to the other. The actual value calculated for the correlation between the cannon lengths of twins of the same sex was 0.513. These figures indicate a high "intensity of inheritance" of the character.

Conclusions

Concerning the three major problems, already mentioned, which these trials were designed to investigate, only one, and this the least constructive, appears as yet to approach solution.

It seems fairly clear from the data presented that the practice of phenotypic selection of Southdown sires for fat lamb production has little to commend it. Selection for excellence in conformation, which is largely the basis of price variation ranging from 2 to 15 guineas in local flock ram fairs over the last few years, does not necessarily identify sires capable of leaving progeny of high quality. Provided they are Southdowns, they are all good for fat lamb production, even large differences in their appearance being almost wholly due to environmental influences.

What of the more constructive aims—the identification of heritable differences in characters of possible economic importance? From these preliminary analyses, the data indicate that some differences do exist. Certainly these differences are small. This was only to be expected; otherwise such tedious methods of identification would have been unnecessary. But before a confident statement of the nature and extent of the heritable variation can be made, further detailed examination of the remainder of the data will be necessary. The evidence presented, however, clearly points to the necessity of applying some such scientific techniques to animal breeding if further progress is to be made.

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TABLE I.

SOUTHDOWN PROGENY TEST TRIAL.

1st Year 1944-45	Comparison	High Grade		Low Grade
	Origin	Stud L		Stud L
	Grade	Stud	v.	Flock
	Price	50-150 gns.		5-10 gns.
	No.	5		5
	No of Ewes/Ram	25		25

Ewes repeated with additions to 360.

2nd Year 1945-46

Comparison	High Grade		High Grade		Low Grade
Origin	Stud B		Stud D		Unknown
Grade	Flock	v.	Flock	v.	"Cull"
Price	14 gns.		13½ gns.		Nil
No.	4		4		4
No. Ewes/Ram	30		30		30

All ewes slaughtered and measured 360.

4-year-old ewes purchased 360.

3rd Year 1946-47

Comparison	High Grade		High Grade		High Grade		Low Grade
Origin	Stud B		Stud D		Stud G		Stud J
	Repeat	v.	**Repeat**	v.		v.	
Grade	Flock		Flock		Flock		Flock
Price	14 gns.		13½ gns.		14 gns.		2 gns.
No.	2		2		4		4
No. Ewes/Ram	30		30		30		30

All ewes slaughtered and measured 360.

TABLE II.

BIRTH WEIGHT (lb.)

GROWTH RATE — REGRESSION OF WEIGHT ON AGE (IN DAYS)

		SINGLES			TWINS			
		Male	Female	All Singles	Male	Female	All Twins	All Lambs
1944-45	Regression	0.438	0.390	0.412	0.370	0.345	0.358	0.379
	Birth weight	9.98	10.18	10.08	9.25	8.84	9.06	9.40
	Number	52	57	109	120	99	219	328
	Wt. at 100 days	53.78	49.18	51.28	46.25	43.34	44.86	47.30
1945-46	Regression	0.587	0.561	0.572	0.541	0.498	0.515	0.525
	Birth weight	9.73	9.02	9.37	8.11	7.28	7.65	8.11
	Number	51	53	104	128	158	286	390
	Wt. at 100 days	68.43	65.12	66.57	62.21	57.08	59.15	60.61
1946-47	Regression	0.556	0.519	0.538	0.506	0.475	0.489	0.512
	Birth weight	10.29	9.50	9.93	8.54	8.30	8.40	8.97
	Number	93	77	170	129	160	289	459
	Wt. at 100 days	65.89	61.40	63.73	59.14	55.80	57.30	60.17

TABLE III.

BIRTH WEIGHT
SIRE VARIATION
MEAN WEIGHT OF SIRE GROUPS (lb.)

	High Grade Stud L Ram		Low Grade Stud L Ram	
	1	9.70	1	9.09
	2	9.29	2	9.53
1st Year	3	8.99*	3	8.99*
	4	9.29	4	9.41
	5	9.59	5	10.06*
	Mean	9.41	Mean	9.40
	Mean all lambs 9.40.		* Significant at 5% level.	

	High Grade Stud B		High Grade Stud D		Low Grade Stud?	
	1	7.95	1	8.15	1	8.37
2nd Year	2	8.49	2	7.78	2	7.86
	3	7.94	3	8.11		
	4	8.33			3	8.05
	Mean	8.17	Mean	8.03	Mean	8.11

Mean all lambs 8.11. Non significant.

	Stud B repeat		Stud D repeat		High Grade Stud G		Low Grade Stud J	
	2	8.59	3	8.56	1	8.87	1	9.19
3rd Year	3	8.75	4	9.06	2	8.96	2	9.40
					3	8.79	3	9.32
					4	8.89	4	9.19
	Mean	8.70	Mean	8.81	Mean	8.88*	Mean	9.27*

Mean all lambs 8.97. Significant at 1% level.

TABLE IV.

GROWTH RATE.

REGRESSIONS OF WEIGHT ON AGE (IN DAYS)

1944-45	HIGH GRADE STUD L						LOW GRADE STUD L						
Ram	1	2	3	4	5	Mean	1	2	3	4	5	Mean	All Lambs
Male Singles	.47	.41	.44	.41	.43	.44	.45	.45	.41	.44	.44	.44	.44
Female Singles	.31	.41	.42	.41	.42	.39	.36	.40	.36	.41	.39	.39	.39
Male Twins	.40	.35	.38	.32	.38	.37	.37	.35	.35	.42	.36	.37	.37
Female Twins	.41	.37	.33	.33	.33	.35	.33	.32	.33	.36	.36	.34	.34
All Lambs	.41	.38	.38	.36	.38	.38	.37	.37	.35	.40	.39	.38	.38

1945-46	Unknown Low Grade				High Grade Stud B					High Grade Stud D				All Lambs
Ram	1	2	3	Mean	1	2	3	4	Mean	1	2	3	Mean	
Male Singles	.57	.56	.62	.59	.59	.64	.59	.57	.60	.57	.67	.53	.57	.59
Female Singles	.59	.55	.58	.57	.52	.55	.57	.59	.55	.57	.59	.51	.57	.56
Male Twins	.58	.55	.49	.55	.52	.58	.53	.57	.54	.52	.60	.53	.54	.54
Female Twins	.54	.52	.48	.52	.49	.50	.51	.49	.50	.51	.45	.46	.47	.50
All Lambs	.56	.52	.50	.53	.52	.54	.52	.53	.53	.52	.53	.49	.52	.53

TABLE V.

GROWTH RATE

REGRESSION OF WEIGHT ON AGE (IN DAYS)

1946-47	High Grade Stud G					Low Grade Stud J					High Grade Stud B		High Grade Stud D		MEAN
Ram	1	2	3	4		1	2	3	4		2	3	3	4	
Male Singles	.61	.63	.53	.51	.55	.61	.52	.62	.58	.57	.54	.56	.51	.39	.56
Female Singles	.53	.53	.59	.53	.54	.55	.53	.51	.56	.54	.51	.54	.48	.57	.52
Male Twins	.46	.54	.47	.52	.51	.49	.51	.47	.51	.49	.55	.52	.48	.54	.51
Female Twins	.50	.47	.47	.47	.48	.44	.49	.48	.48	.47	.49	.48	.45	.47	.48
All Lambs	.51	.52	.52	.51	.513	.53	.51	.50	.53	.515	.52	.52	.47	.52	.512
												.52		.50	

TABLE VI.

THIRD YEAR

CANNON BONE LENGTH (m.m.)

VARIATION WITH AGE AT SLAUGHTER

Age at slaughter (in days)	97-110	111-124	125-138	139-152	153-166	167-181
Cannon length .... (m.m.)	107.5	106.9	107.2	106.9	106.3	106.0

No effect.

VARIATION WITH SEX AND TYPE OF BIRTH

	MALES			FEMALES			
	Singles	Twins	All Males	Singles	Twins	All females	All lambs
1945-46	109.4	108.1	108.5	107.0	106.6	106.8	107.6
n	47	105	152	50	121	171	323
1946-47	108.6	107.9	108.2	105.8	106.0	105.9	107.0
n	80	93	173	73	123	196	369

Difference between sexes 2 m.m. significant at 1% level.

TABLE VII.

CANNON BONE LENGTHS (m.m.)

SIRE EFFECTS

2nd Year 1945-46.

High Grade Stud B		High Grade Stud D		Low Grade Unknown	
Ram 1	107.9	Ram 1	105.9*	Ram 1	109.1*
2	106.1	2	109.2*	2	105.9*
3	107.6	3	109.6*	3	107.9
4	107.3				

* Difference between sires significant at 1% level.

3rd Year 1946-47

High Grade Stud B		High Grade Stud D		High Grade Stud G		Low Grade Stud J	
Ram 2	107.5	Ram 3	107.5	Ram 1	104.5	Ram 1	107.4
3	107.0	4	108.1	2	105.8	2	107.5
				3	104.8	3	110.1
				4	104.5	4	107.4
					104.9*		108.1*

Differences between sires significant at 1% level. This due to differences between sire groups (Stud G and J).