
VOLUME 62 2002

GENETIC PROBLEMS IN INCREASING SHEEP PRODUCTION

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SUMMARY

Present knowledge concerning the breeding of sheep for increased production in New Zealand is reviewed and major gaps in the available information are indicated. Problems of applying existing knowledge to the improvement of Romney Marsh sheep are discussed.

INTRODUCTION

THIS PAPER is written at a time when economic considerations indicate a need for comparatively rapid and sustained increases in production from the sheep industry. In these circumstances, it would seem appropriate to review what is known about sheep breeding under New Zealand conditions, to indicate to what extent the available information is being used, and to point to major gaps in existing knowledge.

Increased production from the industry as a whole will largely come from increased production per acre, since there are no large areas of new land left to develop. Since stocking rate is a major factor in controlling production per acre, it is clear that increasing sheep numbers will be of prime concern in increasing total production from the industry. Hence the contribution of genetics to the improvement of the industry, a contribution which is concerned mainly, but not solely, with improvement of production per sheep, needs to be viewed against a background of increasing sheep numbers. In particular, this means less opportunity for culling in the national ewe flock and means that special emphasis must be placed on the breeding quality of the rams supplied to the industry. As this has traditionally been the job of the stud industry, much of the discussion will be devoted to it. Also, because increasing numbers has mainly to do with the basic breeding ewe flocks, discussion of the special and distinct problems of breeding the sires of prime lambs will be omitted.

THE STRATIFICATION OF THE SHEEP INDUSTRY

The normal stratification of the sheep industry in New Zealand, whereby the cast-for-age and surplus Romney ewes from the hills are mated to rams of the Down breeds on lower country, is too well known to require detailed description. It deserves comment, however, for two reasons: First, it does lead to some simplification of the objectives in breeding Romney sheep in that it was shown a number of years ago (McMeekan and Walker, 1951) that the type of Romney ewe had little influence on the carcass quality of the lambs produced by crossing with Southdown rams. Secondly, it has been pointed out on a number of occasions (Rae, 1953) that, in comparison with the more complex stratifications which occur in great Britain, the simple pattern evolved in New Zealand is comparatively inefficient. The major advantage of the more complex stratification lies in the fact that the basic breed is crossed with a breed such as the Border Leicester to produce a half-bred type which is, in general, of higher prolificacy and milking ability than the purebred. In this way, maximum use is made of any heterosis which may occur.

From the genetic viewpoint, there would appear to be a case for the gradual development of a more complex stratification in New Zealand. Present evidence would suggest that it take the following form: Perendale breeding flocks on the poorer hills; Romney breeding flocks on medium to good hills; flocks in which cast-for-age and surplus Romney ewes are mated to Border Leicester rams for breeding half-bred ewes on good hills and poorer low country, these ewes together with the cast-for-age and surplus Perendale ewes being in turn crossed with Down rams for prime lamb production on low country. An advantage of this system is that, by not going beyond the first cross of the Border Leicester with the Romney, it may make best use of the Border Leicester.

A major question which is raised by any consideration of the stratification in New Zealand is whether a sufficient number of breeds is being utilized to serve the needs of the industry. As a result of comparisons between strains within the Merino breed (Dunlop, 1962) showing that some strains of fine-wool Merino are relatively free from fleece rot and water-induced discolorations, and that intensive stocking rates are possible, one wonders whether the Merino is being utilized adequately in New Zealand. In particular, observation would suggest that none of the breeds of English origin is particularly well adapted to the high rainfall and warm temperatures of Northland, and it may well be worth while investigating the usefulness of the appropriate Merino strains in this area. Much of the disfavour in which the Merino is held in the North Island may well have been due to the early strains being of an unsuitable type.

The second case concerns the production of specialized carpet wool, a wool type which is at present not produced in New Zealand. The Scottish Blackface breed is regarded overseas as the premier breed for the production of this type of wool but it is not available in New Zealand and suffers from the disadvantage of relatively low fleece weight. For some time, it has been realized that sheep of Romney or part-Cheviot origin, homozygous for the dominant N gene (Dry, 1955), produce an acceptable carpet wool and this has been confirmed by recent manufacturing trials at Leeds University (Nash, 1962). In co-operation with a carpet manufacturing firm, trials were started in 1962 on co-operating farms to investigate the commercial aspects of production of wool from N-type sheep. A study of the economics of the production of carpet wool has been made by Schroder (1963). On the basis of evidence presented in his study, he concludes that production of carpet wool using N-type sheep, while still subject to uncertainty concerning the productive ability of the sheep, is likely to be worth proceeding with and that the uncertainties are not sufficient to warrant further delay in developing the industry.

CROSSBREEDING

For the present purpose, discussion of crossbreeding is confined to its function in the formation of breeds which will contribute to the breeding ewe population. Thus any mention of crossing for prime lamb production will be omitted.

At various stages in the development of the sheep industry, a considerable number of crosses of different breeds have been tried out by farmers. Unfortunately, the results have not been documented and, in many cases, the trials themselves have doubtless been inadequate. Apart from some historical studies of the Corriedale breed (Stevens, 1955), the only crosses which have been investigated in any detail are the Cheviot × Romney (Peren *et al.*, 1951; Hewitt, 1957; Rae, 1957), the Border Leicester crossed with Corriedale and Merino (Coop, 1957), and the Border Leicester crossed with the Romney (Clarke, 1962). Results of this work are so well known that a detailed summary is not required beyond indicating that the crossbred ewes have generally averaged between 20 and 40% higher in lambing percentage than the purebred ewes used for comparison. In the case of the Cheviot cross, fleece weight is lower than the Romney, while in the Border Leicester crosses the fleece weights are generally slightly higher. Average differences in body weight exist and this may well have an effect if the comparisons were made on the basis of per-acre production.

A point which must be borne in mind in considering crossbreeding is that prediction of the outcome of any cross is of very limited accuracy. This arises because one may be dealing with a substantial amount of non-additive genetic variation which, by its nature, can only be discovered by trial. Little is known of the extent of heterosis in the crosses mentioned above, although the results of Clarke (1962) in comparing successive generations of unselected interbred Border Leicester × Romney sheep would suggest that it is important in that cross. Knowledge of the extent of heterosis is important in deciding the very practical questions of whether one goes beyond the stage of making the first cross and, if so, what is the best procedure to adopt. With the Cheviot-Romney cross, the first question does not really arise, since it is a type of sheep intended for use on poor hill country and thus must be bred as a self-replacing flock. With the Border Leicester cross, however, if heterosis is important, the best utilization of the breed may be achieved by using it as a crossing sire in a stage of the stratification of the industry as suggested above, although there may well be areas where it is worth while developing the cross as a self-contained flock. With regard to the second question, the methods of breeding a self-contained flock of crossbred sheep are under investigation. From the genetic viewpoint, there would appear to be no overwhelming advantage one way or another in using the first cross sire as against interbreeding, and the issue may well be resolved on grounds of practical convenience.

There is need for more work to be done on investigating the characteristics of different crosses. The grounds for so doing are: (a) that the prediction of results of crosses is difficult, and (b) that crossbreeding is one of the few sources of flexibility which can allow the industry to change relatively rapidly from its present forms of production. To make this flexibility real, requires accumulated information on the productive characteristics of available crosses. In this connection a breed which is currently being used on a small scale by farmers for crossing with the Romney but has not been investigated in any detail is the English Leicester. Some consideration should also be given to importation of some overseas breeds of high prolificacy for investigation of their use in transferring genes for this trait to New Zealand breeds.

THE STRUCTURE OF THE STUD-BREEDING INDUSTRY

Study of the general nature and structure of the stud-breeding industry is important in any consideration of what breeding can do to aid improvement in the sheep stocks of the country. Studies of the information that can be gleaned from flock books have been made by Stevens (1946, 1958), Barton (unpublished, 1952) and Rae (unpublished, 1963). Only a brief summary of the pertinent points will be given here with reference to the Romney breed:

(a) The average size of flock is small although it is increasing (163 ewes mated in 1940 and 219 in 1962). In 1962, 61% of flocks used fewer than five rams.

(b) The time from foundation of a flock to its withdrawal from the flock book is short, over 90% having a life of less than 20 years.

(c) Studies of the origin of single-entered rams indicate the distinct hierarchical structure found in most breed studies. In the Romney breed there is a group of 3 to 5 flocks which may be regarded as a nucleus with 10 to 15 other flocks which are essentially "satellites" of the top flocks. These flocks are generally large and have been established for a considerable period of time.

(d) Stevens (1946) noted that the successful flocks of the Romney breed were largely located in northern Manawatu and the Wairarapa. In the twenty years since Stevens' study, there has been a gradual change in this distribution, with Southland coming into prominence as an additional major centre of dispersal of the breed.

These characteristics of the Romney stud-breeding industry raise several problems. In the first place, the hierarchical structure is a most efficient system of upgrading a breed genetically *provided the nucleus flocks are in fact genetically superior in productivity to the multiplying flocks which in turn are genetically superior to the commercial flocks of the breed.* If this proviso does not hold, then it leads to a static situation or, worse, can be a most efficient way of leading the breed towards the wrong objectives. Moreover, for this structure to have a continuing effectiveness, it is necessary that the nucleus flocks, as long as they retain that status, be making progressive genetic improvement. From information obtained from the 1962 edition of the *New Zealand Romney Marsh Flock Book,* it is possible to make an estimate of how much better genetically the nucleus flocks have to be on average in order that a purchaser of a ram is likely to get one which is genetically superior to the top rams of his own flock. This estimate suggests that the nucleus flocks as a whole need to average about 0.75 of a standard deviation in any particular trait or in any overall measure of productive merit above the multiplying flocks. The crucial question then is, "To what extent are the nucleus flocks genetically superior to the next stratum in the hierarchy"? There is no information on this point although it is not difficult to design experiments to answer the question. On theoretical grounds, it is unlikely that the genetic differences between flocks are large because the hierarchical structure itself is an effective means of reducing these differences and, as noted in (d) above, stud flocks generally and nucleus flocks in particular are run under generally favourable environmental and managemental conditions. In fact, the situation seems to be very similar to that which existed in the dairy industries of New Zealand and other countries prior to the widespread use of artificial insemination. In Britain, at least, one of the early significant results of the use of A.I. was to show that little improvement in milk yield could be achieved merely by buying bulls from fashionable pedigree herds. It is perhaps characteristic of stud breeders that they attribute the phenotypic merit of their stock to genetic superiority rather than to their own skill in management and the benevolence of the conditions under which their stock are run.

The second question which is posed by the structure of the Romney Marsh stud-breeding industry is concerned with heredity-environment interactions. The question can be put in the form: "Is the array of genotypes which gives high productivity in the particularly favoured breeding areas the same as that which gives high productivity in all other areas in which the breed is used?" No information is available to answer this question, yet it is clearly important in assessing the worth of the present breeding structure and in implementing any change. Heredity-environment interactions can take many forms, depending on the particular hereditary and environmental differences which are investigated. One investigation which would be pertinent to future problems in New Zealand would be to determine whether interactions exist when offspring by the same sires are run under high versus low stocking rates. There would be little difficulty in planning such an experiment to include also the investigation of differences between stud flocks. Since either experiment would require a considerable number of sheep, there would be advantages in combining them without major loss of information on either objective.

OBJECTIVES IN IMPROVEMENT

Definition of the objectives in improvement in terms of the characters to be improved and the relative emphasis to be placed on each of them is the initial and often the most important step in a breeding programme. The relative economic importance of the various characters affecting commercial productivity in the Romney breed have been estimated by Rae (1954) and some of the difficulties of this approach have been discussed (Rae, 1958b, 1962). The original results and more recent studies show that increasing lamb production ranks first in importance, followed by fleece weight within the range of suitable quality numbers and fleece grade (in so far as this may be assessed from the effect of style on price). Comparatively minor significance should be attached to body conformation or other characters except in so far as they are correlated to the characters of major importance.

It seems difficult at present to specify the requirements with greater precision. A more detailed specification of the characteristics for wool must await the results of research into processing requirements. Average fibre diameter is the most important measurable characteristic of wool in influencing its end use. The growing use of this measurement in the trading of wool tops and the attempts made to introduce fibre diameter standards for raw wool indicate that it is likely to be the first measurement on the fibre that will in time have to be considered in a breeding programme.

Another area of uncertainty in defining objectives concerns the question of efficiency of conversion of food to wool and lamb (Rae, 1962). From work on various breeds and strains in Australia under pen feeding (both restricted and *ad lib.*) the sheep with higher individual wool production also produced more wool per unit of food intake (Schinckel, 1960; Weston, 1959). Thus until more detailed information is available, it would appear that there is little to lose in selecting for per-head production.

Before leaving the question of objectives, it is pertinent to ask whether it would not be possible to breed a type of sheep which requires a minimum of shepherding — an "easy care" sheep. There is no experimental evidence on this point but observation suggests that this could be done fairly rapidly by allowing natural selection to have a little more effect in the selection process. It is likely to be much more accurate in balancing up the intricate combination of factors involved than any artificially directed selection process. A type of sheep evolved in this manner could be very much to the point in an expanding industry chronically short of skilled labour. This, in fact, has been one of the attractions of the Perendale breed to farmers who are faced with a big job of development on their farms.

PHENOTYPIC RELATIONSHIPS BETWEEN PRODUCTIVE CHARACTERS

Estimates of phenotypic correlations among some of the productive characters of Romney sheep have been given by Rae (1958a). The correlations found among the fleece characteristics, fleece weight, quality number, character score and staple length are essentially similar to those found for other breeds overseas. The correlation between fleece weight and hairiness is close to zero and confirms an earlier estimate by Goot (1945). Correlations between body conformation score and fleece characters are generally small.

Two important relationships have been studied in some detail at the phenotypic level in New Zealand. The first is the association between face cover, fertility, growth and fleece weight. A number of workers (Barton, 1954; Coop, 1956; Cockrem *et al.*, 1956; Inkster, 1956) have found that open-faced ewes produced more lamb than close-faced ewes. Inkster (1956) also noted that in flocks of differing genotype for fertility, although there was a strong negative correlation between face cover and fertility within each flock, the most covered-faced sheep in the high-fertility flock had a higher twinning incidence than the most open-faced ewes of the low-fertility flock. Less face cover is also associated with better body weights. Reports on the effect of face cover on fleece weight are not in agreement. It seems, however, that, when allowance is made for the higher fertility of the open-faced sheep, the differences in fleece weight are small. Investigation of the underlying mechanisms which give rise to this group of associations have been made by Cockrem (1960) who has also indicated the usefulness of the face-cover difference in experimental study of the sheep (1962).

The second association of importance is that noted by Wallace (1961) and Coop (1962) between liveweight at mating and fertility in the same season. The significance of this association from the viewpoint of flock nutrition seems to be considerable but its genetic significance cannot be clear till some knowledge of the genetic relationships involved is available.

These two associations are of considerable importance in the early recognition of potential fertility. Selection for fleece and carcass characters can be adequately carried out before the ewe enters the flock. But the earliest assessment of the ewe's phenotype for fertility can be made only after she has had the opportunity to lamb as a two-tooth. Hence, any method which predicts the likely performance of a ewe before she has had a lambing is useful. Other differences which may assist in early recognition of fertility are the occurrence of and number of oestrous cycles as a ewe lamb (Ch'ang and Raeside, 1957) and whether the ewe was born as a single or a twin. The information required to assess these various sources of information, primarily genetic in nature, has been outlined by Rae (1962) but is not yet available.

Since non-genetic factors such as age, type of birth and rearing, sex and age of dam, tend to obscure genetic differences between individuals, knowledge of their effect on productive characters can aid in increasing the accuracy of selection. Effects of the above factors on fleece characteristics have been noted by Rae (1950) and on weaning weight by Ch'ang and Rae (1961).

GENETIC PARAMETERS OF THE ROMNEY MARSH BREED

In any discussion of plans for improvement, information on the heritability of the productive traits of a breed and the genetic correlations between them is essential. In Table 1, the available estimates of heritability for the Romney Marsh breed are summarized.

The fleece characteristics other than fleece weight have heritabilities of a similar order to those found for other breeds in other countries. The main discrepancy is in fleece weight where the estimates obtained are substantially lower than those obtained for other breeds, particularly the Merino (Rae, 1956). In order to investigate this question further, a selection experiment, in which selection is

TABLE 1: ESTIMATES OF HERITABILITY OF IMPORTANT PRODUCTIVE TRAITS IN NEW ZEALAND ROMNEY MARSH SHEEP

Trait	*Heritability Estimate*	*Remarks*	*Reference*
Greasy fleece weight (hogget)	0.10–0.15	Extensive data	McMahon (1943)
	0.17	640 d.f.* dam-offspring	Rae (1958)
Staple length (hogget)	0.35	ditto	Rae (1958)
Quality No.	0.35–0.40	Extensive data	McMahon (1943)
	0.27	640 d.f. dam-offspring	Rae (1958)
Fleece character (hogget)	0.14	Extensive data	McMahon (1943)
	0.22	640 d.f. dam-offspring	Rae (1958)
Medullation (hogget fleece)	0.63	ditto	Rae (1958)
Weaning weight	0.35	480 d.f. dam-offspring	Ch'ang and Rae (1961)
Body conformation score	0.15	Extensive data	McMahon (1943)
	0.14	640 d.f. daughter-dam	Rae (1958)
No. of lambs reared	0–0.15	495 d.f. daughter-dam 26 sires	Rae and Ch'ang (1955)

* d.f.=degrees of freedom.

directed at greasy fleece weight alone, was set up in 1956 (Rae, 1958d). A preliminary assessment of the progress to date suggests that heritability is higher than indicated by the estimates given above and that useful progress can be made.

Estimates for number of lambs produced also indicate it to be a lowly heritable character. In the main, this agrees with most overseas estimates (Reeve and Robertson, 1953) except that given by Young *et al.* (1963) which indicates a heritability of 0.30 and above for performance at the second lambing. However, responses of this character to selection, as indicated by Wallace (1958) for Romney Marsh sheep, Turner *et al.* (1962) for Merino, and Rae (1958d) for Cheviots, show that worthwhile progress can be made in improving this character.

Estimates of genetic correlations between productive characters of Romney sheep have been given by Rae (1951, 1958a). Fleece weight was found to be positively correlated with staple length and hairiness and negatively correlated with quality number. Staple length was positively correlated with hairiness and negatively correlated with quality number. Although the estimates have large standard errors, the pattern of relationships obtained suggests that selection for higher fleece weight would produce correlated responses in the direction of coarser wool, slightly longer staple length and greater hairiness. Rae and Ch'ang (1955) have noted a negative genetic correlation between fleece weight and fertility of the ewe measured as the number of lambs born. The significance of these results is not clear. It is not certain to what extent the pattern indicated above is fixed and unalterable or to what extent it is a result of past selection and, therefore, temporary and likely to be conditioned by the future direction of selection. At least some comfort may be derived from the results obtained by Cockrem (1959) in mice that substantial progress can be made against the direction of a genetic correlation, presumably by utilizing the genetic variation which is not controlled by the correlation.

Some estimates of the repeatability of traits in Romney sheep have been noted. For example, Wright and Stevens (1953) showed a repeatability of 0.44 for fleece weight, while Rae and Ch'ang (1955) found estimates varying from 0.12 to 0.25 for number of lambs reared.

It is to be noted that the estimates of heritability and genetic correlations are derived from only a few flocks. It is thus important that more work be done in this field over a wider range of flocks.

SELECTION PLANS

Earlier work on selection plans in New Zealand was largely centred on the investigation of progeny testing. For example, the work of McMahon (1943) and Rae (1948) was concerned with establishing that differences occurred between progeny groups by different sires and in showing how progeny testing could be put into practice. The work of Stevens (1949) on the Merit Sire Test of the Corriedale Sheep Society had a similar intention based on the principle of a central progeny-testing station. These studies indicated that there are no essential difficulties in putting a progeny-testing scheme into practice, the remaining question being whether it is worth while using it in view of the fact that it generally leads to an increase in the interval between generations. This question was analysed by Rae (1952) on the basis of information from the Romney breed. The conclusion was that where heritability of the character or index being considered is about 0.4, there is no advantage in progeny testing when compared with individual selection. Where heritability was 0.1, progeny testing (with about 70% of the flock used for testing, the remainder acting as a nucleus) was about 10 to 15% more efficient than individual selection. Thus, from the operational viewpoint, there is no compelling case for the use of progeny testing except in special circumstances.

As mentioned earlier, improvement in more than one character is required. Consequently, some attention has been given to the construction of selection indexes. A general selection index was constructed by Rae (1950) but it does not include fertility. More recently, indexes designed for selecting on the basis of number of lambs reared and weight of lamb weaned per ewe have been calculated (Rae, 1958c, 1963). Perhaps the simplest way of using these last two indexes is in selecting a group of superior sheep for fertility and then selecting for other characters within the group. A detailed discussion of the problem of selecting for fertility is given in the above papers.

It has been noted (Rae, 1952) that a within-flock selection plan based on using selected rams for only one mating season and then discarding them, is a simple practice which could be used. Theoretically, it appears that the decrease in the generation interval achieved by this plan more than offsets the effect of a lowered selection differential to result in a greater genetic gain. There is no experimental evidence yet available to support this contention but the studies by Barton (1951, 1957) which show that the sons of two-tooth sires regularly achieved a higher average sale price than sons of older sires at the Feilding Ram Sales are suggestive since the results appear to be only easily explained as an effect of the generation interval. In this connection, it is to be noted that average age of rams in use in the nucleus group of flocks in the Romney breed is lower than in multiplying flocks. In so far as average age of rams gives an indication of the generation interval, this could be a desirable state of affairs.

In any consideration of increasing sheep numbers, the technique of artificial insemination is likely to have superficial appeal as a method whereby the breeding quality of the rams may be maintained despite the increased number of ewes to be mated. At the outset, it should be said that the difficulties of implementing an artificial insemination scheme for commercial flocks seem sufficiently substantial that any immediate use of it in this way seems unlikely. Hence, consideration will be limited to its use in genetic improvement in a stud industry. From this viewpoint the use of artificial insemination has two properties: because fewer males are used, the selection differential on the male side is increased while in a closed-flock system the rate of inbreeding is augmented. Although nothing is known of the effects of inbreeding on Romney sheep, it is usually accompanied by a decline in merit, especially in characters concerned with survival and reproduction. As size of flock will have a considerable bearing on the rate of inbreeding (whether natural mating or artificial insemination is used), this factor will also affect the comparison of artificial insemination with natural mating. Taking into account these factors, Dunlop and Young (1961) showed that a flock size in excess of 1,000 ewes was necessary before any advantage in genetic progress was obtained when parameters pertinent to wool production in the Merino breed were used. It is thus clear that in the Romney Marsh stud industry, as at present constituted, the use of artificial insemination is of questionable value, although it would not be difficult to envisage an organization between flocks which would achieve the necessary size of flock.

A further point about artificial insemination is worth making. If it is to be used as a technique of improving a character such as fertility, then it will be essential to use progeny testing, simply because one cannot afford to run the risk of using a ram widely unless his breeding worth is known as accurately as possible.

APPLICATIONS AND ORGANIZATION

This discussion so far has been confined to reviewing the information available and to pointing to some of the gaps which need to be filled. It remains now to attempt an assessment of how this information could be used for overall genetic improvement in productivity.

The first question concerns the extent to which the information already available is used currently in practice. In the absence of specific information, this is difficult to assess. The following comments represent the writer's opinion. In the last five years, it appears that breeders have placed more emphasis on improving fertility than formerly. The results of work on face cover have been generally accepted by the farming community but only to a limited extent by the stud industry. The extent to which recording of productivity and the analysis of the records in arriving at selection decisions is used in the stud industry is very limited indeed. In general, one can say that the information available has had very little impact on the objectives and practices of the stud industry.

The second assessment of the information which has to be made concerns whether it is sufficient to serve as a basis for going ahead with a planned breeding programme. Knowing the gaps in the information, and being aware of some of the difficulties encountered in dairy cattle and poultry programmes, inclines one to caution in this matter. But when one examines what was known at the time when large-scale programmes were started with these two species and compares it with what is known at present with sheep, it is the writer's opinion that more than sufficient is known to make a start.

If this answer is accepted as a basis, then consideration must be given to what should be done. The basic requirements of any plan for breed improvement are simplification of the objective in breeding to two or three characteristics of major importance (fertility and fleece weight must be among them), measuring and recording the characteristics required, and then analysis of the records in order to make selection decisions. As most stud flocks in New Zealand are small, the selection would largely be on individual merit and detailed plans have been discussed by Rae (1954, 1963). If it were possible to organize units of the size of 5,000 ewes or more, then consideration of more detailed recording and selection plans possibly with the use of artificial insemination would be justified.

In this connection, the basic problem is not a genetic one but, as Rae (1962) has noted, a problem of organization to achieve three purposes: (a) Increased size of breeding unit where necessary. (b) Technical advice and operational research on breeding matters. (c) Recording and analysis of information for selection decisions. The rest of the discussion will be devoted to considering this problem.

Considering first of all the structure of the stud industry, there would appear to be several possibilities:

(a) In the present hierarchical structure of the industry, the possibility that effort could be concentrated on the existing nucleus flocks of the breed appears superficially attractive. One difficulty in this approach is that in these flocks, because they are the successful flocks of the breed, there is little inducement to look at new approaches to breed improvement. Also, in the writer's opinion, the present nucleus of the Romney breed is too small.

(b) A second approach to the problem would be to induce as many breeders of flocks of reasonable size as possible to concentrate on within-flock selection with only very little introduction of stock from outside. This approach has the advantage that generally within-flock selection will be more efficient than the somewhat risky process of purchase of sires from another flock. Because there is a small amount of inbreeding involved in a closed flock, it will promote the establishment of genetic differences between flocks and will go some way in taking account of any heredity-environmental interactions which may or may not exist. Moreover, the improvement achieved in the flock is immediately available to the commercial industry.

(c) A third possibility is that, by agreement and co-operation between groups of breeders, units of substantial size can be formed. If the flocks involved were reasonably close to one another, the possibility of more complex breeding plans utilizing artificial insemination would be worth investigating. It appears that this development of large units is not likely to take place in the short term but it seems worthy of consideration as a more long-term evolution in the industry. From the short-term viewpoint, concentration on the second approach would seem to be the most acceptable plan.

The next question concerns the organization for recording and analysis of information. In general, if the records taken are fairly simple, such as fertility records, fleece and body weights, the amount of assistance required would be at a minimum and the main emphasis could well be on assistance and encouragement in setting up the recording programme, most of the actual work being done by the flock owner or his employees. It would be not out of the question to imagine that fifty flocks, each of the order of 500 ewes, could be handled under this system with the employment of five or six recording officers. The analysis of these records and their presentation in an appropriate form for the making of selection decisions is not a major problem nowadays. It would require some central organization with access to data processing equipment and with several people trained in analysis of data and in animal breeding, to handle the interpretation and follow-up analyses for the organization. Naturally, if more detailed recording and metrology become necessary, then this would be more expensive in terms of facilities and labour. But it would appear sensible to start with a comparatively simple system and let the additional features grow gradually.

An assesment of whether a programme such as this is worth while is not easy to make. From actual selection studies in progress, it appears that annual genetic gain in productivity of the order of 1½ to 2% of the mean is possible. This rate of gain is very similar to that which is expected in the dairy industry. It would be expected that the cost of the general programme outlined would be well within the figure of approximately £60,000 with which the dairy industry and the Government support the Herd Improvement Department of the New Zealand Dairy Production and Marketing Board.

REFERENCES

Barton, R. A., 1951: *Nature, 168*: 37.
——— 1954: *Sheepfmg. Annu.*, p. 143.
——— 1957: *N.Z. Studmasters Annu. Rev.*, p. 60.
Ch'ang, T. S., Rae, A. L., 1961: *N.Z. J. agric. Res., 4*: 578.
Ch'ang, T. S., Raeside, J. I., 1957: *Proc. N.Z. Soc. Anim. Prod., 17*: 80.
Clarke, E. A., 1962: *Sheepfmg. Annu.*, p. 85.
Cockrem, F. R., 1959: *Nature, 183*: 342.
——— 1960: *Proc. N.Z. Soc. Anim. Prod., 20*: 61.
——— 1962: *Proc. N.Z. Soc. Anim. Prod., 22*: 45.
Cockrem, F. R., Barton, R. A., Rae, A. L., 1956: *Proc. N.Z. Soc. Anim. Prod., 16*: 59.
Coop, I. E., 1956: *N.Z. J. Sci. Tech., 37*: 542.
——— 1957: *N.Z. J. Sci. Tech., 38*: 966.
——— 1962: *N.Z. J. Sci. Tech., 5*: 249.
Dry, F. W., 1955: *Aust. J. agric. Res., 6*: 725.
Dunlop, A. A., 1962: *Aust. J. agric. Res., 13*: 503.
Dunlop, A. A., Young, S. S. Y., 1961: *Artificial Breeding of Sheep in Australia.* University of New South Wales.
Goot, H., 1945: *N.Z. J. Sci. Tech., 27*: 173.
Hewitt, W. R. R., 1957: *Sheepfmg. Annu.*, p. 104.
Inkster, I. J., 1956: *Proc. N.Z. Soc. Anim. Prod., 16*: 66.

McMahon, P. R., 1943: *Proc. N.Z. Soc. Anim. Prod.*, p. 70.
McMeekan, C. P., Walker, D. E., 1951: *N.Z. J. Sci. Tech., 33A*: 45.
Nash, C. E., 1962: Ph.D. Thesis. University of Leeds.
Peren, G. S., Hewitt, W. R. R., Ballard, H. V., Phillips, T. O., 1951: *Sheepfmg. Annu.*, p. 111.
Rae, A L. 1948: *Proc. N.Z. Soc. Anim. Prod.*, p. 97.
——— 1950: Ph.D. Thesis. Iowa State College.
——— 1951: *Proc. N.Z. Soc. Anim. Prod.*, p. 104.
——— 1952: *Proc. N.Z. Soc. Anim. Prod.*, p. 58.
——— 1953: *Sheepfmg. Annu.*, p. 147.
——— 1954: *Sheepfmg. Annu.* p. 155.
——— 1956: *Advances in Genetics, 8*: 189.
——— 1957: *Sheepfmg. Annu.*, p. 114.
——— 1958a: *N.Z. J. agric. Res., 1*: 104.
——— 1958b: *Proc. N.Z. Soc. Anim. Prod., 18*: 5.
——— 1958c: *Sheepfmg. Annu.*, p. 231.
——— 1958d: *Sheepfmg. Annu.*, p. 11.
——— 1962: *Proc. N.Z. Soc. Anim. Prod., 22*: 35.
——— 1963: *Sheepfmg. Annu.*, p. 167.
Rae, A. L., Ch'ang, T. S., 1955: *Proc. N.Z. Soc. Anim. Prod., 15*: 103.
Reeve, E. C. R, Robertson, F. W., 1953: *Anim. Breeding Abstr., 21*: 211.
Schinckel, P. G., 1960: *Aust. J. agric. Res., 11*: 585.
Schroder, W. R., 1963: M.Agr.Sci. Thesis. Massey University College.
Stevens, P. G., 1946: *Proc. N.Z. Soc. Anim. Prod.*, p. 33.
——— 1949: *Canterbury Agric. Coll. Tech. Publ. No. 3.*
——— 1955: *Proc. N.Z. Soc. Anim. Prod., 15*: 11.
——— 1958: *Sheep.* Pt 1: Sheep Husbandry. Whitcombe and Tombs Ltd.
Turner, Helen N., Hayman, R. H., Triffitt, L. K., Prunster, R. W., 1962: *Anim. Prod., 4*: 165.
Wallace, L. R., 1958: *N.Z. J. Agric., 97*: 545.
——— 1961: *Proc. Ruakura Fmrs' Conf.*, p. 14.
Weston, R. H., 1959: *Aust. J. agric. Res., 10*: 865.
Wright, G. M., Stevens, P. G., 1953: *N.Z. J. Sci. Tech., 34*: 430.
Young, S. S. Y., Turner, H. N., Dolling, C. H. S., 1963: *Aust. J. agric. Res., 14*: 460.

DISCUSSION

DR N. F. ROBERTS: *Professor Rae has discussed increasing wool production by genetic selection aimed at increasing cut per head and lambing percentages. Should one not also consider increasing longevity as an important factor in building up the sheep population? An increase of one year in the average age at death would lead to a considerable increase in the sheep population* — i.e., *are not such factors as lamb mortality, wear in teeth, genetic characteristics and husbandry practices likely to increase longevity also important?*

PROFESSOR A. L. RAE: No detailed analysis of the economic importance of longevity in sheep has been made. It is, however, a notably difficult characteristic to select for in an effective manner. Under New Zealand conditions, it is probable that investigation should be directed to the inheritance of, and ways of recognizing early in life, the characteristics of sheep's teeth which lead to a sound mouth at older ages.

DR G. R. MOULE: *Is controlling the plane of nutrition of the pregnant ewe likely to obviate the need for "easy care" ewes?*

PROFESSOR RAE: Controlling the plane of nutrition of the pregnant ewe tends to reduce the incidence of difficulties at lambing. Whether this is likely to obviate the need for an "easy care" sheep cannot be answered until the productive characteristics of such a sheep are known.

DR MOULE: *Are New Zealand breeds attaining their full genetic potential for prolificacy?*

PROFESSOR RAE: I do not know, nor can the question be answered without a fairly complete specification of the environment and management system.

DR MOULE: *In what circumstances has the 1½ to 2% of annual genetic improvement been obtained?*

PROFESSOR RAE: In selection experiments which would refer mainly to stud conditions.

DR A. H. CARTER: *A case was presented for more complex stratification of the sheep-breeding industry on the grounds of efficiency. Although the advantages of crossbreeding are obvious in improving or combining various characters, would the speaker not agree that improvement through mass selection would be more efficient with fewer breeds, in the absence of demonstrated genetic-environmental interactions?*

PROFESSOR RAE: Since the numerical strength of each breed is likely to be sufficiently large so that it does not act as a limitation to selection progress, the advantages of the more complex stratification are likely to outweigh the disadvantages.

PROFESSOR A. E. HENDERSON: *In Professor Rae's single character selection for high fleece weight, in which progress has been made, has there been a change in the fleece weight/body weight relationship?*

PROFESSOR RAE: The ratio of fleece weight to body weight appears to be increasing.

DR D. S. HART: *What is the permissible level of inbreeding in a Romney flock?*

PROFESSOR RAE: Since inbreeding usually causes a decline in characteristics concerned with the fitness of the animal, it is desirable to have as low a level of inbreeding as possible. The problem is really one of balancing the gain which can be achieved by selection within a closed flock against the loss due to inbreeding which results from the flock being closed. It is thus difficult to specify a permissible level of inbreeding. In my experience, flocks with, say, 5 to 8 rams in use can be carried on for a long period without any difficulties from inbreeding.