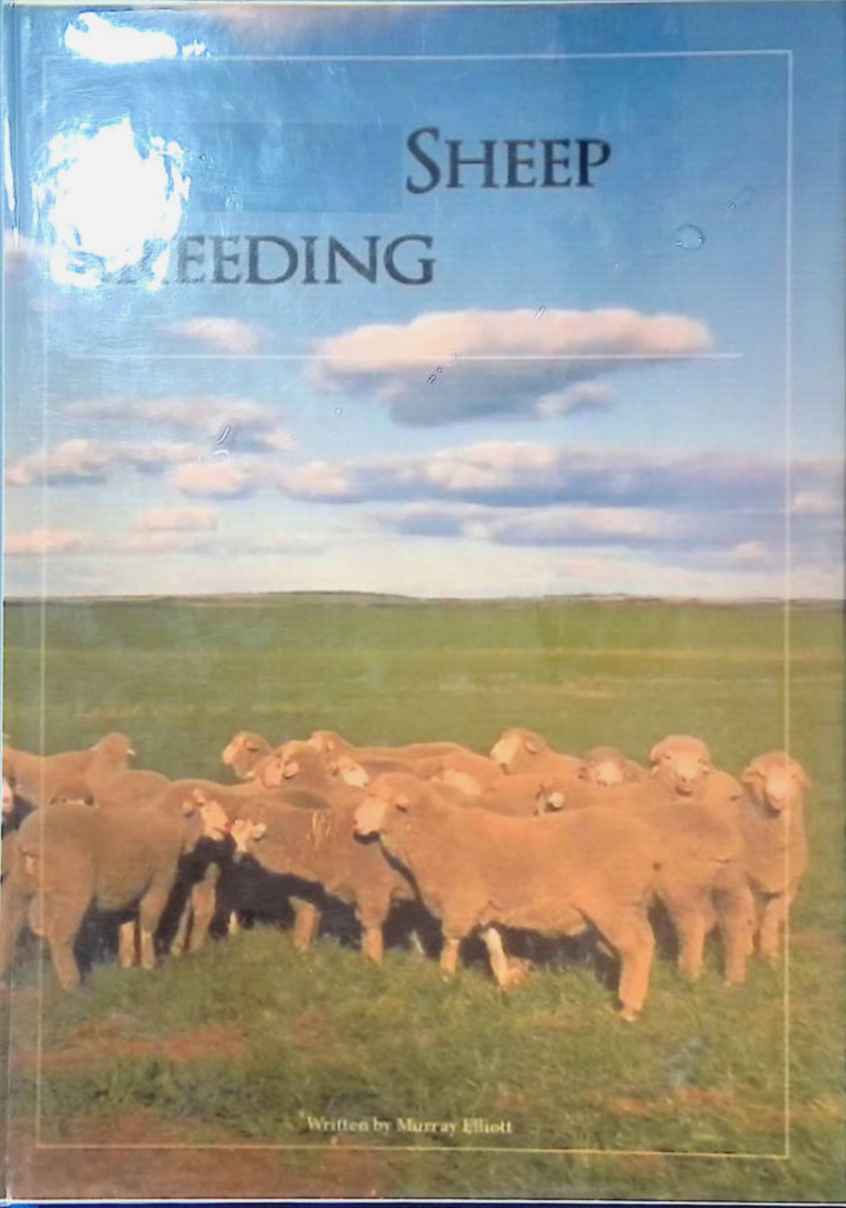
SHEEP BREEDING



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THE SHEEP AND WOOL INDUSTRY OF AUSTRALIA — A BRIEF OVERVIEW

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INTRODUCTION

Australia has an immense sheep industry, the largest in the world (Chapman, Williams and Moule 1973). The gross annual value of the products has exceeded $U.S.1500 million. More than three-quarters of the sheep are bred and kept for apparel wool. Most wool is exported, thereby contributing significantly to Australia's export income. In 1970 the total number of sheep shorn and the total annual wool production in Australia reached record levels of 180 million sheep and 923,000 tonnes of greasy wool. Sheep numbers have since decreased with a corresponding decline in wool production.

Australia produces about 30% of the world's wool, twice as much as U.S.S.R. (the second largest producer), and wool is one of the most important of rural exports. Ninety percent of wool produced is exported—95% if semi-processed wools are included. Japan (34%), Italy (9%), France (8%), United Kingdom (8%) and the Federal Republic of Germany (7%) are the principal buyers, (Bureau of Census and Statistics 1970).

DEVELOPMENT OF THE SHEEP AND CATTLE INDUSTRY IN INLAND AUSTRALIA

Commercial livestock grazing in Australia has been shaped, over a period of more than a century and a half, by three interrelated factors: environment, profit and cultural pressure. Geared essentially to distant export markets, its development reflects the abundance of land and scarcity of labour and capital on which Australia's economic growth was initially based.

The rapid increase in numbers of livestock following their introduction into Australia, and the attendant development of an industry based on use of extensive land areas, calls for critical examination.

What are the factors required for development of a pastoral industry in any new, remote and undeveloped country? It appears that at least four conditions must be co-existent in order to encourage an enterprise on an extensive scale:

1. Availability of great areas of essentially free land producing suitable forage.
2. Demand for animal products, locally or in a foreign market.

3. A low requirement for labour.
4. Suitable animals for foundation stock.

In inland Australia there were for all practical purposes, unlimited areas of free land; its vegetation was dominated by perennial plants, including grasses, forbs and palatable shrubs. The forage was of such a nature that it could be utilized for all classes of domestic livestock—horses, sheep, cattle and goats.

The native pastures were co-extensive with conditions highly favourable for both forage growth and livestock production in good seasons. Winter temperatures permitted year-long grazing of livestock and did not require that shelter be provided. Lack of competition from a large native wildlife population, relatively few predatory animals, and, especially at first, freedom from diseases and pests.

The last point may have been of particular significance (McDonald 1959). When livestock are introduced to an entirely new area they take with them only the diseases with which those particular animals happen to be infected at the time—the others to which their species are subject are left behind. As a net result livestock taken to new areas commonly suffer fewer diseases for a considerable number of years. Another point is that there were no native ungulates in Australia from which pests and diseases could be contracted. For these reasons, domestic livestock introduced into Australia, and spreading through it as colonization proceeded, were singularly free from disease.

Throughout Australia in the early part of the colony's existence the demands were for animal products for local subsistence. This period was ephemeral merging into that in which there was an active market in the early gold mining districts. Sale of animal products to mining communities was more important in Victoria and New South Wales than in other colonies. In addition to edible products, important in the local economy, domestic animals produced items of even greater significance—wool, hides and tallow. These items were non-perishable and compact, withstood shipment for long distances, and had a high value per unit of weight which enabled them to compete successfully for space on cargo vessels against virtually all other commodities. There is abundant documentation of the fact that throughout much of the colonial era the value of the wool commonly represented the entire worth of the sheep (Barnard 1962).

In inland Australia, wool was a highly marketable commodity from the beginning, continuing to be the principal incentive to sheep production until recent times (Barnard 1962).

Livestock raising on the pastoral lands of Australia required a small amount of labour, none of which needed to be highly skilled. With land which was ample in area and initially abundant in forage production, animals could be turned loose to roam freely for most of the year. Each flock of sheep needed a shepherd, and the wool had to be shorn. Labour to meet these requirements was readily available except for periods during the goldrushes or in times of war. Following initial introduction of sheep into the coastal regions of New South Wales, reservoirs of animals accumulated rapidly. Importations from England and from Spain supplemented the natural increase. Selected from the hardy stock which had survived the long sea voyage and by breeding they readily adapted to the environment of their new pastures. Their inherent vigour, coupled with relative freedom from disease already discussed, fitted them admirably to their role as foundation stock for Australia. As Moule (1962) and McDonald (1959) point out there was a considerable amount of breeding and selection among sheep once the inland pastoral areas were opened up.

In summary, all major factors favouring a pastoral industry in a remote new and undeveloped region were found in Australia. Moreover, these conditions were in such a favourable combination that stock raising became a very important industry within a short time (Barnard 1962; Butlin 1962).

Livestock increased at an astonishing rate when simply left to run relatively wild on the grazing lands of the new colonies. It was a cause of wonder even among contemporary observers (Butlin 1962). Some indication of the rapidity with which herds and flocks could build up is afforded by the rates of unimpeded increase in livestock. For the present purpose two years has been used as the minimum breeding age for both cattle and sheep (in practice it often has been nearer one year, especially under the conditions prevailing a century or more ago). These rates of unimpeded increase apply only to ideal conditions of course (Table 1). But with ample forage, a favourable climate, relatively few diseases and essentially no competition or serious predators, the grazing lands of inland Australia approached the ideal in no small degree during several periods (Butlin 1962).

TABLE I

UNIMPEDED INCREASE IN LIVESTOCK NUMBERS

Years	Total Number of Animals Cattle†	Sheep*
1	2	2
5	7	8
10	30	54
15	142	406
20	675	3076
25	3209	—

†Assuming on average one young per birth
*Assuming on average 1.5 young per birth

Periodic droughts caused great fluctuations in livestock numbers (McDonald 1959; Moule 1968; Perry 1967, 1968) but over periods of 10-20 years at a time numbers rose rapidly. The data for sheep numbers, as an example, shown on a logarithmic scale (Fig. 1) provide a simple growth curve which resembles in broad outline, the growth curve of a typical bacterial culture. The initial growth from 1820-1890 was typical of the growth of a new organism in a suitable environment—the numbers increased to 20 million, thereafter increasing steadily to 106 million by 1891 when most of the areas suitable for sheep had been occupied. Then from the year 1891 to the present, the curve shows a general tendency toward a stationary phase in which there are violent fluctuations in numbers. These fluctuations in the arid zone livestock population are thought to be drought related (McDonald 1959; Chapman *et al.* 1973). Excellent accounts of the history of the development of Australia's pastoral industries have been published by Peel (1973), Barnard (1962) and by Alexander and Williams (1973); there are detailed accounts relating to past and current status of each particular livestock industry.

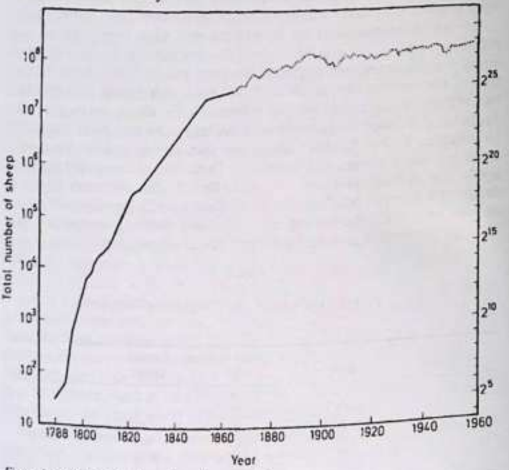

Figure 1—Growth in the Australian sheep population

THE INDUSTRY STRUCTURE

The last 25 years have been a dynamic period for the Australian sheep and wool industry in that there have been great changes in population and production characteristics. During this time span the industry has experienced mixed fortunes, ranging from the relatively buoyant conditions of the early 1950s to those at present where it is being subjected to strong economic pressures.

The sheep industry is dispersed throughout inland Australia and encompasses a wide range of environmental conditions with annual rainfall ranging from less than 250 mm to more than 1000 mm (Fig. 2). Even though there is increasing diversity within the woolgrowing enterprise as annual rainfall increases, wool is always the major product.

The Bureau of Agricultural Economics in its surveys of the Australian sheep industry (Lawrence 1971), divided the sheep grazing regions into three broad zones: the pastoral zone, the wheat-sheep and the high rainfall zones (Fig. 3).

The largest zone in terms of area, the pastoral zone, consists of the arid and semi-arid regions which run through the Northern Territory, Queensland, New South Wales and Western Australia. This zone is characterized by almost no agricultural activity especially towards it inner boundaries. Large sheep flocks are a feature of the sheep grazing areas and the main activity on these sheep properties is wool growing, using Merino-type sheep. Some beef cattle are also run on what are predominantly sheep growing properties.

The wheat-sheep zone is bounded by the pastoral zone towards the centre of the continent and the high rainfall zone at the coastal side. It is the second largest zone in terms of area. Properties in this zone typically combine sheep and/or beef cattle raising with a wheat or other cereal growing enterprise. The majority of the national sheep flock is carried in this zone and many of the flocks produce non-Merino sheep for either direct slaughter or for fat lamb breeding programmes.

The high rainfall zone is the smallest of the three zones in terms of total area but the second largest in respect to sheep numbers carried. This zone lies on the seaboard edge of the continent in each of the States and covers all of Tasmania. In the high rainfall zone sheep are generally carried in conjuction with beef cattle and, as in the wheat-sheep zone, many properties produce prime lambs in the sheep enterprise.

Although the boundaries of these zones are not clear and one zone merges into the next, the surveys reveal appreciable differences in production and land-use between the zones. Of the sheep population 23% are in the pastoral zone, 44% in the wheat-sheep zone and 33% in the high rainfall zone (Lawrence 1971). The boundaries of the pastoral zone coincide with the semi-arid and arid zone as defined by Perry (1967).

Even within the pastoral zone there are regional differences in sheep productivity. Brown and Williams (1970) examined the geographical aspects of the distribution of sheep and their productivity in the pastoral zone.

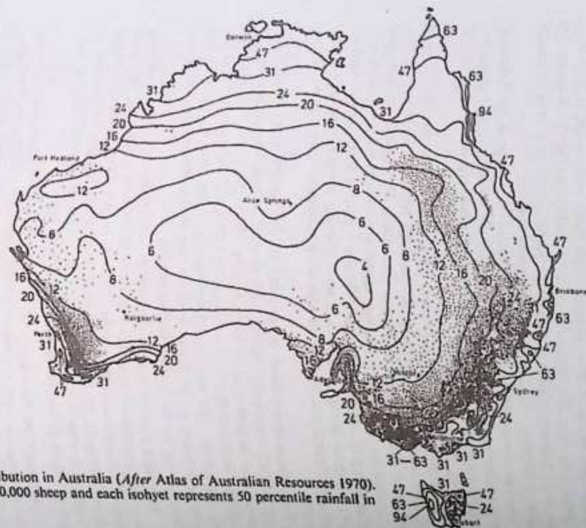

Figure 2—Sheep distribution in Australia (*After* Atlas of Australian Resources 1970). Each dot represents 50,000 sheep and each isohyet represents 50 percentile rainfall in inches per year

Figure 3—Australian grazing industry survey zones (*After* Bureau of Agricultural Economics 1975).

The average greasy fleece weight of sheep in the northern sub-tropical areas of eastern and western Australia were considerably lower than those of sheep in the temperate semi-arid southern areas. Similar north-south trends in marking percentages were apparent in eastern Australia but were not so clearly seen in western Australia. The low productivity of sheep in northern Australia must impose a severe economic penalty on pastoralists in these areas where there are about 6.5 million sheep which produce less than 2.5 kg of clean wool each year.

Three-quarters of Australia's sheep are Merinos (73% in 1970). Other pure breeds include Corriedales (6%) and Polwarths (2%). Cross-bred sheep (over 12%) and Merino comebacks (less than 3%) comprise the remainder.

Sheep are now grazed on more than 85,000 properties that vary greatly in area and size of flock (Tables 2 and 3). Most of the sheep in the inland are run on large properties where capital (Table 4) and labour components (Table 2) are low by overseas standards (Campbell 1965; Waring 1969). The industry covers one-third of the continent (Figure 2) but directly employs or supplies a living for less than 5% of the population (Chapman *et al* 1973). The Merino flocks are found throughout the sheep grazing areas of Australia and although wool is their major product some of these flocks provide ewes that form the foundation of the prime lamb industry.

The history of sheep breeding in Australia is dominated by the development of a number of strains of the Merino sheep, well adapted to the production of medium and fine wool in most of the many and varied parts of the country. There are various detailed authoritative accounts of the introduction of sheep by the early colonists and of the early breeding and husbandry methods (McDonald 1959). The earliest sheep were natives of

TABLE 2

SUMMARIZED STATISTICS OF AUSTRALIAN SHEEP ENTERPRISES†

Attribute	Zone Pastoral	Sheep/Wheat	High Rainfall
Area of holding (ha)	15,725	1,144	546
Sheep/holding	3,900	1,511	1,185
Sheep units/ha	0.18-0.58*	2.1	5.3
Wool/sheep (kg)	4.0	4.1	3.9
Labour units (man-years)	2.8	2.7	1.8
Sheep units/labour unit	2,124	973	1,383

†Summarized values for all States. Values for individual States may differ markedly from the averages shown.

*Extremely variable and hence a range of values is given

Source: Bureau of Agricultural Economics (1976)

TABLE 3

AVERAGE FLOCK SIZES BY ZONES FOR PROPERTIES PRODUCING MERINO APPAREL WOOL

Flock Size	Zone		
	Pastoral	Sheep/Wheat	High Rainfall
Number of sheep		% of properties	
200 — 500	Nil	15.7	21.9
500 — 1,000	1.8	25.2	12.4
1,000 — 2,000	16.8	31.9	28.9
2,000 — 5,000	47.7	23.3	29.4
5,000 — 10,000	25.3	3.5	6.3
10,000 — 20,000	7.1	0.4	1.1
>20,000	1.3	Nil	Nil

Source: Bureau of Agricultural Economics (1976)

TABLE 4

AVERAGES PER PROPERTY FOR SELECTED ATTRIBUTES PERTAINING TO SHEEP AND WOOL PRODUCTION IN THE MAJOR ZONES

Item	Zone		
	Pastoral	Sheep/Wheat	High Rainfall
Total capital invested ($)*	193,024	145,473	150,213
Sheep and lambs shorn	5,244	1,801	2,112
Wool produced (kg)	22,957	7,123	7,932
Ewes mated as % of flock	49.2	50.7	45.8
Lambing %	50.2	66.8	79.2
Wool cut/sheep shorn (kg)	4.4	3.9	3.8
Returns from wool ($)*	39,063	11,877	16,635
Sheep trading gain ($)	5,803	3,994	5,295

Source: Bureau of Agricultural Economics (1976)
* 1972-73 figures

South Africa and Bengal, transported from the Cape and Calcutta. It was not until the introduction of Spanish Merinos, also from the Cape, in 1797 that the foundations were laid for the development of an adapted breed for Australian conditions. The Merino thrived in the new environment, producing superfine wool for the English market. Later, the combined forces of changing markets and the discovery of the inland grazing areas of Australia stimulated the creation of development of two new Merino types which became important as the Australian Merino. The two strains were the medium-wool Peppin and the South Australian strong-wool. The medium-wool Peppin (64's count) was developed by the Peppin brothers at their "Wanganella" property in the Riverina of south-west New South Wales. South Australia breeders favoured a more robust type of sheep with dense, long-stapled wool of 60's count. The Merino sheep has, through selection over the past 150 years, developed varieties suited to hot-dry and cool-wet environments. In hot-dry summer rainfall country the Merino is low in production (3-5 kg greasy wool) and in fertility (30-50% of lambs a year) (Macfarlane 1968a). Chapters in both Barnard (1962) and Alexander and Williams (1973) provide additional information on aspects of the development of the Merino sheep in Australia.

Sheep and wool are part of the Australian tradition. However, the importance of wool has declined; wool prices fell to marginal levels in 1971, stimulating interest in sheep meat production at the expense of wool and in substitution of cattle for sheep (McCarron 1975).

THE OUTLOOK FOR THE FUTURE

In his recent review of the future prospects for the pastoral industries of Australia, Ferguson (1973) cites alternative uses of grazing lands, possibilities of improving ruminant productivity, and decreasing costs of production as questions which will have bearing. Competitions from man-made products (synthetics) could also play a major role. Already man-made fibres have made a major inroad into the market for wool. Vegetable protein could have a bearing on the future market for red meat.

Reduction in the demand for wool stimulated a switch of resources to production of beef cattle. Sheep and cattle have always shared approximately equal proportions of Australia's major photosynthetic resource. The ratio of sheep to cattle numbers has fluctuated in a cyclic fashion reflecting the response of producers to changing relative returns from these enterprises. Sheep and cattle share much of the same rangeland, except in the far north where sheep have been replaced almost entirely. Marked seasonal and year-to-year variations in pasture growth in the inland have favoured the production of wool, since wool can be as efficiently produced on a fluctuating as on a constant feed intake (Ferguson 1962). Wool growth continues on feed intakes insufficient to maintain body weight, while meat production would be negative under such conditions.

Pastoral industries in the inland are non-competitive for land-use with cropping, due to unsuitable climate, soil or terrain. Proclamation of some areas within the arid zone as recreation areas and as National Parks represents some conflict of interest but the actual extent of these special reserves as proportion of the total land area available is small (Costin and Mosely 1969).

Sound ecological reasons have been advanced for removing livestock from much of the arid zone. Unless more conservative stocking is adopted, production is likely to continue to decline in the pastoral zone as desert formation increases.

The grazing industries appear safe from displacement by food crops in the pastoral zone but there is likely to be conflict of interest in land use in high rainfall and wheat-sheep zones as pressure for food grain production increases.

Despite a seemingly inevitable doubling of the world's population by the end of the century, the future prospects for wool are clouded by the uncertainities of its competitive position with the fibre products of the petrochemical industry. However, the exponentially increasing depletion of the world's supplies of fossil fuels and mineral resources may give the competitive advantage to wool. The energy cost of harvesting the photosynthetic resource of inland Australia is small, the ruminant serving as a self-fuelled, self-propelling, self-servicing and self-reproducing harvesting machine. It is also a food or fibre processing factory (Ferguson 1973; Macfarlane 1968).

During one-and-a-half centuries of occupation by graziers their pastoral activities have brought about development of transport and communications systems throughout thousands of square kilometres of arid areas. These facilities are now being utilized in the search for minerals, oil and gas which no doubt will yield far greater returns than wool or meat in years to come. And although in future the relative significance of pastoral production may decline, it must be remembered that in past years, sheep and cattle played a major role both in terms of development and in yielding revenue. In fact for more than 100 years pastoral production has been virtually the only major source of revenue for about four-fifths of inland Australia.

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AUSTRALIAN SHEEP BREEDING PROGRAMMES — AIMS, ACHIEVEMENTS AND THE FUTURE

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INTRODUCTION

Australia does not have a sheep breeding programme in the sense of a planned programme that has been laid down either by Government Departments of Agriculture, by research organizations such as CSIRO, or by organizations of sheep breeders. Thus I have interpreted the title given to me—Australian Sheep Breeding Programmes—to mean existing practices that have evolved since the wool industry was established in Australia at the beginning of last century.

Australia was colonized at a time of rapid population growth during the industrial revolution in Europe with a consequent increased demand for wool. Australia provided 800 million hectares of land sparsely occupied by about 600,000 Aborigines. 65% of the area proved to be suitable for grazing and much of this was unsuitable for competing uses such as crop production and forestry. Today only 2¼% of Australia's land is used for cropping because of the restraints imposed by soil, climate and terrain (Nix, 1973, 1975; Gifford *et al* 1975).

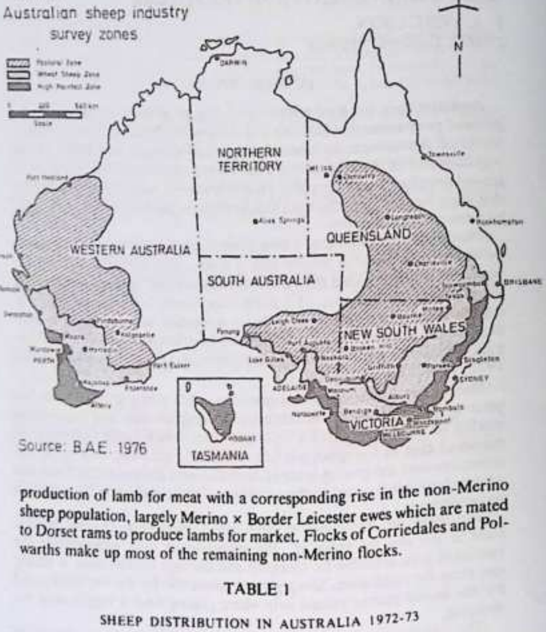
Both sheep and cattle spread into Australia's empty grazing lands but prior to the development of refrigerated transport there was no overseas market for beef. Wool had a high unit value which could withstand the transport cost to European markets. Ultimately the sheep and cattle distributions over the grazing lands of Australia were determined by historical trial and error influenced by the suitability of sheep and cattle for particular environments.

The sheep are distributed in three broad zones (Fig. 1). The pastoral zone is too dry for cropping. The wheat-sheep zone encompasses the restricted area available for cropping and the high rainfall zone is mostly too steep for cultivation. Sheep proved unsuitable for the wet tropics and for the humid eastern coastal strip where grazing land is largely used for dairying.

The variability of rainfall in Australia produces frequent periods of pasture shortage unsuitable for meat production. Wool growth continues on sub-maintenance intakes while bodyweight is being lost. Such conditions favour Merino wool production since the limited arable land precludes the widespread adoption of supplementary feeding.

The stocking rate is much lower in the pastoral zone and property sizes are correspondingly larger (Table 1). In the higher and more reliable rainfall conditions of the wheat-sheep and high rainfall zones there is an increase in

Figure 1



production of lamb for meat with a corresponding rise in the non-Merino sheep population, largely Merino × Border Leicester ewes which are mated to Dorset rams to produce lambs for market. Flocks of Corriedales and Polwarths make up most of the remaining non-Merino flocks.

TABLE 1

SHEEP DISTRIBUTION IN AUSTRALIA 1972-73

Zone	No. of properties	Average property size Ha	Sheep per property	Sheep equivalents per hectare	% Merino	% Crossbred	% Corriedale Polwarth
Pastoral	6,459	24,103	4,947	0.30	97.5	1.9	
Wheat sheep	44,400	1,161	1,605	2.9	79.9	13.4	4.7
High rainfall	28,762	639	1,814	6.0	60.9	18.6	16.5

Source: B.A.E. 1976.

STRUCTURE OF AUSTRALIA'S SHEEP BREEDING PROGRAMME

The expansion of the Merino into the grazing lands of Australia was accompanied by the evolution of different strains of Merino promoted by geographical isolation, different environmental conditions, and increased demand for longer stapled wool. The short stapled fine wools established in the high rainfall zone proved less suitable for the pastoral zone and the medium wool Merino developed by the Peppin brothers in the Riverina became the dominant type in New South Wales. In South Australia a distinctive type of strong wool Merino was developed which spread to Western Australia (Pattie 1973).

A hierarchical three-tiered structure developed in which a group of closed stud flocks called parent studs supplied rams to a second tier of daughter and general studs, the daughter studs drawing outside blood only from their parent stud and the general studs drawing outside blood from more than one parent stud (Short and Carter 1955). In turn, the three kinds of stud supply more than half the rams required by the third tier of commercial flocks (Table 2).

TABLE 2

RAMS SOLD BY SHEEP STUDS IN AUSTRALIA 1971

	No.	%
Parent Studs	13,616	10.8
Daughter Studs	46,915	37.3
Family Groups	60,531	48.1
General Studs	64,968	51.9
All Studs	125,499	100.0

Source: Roberts, Jackson and Phillips 1975

The number of daughter and general studs has increased with the growth of the sheep population, the number of parent studs by definition remaining restricted. The family groups deriving from each parent stud have preserved some degree of genetic diversity within the fine, medium and strong wool strains of Australian Merino. However, the different family groups have unequal influences on the genetic composition of the Merino population (Fig. 2).

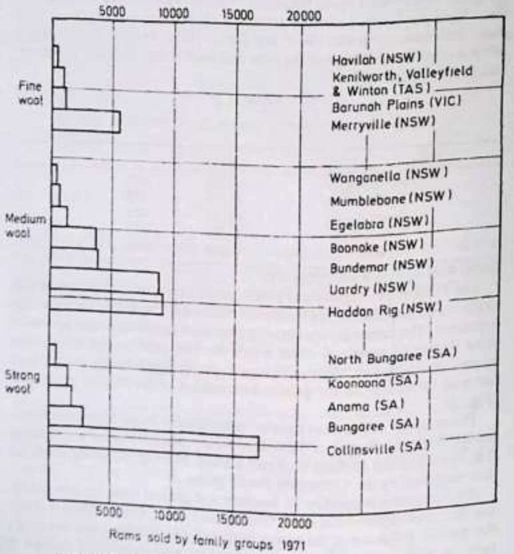
The majority of fine wool rams are now supplied by the Merryville family group, while the Peppin medium wool family groups, Uardry and Haddon Rig, dominate the medium wool ram market. Most of the strong wools are now supplied by the Collinsville family group.

An increasing proportion of daughter and general studs are now breeding their own replacement rams (Connors and Reid 1976), tending to dilute the genetic influence of the parent studs and establishing a two-tier structure. A proportion of the larger commercial flocks (the exact number is unknown) are also breeding their own rams.

In recent years an additional feature of sheep breeding programmes in Australia as in New Zealand is the emergence of the co-operative nucleus breeding systems, the largest scheme being in Western Australia. The co-operating sheep breeders measure performance objectively and contribute their best ewes to a central nucleus flock which in turn supplies rams to the contributing flocks. Ewes from the entire population can thus be drawn on to produce rams rather than only the 2% of the population represented by the traditional stud system. However, the relative efficiency of the two systems probably depends on the extent to which objective measurement of performance is employed and the culling percentage used.

At present the number of rams tested for clean fleece weight and mean diameter by the Merino studs is less than 10% of the number of rams sold.

Figure 2



Source Roberts, Jackson & Phillips 1975

Rams produced by the nucleus flock in the co-operative breeding systems are not only selected on measured performance but are produced from ewes also selected on measured performance. Traditionally, sheep studs have relied on visual methods of appraising performance and appear to remain unconvinced of the merits of objective measurement. The percentage of rams culled by the studs is generally low.

CRITERIA OF PERFORMANCE

In Australia the amount and kind of wool per sheep dominates estimates of value with little attention being given to fertility or bodyweight unlike the practice in New Zealand where environmental conditions are more favourable for meat production.

Traditional selection criteria which are still largely utilized include some characteristics of little value and others which are negatively correlated with wool weight such as crimp frequency. However, the introduction of measured clean wool yield and mean fibre diameter as a basis for wool selling has brought about changes in wool classing which will be reflected in sheep classing. Separate quality count and yield lines within a flock are now combined since crimp frequency, the major determinant of quality count, has a variable relation to mean fibre diameter (A.W.C. 1973). Tops made from the bulked lines have been shown not to be inferior in variability of fibre diameter and length (Andrews and Rottenbury 1975).

The price margin for finer wool has in the past been balanced by the lower fleece weights of finer wool traditionally selected by high crimp frequency. However, more widespread recognition that the positive genetic correlation between fleece weight and fibre diameter is small may lead to a lessening or a reversal of the present trend towards coarser wool and a reduction of the price margin for decreased diameter.

The worsening of the terms of trade for the wool grower over the past 25 years is reflected in a marked decrease in hired labour on sheep properties despite an increase in sheep numbers (B.A.E. 1976). The shortage of labour has focused attention on genetic solutions of problems previously coped with by more labour-intensive non-genetic means. For example, the elimination of skin folds easily achieved by selection reduces shearing time and susceptibility to blowfly strike.

GENETIC PROGRESS

Over the past 30 years greasy fleece weights of sheep in Australia have increased by 0.02 kg or 0.4% per year without any change in yield of clean wool (Figs. 3 and 4). This small increase can be accounted for by a decrease in the proportion of high quality count wool grown (Fig. 5) and by an increase in the area of sheep properties fertilized with superphosphate (Waring and Morris 1974). If correction is made for these influences, levels of wool production appear to have reached a plateau with the existing breeding system.

Figure 3

Trends in greasy fleece weight per sheep 1935–1976. Source: B.A.E. 1973 & A.B.S. 1976.

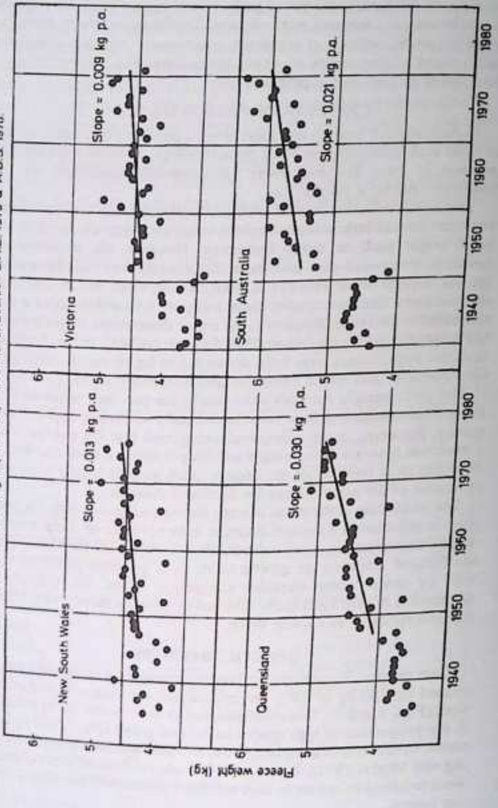


Figure 4

Trends in greasy fleece weight per sheep 1935 - 1976. Source: B.A.E. 1973 & A.B.S. 1976.

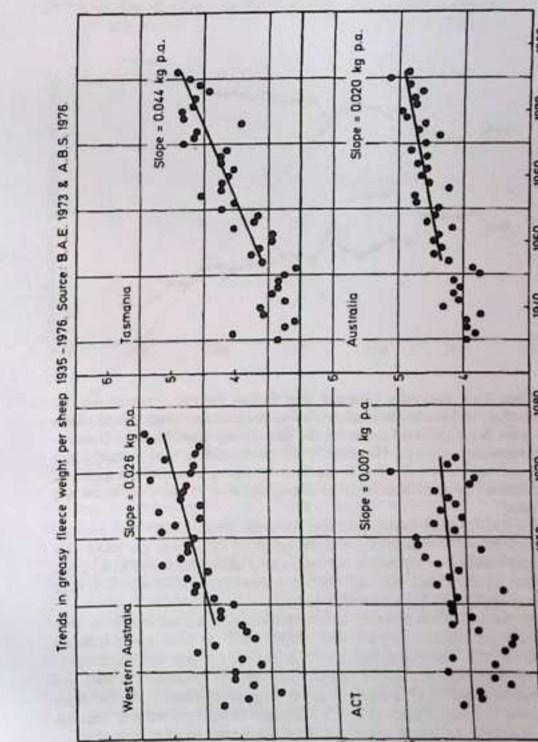
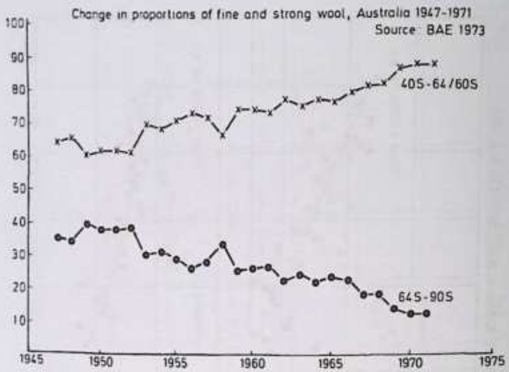


Figure 5



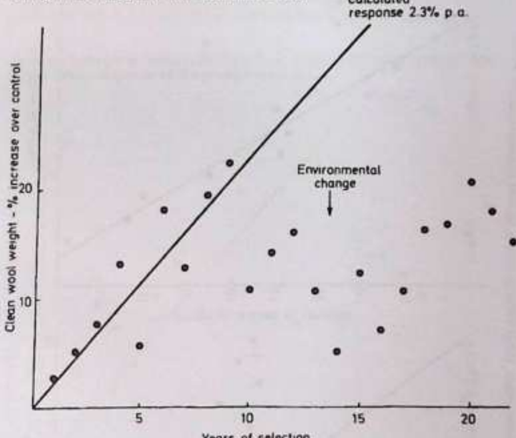
It has been generally assumed that further genetic progress will be achieved if the Merino studs adopt fleece measurement programmes which they have been exhorted to do for the past twenty years by State Government extension services. However, I am less confident than formerly that fleece measurement will result in continued progress now that the results of experimental programmes initiated during the past 25 years are becoming available.

In a CSIRO experiment, selection for clean fleece weight with maintenance of mean fibre diameter and exclusion of sheep with excessive skin wrinkles resulted in the predicted increase of clean fleece weight of 2.3% per year (Turner and Young, 1969) for nine years after which further progress appears to have slowed (Fig. 6).

Another CSIRO experiment in which there was no restriction on fibre diameter or skin wrinkles was duplicated in two environments simultaneously. The initial responses of 6 and 8% per year were in excess of the responses expected on the basis of heritability, selection intensity and variance in clean fleece weights, possibly because the base flock had been unselected for many years (Fig. 7), (Dunlop 1976, Personal communication). However, a plateau appears to have been reached after nine years.

Again, in the N.S.W. State Department of Agriculture Experimental Station, selection for clean fleece weight resulted in the expected response for seven years after which progress has declined (Fig. 8).

Figure 6—Response to selection (1950–1974) for clean fleece weight with restriction on fibre diameter increase and high wrinkle score in Peppin Merino (Source: Turner, Dolling and Kennedy 1968 and unpublished data).



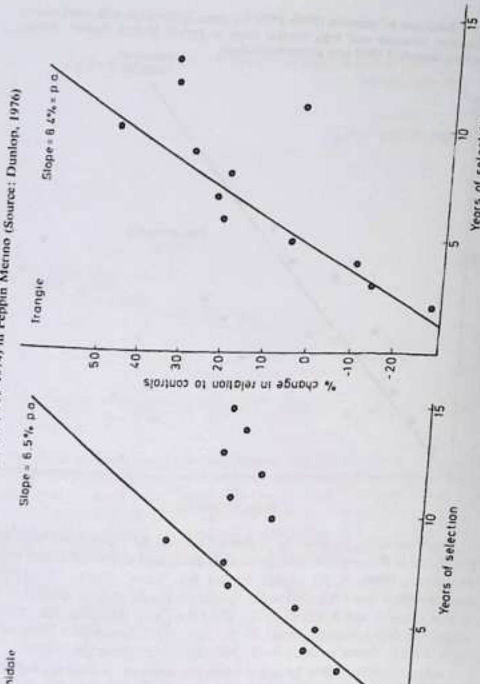
Unfortunately, we have no extensive data on the relative productivity of the sheep in these selection experiments compared with those in stud flocks. However, there is no evidence that the flocks selected on objective measurement have reached fleece weights in excess of those reached in stud flocks (Saville and Robards 1972). Thus there is no guarantee that the use of objective fleece measurements by the studs will increase their fleece weights and thereby fleece weights in the Merino sheep population at large.

Alternatively it may be argued that the apparent plateau in clean fleece weights reached in the selection experiments was due to the small size and restricted genetic diversity of the foundation flocks. The results achieved by co-operative nucleus breeding systems, if adequately documented, will throw light on this question. Both in the national flock and in the selection experiments progress may be limited by nutritional restraints.

THE FUTURE

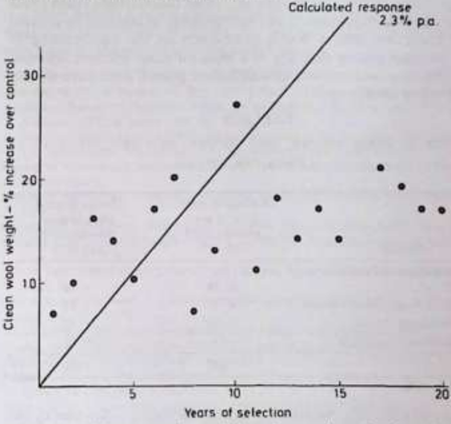
The future of sheep breeding programmes in Australia depends of course on the economic viability of wool as a textile fibre. Analysis of factors influencing wool prices (Table 3) indicate the dominant effects of synthetic

Figure 7—Response to selection for clean fleece weight, (1960-1974) in Peppin Merino (Source: Dunlop, 1976)



fibre prices and the exchange rate in recent years. Unfavourable influences leading to a depression of sheep numbers and diversification to other forms of production will also lead to a further reduction of cost inputs for wool production on sheep properties in Australia. Sheep studs will be disinclined to invest in objective fleece measurement and commercial properties are likely to increase the trend to breeding their own rams.

Figure 8—Response to selection for clean fleece weight (1952–1974) in Peppin Merino. (Source: Pattie & Barlow 1974 and unpublished data)



Unfavourable economic conditions for wool production also lead to a reduction of funds for wool research since in the past these funds have been largely supplied by a levy on wool income. However, assuming more optimistic projections for wool prices and wool production, one can speculate on possible research which might assist the wool industry to increase the genetic efficiency of wool production.

In the existing strains and family groups of the Australian Merino, different characteristics favourable for wool production are present to different degrees (Carter and Clarke 1957; Dun and Hayward 1962; Dunlop 1962, 1963; Jackson and Roberts 1970; Saville and Robards 1972). The South Australian Merino is outstanding in clean fleece weight associated with greater fibre diameter, staple length, and body size. It also has least skinfolds and face cover and has the greatest ability to increase wool production under good nutritional conditions. The Merryville, Egelabra and Haddon Rig family groups are outstanding in density of fibres per unit area, a characteristic not only favourable for increased wool production but probably also for exclusion of water, dirt and vegetable matter from the fleece. The Egelabra and Collinsville family groups are noted for improved colour of the fleece, probably reflecting a decreased suint content. Susceptibility to blowfly strike may be reduced by a low suint of the fleece and by increased density. Although data are limited there are suggestions that different strains vary in other important characteristics such as the maintenance energy requirements and susceptibility to infection by internal parasites. There has been a dearth of research on the interbreeding of strains to increase genetic diversity as a basis for more effective selection based on objective measurement although some general studs have already been established on this tenet.

TABLE 3

TREND IN WOOL PRICES: 1973 TO 1971 AND 1971 TO 1975 (CENTS PER KG)

Change	Change in trend price of wool between 1963 and 1971	Change in trend price of wool between 1971 and 1975
Growth in population and real income per head	+ 24	+ 14
Inflation and exchange rate movements	+ 20	+ 31
Changes in the supply of wool	− 17	+ 12
Changes in synthetic fibre prices	− 134	+ 51
Net effect	− 107	+ 108

Source: Dalton 1976

The selection intensity possible for any characteristic is lowered by the number of characteristics for which selection is practised. Rather than select for all important characteristics simultaneously, general studs can introduce rams known to have particular characteristics developed well above the range in their flock and so achieve a rapid gain to a new level. In this respect research flocks in State Departments of Agriculture and CSIRO may be able to play a role in producing sheep superior in characteristics which are difficult for the stud breeder to measure such as resistance to internal parasites, high fertility and particular wool follicle characteristics.

Improvements in non-genetic aspects of sheep nutrition may reduce non-genetic variance in fleece characteristics and also provide conditions which enhance genetic variation. Thus it is known that Merino sheep provided with optimum diets are capable of producing clean fleece weights of 7-9 kg (Ferguson 1972, 1975) which compares with the present Australian trend average of 2.8 kg. Agronomists and plant breeders have seldom sought potential new pasture plants in terms of their wool promoting capacity and the principal feedstuffs used for supplementary feeding on sheep properties — hay, silage and cereal grains — are not capable of producing maximum rates of wool growth. Improvements in sown pastures and supplementary feedstuffs could thus provide nutritional conditions leading to the expression of increased genetic variation in wool characteristics. The development of supplements which provide increased amounts of cystine should also improve conditions for selection (Ferguson 1975).

I have painted a broad canvas and leave it to my colleagues to develop aspects in more detail. No doubt they will also express their disagreement with some of the generalizations I have made.

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3

SHEEP BREEDING IN FRANCE

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SUMMARY

Sheep production in France is characterized by the dominant demand for a particular type of carcass (18-21 kg) of suckling lambs from a great variety of sheep farming methods. The flocks are small and there are numerous breeds. Many English blood lines have been introduced into the local hardy ewes giving seasonal variation in the possibilities of reproduction. So, the programmes of technical improvements are cross-breeding for meat production, increasing prolificacy by selection or hybridization with Romanov and Finnish breeds and the control of oestrus and ovulation.

INTRODUCTION

There are 7 million ewes aged more than 1 year in France. There has been a tendency towards a gradual increase in this figure since the Second World War (16.6% in the last 10 years).

This chapter will be divided into 3 parts: (1) Characteristics of sheep production; (2) The structure of flocks, zones of sheep production, physiological definitions of the breeds; (3) Important technical advances of recent years.

PRODUCTION

Meat represents 90% of the income from sheep farming. Production has fluctuated around 130,000 tonnes over the past few years, representing a slow but regular increase of 26% in 10 years. However, the production is not sufficient for the national consumption, which is continually increasing (3.3 kg/person) and the deficit is of the order of 60,000 tonnes, or 45% of the national production.

The type of carcass most in demand is that of suckling lambs which represent 77% of the total head slaughtered, and 67% of the net carcass weight; the remainder is composed of cast animals. Carcass weights of lambs slaughtered now range between 18-21 kg at 2½ to 4½ months throughout France, although previously those from the South were lighter, and those from the North, heavier.

Milk is produced by 800,000 dairy ewes. It is destined for the production of quality cheese of which 10% is exported.

Wool represents 4% of the receipts from sheep production. The interest in wool has diminished with decreasing prices.

There has appeared an overall demand for quality meat and milk for cheese, such that bidding prices for these products are high (3 times higher than world prices).

A solid economic organization of the production exists for the collection and sale of these products: almost all of the milk produced, 35% of the wool and 15-20% of the meat. This last being the most recent, continues to increase.

VARIOUS ASPECTS OF SHEEP BREEDING IN FRANCE

(a) *Structure of flocks and zones of production*

The natural and economic areas of sheep farming are very varied. The number of farms where sheep are bred has decreased by 18% in 7 years, and the mean number of ewes per farm has increased from 30 to 40: 47.5% of ewes are found in 15,500 farms (9% of farms) where there are more than 100 ewe-mothers, 80% of farms have less than 50 mothers. French sheep farms are thus very small.

TABLE 1

DIVISION OF FLOCKS BY TYPE OF FARMING

	% Nos.
Indoor sheep-folds	41.6
Semi-out-door	33.4
Out-door	10.9
Transhumance	11.2
Diverse	2.9

The national sheep population tends to be concentrated in regions of traditional sheep farming. These are:

Mountain areas: the animals winter in folds, but have external grazing areas either next to the folds, or a long way away (transhumance). Flock management is based on the exploitation of poor pastures during the gestation period, when there is least need. As soon as nutritional requirements increase intensified areas are used, or feed reserves from spring. The lambs are produced in folds. Sheep are often the only possible form of production and although in these regions, flocks are in excess of 50 mothers, the number is rarely sufficient to ensure a reasonable income.

The mid-west is becoming a specialized area. The number of sheep has increased by 45% over the past 10 years. Sheep are bred entirely on pasture, together with grassland culture which is increasing, and recently the culture of maize has been begun. The intensification necessitates more productive livestock, nutritional supplementation of young on pasture and the destruction of parasites. In this region farmers seek to spread the sale of lambs over a maximum period in order to maintain prices.

The milking area (Causses du Sud—Massif Central) is one of the regions with the greatest density of sheep. The system of breeding is highly evolved, to allow milking machines to be used. Lambing takes place in December and lactating ewes benefit from food reserves grown in spring, mainly lucerne. In summer, the ewes use the extensive pastoral zone and the lambs, after early weaning are fattened in the neighbouring regions. In the Pyrénées Occidentales, where the climate is moist and mild, winter is spent on pasture and the animals move to the mountains in summer. The organization of selection for this production is very efficient.

Sheep breeding may also constitute a supplementary production in other areas:

The pastures of the Atlantic coast on the clay soil surrounding the North of the Massif Central are regions where sheep co-exist with cattle. The principle of this type of breeding is to satisfy the needs of the ewes with lambs at the time of abundant pasture growth from March to July and to sell the lambs before the dry period to leave pasture for the cattle. Flocks are small, usually less than 20 animals.

The industrial cereal area of the Parisian Basin have possibilities for intensive and abundant nutrition in autumn and winter. They produce lambs in the non-breeding season in folds. The possibilities for intensification are greatest, if qualified labour can be sufficiently well paid by a high productivity.

(b) *Animal populations*

Populations should be capable of producing a uniform type of lamb carcass (18-21 kg) from very different areas.

TABLE 2

PRINCIPAL FRENCH BREEDS

		% of total effective
1. *Group of littoral breeds*	Texel, Bleu du Maine, Contentin Avranchin	4
2. *Group of breeds highly crossed with English blood* (areas of extensive culture or pasture, area of mid-West)	Ile-de-France, Berrichon du Cher, Charmoise, Blackhead, Southdown	42
3. *Group highly crossed with Merinos* (areas of extensive culture or mountain, with transhumance)	Merinos précoce, Merinos d'Arles, Merinos de l'Est (wool)	10
4. *Group of rustic breeds*		
Mountain breeds	Limousine, Caussenardes, Préalpes Tarasconaise, Blanc de Lozère, Bizet, Rava	24
Milking breeds	Lacaune, Pyrénéenne, Corse	20

The origin of the breeds is very varied. There are a few imported breeds which have undergone selection towards a French type. Many breeds were created by hybridization between local breeds and English sires, above all Leicester. Others are local rustic breeds improved by selection. During the 1st Empire sheep populations underwent infusions of Merino blood.

A very great effort has been expended during recent years to determine the characteristics of reproduction, in particular seasonal variations in sexual activity.

TABLE 3

CHARACTERISTICS OF REPRODUCTION IN THE PRINCIPAL FRENCH BREEDS

Breed	Mean date of the last oestrus of sexual season	Mean date of the first oestrus of sexual season
Ile-de-France	20 January	15 August
Préalpes	1 March	25 July
Romanov (Russian import)	20 February	20 September
Limousine	9 January	5 July

(From Thimonier 1975)

The periods of anoestrus are thus relatively long but the percentage of animals which go into deep anoestrus, with no ovarian activity is very variable. Ewes of the Ile-de-France breed have 2 months of the year during which 80-100% of females show total inactivity of the ovaries (Thimonier and Mauleon 1969).

PRINCIPAL NEW PROGRAMMES OF TECHNICAL IMPROVEMENTS

There is still a large scope for progress of sheep farming in France in classic techniques, principally in nutrition and disease problems. In fact it would be interesting to explain the motivation behind research programmes which may lead to modifications in sheep production.

(a) Butchering potential of "male" breeds used for large-scale cross-breeding for meat

Following a recent survey, it appears that 46% of farmers use at least one breed of male different from their female breed.

The increase in weight at slaughter of lambs is an objective imposed by the demand for heavier lambs. The French market demands that an increase in weight is not accompanied by an increase in fatty tissue.

Rams of the Berrichon du Cher breed are the most widely used of the rustic breeds in double crossings along with the Romanov.

There is no one breed which is absolutely better than another but genetic combinations may be better adapted to particular farming conditions.

(b) Increase in prolificacy

More than one third of breeders consider that an increase in prolificacy has priority among their breeding problems.

On the average, every female aged more than 1 year only produces 1 lamb per year. It has been estimated that half the breeders could rapidly reach a production of 1.5 lambs per year.

The level of prolificacy varies by 100% among the French breeds, the most prolific being the littoral breeds.

Genetic improvement based on the control of performance has allowed an increase in growth potential. Existing structures are used for the collective organization of selection for prolificacy in the main French breeds.

However, the efficiency of selection remains limited and the search for new criteria means that the discrimination of prolific strains is a major research objective.

The Romanov and Finnish breeds constitute a genetic potential which could rapidly increase the productivity of flocks either by single or double crossing, or by creating synthetic strains. These breeds are beginning to be used in all systems of farming but the economic conclusions cannot yet be drawn and no strategy for their use has been defined.

(c) Oestrus and ovulation control

(i) Induction of pregnancy regardless of season

Since most of the French breeds have a period of anoestrus, this possibility is used for the following reasons:

to mate non-pregnant ewes during spring or autumn, or to have the major production during the non-breeding season: the latter is the most widely used, with excellent results of 70-80% fertility at a single induced oestrus, and 160-180% prolificacy.

an increase in lambing rhythm: the degree of intensification is limited to 3 lambings in 2 years, with 5 months of gestation, 2 months lactation and 1 month weaning followed by mating; that is, 8 months between 2 births.

a planned and regular lamb production enabling contracts for their sale to be organized in advance.

early reproduction in lambs: mating is spread over more than 1½ months in 70% of young females leading to poor preparation of females for lambing. Lambings are spread out, making their surveillance difficult, and leading to high mortality in the newborn lambs.

A first mating and reproduction at 8-9 months with 60-75% fertility is possible, but so far, this aspect remains limited to the milking sheep of the Roquefort region.

Introduction of lambs or ewe-lambs into the normal mating system to produce lambs for intensive breeding: young females are normally mated in August-September during the mating period of non-pregnant adults. But the spread of births in February-March interferes with the next, and principal mating period in April-May. By advancing and reducing the mating period of the young females, early lambing in January can be obtained with a second mating in April-May.

Extensive mating system for lambs: in open-air breeding, parturition occurs in February-March, even April and the new lambs are 7-8 months old in October-November, during the mating period; they are often insufficiently developed, and poor fertility results. If they can be mated during the non-breeding season, when they are 12 months old, this allows a second mating in autumn with the rest of the flock, giving higher fertility in the young females. This method is at present being extensively developed.

(ii) Grouping of oestrus and lambing periods

In milking flocks, it is important to have homogeneous groups for weaning of lambs at 4 weeks, and a precise time for starting to milk the lactating females, since industrial dairies close at a fixed date.

In transhumant flocks, there should be no births in the mountain pastures from June to October, and the spring lambs should be old enough to follow the rest of the flock. Thus, mating must take place at a precise time, either in April-May, or October-November. During the former period, results are variable, but the technique of control allows them to be improved.

In flocks of sheep for milk or meat production, artificial insemination permits the development of selection programmes (large-scale crossing with prolific breeds) or diffusion of the best progenitors. This technique, without detection of oestrus, and perfect synchronization, is rapidly developing—actually about 200,000 animals. It is indispensable for this objective in small flocks.

(iii) Increase in prolificacy

This is a consequence of the use of PMSG, which is administered systematically with all progestagen treatments. The increase in lambing rate is 40 additional lambs for every 100 ewes lambing.

In fact, this presupposes, in order not to have a consequent loss of lambs, that this treatment is done by a good breeder (previous lambing averages 130 lambs for 100 ewes lambing) and that he is well informed of the necessity for increased surveillance of births and of saving the lambs by artificial rearing.

CONCLUSION

In the six-country European Common Market, French sheep production represented more than two thirds of the community production. In the enlarged Europe, French production represents less than one third of the total production and follows a long way behind British production (230,000 t). The rules of the Community game have not yet been defined.

ACKNOWLEDGEMENT

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4

NATIONAL SHEEP BREEDING PROGRAMMES NEW ZEALAND

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SUMMARY

The first national sheep breeding programme established in New Zealand was the National Flock Recording Scheme which was started in 1967. In 1976, as a result of experience gained, a revised system called Sheeplan has been introduced. It contains a greater number of options to meet the requirements of different breeds. The traits recorded are: number of lambs born for each ewe, weaning weight of lambs, later liveweights at 6, 9 and 12 months of age, hogget fleece weight and other fleece traits. The breeder must record number of lambs born but may choose none or any combination of the remaining traits. The main outputs to the breeder are: (i) Two-tooth ewe and ram selection lists containing breeding values, a selection index and production information for the traits recorded; (ii) a summary of the performance of each ewe in the flock updated annually and (iii) summaries of the performance of the progeny of each sire used in the flock.

INTRODUCTION

Breeding plans formulated on a national scale can be thought of as encompassing two main ingredients. The first requirement is a recording service which has as its objective the measurement or assessment of the traits of economic importance on individual animals and along with this, the processing and presentation of the records in a way which will assist in identifying genetically superior animals. The second need is for a plan whereby the genetic merit of the selected individuals may be spread effectively through the population. In New Zealand, in common with many other countries, the main endeavour on a national scale has been devoted to the first requirement: the development of an effective recording scheme. This development is the main theme of this chapter.

SOME BACKGROUND INFORMATION

The way in which a flock recording scheme is organized and the traits recorded depend to a considerable degree on the structure of the sheep industry it is expected to serve.

The stratification of breeds in the sheep industry in New Zealand is essentially that of a two-tier system. The basic breeding-ewe breeds, such as the New Zealand Romney, Perendale, Coopworth and Corriedale are maintained as pure-bred flocks breeding their own replacements on the hill or poorer pasture areas. Surplus young ewes and cast-for-age ewes from these flocks are bought by farmers on lower country and are mated to rams of the specialized meat breeds for prime lamb production, both the ewe and wether lambs being slaughtered. A large number of breeds of sire is available for this purpose including Southdown, Suffolk, Dorset Down, Poll Dorset, Dorset Horn, Hampshire, Border Leicester and breeds such as the South-Suffolk and South-Dorset Down which are derived from crosses with the Southdown.

Partly as a consequence of the two-tier stratification, improving reproductive rate is of high economic importance in the basic breeding-ewe breeds. Wool production is also important but with varying emphasis from breed to breed. It has been found convenient to classify the breeds into groups: fine apparel wool such as Merino and Corriedale, bulky apparel wool such as fine Perendale, general purpose wool such as Romney and Coopworth and specialty carpet wool such as the Drysdale. The selection criteria for these groups have been discussed by the New Zealand Society of Animal Production Study Group (1974).

In the specialized meat breeds, it is clear that high growth rate, low lamb mortality in crosses, reduced fat and increased muscling in the carcass are important requirements. There is some variation between breeds in the relative emphasis to be placed on these traits, the contrast being greatest between larger breeds such as the Suffolk and the smaller breeds such as the Southdown.

Several studies (quoted in Rae, 1964) have shown that the registered ram breeding flocks of the breeds studied (Romney, Southdown and Corriedale) form a typical hierarchical structure, with a small number of nucleus flocks supplying most of the sires for a larger group of multiplying flocks. Hence, a recording scheme has to be able to supply the needs of flocks of varying size and status in the traditional ram breeding structure as well as coping with the specialized requirements of co-operative breeding schemes.

FLOCK RECORDING SCHEMES IN NEW ZEALAND

In the past, several systems of record keeping were designed to assist breeders in recording the information required for pedigree purposes and for a variety of productive traits. Probably the most widely used in the period 1930-1950 was a card index system designed by Waters at Massey Agricultural College (Waters, 1939). This system or adaptations of it is still being used by many breeders. It is a satisfactory system for a small flock. Its disadvantages are the substantial amount of work required in keeping the cards up-to-date and the fact that none of the information is processed to assist in selection.

(a) The National Flock Recording Scheme

The first sheep recording scheme to operate on a national scale in New Zealand was started in 1967 by the Department of Agriculture (now Ministry of Agriculture and Fisheries). It was introduced on the basis of a report prepared by E.A. Clarke and A.L. Rae and the scheme has been described in detail by Clarke (1967).

The scheme catered for two distinct classes of sheep: dual-purpose breeds for which reproductive rate and wool production are important selection objectives, and breeds producing sires for cross-bred prime lamb production where growth rate is of major importance.

In the option for dual-purpose breeds, the traits recorded were: number of lambs reared, weaning weight of the lamb, greasy fleece weights for both ram and ewe hoggets and, at the breeder's option, visual assessments of quality number, grade of the fleece and comments on fleece faults. The measure of reproductive rate used was weight of lamb weaned by the ewe at each lambing.

The inputs supplied by the breeder to the Flock Recording Office were: (i) a mating list giving tag numbers of the ewes mated to each sire; (ii) a lambing list giving tag numbers of lambs born to each ewe and their date of birth, sex, birth and rearing rank; (iii) a weaning weight list and (iv) a hogget shearing list for both ewe and ram hoggets in which fleece weights and fleece observations were recorded.

The most important output was the two-tooth ram and ewe selection lists which were designed to aid the breeder in his selection of replacement rams and ewes and to assist buyers in selecting rams. These lists, in numerical order of tag number, contained: (i) the sire and dam of each individual along with its birth and rearing rank; (ii) the individual's own records for weaning weight (adjusted for birth and rearing rank, age of dam, sex, and age at weaning), hogget fleece weight and fleece traits, and any coded remarks made by the breeder; (iii) a breeding value for weight of lamb weaned based on the average performance of the dam over all her available lambing; (iv) a selection index combining weight of lamb weaned and hogget fleece weight.

In addition to the selection lists, a ewe summary updated annually was produced. It included the lambing performance of each ewe in the flock and served as a basis for the culling of the ewe flock.

The prime lamb sire breed's option was based on recording weaning weight of the lamb which after adjustment for known non-genetic factors was returned to the breeder in a selection list.

At its peak in 1974, about 170,000 ewes from 630 flocks were entered in the National Flock Recording scheme. This represented about 30% of the stud ewes in the country and about 15% of the flocks. Experience with the procedures in practice, comment and criticism from breeders along with further information from research suggested that: (i) The scheme did not have sufficient flexibility to cope with the variety of needs of the different breeds within the two broad options and of the individual breeders within each breed; (ii) It was regarded by some breeders as being too complex and there appeared to be a need for a simple limited option; (iii) There was a strong demand from breeders for sire summaries, an aspect of the scheme which had been planned but never put into operation; (iv) Research had indicated the need to include a wider range of traits (particularly liveweights at various ages). The steps which were taken to initiate a re-examination of the scheme have been detailed by Wallace (1974) and Dalton and Callow (1975) and will not be recounted here. It is sufficient to state that many individual breeders, the New Zealand Federation of Livestock Breeding Groups, Farm Advisory Officers (Animal Husbandry) and Sheep and Beef Officers of the Ministry of Agriculture and Fisheries, research and university personnel have contributed to the formulation of the revised recording scheme called Sheeplan.

(b) Sheeplan

The traits recorded in Sheeplan are: (i) number of lambs born or reared for each lambing of a ewe; (ii) weaning weight; (iii) later weights of ewe and ram hoggets—liveweights taken in the autumn, winter and spring; (iv) hogget greasy fleece weight, and an assessment of quality number, or fibre diameter and a fleece grade along with remarks on faults and other aspects of the fleece.

Number of lambs born or reared must be recorded by all members of Sheeplan. The remaining traits are optional and each breeder may choose the combination of traits which suits his particular breed and the objectives of improvement in his flock. Thus, for a Romney flock, a common combination of traits would be number of lambs born, weaning weight, a winter liveweight for ram hoggets and a spring liveweight for ewe hoggets, fleece weights and other fleece information for ram and ewe hoggets. The simplest scheme (for which a demand was predicted but not yet realized) is the number of lambs born on its own. This supplies all the information required by the breeder to meet the requirement of the breed societies for registration and records at least the economically most important trait.

For breeders of prime lamb sire breeds, a common option would be, in addition to the compulsory number of lambs born, a weaning weight and an autumn liveweight.

(1) Inputs

The input lists supplied by the breeder are, with few exceptions, similar to those described for the National Flock Recording Service. The major difference is the elimination of the mating list and the introduction of fate lists to allow the breeder to enumerate the animals which have either left or have entered the flock. Lambing, weaning and hogget shearing lists follow the same general pattern as described earlier. Additional lists are required for each of the later liveweight options.

(2) Outputs

The underlying principles which have been applied in organizing the information to be supplied to the breeder are:—

(i) That, in addition to the records of each animal adjusted, where necessary, for non-genetic effects, predicted breeding values for the important traits should be supplied.

(ii) That all the available information, including information from correlated traits should be used in predicting the breeding value of each trait. These breeding values may then be combined following the method given by Henderson (1963) by weighting by their relative economic values to give a selection index.

(iii) That provision be made in the processing of the records for differing sets of relative economic values, correction factors, genetic and phenotypic parameters to be used for each breed. Indeed, in the long run, there is no reason why each breeder should not have his own set of relative economic values for the traits he is recording.

(iv) That sufficient pedigree information be supplied so that the breeder does not have to maintain further records to meet the registration requirements of the breed societies.

Thus, the two-tooth selection lists contain, in addition to the sire and dam (and her lambing records), records of adjusted weaning weight, adjusted later liveweight and fleece weight all expressed as deviations from the means of all progeny in the flock of the same sex. They also present breeding values for number of lambs born (or reared), weaning weight, latest liveweight and hogget fleece weight if these have been recorded by the breeder. For number of lambs born (or reared), the primary information is the average number of lambs born (or reared) per lambing of the dam of the individual. The selection index found by using the appropriate set of relative economic values is also included.

As noted earlier, provision is being made for each breed or group of breeds to have its own set of genetic and phenotypic parameters for computing the breeding values of the traits. At present, estimates of these parameters are available for the Romney, Southdown and Perendale breeds. As new information comes to hand, it will be used to update and expand the sets of parameters in use.

For the meat breeds, the selection lists supply breeding values for weaning weight and for autumn liveweight, in both cases using all the weights which the breeder has recorded to increase the accuracy of prediction of the breeding values.

The selection lists are prepared in numerical order of tag number but the breeder can request an additional list presented in descending order of the size of the selection index.

(3) Ewe Summary

This list is produced annually to assist the breeder in making selection decisions about the ewes in the flock. It gives for each ewe the sire,dam and sire of dam, fleece weight and fibre diameter, and the progeny records for each lambing. A breeding value for number of lambs born is also included.

Where the weaning weight option has been taken, two other breeding values are provided: (i) Mothering ability includes two components which indicate the ability of the ewe to rear her lambs successfully. They are lamb survival to weaning expressed as the ratio of number of lambs weaned to number of lambs born and average adjusted weaning weight of the lambs weaned. Selection index procedures have been used to combine these two traits into a score for each lambing of the ewe. These annual scores are then averaged over all the lambings which the ewe has had and this average is used to predict the breeding value of the ewe for mothering ability. When available, the average annual score for mothering ability of the dam of the ewe is also included in predicting the ewe's breeding value for this trait. (ii) Lamb production is an assessment of the total lamb production of the ewe for a particular lambing. The aggregate genotype involved is considered to be made up of the number of lambs weaned and their average adjusted weaning weight, the two traits being weighted by their relative economic values. In predicting this aggregate genotype, a selection index is constructed using number of lambs born, number of lambs weaned and the average adjusted weaning weights. As with mothering ability, this index is worked out for each lambing of the ewe, and the average of all the ewe's lambings is used to predict her breeding value for lamb production. Information on the lamb production of the dam of the ewe is also included in the prediction of breeding value.

A further output related to the Ewe Summary is the Closed Ewe File. This is put out annually and includes all ewes which have died or been culled. It contains the same information as the most recent Ewe Summary for each of these ewes.

(4) Sire Summary

Interpretation of the average performance of the progeny of the sires used in the flock gives rise to several difficulties. These arise because: (i) particularly with traits measured later in the life of the progeny (e.g., later liveweights and especially two-tooth lambing performance of the daughters) the data may be biased by the culling which has taken place; (ii) non-random matings of various types may have taken place in the flock so that the average genetic merit of ewes mated to the different sires may be different;

(iii) the numbers of progeny of the sires used may differ markedly.

The last of these difficulties is overcome by the usual techniques of predicting breeding values of sires. The effect of non-random mating would appear to be not of major significance and could be allowed for if necessary. The effect of selection is more difficult to account for and the techniques suggested by Henderson (1975) are being investigated. In the meantime, the procedure being adopted is to highlight in each sire summary the extent to which culling has taken place in the data.

Sire summaries in Sheeplan are produced at the option of the breeder and as a general principle are printed out at the time the particular input data on the progeny are being processed.

DISCUSSION

It should be noted that the sheep recording programmes which have been developed in New Zealand have been primarily directed towards genetic improvement in the sheep industry. Little attention has been given to recording as an aid to flock management. Consequently, the recording systems have emphasized the performance of the individual animal within the flock rather than the flock as a whole.

In addition, a considerable amount of emphasis has been placed on processing and presenting the records to assist the breeder in making his selection decisions. While this adds to the value of the records in increasing the effectiveness of selection, it requires an extra extension effort to ensure that the records are understood and used properly by both the breeder and the purchaser of rams. The importance of an adequate advisory service closely involved in the organization and operation of the scheme and assisting both the breeder and the buyer cannot be overemphasized.

Finally, New Zealand experience would stress the importance of a recording scheme remaining flexible so that it can accommodate the changing needs of breeders and take account of new research results. Since a great deal of information relevant to improving the effectiveness of the scheme will come from the analysis of records already collected, there is need for a continuing organization to undertake the work involved.

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5

SHEEP BREEDING PROGRAMMES IN SOUTH AFRICA

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SUMMARY

Facilities for breed improvement programmes based on measured performance were provided by the Department of Agricultural Technical Services in 1964. The two performance recording schemes provide free performance recording and fleece measurement facilities as well as an advisory and educational service to sheep breeders.

The limited participation in these schemes is largely attributed to the fact that the traditional stud breeding industry is often not compatible with selection based on measured performance. The greatest support for fleece measurement comes from a newly formed breed society for Merinos where selection is based on an index incorporating clean fleece weight, body weight, wrinkle score and fibre diameter. Between-flock evaluation is done by comparing home-bred progeny to the progeny of rams from a control flock mated to a random sample of ewes and indexes are corrected accordingly to make them comparable. The control flock is kept reasonably genetically stable so that breeding improvement can be measured.

Results of inter-flock progeny tests are given, illustrating that phenotypic differences between flocks provide no indication of genetic merit.

INTRODUCTION

It is known that sheep already existed at the Cape when the seafaring pioneers rounded the Cape of Good Hope towards the end of the 15th century. For many years the colonists farmed with the Hottentot or Cape fat-tailed, hairy sheep and it was only during the early part of the 19th century that the first exotic breed, the Merino obtained a foothold in the Colony. This was the result of the first organized breeding improvement programme for sheep in South Africa initiated by the local Government and embracing a planned back-crossing of the best and whitest indigenous sheep to Merino rams as reported by de Geus (1953). The Merino rapidly increased in popularity with subsequent importations from Germany, France, the United States and Australia to become the most important breed of sheep in South Africa.

Subsequent breeding programmes were aimed at improving local or imported breeds and the development of new breeds better suited to local conditions and demands. A system of upgrading to the new or "better" sheep featured prominently in most cases. A great deal of success has been achieved with these efforts—the Merino has, for instance, been improved considerably as a producer of fine wool; the imported German Merino has undergone such a metamorphosis that its name was recently changed to the "South African Mutton Merino" and well adapted local synthetic breeds of increasing popularity, notably the Dorper, Dormer and Döhne Merino have been developed. Most of this was achieved with little conscious use of modern population genetics. Measurement of production, one of the first steps in applying population genetics to animal improvement (Turner, 1964), was very seldom practised. As from 1964, however, the Department of Agricultural Technical Services began providing the necessary facilities for sheep breeding programmes based on measurement through the introduction of two national performance recording schemes for sheep.

AIMS OF RECORDING SCHEMES

The National Mutton Sheep Performance and Progeny Testing Scheme was introduced in 1964 to provide (a) objective measurements for selection and (b) the necessary data for calculating phenotypic and genetic parameters for the more important mutton breeds. The scheme operates as an on-the-farm recording scheme and corrected weight gain up to weaning and ewe production records are the main selection criteria (Campbell, 1974).

The South African Fleece Testing Centre was founded in 1965 to provide central fleece measurement facilities to woolled sheep breeders. The National Performance Testing Scheme for Woolled Sheep was launched in 1973 to provide a more intensive follow-up service to participating breeders. Traits recorded are fleece weight (greasy and clean), clean yield percentage, fibre diameter, crimps per 25 mm, staple length, body weight and birth status. Sheep are ranked for clean fleece weight and body weight. All fleece measurements are done free of charge.

Through both schemes the Department also provides a specialist extension service to the sheep industry. Short courses in the principles of selection are conducted regularly and the attendance at such a course is a prerequisite for participation in the woolled sheep scheme. The educational and advisory service offered through the schemes is perhaps their most important function as indicated by Turner (1973).

APPLICATION OF PERFORMANCE TESTING TO BREEDING PROGRAMMES

The traditional system of stud breeding in South Africa is often not compatible with scientific breeding programmes based on measured performance. In the case of Merinos this is amply borne out by the fact that only 63% of all registered Merino Stud breeders have thus far applied for membership to the performance testing scheme. The overall effect of the scheme on the Merino stud breeding industry cannot, therefore, be of real significance. Furthermore, selection on performance is often so diluted by consideration of other factors, that it becomes ineffective and most of the participating studs regularly purchase rams from the few parent studs where measured performance plays no role in selection. This situation, to a large extent, also applies to most of the other sheep breeds. The most important single group of participants in fleece measurement is the newly established "Breed Society for Performance Tested Merinos". This Society had a membership of only 34 in 1975 but had more than double as many fleece samples analysed as the 798 members of the "Merino Stud Breeders' Association" founded in 1937.

The "Breed Society for Performance Tested Merinos" was formed in 1972 by a group of 12 commercial wool producers who had previously closed their flocks and were selecting on measurement. Members now also include a few registered studs as well as the central flocks of the only two well established group breeding schemes for Merinos in the country. The Society was founded on the belief that:

(a) production improvement in the Merino industry in future will mainly depend on breeding improvement achieved in the studs are not merely on upgrading,

(b) the industry will only maintain a maximum rate of improvement if performance testing is applied and the data properly utilized and

(c) reasonable genetic differences most probably exist between studs but the differences in appearance and performance is largely due to differences in environmental factors and virtually no indication of actual genetic merit (van der Merwe, 1975).

The Society follows the following selection procedure: As a preliminary selection of young replacement material, all available animals are classed subjectively for breed characteristics and serious defects with not more than 10% being culled. For rams the following traits are measured at the age of 18 months: body weight in kilograms (X_1), clean fleece weight in kilograms (X_2), fibre diameter in microns (X_3) and wrinkle score (X_4) using the standard photographs of Turner *et al.* (1953). The values are incorporated in a selection index proposed by Poggenpoel and van der Merwe (1975) viz. $I = 1X_1 + 7X_2 - 1X_3 - 1X_4$. For ewes the traits body weight in kilograms (X_1), greasy fleece weight in kilograms (X_2) fibre diameter in microns (X_3) and wrinkle score (X_4) are measured. The index for the selection of ewes is: $I = 1X_1 + 4X_2 - 1X_3 - 1X_4$. Rams and ewes with the highest index values are then selected.

Differences in genetic merit between flocks is estimated by making use of a control flock run at the Tygerhoek Experimental Station. The basic flock from which this control was randomly taken can be regarded as having a considerable degree of genetic variability and an inbreeding coefficient of roughly zero (Heydenrych, 1975). It is attempted to keep the control flock genetically stable by randomly selecting 16 ram replacements in such a manner that each father is consistently represented by a son as sire. Rams are individually mated to ten ewes and replaced each year. Ewes are replaced by a second daughter to reach mating age. Where a parent does not, for some or other reason, provide a replacement, a replacement is lotted from the progeny of the other parents but no parent is allowed to contribute more than two members to the following generation of parents. Parent-progeny and brother-sister matings are avoided throughout.

For progeny testing, aimed at estimating inter-flock genetic merit, sets of 12 rams are selected from the control in such a manner that the mean value of each set for each of the four traits mentioned is as close as possible to the mean value of the basic ram population from which the sets are taken. A deviation of not more than two per cent is allowed. Such a set of rams is mated to a random sample of ewes of the breeder who simultaneously mates his own rams to a similar sample of ewes. The two ewe samples must be comparable in all respects. The progeny of the two groups are identified, reared together and evaluated at approximately two-tooth age using the selection index mentioned. It is endeavoured to evaluate a total of approximately 200 or more progeny with a minimum of 70 per group which can be of both sexes.

The difference in breeding value between the breeder's flock and the control flock, expressed as a percentage deviation from the control, is then calculated as follows:

Mean value of progeny from breeder's rams $= \overline{X}_E$

Mean value of progeny from control flock rams $= \overline{X}_K$

Difference between progeny of breeder's rams and control rams:

$$D = \overline{X}_E - \overline{X}_K$$

Difference in breeding value between breeder's flock and control flock:

$$T_D = 2D = 2(\overline{E}_E - \overline{E}_K)$$

Expected mean value of control flock in specific environment:

$$\hat{\overline{X}}_K = 2\overline{X}_K - \overline{X}_E$$

or

$$\hat{\overline{X}}_K = \overline{X}_E - 2D$$

Percentage deviation in breeding value of breeder's flock from control

$$= \frac{D}{\hat{\overline{X}}_K} \times \frac{100}{1}$$

The percentage deviation in breeding value for each specific trait can be calculated thus. It will be used to adjust the within-flock value of each individual trait measured as well as the combined selection index. The performance tests of all rams appearing in the society's catalogue will therefore provide a good indication of true genetic merit for each trait.

The control flock furthermore provides a practically stable gene pool from which samples can be drawn from time to time to measure selection progress in each flock. If a breeder repeats the control test after a number of years, his between-flock performance tests will be adjusted accordingly.

RESULTS OF BETWEEN-FLOCK TESTS

The first round of test matings have already yielded interesting results as illustrated in Table 1 for the property clean fleece weight at 12 months.

TABLE 1

RESULTS OF TEST MATINGS TO CONTROL FLOCK RAMS IN THREE UNRELATED FLOCKS (CLEAN FLEECE WEIGHT AT 12 MONTHS)

Flock	A	B	C
Environment	Winter rainfall pasture	Winter rainfall pasture	Semi-arid scrub
Number of progeny from own rams	88	172	163
Number of progeny from control flock rams	113	211	118
Average clean fleece weight of progeny from own rams (kg)	6.54	4.06	3.08
Difference in breeding value between own flock and control flock (kg) = T_D	+0.34	+0.40	+0.27
Expected average production of control flock in specific environment (kg) = $\bar{X}_E - 2D$	6.20	3.66	2.81
Deviation in breeding value from control (%)	5.48	10.93	9.61

These results clearly illustrate that phenotypic differences between flocks provide no indication of genetic merit. Flock A, with a phenotypic value more than twice as large as flock C, in actual fact has a lower breeding value for the trait recorded.

FUTURE DEVELOPMENTS

Although sheep breeding programmes in South Africa are still mainly practised on traditional lines, there is every reason to expect that this will eventually change, albeit not drastically. The provision of free performance testing services for sheep and the consequent formation of a new breed society which is a far cry from what has always been associated with such institutions, has heralded the change to a population approach to breeding.

Constant revision of breeding programmes, supported by research results, is essential. Of higher priority is, however, the bridging of the communication gap between breeder and geneticist. De Lange (1971) points out that, because science does not have all the answers, communication between breeder, animal scientist and geneticist is rather a case of sharing an attitude than sharing ideas. "The latter will, however, follow automatically if the former is achieved," he concludes. Bridging the gap in attitudes should be the immediate object of all persons and institutions concerned with sheep breeding, not only in South Africa, but in all parts of the world where sheep breeding has not yet fully shared in the opportunities offered by modern science.

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6

SHEEP IN SOUTH-EAST ASIA

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SUMMARY

There are approximately 4.6 million sheep in south-east Asia and of this population, over 90% are found in Indonesia, the majority in West Java. Burma has 180 thousand sheep and West Malaysia, Thailand and East Timor each have 40-45 thousand.

The sheep populations of Indonesia, West Malaysia and southern Thailand consist very largely of a single basic ecotype, generally described as the Kelantan breed in West Malaysia or the Priangan or native sheep in Java. These animals are of small body size and have short tails; only the rams are horned. They are reasonably well covered with a coarse carpet-wool fleece of variable colour and quality, the face always being bare.

In Indonesia, fat-tailed sheep are also seen, more particularly in East Java, Madura, Sulawesi and East Nusatenggara. They are usually white and larger than the short-tailed sheep, with a more restricted fleece covering.

The native sheep of central Burma are quite different from the sheep of Indonesia and the Malay Peninsula. They are larger, with long pendulous ears and a convex facial profile; both sexes are usually polled.

Although there is little information presently available concerning rates of reproduction, body growth or wool growth of sheep in south-east Asia, plans are in progress for the performance testing in Indonesia of selected indigenous ecotypes or breeds and a limited number of exotic breeds. The major emphasis in this area must be upon meat production, and improvement of fleece production is a much more doubtful proposition.

INTRODUCTION

There is scant information concerning the sheep of south-east Asia and the population is not large, totalling approximately 4.6 million (F.A.O. 1973). The majority of this population is in Java, Indonesia having approximately 3.5 million sheep, compared with 180 thousand in Burma, 40-45 thousand each in West Malaysia, Thailand and East Timor and 29 thousand in the Philippines; none of the remaining countries in the area has a sheep population greater than 13 thousand. Within Indonesia, the greatest concentration of sheep is in West Java, with 65-70% of the total population, followed by Central Java (including Jogjakarta) which has about 20%; other regions where sheep are found are East Java, Nusatenggara (the Lesser Sunda Islands), Sumatra and Sulawesi. Sheep are kept for use in traditional ceremonies, meat production and the value of their skin.

The only breeds from this area that have been described as such are the Priangan and Javanese fat-tailed sheep (kambing kibas), both from Java (Fischer 1955), and the Kelantan sheep from West Malaysia and southern Thailand (Smith and Clarke 1972).

This communication records preliminary observations on several sheep breeds (or ecotypes) from south-east Asia, particularly in relation to their fleece and wool follicle characteristics, and discusses the potential of these sheep and present sheep breeding programmes.

MATERIALS AND METHODS

Flocks of sheep were observed and inspected throughout West Malaysia and Java, and also in central Burma, southern Thailand and west Sumatra. Particular attention was paid to physical conformation and reproductive phenomena; where possible, the reproductive tracts of ewes slaughtered for mutton were examined. On the basis of current oestrous and lambing activity, together with the evidence of ovarian activity or foetal development in slaughtered ewes and the estimated age of lambs at foot, it was possible to make a valid assessment of ovarian activity throughout the year.

Skin and fleece samples were obtained from the mid-side region of adult sheep where conditions permitted. Sampling procedures and laboratory techniques for the skin samples closely followed those described by Clarke (1960), whilst laboratory measurements of the fleece samples were made by the methods described by Chapman (1960).

RESULTS

The Kelantan sheep of West Malaysia and southern Thailand, the Priangan sheep of West Java and the native sheep of Central and West Java, Jogjakarta and Sumatra are of very similar conformation, being of small body size with a straight facial profile and semi-pendulous ears of medium length; many of the sheep (5-35% within individual populations) have only vestigial ears (microtia). Tassels (or wattles) are sometimes present on the neck. The tail is short (usually less than 12 cm in length) and thin. The rams are horned and usually have a mane and ruff of coarse hair whilst the ewes are polled but occasionally have small scurs or horn buds. These sheep are reasonably well covered with a carpet-wool fleece of variable quality and colour, the face always being completely bare. Because of the ubiquitous presence of body lice (*Damalinia ovis*) and the resultant fleece damage, together with the almost total absence of shearing at any time other than immediately prior to slaughter, it was not possible to make any valid estimate of fleece weight—however it would appear not to be greater than about 1 kg. Bodyweight is 30-50 kg for mature rams and 20-40 kg for mature ewes. Ewes are very prolific, often lambing twice within the year and having a high incidence of multiple births. There seems to be no well-defined period of seasonal anoestrus.

In East Java, and, to a lesser extent, Central Java, fat-tailed sheep (kambing kibas) are found: these are usually short-haired and white, usually with a small amount of wool over the back and mid-sides. They are generally larger than the short-tailed sheep described above and have pendulous ears and a straight or S-shaped fat tail. Sheep of this type are also found throughout Sulawesi, Madura and Nusatenggara.

Both the short-tailed and fat-tailed sheep of the Malay Peninsula and Indonesia are usually raised in small flocks of 5-10 animals. During the day they may be tethered or allowed to roam freely, grazing by roadsides, streams and between rice fields. At night, they are usually herded into lightweight bamboo enclosures, with the floor about 60 cm or more above the ground. Food supplements are rarely provided, except in the case of the short-tailed sheep of the Garut region in West Java, which are trained for ram fights.

The mature sheep of central Burma are also larger than the short-tailed sheep of West Malaysia and Indonesia, having long pendulous ears and a definitely convex facial profile: both sexes are usually polled.

The results of the various measurements of wool follicle populations are shown in Table 1.

TABLE 1

WOOL FOLLICLE CHARACTERISTICS (MEAN±S.E.)
OF SOME SOUTH-EAST ASIAN SHEEP BREEDS

Breed and location	Native sheep, Jogjakarta, Java			Kelantan sheep, West Malaysia		
Number of sheep sampled		5			53	
Follicles/mm²	8.4	±	0.4	6.2	±	0.3
Primary follicles/mm²	3.2		0.1	3.0		0.1
S/P ratio	1.7		0.1	1.1		0.1
Fibre thickness ratio	3.3		0.4	2.6		0.1
Mean fibre diameter (μ)	40.3		1.9	49.6		1.5
% Medullation	32.8		4.8	41.8		2.3

Table 2 shows fleece measurements in sheep from three south-east Asian countries. The fibre diameters and percentage medullation of the Javanese and Kelantan fleece samples were similar to the values obtained from skin sections.

The mean fibre diameter of the Burmese fleece samples was significantly greater than that of the Kelantan ($P<0.01$) and both groups of Javanese fleece samples ($P<0.001$). Percentage medullation was greatest in the fleece samples from the Burmese sheep and was significantly greater than in the Javanese samples.

TABLE 2

FLEECE MEASUREMENTS (MEAN±S.E.) IN SOME SOUTH-EAST ASIAN SHEEP BREEDS

Breed and Location	Number of specimens	Staple length (cm)	Fibre diameter (μ)	Percentage medullation
Native sheep (Central Java)	20	6.8 ± 0.5	39.6 ± 2.0	42.6 ± 3.4
Priangan (West Java)	5	4.4 0.8	35.0 5.0	32.5 7.0
Kelantan (West Malaysia)	4	4.5 0.7	47.3 3.4	71.9 5.0
Native sheep (Central Burma)	16	3.9 0.1	66.7 5.7	82.1 2.9

The fleece samples of the Priangan and Javanese native sheep did not differ significantly in either mean fibre diameter or percentage medullation.

DISCUSSION

The indigenous sheep population of Java, Sumatra, West Malaysia and southern Thailand appears to consist of a single basic ecotype, described as the Priangan in West Java (Fischer 1955) or the Kelantan in West Malaysia and southern Thailand (Smith and Clarke 1972). The sheep of Java, however, show greater variability than those of the Malay Peninsula or Sumatra. The Priangan is nominally descended from crosses of Australian Merino and Cape fat-tailed sheep with the small, short-tailed native sheep of Java (van der Planck 1949; Fischer 1955), however the present evidence of such infusion is minimal.

Both van der Planck (1949) and Fischer (1955) have described fat-tailed sheep (kambing kibas) as being more prevalent in East Java, Madura, Sulawesi and East Nusatenggara. The larger size and white colour of these sheep was also remarked upon by Fischer (1955) who suggested that they may have been originally introduced by Arab traders: they might just as well owe their origin to the Cape fat-tailed (Africaner) sheep of South Africa, which were introduced into the East Indies by the Dutch.

The fleece of the Javanese sheep (both the Priangan and native sheep) carries less medullated and more fine fibres than that of the Kelantan sheep and this could be interpreted as being due to the infusion of Merino blood. The mean fibre diameter and percentage medullation of the fleece from Kelantan sheep was as previously reported by Smith and Clarke (1972) and Ryder (1974).

The mean fibre diameter of the central Burmese sheep was similar to that previously reported by Lang (1958) and clearly these sheep have little in common with those of southern Thailand, West Malaysia, Sumatra or Java, differing both in fleece type and body conformation. In the past, there have been introductions of Indian sheep into Burma and this has had an obvious effect upon the the conformation on most of the native sheep.

Although the fleece of the Burmese native sheep shows little potential for utilization, the fleece of the Javanese sheep, in particular, appears to be suitable for carpet-wool production, although lacking in staple length. It is, in fact, used for this purpose on a small scale in West Java, where there is a carpet factory at Bogor, however the sheep are rarely shorn except at slaughter.

In recent years, Corriedale sheep have been introduced to central Burma and Suffolk and Dorset Horn sheep to Java. However, critical information concerning the performance of such exotic breeds relative to that of indigenous ecotypes under controlled conditions is lacking.

Since there is a limited domestic and export market for wool of the quality that can be produced and since the fleece may, in fact, be detrimental to the well-being of sheep in this environment there is little current interest in development of wool production. The main features desired in south-east Asian sheep, which provide meat that is acceptable to the majority of the population, with no religious restrictions, and which are ideally suited to smallholder production systems, are prolificacy, high growth rate and disease resistance.

The prolificacy of the short-tailed sheep of the Malay Peninsula has been described by Smith and Clarke (1972) and, in Indonesian breeding programmes, the main concern will be to preserve, and if possible, enhance this prolificacy.

The main purpose in introducing exotic breeds is to increase growth rate and, presumably, mature body size. So far, Suffolk and Dorset Horn sheep have been used, but other breeds considered are the Wiltshire Horn, Dorset Down, Dorper, Awassi and Mandya. Concurrent with the performance testing of any such introduced exotic breeds, and their crosses, selected populations of Priangan, fat-tailed and other indigenous ecotypes will be evaluated. All of the above breeds have extended breeding seasons (9 months or more per annum) and have a significant incidence of multiple births, so that the use of such breeds to improve meat qualities would not be to the detriment of prolificacy.

At present there is considerable interest in Java in sheep breeding programmes, but until there has been a preliminary assessment of the productive potential of indigenous ecotypes under improved management conditions, it would be presumptuous to define or suggest any programme using introduced breeds.

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7

SHEEP BREEDING IN THE U.S.A.

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SUMMARY

A decline of 45% in the number of breeding ewes has occurred in the last 10 years. This has had a major impact on many aspects of the industry, including breeding. A majority of ewes are Rambouillet (Merino) or related breeds. The Suffolk, Hampshire and other British breeds are also important in numbers, especially in farm flocks. There are few organized breeding programmes and their impact is small. Much of the effort for breed improvement by pure-bred breeders is focused on the show ring.

An organization of sheep producers, called Sheep Industry Development Programme (SID), has an active programme to expand the sheep population and production. SID activities have included organizing educational programmes for producers and developing innovative and pilot production programmes.

The major effort in sheep breeding research is conducted in the North Central regional research project. This is a co-ordinated effort of University and USDA experiment stations involving activities in several disciplines, various environments, geographical areas and management systems. Much of the activity in breeding is focused on breed evaluation and utilization. This research has been motivated by increasing interest in more intensive types of production, increasing efficiency of production and evaluation of the Finnsheep.

INTRODUCTION

The sheep industry of the U.S. has experienced a drastic decline in numbers of breeding ewes since World War II. This decline has been accelerated in recent years. Total number of breeding ewes was 9,334,000 on January 1, 1976 (USDA, 1976). This reflects a decline of 7% since 1975 and 45% in the last 10 years. Some notable changes in the geographical distribution of the sheep population have also occured concomitantly with the general decline. A substantial portion of the decline has taken place in the large flocks in the western range areas and proportionately less in the farm flock states of the corn belt or midwest. A change has also been noted in the relative amount of income from wool *v.* lamb. Total income from wool and lamb has changed from a proportion of 25% from wool and 75% from lamb, 15 years ago, to 17% from wool and 83% from lamb today. The decline in sheep numbers has had a major impact on breeding programmes and many other facets of the industry, including marketing, labour, predator control, management and nutrition.

BREEDS AND BREEDING PROGRAMMES

Accurate and detailed information on the breed composition of commercial flocks and their distribution throughout the U.S. is not known. It has been estimated (Whiteman, 1968) that most of the commercial ewes in the western range country carry some fine wool breeding, namely Rambouillet (or Merino). These flocks may consist of grade Rambouillet or related breeds such as the Columbia, Targhee and Panama. In other areas and also to some extent in the west, many flocks consist of blackface cross-bred ewes produced by mating fine wool type ewes to Hampshire or Suffolk breed rams. Many commercial farm flocks consist of grade Hampshire or Suffolk breed ewes. Other breeds employed to a lesser extent, but in some areas an important segment of the population, are the Cheviot, Corriedale, Dorset, Lincoln, Montadale, Oxford, Romney, Shropshire and Southdown. The largest number of registrations of pedigree animals in 1975 was the Suffolk breed (46,970) followed by the Hampshire (17,157) and Rambouillet (10,041).

There are very few organized breeding programmes and the impact of those that do exist is likely very small. Pure-bred societies have breed improvement programmes, but the extent of breeder participation is variable and often limited. It has been estimated that only 2% of all pure-bred flocks were enrolled in a performance testing programme (Parker, 1968). The principal medium of "breed improvement" is through the show ring and through pedigree selection of related individuals based on show ring standings. Government support for breed improvement of economic traits, such as, lamb growth rate, weaning weight, carcass attributes or ewe productivity has been very limited. Support has usually been in the form of educational programmes. Furthermore, the structure of the marketing system has not usually provided a direct incentive to pure-bred breeders to improve performance or carcass traits within breeds. However, market values have been important for shifts in selection between breeds. Cross-breeding to produce market lambs for slaughter has been well accepted, but much of the effort is haphazard.

SHEEP INDUSTRY DEVELOPMENT PROGRAMME (SID)

Despite the decline in sheep numbers there has developed in recent years a more concerned and concentrated effort on the part of the sheep industry to encourage and accept technological improvements in various aspects of sheep production, including breeding. In some sense a new era of optimism and renewal has developed in the industry. Much of this effort is focused in the activities of the Sheep Industry Development Programme (SID), a production oriented programme of the American Sheep Producers' Council. This organization of sheep producers and lamb feeders has directed its primary attention to marketing and to promoting lamb and wool. The activities of SID have been instrumental in organizing various educational programmes for producers, including symposia on breeding and geneticr. SID has also been actively involved in developing innovative and pilot programmes in various phases of sheep production in co-operative efforts with producers. A recent development in the industry, initiated by SID, is the "Blueprint for Expansion Programme". This programme is proposed as a concerted effort to expand sheep production in the U.S. Among the significant goals of this programme is the aim to expand the total amount (weight) of lamb marketed, by 50%, in the next 10 years. Achievement of this goal is proposed by a 10% increase in lamb weight at slaughter (following a consistent trend of 1% annual increase), by a 10% or more increase in number of lambs marketed (also consistent with present trends and use of more prolific breeds such as Finnsheep) and by a 25 to 30% increase in breeding ewe numbers. Other specific programmes related to expansion are concerned with marketing, predator control, environment protection and land use planning, labour and management training programmes, research expansion and co-ordination, animal health and industry organizational structure. The goals for expanded production are accepted as realistic by the industry and the general programme has wide acceptance. However, in view of recent declines in the industry much effort will be required for this programme to succeed. Record high prices paid for lambs in 1976 will provide a basic incentive for expansion.

REGIONAL RESEARCH IN BREEDING

Research in sheep breeding is conducted at State (Universities) and Federal (U.S. Department of Agriculture) experimental stations. The research activities of the various state experimental stations are co-ordinated on a regional basis. At the present time there are two regional projects. The principal breeding effort is in the North Central regional project (NC-111). This effort is composed of contributing projects to the general project title of "Increased efficiency of lamb production". The general objective of this co-ordinated research is to "develop and evaluate systems for more efficient lamb production by combining breeding, nutrition, physiology and management procedures, under varying geographical and environmental conditions". Specific objectives are:

1. Develop effective short term methods for utilizing genetic variation in fertility, breeding season, lambing rate, lamb survival, growth and carcass traits under various management systems.

2. Develop and evaluate accelerated lambing systems suited to available genetic stocks.

3. Establish the nutrient needs of sheep under various management conditions.

4. Determine land, labour, housing, equipment and health requirements

for lamb production under various management systems. Cost analyses will be included where appropriate.

A brief description of each of the contributing projects of the various state and federal stations to NC-111 is given in tabular form in Table 1. It should be noted that emphasis varies among stations in the kinds of contributing projects. This is noted in Table 1 by reference to the specific objectives listed above (1 to 4) for each station.

A predecessor to the present NC-111 regional project was the North Central regional technical committee on sheep breeding (NC-50). Results of that study have been summarized in part in a regional publication (North Central Regional Publication 198, 1970).

TABLE 1

CONTRIBUTING PROJECTS TO REGIONAL RESEARCH IN SHEEP BREEDING AND PRODUCTION (NC-111)

State	Project — Investigations	Contribution to Objective Number*
California	Long term selection for weaning weight and multiple births in Targhees, evaluate crosses of Targhee and Suffolk with Finnsheep, management systems, drylot *v.* range	(1,3)
Idaho	Evaluate Panama and Panama X Finnsheep, Suffolk terminal sire breed, growth, carcass merit, nutritional requirements, energy levels	(1,3,4)
Indiana	Finnsheep crosses with Columbia, Dorset and Rambouillet, terminal sire breeds, Suffolk, Hampshire, Shropshire, Southdown, intensive production system, accelerated lambing, nutrition, management	(1,2,3,4)
Kansas (Colby)	Hampshire × Rambouillet, Dorset × Rambouillet and Rambouillet ewes, drylot *v.* year-around grazing, accelerated lambing, nutrition, housing, equipment, two management systems	(2,3,4)
Kansas (Manhattan)	Forage utilization, body composition, growth efficiency, environmental effects and performance, intensified production system	(2,4)
Kentucky	Nutrient utilization early weaned lamb, forage use, ewe breed and body size related to productivity	(3,4)
Minnesota	Evaluation of Finnsheep with crosses of Targhee and Suffolk, F_1, F_2 and backcrosses, terminal sire breeds Dorset, Hampshire, Oxford, Suffolk, heterosis and recombination effects, breed development, ewe productivity indices, longevity, lamb growth, efficiency, physiology, out-of-season breeding, management, nutrition, intensive lamb production, forage utilization, buildings, environment	(1,3,4)
Missouri	Evaluate systems of production, accelerated, modified and conventional lambing, Finnsheep, Dorset, Rambouillet cross-bred ewes, nutrition, management, equipment	(3,4)

TABLE 1 (continued)

State	Project — Investigations	Contribution to Objective Number*
Oklahoma	Five cross-bred ewe combinations of Finnsheep, Dorset and Rambouillet under intensive production, accelerated lambing, terminal sire breeds are Hampshire, Suffolk and Hampshire × Suffolk cross, management	(1,2,4)
Ohio	Management systems, housing, accelerated lambing, nutrition, use of Finnsheep genetic material, confined *v.* non-confined production, forage utilization, labour requirements	(1,2,3,4)
Oregon	Breed of sire effects on F_1 growth, carcass and maternal performance, eight cross-bred groups (Romney, North Country Cheviot, Dorset, Finnsheep, Suffolk, White face), hill *v.* irrigated pasture, management systems, measure appetite, feed efficiency, growth	(1,3,4)
Texas	Develop and evaluate methods to improve reproduction efficiency, accelerated lambing, endocrine stimulation, selection, management, disease. Finnsheep crosses *v.* Rambouillets	(1,2,4)
Illinois	Management, housing—confinement *v* pastoral, nutrition, breeds and cross-breds, accelerated lambing, synchronization of oestrus, early weaning	(1,2,3,4)
North Dakota	Confinement systems of production, nutrition, energy levels, maintenance, breed evaluation for confinement management, Hampshire, Suffolk, Cheviot, Columbia	(2,3)
USDA—U.S. Meat Animal Research Center, Clay Center, Nebraska	Identification and development of superior genetic resources, utilization of genetic resources, selection between/within breeds, development of breeding programmes, hormone and nutritional investigations. Develop, evaluate, facilities, equipment, procedures to minimize labour requirements. Develop production strategies, evaluate three production systems with varying management intensities Germ plasm evaluation: reproduction, growth, carcass performance using Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale and Finnsheep Germ plasm utilization: evaluate individual and maternal heterosis, recombination loss in Suffolk × Hampshire, F_1, F_2, F_3 and backcrosses, develoment of multibreed synthetic combination using (1) Finn, Rambouillet and Dorset, and (2) Finn, Suffolk and Targhee Maternal breed selection criteria: develop and evaluate selection criteria; develop superior germ plasm resources for industry use Maternal breed selection criteria: develop and evaluate selection criteria for heavy market weight lambs; selection in Suffolks Nutrition, ewes and lambs. Out-of-season breeding ewes and rams. Heavy lamb production, carcass attributes, lamb carcass composition and palatability Livestock engineering, shelter, predator control, flock health, disease, management Management systems: models of production, varying management intensity	(1,2,3,4)

TABLE 1 (*continued*)

State	Project — Investigations	Contribution to Objective Number*
USDA Agricultural Research Center Beltsville, Maryland	Nutrition, management, accelerated lambing, utilization of Finnsheep combination with domestic breeds, development of Morlam synthetic for year-around lambing	(1,2,3)
USDA U.S. Sheep Experiment Station Dubois, Idaho	Develop methods to maximize total pounds of market lamb/ewe in the flock. Accelerated lambing, selection, nutrition, management systems for orphan lambs, evaluation of Finnsheep crosses in a range environment, marketing lambs at heavier weights, study death losses, predator control	(1,2,3,4)

* Contribution to specific objective number, 1, 2, 3 or 4 of the regional project (see text).

A second regional project is in the western region and the project title is "Increased efficiency in marketing lamb and mutton" (W-137). The objectives of this project are:

1. To evaluate the marketing potential of heavy lambs (including intact males) as compared to current market lambs.
2. To determine ways of utilizing lamb and mutton to increase consumer acceptance.

A brief description of each of the various state experimental stations contributing projects to the western regional project is presented in Table 2.

Much of the current research in sheep breeding is focused on breed evaluation and utilization. This research has been motivated in part by an increasing interest in the industry in more intensive forms of lamb production, improving efficiency of production and the use of Finnish Landrace breed (Finnsheep). A major stimulus to research in sheep breeding came with the importation of the Finnsheep breed to the U.S. in 1968. The first importation came from Ireland and was a joint effort of the University of Minnesota and the U.S. Department of Agriculture. This breed is widely recognized for its prolificacy and the primary reason for the importation was to assess its genetic potential for increasing productivity of domestic flocks (Oltenacu and Boylan, 1976a).

MINNESOTA RESEARCH IN BREEDING

(a) *Finnsheep evaluation and use*

Research at Minnesota with the Finnsheep was designed to assess its potential genetic contribution in a series of cross combinations with domestic standard breeds. Finnsheep rams were mated to ewes of the Minnesota 100, Suffolk and Targhee breeds. F_1, F_2 and various back-cross progeny were produced.

The Finnsheep reached sexual maturity at a younger age than domestic standard breeds. About 95% of the Finnsheep ewes produced their first

TABLE 2

CONTRIBUTING PROJECTS TO REGIONAL RESEARCH IN MARKETING LAMB AND MUTTON (W-137)

State	Project — Investigations	Contribution to Objective Number*
California	Carcass attributes of heavy lambs, efficiency of production, slaughter lambs at various weights from selected and control lines of Targhee, Finnsheep crosses; Suffolk is terminal sire breed	(1)
Idaho	Use of beef and pork fat in processed lamb and mutton products, taste panels, consumer evaluation, major emphasis to develop lamb and mutton products, Evaluate production costs, carcass quality of male lambs, heavy carcasses, Finnsheep cross carcasses	(1,2)
Oregon	Economic study—price response function, marketing lambs	(1)
Utah	Evaluate ram and ewe lamb carcasses, Targhee, Columbia and Rambouillet breeds, quality, composition, taste panel analyses, flavour, texture of light *v.* heavy carcasses. Develop cured meat products from deboned mutton, mechanical deboning evaluated	(1,2)
Washington	Evaluate heavy *v.* conventional weight carcasses, costs of production and returns, various breed combinations including Finnsheep. Study use of antioxidants on lamb and mutton flavour	(1,2)
Wyoming	Selection in Columbia and Suffolk based on cutability at 73 kg liveweight. Study physical, chemical and nutritional composition of mechanically deboned meats, emphasis on flavour	(1,2)

* Contribution to specific objective number, 1 or 2 of the regional project (see text).

lambs at 12 months of age *v.* only 51% of the Targhee ewes. The earlier sexual development of the Finnsheep was also apparent in Finnsheep cross-breds. About 92% of F_1 ewe lambs produced lambs at 12 months of age (Table 3).

Dickerson and Laster (1975) observed that the percent of female lambs reaching puberty at a specified date was far higher for Finn-sired (72%) than for Rambouillet-sired (38%) crosses or pure-breds (34%) of Suffolk, Hampshire, Dorset, Targhee, Corriedale or Coarse Wool breeds.

Mature Finnsheep ewes had markedly larger litters (3.2) at lambing than pure-bred Minnesota 100, Suffolk or Targhee ewes (1.4). F_1 and F_2 ewes also exceeded the pure-breds (Table 3). Meyer and Bradford (1973) reported similar results for litter size for Finn-Targhee cross-bred and Targhee ewes, 2.2 *v.* 1.5, respectively.

Although Finnsheep sired lambs (F_1) were smaller than standard breeds, 3.3 *v* 3.6 kg, at birth their vigor and survival to weaning was remarkably good. Finnsheep sired lambs had a survival rate of 84% *v.* 80% for the average of Minnesota 100, Suffolk and Targhee (Oltenacu and Boylan, 1976b). Dickerson, Glimp and Laster (1975) reported that preweaning death loss of Finnsheep sired lambs was only about one half as great as Rambouillet sired lambs (19 *v.* 39%).

Finnsheep F_1 cross-bred lambs had good early growth rates. They compared favourably in body size at weaning at 70 days to the average of the Minn 100, Suffolk and Targhee breeds (17.8 *v.* 17.4 kg). Only the straightbred Suffolk lambs exceeded Finn × Suffolk lambs in weaning weight (21.04 *v.* 19.78 kg). Dickerson, Glimp and Gregory (1975) reported favourable early growth of Finn-cross lambs compared to crosses of several U.S. breeds. When litter size and lamb weaning weights were combined into an index of ewe productivity Finsheep cross ewes, F_1, F_2 and back-crosses, exceeded the performance of the standard domestic breed ewes (Oltenacu and Boylan, 1976c).

Carcass merit of Finnsheep F_1 lambs was slightly less than pure-bred Minnesota 100, Suffolk and Targhee breeds, but still commercially acceptable

TABLE 3

LEAST SQUARES MEANS FOR PERCENT OF EWES LAMBING AT 12 MONTHS OF AGE OF THOSE JOINED TO RAMS AND LITTER SIZE OF EWES LAMBING

Breed of ewe	% lambing at 12 months of age	Litter size: 1 year ewe	Litter size: Mature ewe
Finnsheep	95± 4	1.7	3.2
Minn 100 (M)	75± 4	0.9	1.2
Suffolk (S)	90± 4	1.2	1.5
Targhee (T)	51± 5	1.1	1.4
Average (Standard breeds)	72± 2	1.1	1.4
F×M	94± 3	1.3	2.0
F×S	87± 4	1.4	2.1
F×T	95± 4	1.4	2.1
Average (F_1)	92± 2	1.4	2.1
F_2 (F×M)	90± 6	1.4	2.2
F_2 (F×S)	82± 7	1.2	2.0
F_2 (F×T)	91± 7	1.2	—
Average (F_2)	88± 4	1.3	2.1
F×(F×M)	95± 6	1.7	2.2
F×(F×S)	97± 6	1.7	2.1
F×(F×T)	85±10	1.3	—
Average (Back-cross to Finn)	92± 4	1.6	2.2
M×(F×M)	75± 7	1.0	—
S×(F×S)	93± 7	1.4	—
T×(F×T)	69± 8	1.2	—
Average (Back-cross to Standard)	79± 4	1.2	—

(Table 4). Finnsheep cross-bred lamb carcasses generally had less external fat than carcasses from domestic breeds. However, significant differences were observed in amount of internal fat. Finnsheep cross-breds had more kidney and pelvic fat than domestic breeds, 4.3 *v.* 3.1% (Table 4) A larger amount of kidney and pelvic fat in ¼ Finn-Targhee cross-bred lamb carcasses compared with Targhees was also noted by Rattray *et al.* (1973). Details of lamb carcass merit of various Finnsheep cross-breds is reported elsewhere (Boylan, Berger and Allen, 1976a). It has also been observed that the palatability of Finn sheep cross-bred lamb carcasses may be enhanced, compared with domestic breed lambs, because of a greater amount of unsaturated to saturated fats, thus reducing the "tallowy" effect sometimes observed in lamb fat (Boylan, Berger and Allen, 1976b).

Results from research suggest that the Finnsheep breed can be effectively used in sheep breeding programmes to achieve a significant increase in productivity Optimum use will depend on the management system employed. Many producers should benefit by using cross-bred ewes of ¼ to ½ Finnsheep breeding (Boylan, 1975). This recommendation is made with the assumption that the Finnsheep cross-bred ewe is mated to a meat type terminal sire breed ram to produce a market lamb for slaughter.

(b) Utilizing heterosis; recombination loss

Utilizing individual and maternal heterotic effects can be distinctly advantageous. Recent studies at Minnesota showed that by using a specific 3-breed crossing system total flock productivity for weight of lamb weaned per ewe could be increased by 20 to 32% over the average of the parental breed performances. Columbia, Suffolk and Targhee breeds were evaluated on straight-bred (pure-bred) performance, single crosses and in a specific 3-breed cross-breeding system (Rastogi, 1972). The specific 3-breed cross-breeding system utilized a cross-bred ewe. The system capitalized on both individual and maternal heterotic effects. The cumulative effects over the life cycle of the lamb was high even though individual heterosis for many lamb performance traits was low; about 4% for daily gain and 3% for age at market weight (Rastogi *et al.*, 1975). The way in which the breeds were combined was important in achieving maximum productivity in the specific 3-breed cross. Heterosis was also observed in this study for feed efficiency during the post-weaning growth phase (from 23 to 50 kg). The average amount of heterosis in feed efficiency was 3.2% (Teehan, 1974). In view of the importance of feed costs in lamb production, significant economic advantages should accrue from utilizing heterosis in feed efficiency.

Recombination loss in heterotic effects was assessed in the cross-breeding study. Generally the recombination loss was small (Teehan, 1974). This suggests that reduction in performance in subsequent generations of a synthetic population would be small. This gives support to the idea of developing superior synthetics (new breeds) from promising cross-bred combina-

TABLE 4

A COMPARISON OF LEAST SQUARES MEANS OF PURE-BRED AND CROSS-BRED (F_1) PERFORMANCE FOR SEVERAL CARCASS TRAITS

Breeding group[a]	N	Hindsaddle wt, kg	Kidney and pelvic fat, %	*Longissimus* area, (cm)²	Fat thickness over *longissimus*, mm	U.S.D.A. yield grade	U.S.D.A. quality grade
Pure-breds ($\overline{P}$)	66	10.66±0.03	3.11±0.12	13.36±0.25	4.19±0.19	2.97±0.05	10.76±0.11
Cross-breds ($\overline{C}$)	169	10.19±0.02	4.27±0.07	13.13±0.16	3.25±0.17	3.08±0.03	10.27±0.07
Difference ($\overline{P}-\overline{C}$)		0.47±0.03**	−1.16±0.12**	0.23±0.26	0.94±0.20**	0.11±0.06	0.49±0.11**

** $P<.01$

[a] Pure-bred values are the mean of least squares means for the Minnesota 100, Suffolk and Targhee breeds. Cross-bred values are the mean of least squares means for the F×M, F×S and F×T breeding groups.

tions. Further research in this area is planned at Minnesota. Development of synthetics has been initiated at the USDA Meat Animal Research Center.

(c) Foreign breeds

Sheep germ plasm resources available in the U.S. are limited to existing breeds introduced in the early development of the country with the exception of the Finnsheep, introduced in 1968. This limitation restricts the genetic potential for improvement of domestic sheep and effective utilization of natural resources. Imports are limited or restricted because of animal health quarantine regulations. In 1975 additional restrictions were imposed, virtually eliminating introduction of breeds not presently in the U.S. Animal breeders have long advocated the need for access to foreign breeds and have suggested development of procedures for importation (Lush, 1961). This need, with special reference to the sheep industry, was re-emphasized by Boylan (1968). Little has changed and the status quo remains. The present USDA policy lacks imagination and represents a negative approach to utilization of world resources for food and fibre production.

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8

NATIONAL SHEEP BREEDING PROGRAMMES — GREAT BRITAIN

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SUMMARY

The British sheep industry is relatively small in relation to total livestock production but forms an important enterprise in hill and upland areas. Sheep are reared under widely different conditions using a large number of breeds. Stratified cross-breeding systems are used, many starting with hill breeds and crossing them to give cross-bred ewes which in their turn are mated to Down breeds to produce slaughter lambs. Selection objectives vary between breeds and management systems.

Recording is carried out by the Meat and Livestock Commission and comprises three schemes: i) Commercial—Whole Flock for the collection of physical and financial data on sheep performance ii) Commercial—Individual Ewe for the contemporary comparison of breeds and groups within breeds and iii) Pedigree—Individual Ewe for the selection of breeding stock.

Study of the genetic influence of different breed groups shows the value of concentrating improvement attempts on hill breeds, Longwool crossing breeds and Down breeds. Where the establishment of controlled schemes for selection for commercial characters is difficult, as in hill breeds, special development flocks are being set up.

Much research work relevant to sheep improvement is carried out in Britain. Some of the current work at ABRO is reviewed and the results from comparisons of slaughter lamb sire breeds are presented.

THE BRITISH SHEEP INDUSTRY

In order to understand the problems faced in the improvement of British sheep and the methods being adopted it is necessary to consider the nature of the sheep industry in Britain. This industry is a complex one with different regional patterns and many local variations, but some attempt at summary is nevertheless necessary.

The total sheep population in Britain is about 13¼ million breeding ewes. These are kept in around 74,000 flocks and the flock size averaged 174 ewes in 1974. Sheep production tends to be an enterprise of the less fertile areas so that while less than 30% of holdings have sheep in England, about 50% do in both Scotland and Wales. As a proportion of the total output from all livestock, that from sheep is relatively small amounting to only about 6% of the total. Of the returns from sheep only around 10% comes from wool so that the industry is primarily oriented towards the production of meat.

The relatively small size of the sheep industry is not dictated by low consumer demands for the product, unlike the situation in many European countries. The average annual consumption of carcass meat (excluding manufactured products) is estimated at 7.1 kg of mutton and lamb, thus exceeding the consumption of pork (5.5 kg) but falling someway behind that of beef and veal (12.8 kg). The home production of mutton and lamb has never met the demand of the home market and over the years 50-60% of supplies have been imported, mostly from New Zealand. The trading position is changing with decreasing imports from New Zealand and a growing export of fresh lamb carcasses to the EEC.

The average annual lamb crop reared has been estimated by Read 1974 at 105%. This figure is made up of very different levels of performance in different environments. The 44% of breeding ewes kept on hill farms average 0.8 lambs per ewe, while those 17% on upland farms average 1.2 lambs and the remaining 39% of ewes on lowland farms average 1.3 lambs. Despite the low level of performance on the hills, sheep production has remained a major enterprise in these areas. As the only feasible form of livestock production in many remote areas, sheep production in these localities has attracted government support in the form of various direct and indirect subsidies.

It is always a matter of surprise to recall that in Britain there are at least 50 breeds of sheep. Some of these are represented by only small numbers but even excluding breeds with less than 25,000 ewes one is still left with 24 breeds. Most of these have limited distributions and fit in with the main production systems as shown in Table 1.

The hill breeds listed are for the most part confined to particular geographical areas although this localization is not as marked as it used to be. Most of the sheep kept on the hills are pure-breds and usually these breeds stay there for only part of their productive life. Having produced 3, 4 or 5 lamb crops on the hills they are sent for 2 or 3 further lamb crops to less severe upland conditions where a common practice is to mate them to a Longwool ram, usually a Border Leicester or a Bluefaced Leicester. The cross-bred female lambs from this mating are then used for breeding purposes in the lowlands, being mated to Down breeds to produce lambs for slaughter.

The stratification of the sheep industry is a long-established feature and one which has become commercially regularized. Thus particular crosses, such as the Greyface (Blackface x Border Leicester) and the Scottish Halfbred (North Country Cheviot x Border Leicester) are standard articles of commerce. It would be wrong to give the idea that the stratified crossing system is a rigid one because many variations on the established system are

TABLE 1

PRINCIPAL BRITISH BREEDS GROUPED BY BREED CLASS (SOURCE MLC 1972)

Hill breeds	Scottish Blackface	Welsh Mountain
	Swaledale	Improved Welsh
	Dalesbred	South Welsh Mountain
	Derbyshire Gritstone	Black Welsh Mountain
	Lonk	Radnor
	Herdwick	Beulah Speckleface
	Rough Fell	Hardy Speckleface
	North Country Cheviot	Exmoor Horn
	South Country Cheviot	Shetland
Upland breeds	Clun Forest	Greyface Dartmoor
	Kerry Hill	Whiteface Dartmoor
	Devon Closewool	
Romney	Kent or Romney Marsh	
Devon	South Devon	Devon Longwool
Lowland	Dorset Horn	Wiltshire Horn
	Polled Dorset Horn	Lleyn
	Improved Dartmoor	Llanwenog
Longwool	Border Leicester	Lincoln Longwool
	Bluefaced (Hexham) Leicester	Leicester
	Teeswater	Colbred
	Wensleydale	
Down	Suffolk	Southdown
	Dorset Down	Shropshire
	Hampshire	Ryeland
	Oxford	

to be found locally and in response to changes in the market. The latest survey on the breeds kept for lamb production in Britain was carried out by the Meat and Livestock Commission in 1972 and this recorded the existence of over 300 different crosses. Many were present in only small numbers but the survey did reveal that about 20% of Down x Scottish Halfbred ewe lambs were retained for breeding. In addition many draft hill ewes are mated directly to Down breeds for the production of slaughter lambs.

Lambs slaughtered for the national flock are a variable product reflecting the breeds and crosses used and different systems of production. Except for about 2% of lambs produced out of season to obtain high early spring prices, most lambs are produced on grass with a proportion of these being fed rape or root crops as the grazing season ends. The number of lambs slaughtered each month increases from April to October and then declines. The price paid usually changes in inverse ratio to the numbers slaughtered and early lambs are sold at lighter carcass weights in attempts to achieve the highest price.

OBJECTIVES FOR SHEEP IMPROVEMENT

The complexities of the sheep breeding scene in Britain bring with it problems in deciding upon improvement objectives. For sheep which are kept in different environments there may well be different objectives. Thus on the hills, multiple births are by and large regarded as a distinct disadvantage. Those hill farmers with some improved land on their farms may accept a proportion of ewes with twins which can be segregated on the better ground but increasing the proportion of twins would cause them major problems of husbandry. Many lambs from hill flocks are sold in store markets at the end of the season and the lightest animals make very poor prices. To the majority of hill farmers improvements in weight of lambs at weaning would be a reasonable objective but changes in prolificacy is definitely not. In upland production systems increased numbers of twins are an advantage provided they do not place too many additional calls on the limited labour force. Many of the ewes used in these upland areas are, however, older draft ewes of hill breeds so there is seen to be some conflict of interest between the hill farmer who did not require prolificacy and the upland farmer who could use it in limited measure. To some extent the change in nutritional circumstances of the ewe produce the kind of change which is required. Blackface ewes seem to respond well to the improved nutrition and draft ewes may well give lamb crops of around 150%. Other hill breeds such as the South Country Cheviot respond less well (Gunn and Doney 1974) and so are less suitable for use in such a system. For lowground production the situation may differ again. A small proportion of farmers attempt to produce lambs for slaughter as early as possible in the season before the price for lamb falls dramatically and they again prefer singles to twins for their marketing circumstances. For farmers producing the bulk of their lambs in mid to late season additional twins certainly are a major economic advantage.

Other selection objectives also cause difficulty according to environmental circumstances. If we seek to improve growth rate then it is necessary to face up to the problems created by correlations between growth rate and mature body size. If mature body size is increased then it seems inevitable that the maintenance requirements of those ewes will also be increased and that the number that can be kept on the same area of the land must be reduced. Numerical relationships between these factors are, however, largely unknown and changes in grazing pressure on extensive pastures may take many years to manifest themselves. The improvement of growth rate may also run into complications through the demand of the meat trade for carcasses with a certain level of fat cover. The use of a genotype with a higher growth rate may not necessarily be advantageous if the lambs do not reach the required degree of fatness for sale till later in the season, and so enter a period of lower prices, or if such lambs cost more to feed because the natural pastures are becoming exhausted and supplementary feeding becomes necessary. In such circumstances there must be real doubts about the economic value to be attached to growth rate since there is no guarantee that in a particular set of circumstances an increase in growth rate will guarantee an improvement in the overall economics of that system.

No attempt will be made here to examine further desirable selection objectives but it should be noted that in practice a great deal of attention is paid to breed characteristics. In a country where there are so many different breeds and crosses in use, the identification of breeds in the market place is a matter of concern and it is therefore not surprising that breeders should pay considerable attention to the trade marks of their particular product.

DEVELOPMENT OF SHEEP RECORDING IN GREAT BRITAIN

Although many attempts have been made to develop sheep recording and related improvement schemes the majority of early attempts in Britain met with only limited success and none achieved national status. In some localities good coverage was obtained and Mr. H.B. Parry started one scheme in the Oxford area in 1952 and this was recording some 12,000 ewes by 1968. The Eastern region of the National Agricultural Advisory Service also instituted a ewe recording scheme in 1958 and this had grown to some 2,000 ewes by 1968. Allied improvement activities also took place during this decade with the development of co-operative ram performance testing in Wales and the introduction of a scheme by the British Wool Marketing Board offering free assessment of ram fleeces. No nationally available recording scheme was, however, available until the arrival of the Meat and Livestock Commission (MLC) which was created in 1967. Since this body has prime responsibility for sheep improvement in Britain it is necessary to explain briefly the status and purpose of the Commission.

The Meat and Livestock Commission was set up by Act of Parliament in 1967 to promote greater efficiency in the livestock and livestock product industries of Great Britain. It took over the obligations of the Pig Industry Development Authority which had been operating with a similar remit up until that time and extended the work to cover sheep and beef cattle, although still excluding wool, dairy cattle and milk. Although the Commission is concerned with efficient marketing and distribution it is not a marketing board and has no trading powers. The functions to which particular attention is given are livestock improvement, carcass evaluation and classification, the provision of market information and the promotion of sales of home produced meat. Income is obtained from a levy on all animals slaughtered and the current levels are cattle 68p, calves 8p, sheep 4p, pigs 20p, giving an annual total of £3.8 million in 1975.

The Sheep Improvement Services branch of the MLC concentrates its work on the livestock side of the sheep improvement into two main areas.

The first area is in the improvement of management which is seen as presenting an opportunity for very large and rapid returns through the exploitation of the potentialities of existing breeds and crosses. The second area of activity is in genetic improvement and this takes the form of both breed comparisons and within-breed selection. To cope with these various needs recording is organized into three distinct schemes:

(i) commercial, whole flock
(ii) commercial, individual ewe
(iii) pedigree, individual ewe.

The extent of these recording schemes is shown in Table 2.

TABLE 2

NUMBERS OF MLC RECORDED FLOCKS

	1971/72	1972/73	1973/74	1974/75
Commercial, whole flock	548	713	788	827
Commercial, individual ewe	51	58	51	58
Pedigree, individual ewe	264	292	297	294
Total	863	1063	1136	1179

The number in the various schemes has not grown greatly over the years due to a policy of restricting entry to those flocks where recording was thought to be of value.

The most widespread scheme is that for commercial whole flock recording. This is designed to obtain physical and financial data on the inputs to and outputs from a flock so that the balance sheets can be drawn up and gross margins calculated. Although the body weight of ewes may be recorded and lambs weighed at 8 weeks of age, no individuals in the flock are identified and this scheme is directed towards providing management information. This form of recording shows up a wide range of results and the factual information collected on the physical and financial performance of the flocks is used extensively for advisory and educational purposes. Ewes are individually recorded in a smaller number of commercial flocks where parentage is known and where it is thought likely that comparative information about different breeds or crosses can be obtained within the same flock. Body weights of ewes are also taken and lambs weighed at 8 weeks of age and if possible at slaughter.

The third category of recorded flocks is that for pedigree flocks which are already recording the sire and dam of every lamb born. This scheme records additional performance data on the individuals in a flock and breeders are given lifetime summaries of the performance of their ewes and a simple index to help in the choice of breeding animals. The Down flocks are well represented in this scheme, and to a lesser extent the lowland breeds but the hill breeds are poorly covered due to the difficulties of recording in extensive conditions.

THE STRATEGY FOR GENETIC IMPROVEMENT

At an early stage of development of the Commission's improvement work with sheep, a Scientific Study Group was set up to review the scientific aspects of the Commission's existing and proposed improvement schemes. That review proved especially difficult for sheep because of the large number of breeds involved, the many production systems employed and the often conflicting nature of objectives for improvement. Some indications of where attention might most profitably be focused was provided by considering the genetic contribution of different breed groups to the estimated national production of lamb carcasses, as shown in Table 3.

TABLE 3

NUMBER OF EWES IN PURE-BRED GROUPS AND ESTIMATED GENETIC CONTRIBUTION TO LAMB CARCASS PRODUCTION (AFTER READ 1974)

Breed Group	Million ewes	Genetic contribution (%)
Hill	6.9	36
Upland	0.8	8
Longwool	0.02	13
Down	0.24	37
Lowland	0.6	6

In relation to their number hill ewes contribute relatively little directly to lamb production because of the low level of productivity on the hill and the need to retain a high proportion of ewe lambs as breeding stock. The genetic effect of these breeds is, however, increased by the large numbers of cross-bred breeding stock which derive from them. The Down breeds are seen to make a very important contribution, as would be expected from their widespread use as terminal sires. Although the Longwool breeds have a relatively small effect in total this can be seen as coming from a very small pure-bred population. In national terms, the three preceding groups would account for 86% of the output of lamb carcass meat and it therefore seemed reasonable to concentrate efforts on them.

As a first step the Study Group recommended that breed and cross comparisons should be organized so that commercial flock owners could make better decisions relevant to their own management systems. The MLC has begun the first phase of a comprehensive trial to compare ram breeds as the sires of lambs for slaughter. The breeds being compared are the Border Leicester, Dorset Down, Hampshire Down, Ile de France, North Country Cheviot, Oxford Down, Southdown, Suffolk and Wensleydale.

The creation of improvement schemes for each breed would be an expensive undertaking and the Study Group suggested the establishment of a limited number of 'development' flocks in which the feasibility of selection schemes could be tried. Such flocks were to have defined selection objectives and would be operated under the direction of the MLC with their financial assistance. If these schemes were successful then such flocks could provide a useful source of breeding stock. The MLC has now identified 7 potential development flocks in the Scottish Blackface, North Country Cheviot, Welsh and Swaledale breeds. In the Down breeds, where a number of quite large flocks are individually recorded by breeders, it appears that no special efforts may be necessary to establish selection schemes for commercially important traits.

In addition to the mainstream of MLC activity there are a number of pilot ventures under way which will not be described but do testify to widespread interest in ways and means of improving sheep.

RESEARCH INTO SHEEP IMPROVEMENT

Many Universities, research institutes and advisory bodies in Britain are involved in sheep research, aspects of which are pertinent to sheep improvement. No attempt at an overall summary will be made here but it may be useful to describe some of the current investigations at the Agricultural Research Council's Animal Breeding Research Organization (ABRO) which seem particularly relevant to sheep improvement problems.

Despite the widespread use of cross-breeding in Britain the experimental evidence for the adoption of the practice is often lacking. The use which is made of this breeding method is often designed to utilize complementarity rather than to take advantage of heterosis. Crossing of hill breeds utilizes breeding stock which can be produced cheaply on the hills and the crossing process changes the performance characteristics to make the cross-bred ewe more suitable for use in better conditions. A question which is still largely unanswered is whether there is a useful amount of heterosis in crosses of hill breeds and whether this might be utilized in the exploitation of these severe environments. Under upland conditions some evidence for heterosis was found by Wiener and Hayter 1975 particularly in crosses of the Scottish Blackface and South Country Cheviot breeds. Another experiment is in progress on a Welsh hill farm involving the Welsh and Scottish Blackface breeds and the preliminary results show evidence of a rather low level of heterosis (Purser 1975). More recently a large cross-breeding experiment has been started on a Scottish hill farm and involves crosses of the Scottish Blackface stock with Swaledale, North Country Cheviot, Derbyshire Gritstone and Exmoor Horn rams.

ABRO has also carried out some comparisons of sire breeds, picking out a few breeds which seemed of particular interest at the time the trials were started. Breeds which were comparative newcomers to Britain were used alongside existing Down breeds. The Oxford was used as a control—a small control flock of this breed is maintained—and alongside it the Suffolk and

Dorset Down as common British breeds along with the Oldenburg, Ile de France and Texel as imported breeds. Lambs from these crosses were slaughtered at two weights and subjected to full carcass measurement with a proportion of them being dissected. The results are summarized in Table 4.

TABLE 4

COMPARISON OF SLAUGHTER LAMB SIRE BREEDS — AVERAGE OF RESULTS AT 35 AND 40 Kg LIVEWEIGHT SLAUGHTER

	Dorset Down	Ile de France	Olden-burg	Oxford	Suffolk	Texel
No. of lambs	343	343	295	322	339	351
Av. birth wt. (kg)	3.8	3.7	3.8	4.1	3.9	3.8
Av. 8-week wt. (kg)	19.2	18.9	19.4	20.6	19.9	19.2
Age at slaughter (days)	170	173	168	150	158	168
Killing-out %	44.0	44.0	42.1	43.5	43.5	44.3
Carcass grade (points) (1 poor, 7 excellent)	3.6	3.3	2.8	3.1	3.2	3.2
No. dissected	40	41	43	46	47	51
Total lean (kg) in left side	4.26	4.33	4.28	4.32	4.29	4.67

Quite marked breed differences were found and illustrate the utility of different breeds for various production systems. The Dorset Down produced lambs that graded well and would be appropriate for early lamb production, although not showing the highest growth rate. From these comparisons the Texel breed stood out as producing a markedly leaner carcass suggesting it might be useful for the production of lambs for slaughter at heavy weights.

Comparative trials have also been carried out with alternative dam breeds including the Finnish Landrace. These will be described in another section of this book and so will not be elaborated on here except to record that extensive experimentation with many different co-operators both from the advisory field and individual breeders does take place as needs arise.

A recent innovation on the British scene is an attempt by ABRO to introduce the concept of group breeding schemes to sheep farmers which is being attempted in two breeds. In Wales discussions are in progress with Welsh Mountain breeders and with the Agricultural Development Advisory Service and similar discussions are taking place in Scotland, this time with the East of Scotland College of Agriculture, with the object of establishing a group of Scottish Blackface breeders. Both approaches will involve a degree of breeder co-operation that has not been attempted before in Britain. The degree of interest which is present in sheep breeding and a growing concern with the financial details of sheep production systems makes the timing opportune.

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9

SHEEP BREEDING IN URUGUAY

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SUMMARY

Sheep production is one of the main industries in the country, Uruguay being the fifth largest wool exporter in the world. The present sheep population is estimated at 18 million. Corriedale, Polwarth, Australian Merino and Merilin are the main breeds. The composition of the national flock reflects the emphasis that is placed on wool production and the predominant semi-extensive production systems. The present breeding structure follows the common hierarchical pattern and the difficulties in introducing new breeding systems are almost identical to those of other countries. A performance recording scheme (flock testing service) was started in 1969 with relatively good success and several points concerning the efficiency of the scheme are discussed. More effective extension work at the commercial level and support for the activities of the more enthusiastic breeders are being emphasized. Alternatives to the present system, such as co-operative nucleus breeding schemes will be encouraged.

INTRODUCTION

Uruguay has a total area of 18.5 million ha, of which 85% can be considered as productive. Approximately 13 million ha are under native or improved pastures and are utilized for grazing sheep and beef cattle.

Climatic conditions are quite uniform throughout the country, with an average annual rainfall of 1000 mm and average daily temperatures of 12-13°C in July and 24-25°C in January. There are however, great variations in the average rainfall between years and also within years between seasons.

Most of the farms are mixed and run beef cattle and sheep together. The average ratio of sheep/beef cattle in the country is around two, but ranges from four in the so-called sheep areas to one in the more productive areas, and the average stocking rate is around six dry ewes/ha.

SHEEP PRODUCTION

Sheep production and especially wool production is one of the main industries in the country and represents nearly 30% of the value of total exports, making Uruguay the fifth largest wool exporter in the world. In recent years its importance has declined and there has been substitution of sheep by beef cattle. As a consequence there was a reduction in sheep numbers of 10%. The present sheep population is estimated at 18 million sheep and there are some indications that this is increasing again.

There are 36,363 farms running sheep, distributed according to flock sizes as shown in Table 1.

TABLE 1

DISTRIBUTION OF SHEEP FARMS ACCORDING TO FLOCK SIZES

Flock Size	Number of Farms	%	
1-99	15,376	42.3	
100-299	7,526	20.7	
300-599	4,575	12.6	
600-999	2,917	8.0	24.5% of the total sheep
1,000-2,499	3,770	10.4	
2,500-4,999	1,441	4.0	
5,000-9,999	586	1.6	
>10,000	172	0.5	
Total	36,363		

In general, systems under which sheep production takes place, can be described as semi-extensive, with relatively more use of land and labour than capital, sheep usually being relegated to the poorest pastures. This situation is quite similar throughout the country and there is no specialization of farms to particular productions such as fat lambs, cross-bred ewes, etc.

The main objective of the sheep industry is the production of wool, the home market for fat lambs being very poor. Mutton meat, mainly cast-for-age ewes and wethers, is quite popular in the country areas where the consumption reaches 33.5 kg/person/annum, compared with 0.5 kg in the main cities.

There have been marked changes in the proportion of breeds with the years, particularly an increase in the proportion of Corriedales, Polwarth and Merilin* and a decrease in the proportion of Australian Merino, Rambouillet Merino, Romney and crosses. The present breed distribution (Table 2) seems to reflect the characteristic instability of marketing conditions for different types of wool, mutton and lambs.

The present structure of the national flock (Table 3) reflects the emphasis that has been placed on wool production, and the predominant production systems.

Sheep production is very dependent on the variations in pasture production throughout the year, with marked shortages during winter and summer. The growth of lambs after weaning in the summer is usually very slow and as

* An Uruguayan breed approximately $\frac{1}{4}$ Lincoln–$\frac{3}{4}$ Rambouillet merino developed in 1930.

a consequence, on average only 50% of the females are mated for the first time as two-tooths (1½ years). Lambing normally takes place in July-August, except for many Polwarth and Merino flocks that are mated in the spring. As a result of a poor nutritional level in the last stages of pregnancy and very severe climatic conditions during lambing, the average reproductive efficiency is low (70-75% of lambs marked/ewe joined) with very marked variations between years. Lamb mortality ranges from 15% in good seasons up to 35% in bad seasons. It has been shown in Uruguayan conditions (Azzarini and Ponzoni 1971) that the reproduction performance can be considerably increased with spring lambings.

TABLE 2

DISTRIBUTION OF BREEDS

Breed	Sheep Numbers	%
Corriedale	8,500,000	50.1
Polwarth	1,500,000	8.9
Aust. Merino	700,000	4.1
Merilin	1,000,000	5.9
Romney	350,000	2.1
Crosses	4,900,000	29.0

SHEEP BREEDING

(a) The traditional system

There were several stages in the history of sheep breeding in Uruguay characterized by the predominance of different breeds and the utilization of different breeding systems. An initial period of grading up to Merino-type breeds, especially the Negrette from Spain, the Rambouillet from France, the Vermont from U.S.A. and the Australian from Tasmania, was followed by a strong predominance of Lincoln and Romney crosses at the beginning of the century when there was an important demand for mutton meat in Europe. As a consequence of the reduction in the sheep meat market and of good prices for wool, a period of alternated cross-breeding started with the use of Merino rams on cross-bred flocks when the wool became "too strong" or the use of Lincoln or Romney rams when the flocks became "too fine and small". The result was a great variation in wool characteristics within individual clips.

In 1935, a Sheep Improvement Commission was created to orientate sheep breeding in the country and it started a process of grading up to pure breeds such as the Corriedale and Polwarth, which were imported at that time, Merino and Romney. During that process, a system of identifying superior graded-up animals was created, in which both males and females were inspected for the first time before the first shearing. Those without obvious faults, and reaching the breed type standards and a certain level of productivity (subjectively appraised) were given a single tattoo. The single tattooed animals were inspected again the following year and those reaching more strict levels of performance were given the double tattoo. Three different types of ram breeding flocks were differentiated: the registered, the non-registered double tattoo and the non-registered single tattoo, and a clear dependence between the three was originated with the registered flocks on top of the hierarchy.

TABLE 3

COMPOSITION OF THE NATIONAL FLOCK BY CATEGORIES (*)

Categories	Numbers	%
Rams	310,000	2.0
Breeding ewes	7,400,000	50.0
Ewe hoggetts (not mated)	2,150,000	14.6
Male hoggets (castrated)	1,750,000	11.9
Wethers	2,500,000	17.2
Others (†)	600,000	4.3

(*) Lambs not considered.
(†) Animals which are slaughtered during the year for consumption on the farm.

This system, which is still operating, was successful at the beginning in orienting the producer and raising the level of production probably as a consequence of a wide genetic variation in traits readily assessed by visual appraisal and the elimination of major faults. Even though there is no evidence of what genetic progress is being made, it is very likely that the present methods are not adequate to ensure high rates of improvement. The registered flocks, whose importance is over-emphasized under the present system, in many circumstances are quite small, and because of the high economic value of the pedigree in itself, culling is usually very light: (Ponzoni, R. 1973). In the non-registered ram breeding flocks, which are larger and more numerous, selective pressure has been stronger but the identification of superior animals (particularly the double tattooed) has been made on a purely subjective basis, including many characteristics not directly related to productivity and on a "between stud" basis.

Because of the presence in most studs of non-registered ram breeding flocks, a study of the pedigree flock books does not give an accurate picture of the breeding structure of the industry. A survey was made last year covering 600 studs with the objective of determining the breeding practices commonly used in the studs and the breeding structure of the sheep industry. Results are still being analysed but so far there are indications that it follows the common hierarchical pattern. However, there appears to be a higher proportion of stud animals in the top level of the hierarchy, while secondary studs are not as tightly associated with a particular top stud, compared with the Australian situation. As in any hierarchical breeding structure, the genetic progress in the whole industry will depend on what genetic progress is being made in the top studs.

The National Sheep Production Survey (Cardellino *et al.* 1972) showed that approximately 10% of all the commercial flocks with more than 600 sheep have a selected nucleus (mainly on the basis of tattooing) in which rams bought from studs are used, to produce rams for their own commercial flocks.

(b) Flock Testing Service, a new approach

A performance recording scheme was started in 1969 with the purpose of introducing more effective breeding methods, through the objective measurement of economically important traits. The service is run by the Uruguayan Wool Secretariat (S.U.L.) and the Sheep Improvement Commission that now belongs to the Secretariat, with representation from all the sheep breed associations. The service is free, but in fact is funded by the whole industry.

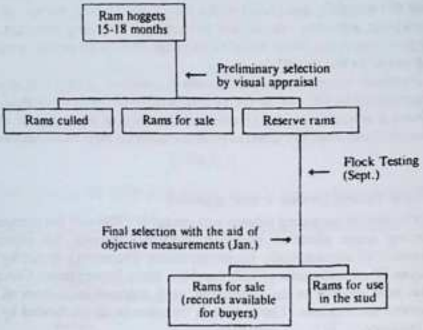
Ram hoggets, registered or unregistered, are measured when they are 15-18 months old. At shearing time, records of greasy fleece weight and body weight of the shorn animals are taken and a visual appraisal of the quality number, colour, character and handle of the fleece is made. A mid-side sample of wool is taken and sent to our wool laboratory where yield %, staple length and fibre diameter by air-flow method are determined. The data are processed in a computer and the animals ranked according to their clean fleece weight. The rest of the traits are expressed as deviations from the average.

The stud breeder is assisted by extension officers at shearing time, in collecting records and wool samples. Once the records are computed, the extension officer returns to the stud in order to advise on the correct interpretation of the results. No selection indices have been used so far. In the studs where pedigree records are kept, correction factors are applied to animals born as twins and being the progeny of maiden ewes.

In order to make the Service more flexible, there are two possible schemes. In Scheme I (Figure 1), ram hoggets prior to shearing are visually classed and only the reserve rams are shorn and recorded. This system is mainly used in those studs which sell rams in full wool before the end of the year.

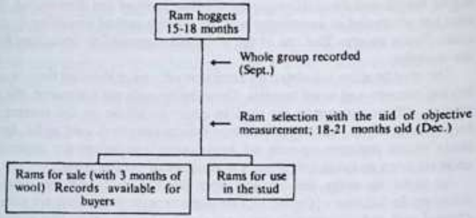
The effects of this preliminary culling on the selection differentials for traits of economic importance, will depend on the proportion selected as reserve rams, the criteria used in selecting them and its relationship with productive characters.

Figure 1— Flock Testing Service. Scheme I.



In the Scheme II (Figure 2), the whole group of ram hoggets is recorded, except for a small proportion of animals culled for obvious faults.

Figure 2— Flock Testing Service. Scheme II



The final selection of the rams with the aid of records is done in Nov.-Dec. at 18-21 months of age, and most of the rams are used for the first time as two-tooth. The rest of the rams are sold at auction in their own studs with 3-4 months of wool and all the records available for buyers. Extension officers assist the ram buyers in the correct interpretation of the results.

Several factors are important in evaluating the efficiency of a performance recording service:

- the number of studs using the service
- their continuity
- their relative importance according to the present breeding structure
- the proportion of animals being recorded with respect to the total available
- the use that is effectively made of the records in their selection programmes.

The number of studs using the service has increased from 12 in 1969 to 70 in 1975 of which 65% are Corriedales, 25% Polwarths and 10% Merino and Merilin.

The level of continuity has been high, with 85% of the studs that used the service in 1970 continuing to use it through 1975.

From the point of view of dissemination of genetic improvement to the whole industry under the present breeding structure, the relative position in the pyramid of the studs using the service is very important in determining the overall efficiency of the service. At present, 40-50% of the top Corriedale and Polwarth studs are using the service regularly.

The number of hogget rams recorded per stud varies from 20 to 300 with an average of 60 and expressed as a proportion of the total number of rams available in each stud, the range is from 25 to 90%, the proportion tending to increase in the big studs.

A performance recording scheme is essential to implement efficient selection programmes but unless an adequate use of the available records is made, very little is going to be achieved simply by measuring the performance of the animals. Some checks have been made to see which rams were actually used from those recorded. The results varied considerably, the best being obtained in some studs measuring the performance of all their hogget rams and effectively using as 2-tooth and for two years, rams from the top 5% in fleece weight; the worst in some studs using the service only to check their traditional selection or for curiosity.

The rate of increase in the number of studs has not been very exciting and the difficulties in convincing stud breeders to use new breeding systems are almost identical to those of other countries. In general, the need for a change in the present methods is not recognized. A stud is a commercial activity whose benefits are closely related to the number of rams sold each year and their prices, rather than genetic progress in any characteristic. This activity is carried out in a system where shows are very important, where much attention is paid to characteristics of very doubtful importance (breed type, constitution, etc.) and where the pressure from the demand (ram buyer) for any change is very small. The adoption of more efficient breeding methods at the stud level is very difficult and slow if there is not a simultaneous change in the attitude of ram buyers, which means that more effective extension work at that level is required. However the attitude of some of the biggest Corriedale studs utilizing the scheme II for some years with economic success and promoting the use of measurements at ram auctions, has had and will probably have a great impact in putting more pressure on other studs to do the same.

In the so-called dual purpose breeds, although the term is not very precise, characteristics related to conformation are normally included in the selection criteria. It has been shown (in preparation) in Uruguayan conditions, working with Corriedale wethers (two and four tooth) and confirming earlier results of Tallis and Turner (1964) with Merinos, that body weight is the best indicator of meat production and that there was a very small variation in the proportion of the hindquarter with respect to the total carcass, thus showing little scope for improvement through selection of the hindquarter to forequarter ratio.

The present programme is far from perfect and was the result of a compromise between the scientific and the breeders' points of view, and adapted to the existing situation. Some modifications will be introduced, mainly the elimination of some subjectively appraised traits such as handle and character and the elaboration of selection indices with different alternatives of economic weights as a complement to the present information.

All the possible avenues of producing significant changes in the current breeding methods will be exploited, especially more effective extension work at the commercial level and continuing support and assessment of the activities of the more enthusiastic breeders.

Alternatives to the present system are being encouraged, such as the formation of co-operative nucleus breeding schemes, and technical assistance is given to those commercial producers running their own ram breeding nucleus flocks.

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10

THE SHEEP INDUSTRY AND SHEEP BREEDING IN RUSSIA

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Sheep production takes an important place in the national economy of the USSR. The share of sheep production in the total agricultural production is 6.2%, and of the total animal production is 10.1%. In some areas of the country it is considerably greater. For example, in the North Caucasus it comprises 17.8% of the animal production, in Kirgizia 27.5% and in Turkmenia 80.0%.

The development of the sheep industry in the USSR is determined mainly by the requirements of the national economy for meat and wool products. The important basis for developing sheep production in the USSR is the availability of large areas of semi-desert, steppe and hill pastures, which are not suitable for breeding of any other kinds of livestock.

Of the different sheep products wool is the most important, although sheep meat is also important. In terms of the total meat consumption of the country in recent years mutton comprises 8-9%, compared with some Middle Asian countries where it approaches 60%.

In addition to wool and meat production large amounts of Karakul and furcoat pelts are produced which meet the requirements of both the national and foreign markets.

Wide variations in the climatic conditions of the USSR have allowed the evolution of many breeds of sheep with different purposes. Nevertheless, in recent years much attention has been given to the development of fine and semi-fine wool sheep breeds, producing the most valuable wool types.

In spite of the long standing presence of suitable environments for sheep breeding this branch of Animal Husbandry was greatly influenced by the First and Second World Wars and the Russian Revolution. Before the First World War and the revolution Russia had a sheep population of 89 million, including 4.5 million Merinos. By 1924 the total sheep population had been considerably reduced to only 350 thousands of these fine-woolled sheep. In order to correct this reduction the Government took some drastic measures, including the establishment of large specialized sheep farms and the training of sheep specialists, and encouraged further developments of research work. Much was done to convert a low-productive coarse-wool sheep industry into a highly productive one producing fine and semi-fine wool fleeces. This increase was attained by pure-breeding as well as by mass crossing of coarse-wool ewes with fine-fleece rams. Valuable flocks of fine-fleeced sheep and breeding studs producing animals for selling to commercial sheep farms were established in a comparatively short period of time.

Temporary occupation of the sheep breeding regions of the Ukraine, North Caucasus and Volga during the Second World War resulted in another major reduction in the sheep population mainly of fine-fleeced sheep breeds. During the war improvement of sheep production in other regions of Russia was also stopped.

For these reasons it is reasonable to consider that the major improvements in sheep production leading to a raising of its productivity have been achieved during the postwar period, i.e. during the last 25–30 years.

As a result of the widespread use of artificial insemination the conversion of low productive coarse-wool sheep breeds into fine and semi-fine fleeced breeds, alongside the establishment of some new breeds of high wool and meat production, was successfully achieved in a short period of time.

Fine-fleeced sheep breeding in the USSR was moved away from the geographic areas of its evolution—South Ukraine and North Caucasus—and new zones of fine-wool sheep production were established on the Volga and Urals, in West and East Siberia, in Kazakhstan and Kirgizia. With the establishment of new "breeds" the problem of breeding fine and semi-fine fleeced sheep in the hill regions of Caucasus, Kirgizia and Kazakhstan to replace their local coarse-wool animals was overcome.

At present attention is being paid to improving nutrition which should allow further development and perfecting of the fine-fleeced sheep breeds in the country.

The establishment of some semi-fine fleece and dual purpose sheep breeds for the steppe and hill regions of North Caucasus, Volga, Kazakhstan and other zones, was also undertaken.

The increase in sheep population and gross output of wool is shown in Table 1.

TABLE 1

SHEEP POPULATION AND WOOL PRODUCTION IN THE USSR IN RECENT YEARS

	1950	1960	1970	1975
Sheep population (millions)	77.6	136.1	130.7	145.3
Wool production (thousand tons)	172	354	417	504
% fine and semi-fine wool	18.6	54.2	66.6	77.0

As can be seen from Table 1 the gradual increase in the sheep population was accompanied by an increase in wool production. The increase in wool production resulted mainly from an increase in fine and semi-fine wool fleeces.

The most widely spread fine-fleeced breeds of the USSR are the following:

Caucazskaya breed: dual purpose breed found in North Caucasus.
Askanijskaya: dual purpose breed, South Ukraine.
Altajskaya: dual purpose breed, Altai territory.

Soviet Merino: wool and/or wool and meat, breed. It is the major breed and is located in the North Caucasus, the Volga region, Ukraine, Siberia, Kazakhstan.

Groznenskaya: wool breed, semi-desert regions of the North Caucasus.

Stavropolskaya: wool breed, steppe regions of the North Caucasus and Volga.

Kazakhskaya: fine-fleeced dual purpose breed, Kazakhstan.

Kazakhski Archaro: Merino breed, which was bred by hybridization with wild rams (Archaro). They are bred in the hill regions of Kazakhstan.

Kirgizskaya: fine-fleece breed, hill regions of Kirgizia.

Zabaikalskaya: fine-fleece breed well adapted to the severe climatic conditions of East Siberia.

Semi-fine fleece breeds are as follows:

Zigaiskaya breed: South Ukraine, Kazakhstan, Moldavia.

Kuibishevskaya breed: well suited to breeding in areas with high rainfall (Central Russia).

Severo-Caucazskaya: dual purpose breed, steppe zones of the North Caucasus.

Tjan-Shanskaya breed: hill regions of Kirgizia.

Some other important breeds, bred in different regions of the USSR are as follows:

Karakul breed: pelt production, semi-desert regions of Middle Asia and Kazakhstan.

Romanovskaya breed: fur coat pelt production, North of the European part of the country.

Edilbaevskaya (Kazakhstan), Gissarskaya (Tadjikistan and Uzbekistan), Djaidara (Uzbekistan) breeds are of interest as fat-tailed breeds.

The establishment of the large number of highly productive sheep breeds in a short time was the result of continuous and persistent efforts of sheep breeders and research workers.

In his *Manual on the Establishment and Perfection of Fine Fleece Sheep* the scientist M.F. Ivanov, reported that the major objectives of sheep improvement were:

1. The identification of the most productive genotypes from among the best animals (phenotypes) for the different characters of importance to the sheep industry.
2. The fixation of the best genotypes and their rapid reproduction.
3. The creation of the certain highly productive lines from among best genotypes.
4. Replacement of bad genotypes by much better ones.
5. The creation of new, better genotypes by means of combination of different lines.
6. The use of small mutations for the establishment of new valuable genotypes.

For the identification of the valuable genotypes, mainly among rams, progeny testing was used on a large scale.

In the course of establishing a fine-fleeced dual purpose sheep industry with the use of imported English breeds, it became evident that they were not well adapted to the Russian climatic conditions and management. This difficulty led to the application of cross-breeding as the main route for the establishment of semi-fine fleeced sheep of an early maturity. In contrast to other countries, this was achieved by crossing coarse-wool and semi-coarse wool ewes with meat-and-wool rams. New breeds and breeding groups of dual purpose sheep were established followed by careful and intense selection for the most desirable types and individuals.

At present sheep improvement programmes are carried out not only on the best stud farms, but also on commercial farms. Line breeding is the important method of selection in the leading stud farms. It allows the individual traits of the best breeds and animals to be selected and promotes the division of the breeds into different quality groups. These are then combined to produce hybrids which not only allows inbreeding to be avoided under general conditions, but also promotes the phenomenon of heterosis.

One important feature of the sheep stud industry is the fact that each breed has several specific stud farms in different climatic areas, each of which produces specific hybrids for particular regions and are the major reproducers of the young stud animals in the country.

The main method of selection and improvement in commercial flocks is cross-breeding. As the result of intensive research work, the most suitable cross-breeding programmes were developed, taking into account the factors influencing the efficiency of cross-breds, particularly the exploitation of heterosis effects.

Breeding programmes are of great importance in the improvement of sheep production in Russia. There are specific programmes for stud farms, stud stations and individual breeds. The existence of such programmes helps in avoiding errors in selection, gives it purpose and raises the efficiency of the breeding work in general.

Until recently the improvement of breeding and productive traits in the sheep was carried out mainly by the mass conversion of low productive sheep breeds into highly productive ones by the use of the best rams from the best breeds. Along with this type of work, there currently exists the possibility of transmitting large numbers of highly productive ewes to the zones with sheep of low productive potential (breed substitution) which should result in the rapid improvement of sheep breeding in these regions.

The existing methods of sheep production on most farms rely on the extensive use of natural pastures, and in most regions are labour intensive: the level of mechanization is low. The extensive nature of sheep production in many areas of the USSR prevents the widespread application of mechanization, thereby limiting intensification and reducing the costs of the production.

In this connection fundamental changes are taking place at present in some regions. The main direction of the change is in the specialization and concentration of sheep production. One method of intensification is the introduction of new advanced methods of technology on an industrial scale.

Recently a number of small farms have been turned into larger ones with a consequent increase in the level of mechanization. These are found in the regions of intensive crop production, with an integration of pasture within the arable rotation. In summer the sheep are normally grazed on these cultivated pastures and then housed in the winter. The important change in the organization of indoor housing of sheep on large farms relates to changes in the preparation of feeds on a commercial scale. The grinding of hay, straw, silage, mixing them in given proportions and supplying the necessary concentrates, protein and vitamins result in the preparation of complete feeds which are pelleted. Different mixtures for different sex and age groups of animals are prepared to raise their productivity and thereby reduce the cost per unit of production. Such a feeding system provides an increase in nutritive value of rations and allows the process of feed distribution, which is the most laborious part of the operation, to be fully mechanized.

A consequence of intensifying sheep production in the intensive arable areas, even allowing for the provision of fencing and water drinking facilities, is that it allows all feeds to be used efficiently and a reduction in labour costs.

This intensification is taking place on many farms now with 5 to 10 thousand head of sheep. In addition feedlots for sheep fattening are being developed as well as changes in the enterprises providing flock replacements.

Judging from the limited information available at present such mechanized farms are economically viable and efficient. It is still early days yet, and there are many problems still to be solved.

The national programmes for future sheep improvement relate to further increases in the profitability of the sheep industry. The most important of these are:

1. Concentration and specialization of sheep production. This includes the establishment of specialized sheep farms on the basis of new developments; specialization of sheep production within individual farms and regions, as well as within the large-scale industrial regions of the country. Stavropol territory, for example, will be specialized to supply other regions of the country with stud animals. Big capital investments will be supplied for the farm building construction, irrigation and watering to improve natural pastures and to establish new cultivated pastures.
2. Further improvement of sheep breeds and their proper distribution in different areas. The testing of various breeds from an economic point of view in the areas of their localization was initiated to select the most productive and adaptable types for particular regions and climatic conditions.

3. Intensification of the breeding programme. More new breeds and hybrids are being established with the application of modern technology. The basic requirements of these breeds are as folllows: high prolificacy, good meat and wool production, early maturity, disease-resistance at high concentrations of animals (stress-resistance).
4. The wide use of cross-breeding in commercial flocks.
5. The establishment of breeding evaluation units for the rapid and reliable genetic selection of stud animals, mainly sires, with the purpose of using only the most desirable genotypes in sheep breeding programmes.
6. Further perfection of the selection methods, the development of suitable selection indices, the use of computers for the analysis of breeding records, the modification of the methods of sheep tagging, etc.

11

METHODS OF IMPROVING PRODUCTION IN CHARACTERS OF IMPORTANCE

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SUMMARY

The first step is to define the characters of importance, which are given as:

For Wool Production

High clean wool weight per head

Average fibre diameter (medium to fine for apparel wool, coarser for carpet wool)

Percent clean yield (optimal level not clearly defined)

Percent medullation (zero or low for apparel wool, certain percentage for carpet wool)

For all Types of Production (wool, wool+meat, meat)

Reproduction rate (high level)

Easy-care features: Skin wrinkle score (low value)
Face cover score (low value)

If Meat is a Product

Body weight (high value)

Early growth rate (high value)

Fleece protection during growth is important, but relevant characteristics are not yet clearly known; there is a considerable amount of current research.

The Objective Measurement Policy Committee of the Australian Wool Corporation indicated clearly that crimp number is not important in processing by omitting it from the list of desired characteristics. The OMPC also considered that between-fibre diameter variation within mobs is unimportant in the Australian clip, but along-fibre variation may sometimes be sufficiently great to cause processing problems. Current research on these two sources of variation is discussed, but it is stressed that more information is needed about the **exact** importance of diameter variation to the processer, and about its tolerance limits, before further selection criteria are added.

The OMPC findings relate to Australian wool sold on world markets; elsewhere there may be a need to study the requirements of local markets or of home consumption.

The classic techniques for genetic improvement are selection and cross-breeding. Australian recommendations for selection are discussed, as well as results of experiments confirming them. A common concept is that cross-breeding will lead to faster improvement than selection; this concept is challenged and some comparisons made of likely gains by each method. In particular, when a large population is to be improved, it should be remembered that selection can be done simultaneously throughout the population, but limitation on the number of males available will restrict improvement through cross-breeding.

The importance of a large genetic difference between a ram-breeding source and its dependent flocks is stressed, as well as a high rate of genetic gain when the ram-breeding source is under selection.

DEFINING IMPORTANT CHARACTERISTICS

Sheep produce mainly wool (apparel or carpet), meat, milk and skins; subsidiary uses (manure and transport) will not be considered here. Besides quantity and quality of commercial products to satisfy his market, the breeder is concerned with the sheep's ability to produce in a given environment at minimum cost. He is therefore interested in many characteristics, but must keep the number low to obtain greatest genetic progress in improving them.

(1) *Wool*

(*a*) Apparel wool

The Final Report of the Australian Wool Board's Objective Measurement Policy committee (AWB 1972) provides a good starting-point for defining the important characteristics of apparel wool, as required for commercial use on the world market. Other requirements are discussed later.

The OMPC list will be re-arranged under the headings of quantity, quality, and protection during growth.

(i) Wool quantity

Clean wool weight is the commercial product, but would it be per head or per unit of input (feed and other costs)? Most costs are per head, and wool weight/unit of feed ("efficiency of conversion") is correlated with weight per head (Turner and Young 1969, Turner and Dunlop 1974*). Wool weight per head therefore stands as the general definition of quantity-greasy weight for all except final selection of stud rams, since the correlation with clean weight is high (+0.8 to +0.9).

* Reviews are quoted where available, together with subsequent papers.

Efficiency of conversion is important with hand-feeding; is it equally important for pasture-fed sheep with a fluctuating feed supply (Dolling 1960)? Selection for high wool weight increases efficiency, but the gain is estimated as 40-70% of the potential under direct selection for efficiency (Turner and Young 1969). The cost of efficiency tests, and the obligatory reduction in numbers tested, need to be balanced against the value of increased genetic progress in efficiency; this exploration has not been undertaken. Selection on wool weight/body weight is no better for increasing efficiency than selection on wool weight alone, if decreases in body weight are controlled (Turner and Young 1969).

A high *percent clean yield* is important both to producer and processer, but some wax and suint may be needed for fleece protection.

(ii) Wool quality

The OMPC list of important characteristics is:—

Average fibre diameter,

Average fibre length (controlled by breakage),

Distribution of fibre length (also controlled by breakage),

Fibre strength (as far as it is determined by "soundness"),

Coloured fibres (in otherwise white wool).

Pigmentation of whole fleeces was not mentioned; the world market demands mainly white wool, though there is a current fashion for natural colours. "Colour" (degree of whiteness) was also not listed, but the text mentioned the need for scoured wool capable of taking desired shades. A clearer statement about permissible levels of "creaminess' is needed from processers.

Medullation was not mentioned at all; no medullation, or a low percentage, is required for apparel wool. Australian wools meet this requirement, but medullation may be a problem elsewhere.

Two notable omissions from the OMPC list are crimps per unit staple length and fibre diameter variation.

Crimp is unimportant in processing except in a few special circumstances. Further, over the last 3 decades it has been shown to be unreliable in its traditional role as a guide to diameter (Lang 1947, Roberts and Dunlop 1957, Turner, Dolling and Kennedy, 1968, Turner, Brooker and Dolling, 1970, AWC 1973), while, because of its high negative genetic correlation with wool weight, attempts to raise weight while maintaining crimp will greatly hinder selection response.

Variability in fibre diameter can arise between or along fibres. The latter is mentioned by OMPC as important under "fibre strength" and "soundness", but within Australian flocks between-fibre variation was regarded as acceptably low.

The components of between-fibre variation within one mob have been estimated as contributing to total variation (AWB 1972, Dunlop and McMahon 1974)—

	%
Fleeces	19
Body regions	5
Fibres within staples	76
	100%

Diameter variation along the fibre (which may affect soundness) may contribute 20-75% of total variation, depending on seasons.

The OMPC conclusion that between-fibre variation can be ignored is not universally accepted within Australia, and may not be valid for breeds elsewhere. Before yet another selection criterion is added however, further evidence is required from processing trials about the exact effects of diameter variation, with specification of permissible limits.

In the meantime, research on genetic aspects of within-staple diameter variation is in progress, concentrating on the skin, and working with both horizontal and vertical skin sections. On horizontal sections, diameter variation can be split into 4 components:

Difference in mean diameters of fibres from primary and secondary follicles ($\overline{D}_P - \overline{D}_S$),

Variation among fibres from primary (VD_P) and secondary (VD_S) follicles,

Ratio of secondary to primary follicles (S/P).

For the Australian Merino, preliminary investigations indicate that S/P is so large and ($\overline{D}_P - \overline{D}_S$) so small that VD_S becomes the major component. Further, there are more "outlying" fibres of extra high diameter from secondary than primary follicles. More data are needed (Turner unpublished).

The high cost of measuring horizontal sections has led to investigation of a possible genetic correlation between evenness of follicle depth (scored on vertical sections) and between-fibre diameter variation (Nay, in progess). If a correlation is demonstrated, a cheaper score for diameter variation will be available.

Diameter variation along the fibre is largely influenced by nutritional changes, but there is evidence that individuals differ in their ability to maintain an even diameter (Jackson and Downes, in progress).

Fibre length is listed as important, but is expensive to measure; the easily-measured staple length is correlated with it, though not highly. As will be seen later, staple length increases under selection for wool weight, so need not be a separate selection criterion.

Coloured fibres in a white fleece are a disadvantage, but there is no information about their inheritance.

(iii) Fleece protection during growth.

The important features are:—

Weathering (damage from sunlight, dust penetration etc.),
Soundness (already discussed),
Vegetable matter (amount, type, distribution),
Discoloration (due to fly-strike and "fleece rot").

There are many traditions and opinions about characteristics which will protect the fleece during growth, and since the OMPC Report research in the area has intensified. So far there are few established conclusions.

The characteristics under investigation include:—

Grease content (absolute and relative amounts of wax and suint),
Fibre population density,
Staple size,
Crimp (which may be important in holding fibres together, though not in processing).

One characteristic (degree of skin wrinkle) has been shown to be related to fly-strike, plainer sheep being less susceptible.

(iv) Attention to end users.

The OMPC findings relate to Australian wool, most of which is Merino. They can be extrapolated to apparel wool sold on the world market. Local markets, or wool grown for home consumption, may have different requirements. Pigmented wool is demanded in many countries to save dyeing costs in making all-purpose blankets, used also as cloaks, while hand processing may call for a higher average fibre diameter than commercial processing.

The end use of the wool must always be considered in developing selection criteria.

(b) Carpet wool.

No publication similar to the OMPC Report exists for carpet wool. Quantity characteristics are likely to be the same as for apparel wool. Considerable work on desirable quality characteristics of Indian carpet wools has been done at the Wool Research Association, Bombay, under the direction of Messrs. A.D. Sule and G.R. Kulkarni (Wool Research Association 1971-74). Based on this, one definition of desirable characteristics for Indian carpet breeds is (Sule, personal communication):—

Average fibre diameter	36-40 μm
Percent fibres without medullation	At least 40%
Percent fibres with medullation:	
Heterotype (interrupted medulla)	At least 20%
Hair (medulla 60% of diameter)	Not more than 10%
Kemp (shed fibres)	0 or under 2%
Length	3-3½ inches.

TABLE 1

IMPORTANT CHARACTERISTICS FOR WOOL
A=APPAREL WOOL, C=CARPET WOOL
W=WORLD MARKET; L=LOCAL MARKET; H=HOME USE

Characteristic	Type of Wool	Market	Requirements
Clean wool weight per head	A or C	All	High
Average fibre diameter	A	W	Medium to fine
		L or H	Coarser, but no exact specifications available
	C	All	Coarser (within limits)
Percent medullation	A	W	Zero or low per cent
		L or H	Higher levels acceptable (of necessity)
	C	All	Certain percentages desirable
Length	A or C	W	Minimum lengths specified
		L or H	Various lengths used
Pigmented fleeces	A	W	White (except in special cases)
		L or H	Strong demand for pigmented as well as white
	C	W	Generally white, but some demand for pigmented
		L or H	Strong demand for pigmented as well as white
Pigmented fibres in white wool	A or C	W	Undesirable
		L or H	Acceptable
Colour (degree of "whiteness")	A or C	W	Stated to be important but clearer specification required
		L or H	Unimportant
Variability of fibre diameter (between fibres)	A	W	Australian wool: Considered within acceptable limits but clearer specification of "acceptable limits" needed
			Other wool: More information required before Australian findings extrapolated
		L or H	No information
	C	All	No specific information
Protection during growth: Soundness (diameter variation along fibre) Weathering Vegetable content Discoloration	A or C	All	All features important, but more information required about characteristics which might offer protection such as: Wax, suint (content & ratio) Crimp Staple size Fibre population density

The Indian workers stressed that the definition might not apply to breeds outside India. Earlier enquiries (Turner 1973a) led to the conclusion that the main function of medullation was to lower costs, but Mr. Sule (personal communication) considers that heterotype fibres contribute to "springiness".

(2) *Meat*

The main characteristics important for meat production are:—

Reproduction rate,
Body weight,
Early high growth rate.

Reproduction rate (defined as number of lambs born, or weaned, per ewe joined) is important for all aspects of sheep production. The main contributor to a higher rate is the incidence of multiple births.

Body weight or early growth rate are not important to wool production, but become so when meat is considered.

Meat quality is largely affected by pre- and post-slaughter handling; there is little information about related characteristics on the live animal.

(3) *Milk*

Australia has only one sheep-milk farm. The most thorough genetic research on sheep-milk production is done in France, and will not be summarized here.

(4) *Skins*

Skins are an important by-product in Australia, and a main product in some other countries, but little information is available on which selection criteria can be based. Research is in progress in the W.A. Department of Agriculture.

(5) *"Easy-care" features*

Labour costs are so high in Australia that features likely to reduce maintenance costs must be considered. Some which have been investigated are:—

Skin wrinkle score: Plain-bodied sheep are easier to shear, have fewer shearing cuts, and less fly-strike. In addition, they have a longer staple and higher reproduction rate, and often no less clean wool than sheep with a higher wrinkle score (Turner and Young 1969, Dun and Eastoe 1970).

Face cover score: open-faced sheep reduce wigging costs. The once-vaunted correlation between face cover and reproduction rate, however, is not high enough to be of value for indirect selection.

(6) *Conclusions*

Characteristics important for wool (apparel or carpet) are summarized in Table 1.

End use has been taken into consideration, via three avenues:

W = Sale on world markets, for commercial use,

L = Sale on local markets,(e.g.), from one village to another,

H = Home use, that is, processed by the grower.

In many cases, wool in categories L and H would be processed by hand.

Summarizing from Table 1 and Sections (b-e), the following important characteristics have definite information on which to base selection criteria:—

Main product	Characteristic	Requirement
Wool	Clean wool weight per head	High level
Wool	Average fibre diameter: Apparel wool Carpet wool	 Medium to fine Coarser
Wool	Percent medullation: Apparel wool Carpet wool	 Zero to low percent Certain percentage
Wool, or Wool+Meat, or Meat	Reproduction rate (number of lambs born or weaned per ewe joined)	High level
Wool+Meat, or Meat	Body weight and Early growth rate	High levels
Wool, or Wool+Meat, or Meat	Easy-care: Skin wrinkle score Face cover score	 Low levels

Fleece protection during growth is important for wool, but no definite objective selection criteria are yet available. None are available for skins. Further, body weight is included as a criterion in many programmes, largely because many costs are on a per head basis, but there is no work available to assess its correlation with efficiency, such as exists for wool weight.

GENETIC IMPROVEMENT

The classic techniques for genetic improvement are:—

1. Selection
   - (a) Direct
     - (i) Mass selection on individual phenotype
     - (ii) Using relatives' performance (with or without (i))
   - (b) Indirect on correlated characters

2. Cross-breeding
   (a) Changing the genotype
   (b) Exploiting heterosis

In many cases, (2) will be combined with (1).

The usual statement is that heritability level is the main criterion for choosing between (1) and (2), but other points for consideration are:—

Products wanted, and the characteristics defining them,

Levels of these characteristics for the flock in the environment under consideration, as well as for the type considered for crossing (or the cross-bred itself) *in that same environment*,

Genetic correlations between the characteristics, as well as their heritability levels,

Whether or not major genes control any production characteristics (e.g. pigmentation); use of heritability is based on an assumption of additive gene action.

The heritability levels of the characteristics listed on p. 98 are all high enough for successful selection (Turner and Dunlop 1974), there are no antagonistic genetic correlations provided diameter replaces crimp for assessing quality (Turner 1972), and most are controlled by additive genes. But the need for looking at the desired product is illustrated if we consider the impossibility of using selection alone to turn a Merino flock, with zero medullation, into a carpet-wool flock with 30% medullation in the fleece.

Because 75% of Australian sheep are Merino, with apparel wool as the main product, selection has received considerable attention here. The most useful course in this Section is to state the Australian recommendations and what might be achieved by them, then to make a comparison between genetic gains through selection and through cross-breeding. The latter becomes particularly relevant when so many countries, including Australia and New Zealand, are importing, or planning to import, exotic breeds for crossing with existing flocks. Gains by each technique will be considered at two levels:

For individual flocks breeding their own rams, or groups of flocks dependent on a central stud (or studs) or nucleus,

For a large population, such as might be involved in the case of exotic imports.

(1) *Selection*

(a) Wool-producing, or wool-and-meat-producing flocks

(i) Australian recommendations

These are:

- Mass selection (on individual performance) will be used in most cases.

- Performance records on relatives will be needed only:
  - —For progeny tests on rams when AI is to be used, or when rams from different sources are to be compared.
  - —For selecting rams on reproduction rate, when female relatives are needed. Dam's performance is more profitable than that of any other female relative, but if written records are kept those for different types of relative can be combined.
- The main selection criteria should be based on objective measurement, namely:—
  - —Wool weight per head (greasy weight for all except final ram selection, when clean weight should be used).
  - —Average fibre diameter (rams only, because of cost).
  - —Body weight (not necessary if wool is the only product, but to be included when meat is considered).
  - —Number of lambs born (or weaned) (for rams, by the dam; for ewes, combination of dam's and own performance).
- Other characteristics related to maintaining the animal at low cost should be based on definite information, such as:
  - —Degree of skin wrinkle,
  - —Amount of face cover.

These recommendations are for Australian conditions, under which sheep are mostly run at pasture all the year round in fenced paddocks, without shepherding. Labour costs are high. Written performance records have rarely been kept in the past, except on a few studs, but their use is increasing.

These conditions raise difficulties in identification at birth of multiple-born lambs or multiple-bearing ewes, and the following characters have been investigated for use in indirect selection (parameters from Young, Turner and Dolling 1963):—

Character	Genetic correlation with number of lambs at 1st 3 lambings		Gain under indirect as a percent of gain under direct selection	
	Born ($h^2=0.4$)	Weaned ($h^2=0.2$)	Born	Weaned
Body weight	+0.2	+0.5	26	65
Skin wrinkle score	−0.2	−0.3	19	29
Face cover score	−0.1	−0.3	10	29

In the case of wrinkle and face score, selection would be for lower values. Selection for plain body has the added advantage of having a direct effect on the ram's fertility (Dun and Eastoe 1970). Clearly no indirect selection is as efficient as direct, but body weight and wrinkle score will confer some advantage if direct selection is impossible.

Hormone levels are under investigation as a means of indirect selection, and are being discussed elsewhere in this book.

The recommended age for selection is prior to first joining (usually at 1½ years of age). Preliminary selection techniques are available (Nay 1973), but there is no space here to discuss their effects (Turner and Evans, in preparation).

(ii) Combining characteristics.

Given individual selection criteria, the question arises of how to combine them.

Firstly, average fibre diameter is of great importance, but what diameter should be the aim? Turner (1973b) used results of sales by measured sample to obtain regressions of price on average diameter, and was able to show that selection for increased fleece weight, while keeping diameter from increasing, is in most cases more profitable (in terms of money return per head) than selection for finer diameter. Once the average clean wool weight has reached 4.5 kg, however, reducing diameter (without losing fleece weight) may be more profitable than increasing fleece weight, depending on the existing average fibre diameter.

Diameter can readily be kept from increasing by rejecting rams with a diameter more than one standard deviation (approximately 2μm) above their group mean, even though their wool weights may be high.

The question of combining wool and body weights, when meat production has to be considered, has received some attention. Turner and Evans (in preparation) have developed charts designed to estimate the relative economic values (REV) of wool weight and body weight for a range of prices for wool, lambs and carcase, and from them have suggested the following selection indices:

(6 to 8) × greasy wool weight + body weight

(8 to 10) × clean wool weight + body weight

Selection for reproduction rate can be achieved by selecting on dam's performance, taking twin-born animals if records are not kept, (Young and Turner 1965), or selecting on the dam's lifetime performance if they are (Rae 1963, Turner 1968). Young and Turner (1965) discussed methods of selecting simultaneously for reproduction rate and wool weight, in the absence of written records, but no-one has yet published figures for the optimum combination for wool weight (maintaining diameter), body weight and reproduction rate.

(iii) Confirmation of recommendations.

The estimates of heritability for sheep production characteristics, and of the genetic correlations among them, have been confirmed in selection experiments, which have been listed and discussed by Turner (1976). In only one experiment out of a total of 9 (Pattie and Barlow 1974) has clean wool weight failed to show a continuing response; in all others the response has ranged up to 7% per annum.

There is no experiment in which selection includes all the recommended characteristics, but in one (CSIRO) selection has been based since 1950 on high clean wool weight, with rejection for high fibre diameter and high wrinkle score. The increase in clean wool weight has averaged just over 2% per annum, except for a period of drought years. There are 2 groups, in one of which the selection for quality was changed in 1961 to maintaining crimp instead of diameter. Response in clean wool weight with diameter maintained has been over 2%; with crimp maintained only 1% per annum. Neither body weight nor reproduction rate has changed under selection for high clean wool weight.

In another CSIRO selection experiment, with selection only for reproduction rate, results have been:

Group	Selected for	Begun	Lambs born/100 ewes joined to ewes aged 2-7 years (1972)
B	High No. lambs born	1959	209
T	High No. lambs born	1954	137
O	Low No. lambs born	1954	112

Wool weight has not suffered under selection for high reproduction rate.

Reference should also be made to the several breeds in the world which have exceptionally high reproduction rate—for example, the Finn, Romanov, Chios and Dahman. From what is known of their history, it seems selection in the past has contributed to their high performance.

(iv) Meaning of results in practice.

The CSIRO results are for the actual groups being selected. In practice, there will usually be a central nucleus (or stud) under selection, from which flocks will draw their rams. The relationship between the nucleus and the dependent flock is shown in Table 2.

The ratio of gain in flock and nucleus eventually becomes the same, but the flock will always be 2 generations behind the stud in production level. The time taken to reach the same rate of gain depends on the difference in genetic level at the start. If $d = 2\Delta G$, then flock and nucleus will have the same rate of gain (ΔG) from the start. If $d < 2\Delta G$, the rate in the flock is lower at the start and slowly rises to that of the nucleus. If $d > 2\Delta G$, then the rate of gain in the flock is *higher* initially than in the nucleus, but decreases until it is equal.

There are benefits to a whole system of nucleus and dependent flocks in ensuring that the nucleus has:

The highest possible genetic level,

The highest possible rate of gain.

These points will be discussed elsewhere in this book, but an important point is that the cost of achieving high levels in the nucleus should be balanced against the size of the system which benefits from them.

It is possible to set up a number of model systems and to determine in them the benefits of selection. To do this, a flock composition must be chosen, since this varies at different times of year. The composition at selection time would be:

Breeding ewes mated the previous year,

Young animals aged 1½ years (unselected),

Weaners (both sexes),

Mature rams.

Most of the wool comes from the ewes, so Table 3 gives gains each year under selection for the breeding ewes (before replacements are made) and the 1½-year-old ewes. Columns 2 and 3 show the gain in production level over that in Year 1, while Cols. 3 and 4 show the total *extra* production through selection since Year 1, obtained by cumulating the figures in Cols. 2 and 3.

Table 3 can be used for a nucleus, to estimate gains and balance them against costs. The same can be done for a dependent flock, entering the Table two generation-lengths behind the nucleus. For example, with a generation length of 3.25 years, a dependent flock would reach between Years 8 and 9 the level reached by the nucleus in Year 15.

(b) Meat-producing flocks

The requirement for meat-producing flocks would be high reproduction rate and high body weight at weaning, rather than at 1½ years. At this age, corrections for birth type (single or multiple) and age of dam and lamb are required for accurate selection. These are built into the performance-recording programmes already in operation in New Zealand and being constructed in Australia.

(c) Selection in a large population

Selection within flocks, or within nuclei supplying their dependent flocks, can be practised simultaneously throughout a large population. As will be seen later, this is in contrast with the cross-breeding situation.

(2) *Cross-breeding*

Selection within flocks can lead to steadily increasing gains for the important sheep production characteristics, *provided* there is genetic variation on which to operate. What has cross-breeding to offer?

Selection operates on genes assumed to have mainly an additive effect. Cross-breeding may operate through bringing in new genes with additive effects; either a new genotype is developed with genes from each parent, or crossing is continued till the old genotype is replaced by the new ("grading-up"). This kind of cross-breeding has occurred everywhere in developing new strains or breeds.

TABLE 2

RELATIONSHIP BETWEEN A NUCLEUS AND A FLOCK DRAWING RAMS FROM IT

ΔG = Gain per generation in nucleus, due to selection
d = difference in genetic level of nucleus (N_o)
and flock (F_o) at start
(After Bichard, 1971)

Generation	Production level		Change from preceding generation	
	Nucleus	Flock	Nucleus	Flock
0	N_o	$F_o = N_o - d$	—	—
1	$N_o + \Delta G$	$\frac{1}{2}(N_o + F_o)$ $= N_o - \frac{1}{2}d$	ΔG	$\frac{1}{2}d$
2	$N_o + 2\Delta G$	$N_o - \frac{1}{4}d + \frac{1}{2}\Delta G$	ΔG	$\frac{1}{4}d + \frac{1}{2}\Delta G$
3	$N_o + 3\Delta G$	$N_o - \frac{1}{8}d + \frac{5}{4}\Delta G$	ΔG	$\frac{1}{8}d + \frac{3}{4}\Delta G$
4	$N_o + 4\Delta G$	$N_o - \frac{1}{16}d + \frac{17}{8}\Delta G$	ΔG	$\frac{1}{16}d + \frac{7}{8}\Delta G$
5	$N_o + 5\Delta G$	$N_o - \frac{1}{32}d + \frac{49}{16}\Delta G$	ΔG	$\frac{1}{32}d + \frac{15}{16}\Delta G$
y	$N_o + y\Delta G$	$N_o + (y-2)\Delta G$	ΔG	ΔG

ross-breeding may also operate by exploiting "hybrid vigour erosis)" *if it occurs*. This is a phenomenon which sometimes appears the crossing of genetically distinct groups (breeds, strains, inbred characteristics in the cross then have levels different from the mid- level which would be predicted if genes acted additively. The ce may theoretically be positive or negative, but is only of practical positive, and if the cross is superior to the better parent. The uperiority of a cross over the *inferior* parent is sometimes incor- led hybrid vigour. Additive genes derived from the superior tribute to the cross; hybrid vigour *may* add something more, but s present.

gene effects, obtained either through selection or crossing, are and, in the case of continued selection, cumulative. Hybrid present in the first cross later gradually disappear, so that the continually made to obtain maximum benefit.

f hybrid vigour therefore depends on the amount which is o groups in question are crossed. The amount of informa- sheep is not great, and no work has been done to estimate ng separate populations and continually crossing them.

compared with the cost of selection or crossing (without heterosis) + selection. For these reasons the present discussion will be confined to changing the genotype through crossing.

(a) Changing the genotype (without selection).

(i) For one flock.

The procedure is to introduce animals (usually rams) from one (or more) genetic groups into another. For example, a flock owner decides to change the strain of rams he buys, or a country with a low-producing native breed looks to introducing exotic breeds.

Cross-breeding should not be started without an evaluation of the cross. This means not only estimating whether heterosis is present (with sheep it is frequently unimportant), but, more importantly, how the introduced group, or its cross, will compare with the existing group *in the existing environment.*

Let us take one Indian cross-breeding experiment as an example. Results have been variable, but one will serve as illustration (CSWRI 1972). The American Rambouillet has been crossed with various native breeds at the Central Sheep and Wool Research Institute in the semi-arid area of Rajasthan. The Rambouillet at home produces 4-5 kg of greasy wool, with a diameter of 21-23 μm and virtually no medullation. One native Indian breed (Chokla) produces 1-2 kg, with a diameter of 26-30 μm and 20-40% medullation. Predicting from these, a first-cross with no heterosis might produce 2.5-3.5 kg of wool, with a diameter of 23.5-26.5 μm and 10-20% medullation.

Breed	Greasy wool weight (kg)	Fibre Diameter (μm)	Percent medullation
½R½C — F1	2.2	21	22
— F2	2.2	22	16
⅝R⅜C	2.2	20	12
¾R¼C	2.0	17	8
Rambouillet (R)	2.3	17	0
Chokla (C)	2.0	26	45

Fleece weight in the first-cross is below what would be predicted on Rambouillet home performance, but in agreement with its much lower performance in Rajasthan. The diameter of the Rambouillet is finer in Rajasthan; diameter and medullation are both about half-way between the parents in Rajasthan.

An increase in R genes leads to predicted falls in diameter and medullation, but to no further increases in fleece weight—in fact, an actual fall for ¾R. The parent fleece weights, however, are themselves not far apart under Rajasthan conditions.

These results make clear the dangers of extrapolating from one environment to another, and emphasize the need for evaluation by contemporary comparisons—not necessarily of the two parent breeds, but of the native breed, the F1, and, preferably, the F2 as well.

An argument advanced in favour of cross-breeding, compared with selection, is that results can be achieved more quickly. Is this true? To begin with, a cross must be evaluated. This means setting aside part of the existing flock, splitting the part at random into two halves, one to be mated to rams from the existing flock, the other to introduced rams, whether of a different strain or a different breed. This should be done in at least two years, the resulting progeny being run together and compared. Wool can be compared at 1½ years of age which means completion of the comparison 3 years after commencement. It would be preferable to compare ewe lambing percentages as well, for at least the first 2 lambings, which adds 2 years to the evaluation period (up to weaning), making the total 5 years.

The second half of Table 3, which deals with crossing without selection, compares this procedure with selection. Extracts are:

Ewes	At Year	Production level: Selection	Production level: Crossing	Total extra production since Year 1: Selection	Total extra production since Year 1: Crossing
Breeding flock	10	Base + $4.0\Delta G_a$	Base + 0.6c	$12\Delta G_a$	1.2c
	15	Base + $9.0\Delta G_a$	Base + 1.0c	$47\Delta G_a$	6.0c
1½-years-old prior to selection	10	Base + $8.0\Delta G_a$	Base + 1.0c	$36\Delta G_a$	4.0c
	15	Base + $13.0\Delta G_a$	Base + 1.0c	$91\Delta G_a$	9.0c

For equivalent gains, c (the difference between the existing breed and the cross) need to be 8-10 times ΔG_a (the annual genetic gain). If wool weight is under selection and ΔG_a is 2%, then the half-bred must have a fleece weight more than 20% above the existing breed if crossing is to be more benefit than selection, after 10 years. This means that the introduced group (breed or strain) must produce 40% more than the existing group, in the existing environment.

(ii) For a large population.

Selection can be done simultaneously throughout a large population. The problem with crossing is limitation on the number of introduced males. Again various models can be set up, but one example will serve. This was worked out recently in relation to the number of village flocks in India which could be influenced in 20 years by a central stud of 3000 exotic breeding ewes. This stud was assumed to supply rams to 12,000 ewes in centres which would produce cross-bred rams for distribution. Surplus pure exotic rams were assumed supplied direct to village flocks. Using natural service for cross-bred and AI for pure-bred rams, it was estimated that the following numbers of ewes could be brought into the scheme:

In 10 years 1.4 million

In 20 years 2.8 million

The average percent of exotic genes for breeding ewes in the village flocks would be:

	In 10 yrs.	In 20 yrs.
Served by pure-bred then $\frac{3}{4}$ bred rams	36	53
Served by cross-bred rams ($\frac{1}{2}$ and $\frac{3}{4}$)	20	33

(b) Changing the genotype (combined with selection).

TABLE 3

GAINS UNDER SELECTION AND CROSS-BREEDING
(EWE LIFE ASSUMED 5 YEARS)

	Selection				Cross-breeding (without selection)			
	Gain from base year (in terms of ΔG_a*)		Cumulated gain from base year (in terms of ΔG_a)		Gain from base year (in terms of c**)		Cumulated gain from base year (in terms of c)	
Year	Breeding*** ewes	1½-year old ewes	Breeding ewes	1½-year old ewes	Breeding ewes	1½-year old ewes	Breeding ewes	1½-year old ewes
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	1.0	0	1.0	0	0	0	0
4	0.2	2.0	0.2	3.0	0	0	0	0
5	0.4	3.0	0.6	6.0	0	0	0	0
6	0.8	4.0	1.4	10.0	0	0	0	0
7	1.4	5.0	2.8	15.0	0	1.0	0	1.0
8	2.2	6.0	5.0	21.0	0.2	1.0	0.2	2.0
9	3.0	7.0	8.0	28.0	0.4	1.0	0.6	3.0
10	4.0	8.0	12.0	36.0	0.6	1.0	1.2	4.0
11	5.0	9.0	17.0	45.0	0.8	1.0	2.0	5.0
12	6.0	10.0	23.0	55.0	1.0	1.0	3.0	6.0
13	7.0	11.0	30.0	66.0	1.0	1.0	4.0	7.0
14	8.0	12.0	38.0	78.0	1.0	1.0	5.0	8.0
15	9.0	13.0	47.0	91.0	1.0	1.0	6.0	9.0
20	14.0	18.0	107.0	171.0	1.0	1.0	11.0	14.0

* ΔG_a = annual genetic gain
** c = difference between existing breed and half-bred with introduced breed
*** Ewes mated previous year, before replacements added.

The figures in Table 3 assumed no selection. Obviously selection can be imposed on crossing, and the situation would then become similar to one in

...cks drew from a superior nucleus (Table 2). There could be central
...-bred and cross-bred animals, as described in the Indian ex-
... Table 2 the difference between flocks and pure-bred
... and between flocks and cross-bred nucleus d_2. Rates
...uld supply the ΔG values.

...t always the same as inheritance within
... predicting the results of crossing.
...tion another. Does the Merino
...n likely to cause problems in
...is question is currently
...chieve...

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In reviewing the results of the experiment to 1965, Pattie and Barlow (1974) concluded that response had reached a plateau. However, it is not clear if response really has ceased; given the considerable year to year fluctuations in relative performance this would in any case be difficult to assess. In order to remove some of these fluctuations, the percentage differences between the flocks have been averaged for 5 four-yearly intervals (1952-55 drops, 56-59 etc.) and a final three year period (1972-74 drops). The Fleece Plus flock's superiority was then as follows: 11.8, 17.3, 17.7, 16.2, 19.1 and 19.8%. While this break-up of the data is completely arbitrary, it is suggested that response to selection is still being achieved, if at a slow rate.

(b) Adult Wool Production

In selecting for increased wool production, the general aim is to increase flock productivity. Hogget records are recommended as the basis for selections because they are available before animals normally enter the breeding flock, and because hogget performance is thought to be a reliable guide to an animal's breeding value for wool production.

Greasy fleece weights are available for ewes in the Fleece Plus and Random flocks for the period 1959 to 1971. The records were for shearings 2 to 7, when ewe ages ranged from 21 months to 6 years 9 months. The results indicate that selection for increased hogget clean fleece weight has increased greasy fleece weights at all adult shearings, as Brown, Turner and Dolling (1966) also found. For an improvement of 10 per cent in hogget clean fleece weight, adult greasy fleece weight has been increased by 7.7%, or by 0.35 lb greasy wool per head. A proportion of this gain would represent current flock gains, due to positive phenotypic regressions of adult fleece weights on hogget performance.

(c) Crimp and Diameter

Selection for increased fleece weight produced wool with fewer crimps per inch and with a higher average diameter. The most recent information indicates a reduction of 32% in crimp frequency (8.4 v 11.0 crimps per inch) in the Fleece Plus ewes, and an increase of 7% in average fibre diameter (21.2 v 19.9 μm). These changes, when expressed as realized genetic correlations, are in good agreement with expectations. In selecting for increased fleece weight, less selection pressure is lost maintaining average fibre diameter than if crimp frequency was kept constant.

(d) Live weight and feed efficiency

Selection for increased fleece weight has not lead to an increase in hogget live weights, confirming the earlier estimates of the absence of any genetic correlation between these traits. Averaged over the three most recent drops t Trangie (1972-1974), the Fleece Plus ewe hoggets were 3% lighter off-ears. Pen-feeding studies indicate that Fleece Plus ewes produce more wool than Random ewes primarily because they are more efficient and not because they eat more (Williams and Winston 1965).

(e) Wool Yield and Fleece Rot

Selection for increased fleece weight has increased yield, with yields in hogget ewe fleeces (1972-74 drops) averaging 67.7% in the Random flock, and 71.9% in the Fleece Plus flock. An increase in wool yield in the Fleece Plus flock would be expected from estimates of genetic correlations (Morley 1955), and has also been found in CSIRO flocks selected for increased fleece weight (Turner, Dolling and Kennedy 1968).

There is a danger that increasing wool yield will expose the fleece to fleece rot, weathering and dust penetration. For example, fleece rot predisposition has been shown to be positively correlated with yield, both phenotypically within flocks (Hayman 1953) and genetically across strains (Dunlop and Hayman 1958). Barlow (1974) examined data from four drops of ewes and found fleece rot scores (indicating both incidence and severity of fleece rot) to be higher in Fleece Plus ewes than in Random ewes. These data have now been extended to cover 12 drops of both rams and ewes and there is no evidence of any difference between the Fleece Plus and Random flocks. Despite this result, one has to ask if it is wise to continue to increase wool yield.

(f) Reproductive Performance

Published estimates of the correlation between fleece weight and reproductive performance are in poor agreement, even in sign (Turner 1969). The traits appear to be uncorrelated in the CSIRO Merino flock (Young, Turner and Dolling 1963; Turner, McKay and Guinnane 1972), while Kennedy estimated a strong negative correlation in the Trangie population.

Selection for increased fleece weight at Trangie has reduced the number of lambs born per ewe joined, by increasing the proportion of dry ewes. In the period 1962 to 1969, the average difference in the percentage of ewes lambing in the Fleece Plus and Random flocks was 12%. This difference appears to have existed since the early years of the experiment (Barlow 1974), without increasing in magnitude. Such a result may be peculiar to the Trangie flock, as this is the only population in which the incidence of dry ewes has been found to be heritable (McGuirk, in preparation).

CONCLUSIONS

Selection for increased hogget fleece weight at Trangie has been effective in increasing both hogget and adult wool production. Gains in hogget production have been of the order of 20% in the eight generations of selection since 1951. The initial rates of gain have not been maintained and the realized heritability of fleece weight is currently less than the estimate by

Morley (1955) obtained for the Trangie population. Despite this picture, it is not clear if a plateau has been reached, as Pattie and Barlow (1974) suggested.

Results from the Fleece Plus flock are of considerable relevance to recommended breeding programmes for the Merino industry. However, too much should not be read into the pattern of response in any one selection flock, as considerable variation can be expected between replicate selection lines (Hill 1974). Of much more general interest is the average pattern of response in the various selection lines for increased fleece weight currently maintained in Australia.

Correlated responses to selection for increased fleece weight are generally in good agreement with expectations, at least in direction. The negative genetic correlation with ewe reproductive performance deserves further study; a more detailed description of reproductive performance is clearly needed. The increase observed in wool yield may reduce the fleece's resistance to fleece rot, dust penetration and weathering. If, in selecting for increased fleece weight yield was maintained at a constant level, this would mean markedly reducing the efficacy of fleece weight selection programmes, by the order of 25 to 30%.

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13

SELECTION OF MERINO RAMS FOR EFFICIENCY OF WOOL PRODUCTION

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SUMMARY

Rams pre-selected for high body weight and high wool production were tested for feed utilization efficiency before final selection for use in a 1975 artificial insemination programme in Western Australia.

Twenty-seven Merino rams from the Australian Merino Society nucleus flock, were individually penned and conditioned on a diet composed of lucerne, formalin-treated rapeseed meal, wheat and mineral supplements, for three weeks. On completion of conditioning, the rams were fed the standard diet (16.7% C.P. 2.64 Mcal. DE/kg) for 100 days. Feed intake in these trials was restricted to maintain constant body weight.

Body weight of rams was correlated with both wool production ($r = 0.55^{*}$) and with maintenance requirements ($r = 0.93^{**}$). The mean production of clean wool per kg of feed was 16.4 ± 0.71 g; the larger rams being less efficient ($r = -0.463^{*}$). Substantial differences in feed conversion efficiency between animals of similar body weight were also recorded.

During 1975-76, twelve of the previously tested rams were fed at maintenance level for eight weeks while being used in artificial insemination. Their maintenance requirements then were 26% higher than during the period of testing when the rams were not in use.

INTRODUCTION

The rate of wool production is determined not only by the feed intake which reflects the availability and palatability of feed and appetite of individual sheep, but also by the efficiency of conversion of digested nutrients to wool (Ferguson, 1956). Differences in wool production between animals are associated with differences in feed conversion and the higher producers are usually the most efficient (Turner and Young, 1969). Dolling (1970) found no variation in ability of Merino sheep to digest the ration and stated that the efficiency of utilization of digested nutrients determines individual performance. A substantial proportion of the variability in fleece production between animals of similar body weight is caused by differences in the efficiency of food conversion. However, if there is a large difference in body weight, the contribution of efficiency is reduced and the feed intake accounts for a higher proportion of changes in wool production (Pattie, 1973).

RESULTS AND DISCUSSION

During the trial, four rams were removed due to low appetite and one with lameness. Three others were older than 18 months when the trial commenced and are not included in the results. Regression analyses were used to examine the relationships between:

(a) Body weight (x, mean = 67.6 kg, SE = 3.46) and feed consumption (y) for maintenance.

$$y = 1.67x + 6.56 \ (r = 0.932^{**})$$

(b) Body weight (x) and feed consumption (y) for maintenance in A.I.

$$y = 1.94x + 18.0 \ (r = 0.561^{*})$$

(c) Body weight (x) and clean wool production (y)

$$y = 0.015x + 0.93 \ (r = 0.552^{*})$$

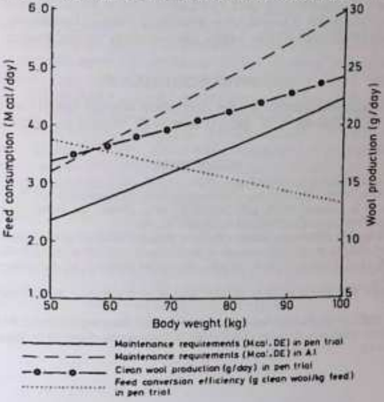
(d) Body weight (x) and feed conversion efficiency (y) (g of clean wool/kg of feed)

$$y = -0.10x + 23.4 \ (r = -0.463^{*})$$

* $P < .05$
** $P < .01$

Daily production of wool and daily feed requirements are presented in Figure 1.

Figure 1—Effect of liveweight on wool production and feed requirement of rams



Maintenance requirements were lower than those indicated by N.A.S. (1968). The expected relationship between food requirements and body weight was

$$D.E. = 2 \times 70 \text{ W kg}^{0.75} \qquad \text{N.A.S. (1968)}$$

but was in fact $D.E. = 2 \times 68 \text{ W kg}^{0.75}$

The difference is small and is in part accounted for by increase in wool weight on the ram during the trial period which was accompanied by a corresponding decrease in body tissues to maintain constant overall weight.

Difficulty has been experienced maintaining the body weight of working rams during the A.I. period. The 26% increase in maintenance requirements recorded here (although significant) is insufficient to account fully for the problems encountered. It seems that rams have depressed appetites during the working period as well as a higher maintenance requirement.

The results show an expected increase in maintenance requirement with higher body weight. Wool production increased at a lower rate with the result that feed conversion efficiency was significantly less for large rams than small rams ($P<0.05$). This confirms trends observed in previous years.

This subject is important because the Australian Merino Society places much emphasis on body weight in its selection index. It seems this may be reducing improvement in the efficiency with which sheep convert feed to wool.

Clearly it is important to have more information about this relationship. Until this is available, it would seem sensible to restrict comparisons of feed conversion efficiency to rams within narrow body weight ranges.

ACKNOWLEDGEMENTS

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SELECTION FOR INCREASED PROFITABILITY IN A FINE WOOL MERINO FLOCK

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SUMMARY

An integrated selection programme practised on a fine wool Merino flock in western Victoria is described and discussed. The characters selected for, collection and use of data, and integration of the programme is described. Data indicating heritability of susceptibility to tender wool and independently to worm infestation is presented and discussed. Selection for increased Clean Fleece Weight, using a rating derived from the Clean Fleece Weight of each sheep compared to its micron, is explained and compared to selection using Clean Fleece Weight alone.

INTRODUCTION

The shift in stock breeding towards objective assessment and separate selection of individual characters and the division from intuitive holistic selection has been a subject of debate and interest for years. The many attempts to integrate these methods are clearly of interest.

The economic success of a selection programme depends on the total effect of the whole scheme, and the success of any programme is difficult to evaluate, let alone anticipate. The economic value of selection for any individual character depends on the level of that character in the population under selection since the economic value will depend on the rate of progress made, and different rates of progress will be made when the desired character is at different levels. Excessive emphasis on a character can be economically as damaging as neglect—it is unfortunate that characters vary in their ease of measurement, since when measurement is practised those characters measured are often overemphasized. Holistic, intuitive assessment, with objective data presented, is suggested as the only practical way of balancing and integrating a selection programme.

Constitution in stock is considered an important characteristic, though constitution, and its selection, is seldom clearly defined. Heritability of constitution has long been assumed, and in practice demonstrated. Variation between and within populations of sheep exists for the characteristic. The separation of constitution into characters, and the performance of these in independent gene pools, is thus clearly of interest.

The selection programme discussed is part of a commercial enterprise. The sole aim is to increase profitability by:

METHODS, RESULTS AND DISCUSSION

(a) Increased Production

(i) Wool Production

The quantity of wool production is increased mostly by careful classing using fleece test ratings. All 1 year old rams (to be classed to stud, flock, or sale next year) and all replacement stud ewes are fleece tested.

Fleece test ratings are derived from graphs made independently for each group of ewes or rams that are run together and are of the same age. The graph is made from the Clean Fleece Weight (CFW) of each sheep plotted against its micron (see graph in Appendix), an average line of best fit is constructed to suit the cloud of individual measurements. (The gradient of this line varies from group to group, but a decline in CFW with finer micron is always seen.) Lines are then drawn parallel above and below the line of best fit at 0.23 kg intervals. These lines are used to determine each sheep's CFW/micron rating, all sheep within the same pair of parallel lines have the same rating, which is different to all the other sheep on the graph. The classes immediately above and below the line of best fit are always labelled C and D respectively, and ratings range from A++ to G. There are two advantages of this method. Firstly, as each ram is presented for classing at 2 years old the classer is given a simple, effective and easily comprehensible rating which replaces the confusion of giving two figures that are only of importance in relation to each other. Secondly, as Tables 1 and 2 demonstrate, this method prevents the shift towards the stronger average micron in the next generation that would result from CFW selection independent of micron.

TABLE 1

COMPARISON OF SELECTION OF TOP 50 RAMS USING CFW and CFW/MICRON RATING

Method of Selection	Micron Group >20.0	19.9-18.5	18.4-17.0	<17.0	Total
CFW with micron rating					
Classed in	—	17	26	6	50
Classed out	4	7	20	1	31
CFW alone					
Classed in	2	21	25	3	51
Classed out	2	3	21	4	30

TABLE 2

NUMBER OF SHEEP MISCLASSED USING CFW SELECTION RATHER THAN CFW/MICRON RATING SELECTION

	Micron Group				
	>20.0	19.9-18.5	18.4-17.0	<17.0	Total
No Rams					
Classed in	2	4	—	—	6
Classed out	—	—	2	3	5

Figure 1—Clean Fleece Weight in relation to fibre diameter (1973 drop rams)

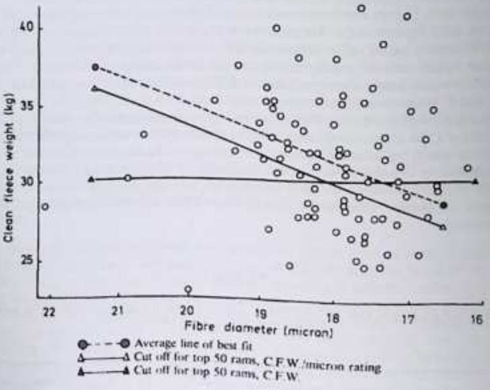

Figure 1 shows the line of best fit drawn for the 1973 drop rams. The fleeces were grown between August 1973-74, 4-16 months old. Usually about 50 rams are retained to service the stud and flock; the graph shows the cut-off lines for the top 50 for CFW or for CFW/micron rating. For this group of 81, 13.6% of rams would be misclassed using independent CFW selection, and this would result in a shift towards stronger micron. Sheep with the most different micron from the group (< 10%), particularly at the stronger end of the range, do not usually conform to the trend in the graph.

The replacement stud ewes are given the same fleece test, the top 20% CFW/micron rating ewes are called weight elite ewes. Half of these are mated to the most superior stud sires for CFW/micron rating—to increase the probability of breeding superior wool cutting sheep.

(ii) Sheep Production

To increase sheep production/ewe mated account of the mother's breeding performance is taken in selecting the stud sires. Rams with mothers that have been both regular and successful (low culling rate of progeny) breeders are preferred. As well, some of the very successful ewes are carried on under special care when their mouths deteriorate (when they would normally be culled) to breed more lambs. At classing some size and fleece weight is allowed for twins, but there is no direct bias for twinning. Twinning should, for a flock run under similar environmental conditions over several generations, already be at the optimal level for the flock. The level of twinning in the flock discussed can be explained by the very high mortality of both twins in a poor season. Selection towards a higher rate of twinning could result in a decrease in lambing success—through increase in the proportion of mortality to births and through increases in culling—unless environmental conditions are altered.

Lambings that require assistance are noted on the cards of the lambs and ewes; passenger and barren ewes are culled.

(b) Quality of Production

Quality is assessed at classing, and a lot of importance is placed on it. At classing, the sheep that as lambs showed wrinkles and primary follicles are checked for these characters—thus there is little possibility of missing faulty sheep, particularly since these faults are at very low levels (cullings for hair and wrinkles being less than 1%).

(c) Decreased Cost of Production

Selection towards decreased cost of production has been increased with a shift towards minimal management—with low cost and labour input.

The stud sheep are run under similar or more rigorous conditions compared with flock sheep—classing leading to selection of sheep most suited to commercial conditions. It is a tragedy that the market place forces those whose income comes mainly from the sale of sires to treat their stock to more favourable conditions than the progeny of the sire sold.

Weaner rams are deliberately run on poorer quality pastures during summer to "sort them out". The sheep that continue to produce satisfactorily and do not show tender wool, are of interest. Both young stud ewes and rams are run without supplementary feeding, and under a low drenching regime. Young stud sheep are classed at two years old when 18 months has usually passed since the last drenching.

(i) Tender Wool

Table 3 indicates difference between stud sires in the susceptibility to tender wool. These differences are repeatable. Thus, no ram showing tender wool as a 1 year old is used as a stud sire.

TABLE 3

TENDER FLEECES, 1973 DROP RAMS

Progeny group	No. tender fleeces	Total in group
A	3 (25%)	12
B	3 (33%)	9
C	—	6
D	1 (10%)	10
E	2 (25%)	8
F Syndicate	1 (7%)	14
G Syndicate	3 (13%)	23

(ii) Worm Infestation

Groups of the same age run together and are examined for scouring (the staining of wool with faecal material). The amount of scouring is categorized:

Clean—no contamination from scour.

O.K.—some stain, superficial and not sufficient to cause flystrike.

Plug—some dagging on the wool around the anus, restricted to this area but sufficient to allow flystrike.

Very Dirty—extensive scouring covering a considerable area around the anus, and showing accumulation of dags on the back legs and scrotum.

In practice scouring can be attributed to several factors—worm infestation, changes of feed, and illness. Young stud sheep, rams and ewes, have been examined in the last two years when less than 1 year old and at 1.5 years. In each case the whole group, and all individuals within it, had not been drenched for several months, and in each case considerable differences existed between the sires' progenies.

Tables 4 and 5 show the figures for two consecutive drops of rams at a similar age, and the age of the sheep and the conditions at the time allow scouring from causes other than worm infestation to be disregarded. The data clearly indicates heritability of susceptibility to the effects of worm infestation. The ewes that bred these rams were mated randomly with regard

TABLE 4

SCOURING FOR 1973 DROP RAMS* ON 26 NOVEMBER 1974

Progeny Group	Degree of Scouring % Clean	O.K.	Plug	Very dirty	No. rams
A		33	50	17	12
B	22		45	33	9
C			50	50	6
D	40	10	40	10	10
E	22	33	45		9
F Syndicate		21	58	21	14
G Syndicate	17	9	61	13	23

* Last drenched 28/9/73, run together since 2 months old.

TABLE 5

SCOURING FOR 1974 DROP RAMS* ON 9 SEPTEMBER 1975

Progeny Group	Degree of Scouring % Clean	O.K.	Plug	Very dirty	No. rams
F	50	38	12		8
G	84	8		8	12
J	100				2
L	75	25			8
M	60	20	20		10
R	75		12.5	12.5	8
S	55	33	11		9
W Syndicate	—	50	43	7	14
X	89	11			9
Y	75	8	17		12
Z	80	20			5

* Last drenched 15/8/74, run together since 2 months old.

to this character, and the sires selected to breed these rams were considered the best rams overall.

It is of relevance that the sire of the X1974 drop rams has never scoured and now has not been drenched for 3.5 years, and the sire of this ram was the father of the E1973 drop rams, the most superior group for this character in their drop. The B and C1973 rams made the W1974 syndicate, the C1973 ram siring the majority of lambs. For the 1974 drop rams, the F, S, and W groups were the only ones sired by older rams that were not selected as stud sires after experiencing minimal drenching and care, and these showed the greatest amount of scouring.

Differing resistance to parasites is seen between and within breeds of sheep. The differences observed suggest a value in selecting for increased resistance or tolerance since the cost in production loss, and treatment for worm infestation at high stocking rates is considerable. The differences shown within Tables 4 and 5 suggest that rapid progress can be made.

It can be seen that heritabilities of Clean Fleece Weight, susceptibility to worm infestation and to tender wool appear to function independently. (The B and C1973 drop rams were the relatively heaviest cutting rams, and their progeny were the heaviest cutting group. However, C1973 rams were the most susceptible to the effects of worm infestation, but showed no tender wool, whereas B1973 rams showed a considerable amount of tender wool, though they were not so inclined to scour.)

(d) Integration

The integration and balancing of the selection programme is effected by tha sheep classer. His judgment evaluates the characters and assesses their importance in the sheep and in the flock. The success of a breeding programme rests squarely on his shoulders. None the less, it would appear that factors other than those generally selected for may well have a significant influence on the overall efficiency of a sheep enterprise and may be worthy of consideration in the selection of breeding stock.

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THE IMPACT OF ENVIRONMENTAL FACTORS ON SHEEP BREEDING IN THE SEMI-ARID TROPICS

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SUMMARY

Modifications to the existing environmental conditions (e.g. provision of natural shade) can lead to a significant improvement in the production performance of tropical sheep. Alternatively, the selection of "adapted" animals from within the existing gene pool also leads to significantly better production performances. The judicious use of both strategies together with the infusion of genetic material from high producing animals from more temperate regions are discussed in relation to the environmental physiology of tropical sheep.

INTRODUCTION

The harsh semi-arid tropical environment exerts a profound influence on the production characters of sheep. Animals are of small body size, return low wool cuts and exhibit a poor reproductive performance. Any attempts to improve productivity from tropical areas may include an alteration of the natural environment to lessen its impact on the animal or, alternatively, the breeding of sheep which are capable of adequate production under existing environmental conditions. This chapter examines these strategies in relation to current research efforts in semi-arid tropical Queensland.

METHODS AND RESULTS

(a) Alterations to the environment

The provision of shade is an obvious means of alleviating environmental heat stress. This treatment can be included in management strategies at the time of joining to improve the pregnancy rate of Merino sheep (Table 1).

Shade facilities can also be used to improve lamb survival. Heat stress in the last month of pregnancy markedly restricts the growth rate of the foetal lamb in the absence of nutritional intervention (Table 2).

Since the low survival rate ($\approx 20\%$) of small birth weight lambs (< 2 kg)is an important aspect of reproductive wastage in this environment the provision of shade can be of marked benefit to pregnant ewes and newborn lambs.

TABLE 1

THE SIGNIFICANT ($p<0.01$) EFFECTS OF SHADE AND IODINE SUPPLEMENTATION AT JOINING ON THE PREGNANCY RATE OF SUMMER–JOINED MERINOS

Group	Number of Sheep	
	Joined	Pregnant
Control	196	112 (57%)
Shaded	199	145 (73%)

TABLE 2

THE EFFECTS OF MATERNAL HEAT STRESS ON LAMB BIRTH WEIGHT

Group	Lamb birth weight (kg)	Ewe live weight (kg)
Heated	2.3	39.2
Control	3.6	39.0

Ewes were paired on the basis of foetal size (110 days) and pair-fed during treatment period

The propagation of natural shade trees is an economical and practical means of altering the environment. A glen of 66 Athel pine (*Tamarix aphylla*) cuttings have attained a height of 2.5 m in the 18 months since planting. This shade glen covers an area of 10,000 m^2 and as such offers an excellent means of tempering environmental heat stress to maximize fertility.

(b) Selection for environmental adaptation

Studies in environmental physiology have identified "adapted" Merinos within the existing gene pool. These animals have a significantly lower rectal temperature and respiration rate when exposed to summer conditions (Table 3).

Adapted sheep also exhibit significantly better production performances than their less adapted counterparts in the same flock (Table 4).

The measurement of sweating rates of tropical sheep has shown that this avenue of evaporative water loss (200 ml/h) greatly exceeds the respiratory component (50 ml/h). The significance of this finding in relation to body

TABLE 3

MEAN RECTAL TEMPERATURES AND RESPIRATION RATE OF "ADAPTED" AND "NON-ADAPTED" SHEEP DURING EXPOSURE TO SUMMER CONDITIONS

Group	No. of sheep	Mean rectal temperature (°C)	Mean respiration rate per min.
Non adapted	50	40.1	185
Adapted	48	39.2	110

Differences are significant $p<0.01$.

TABLE 4

THE RELATIONSHIP BETWEEN EWE BODY TEMPERATURE AND PRODUCTION PERFORMANCE (LIVEWEIGHT, PREGNANCY RATE)

Group	No. of sheep	Ewe liveweight* (kg)	Pregnancy rate*
Adapted	98	39	58%
Non-adapted	103	35	36%

* ($p<0.01$).

temperature regulation of woolly sheep and the degree to which this index can be used to screen animals for environmental adaptation await elucidation.

Assessments of the respiration rates of sheep exposed to environmental heat stress is currently the most successful means of identifying "adapted" sheep. In screening animals on this basis it is essential to undertake the test at a time when environmental conditions maximize the between sheep differences in thermoregulatory efforts. Significant ($p<0.01$) rectal temperature differences between "adapted" and "non-adapted" sheep were demonstrated when ambient temperatures exceed 37°C. These differences were not significant when ambient temperatures were below 37°C. This threshold can merely be taken as a guideline, since the efforts of humidity and flock genotype would be necessary considerations for each set of circumstances.

DISCUSSION

When considering the impact of a tropical environment on sheep breeding programmes it is pertinent to first establish the importance of both physiological and behavioural responses to environmental conditions. If an adequate availability of natural shade and pasture allows sheep to adopt grazing patterns which minimize exposure to heat stress then the animal's behavioural responses may be of paramount importance. Alternatively, lesser amounts of shade and available pasture may produce symptoms of heat stress in more temperate regions, particularly when the strain or breed of sheep pastured in that region has poorly developed adaptation mechanisms. It is necessary, therefore, to consider the type of sheep and the prevailing conditions in an integrated fashion in order to make valid judgment of the importance of the type of genetic material which should be propagated in a particular environment.

It is apparent from the results presented herein that it is possible to improve the productivity of tropical Merinos. This can be achieved by either altering the existing environment or selecting adapted sheep from within the existing gene pool. It is not yet clear what further gains can be made by the judicious use of both strategies. The provision of shade is both economically and practically feasible. The selection of "adapted" Merinos is most easily undertaken by an assessment of respiration rates during exposure to natural summer conditions. The physiological mechanisms underlying the expression of this adaptation are however obscure.

It would also be possible to select tropical animals on the basis of production performance. Ram breeding programmes aimed at achieving this goal have been initiated at the Toorak Research Station. These studies assume that the increased production stemming from environmental adaptation can be readily measured and propagated provided that natural environmental conditions prevail at the time of selection. More basic studies of environmental physiology are however indicated so that the gene pool can be prudently extended beyond the bounds of that currently available in the region. The ceiling for production may well be further increased by the infusion of genetic material from more temperate parts of the continent. Some of the likely attributes of this strategy are presented in the next chapter in this book (Stephenson, Tierney and Hopkins).

It is possible that exotic sheep may be of some benefit to the breeding programmes of tropical Merinos if the future wool and mutton markets warrant their inclusion. An evaluation of the environmental adaptation of such animals could be made by preliminary observations of respiratory rates during exposure to conditions which mimic the natural summer conditions in Australia. The integration of this data with more general information pertaining to the physiological, behavioural and genetic implications of their introduction would obviously be indicated. The likely impact of their importation to Australia would need to be substantial if it is to outweigh the long-term disadvantages of changes in wool quality and the establishment of numerous breeds and their associated societies.

HUSBANDRY AND GENETIC CONSIDERATIONS AFFECTING SHEEP BREEDING IN THE SEMI-ARID TROPICS

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SUMMARY

The implementation of breeding programmes and collateral husbandry techniques can increase the productivity of tropical Merinos. Significant increases in lamb survival, lamb growth rate, mature live weight and greasy fleece weight are reported. The impact of these findings in relation to the development of flocks of improved fertility and/or dual-purpose qualities are discussed.

INTRODUCTION

A great disparity exists between the productivity of tropical Merinos and their counterparts depastured in more temperate climates. This disparity highlights the problems associated with sheep breeding in the tropics. Nutritional inadequacies and climatic extremes impose severe restrictions on production throughout much of the year. Survival rates of adult sheep are comparable to those of other environments, however, production and reproductive efficiencies are markedly lower (Moule, 1966; Rose 1972). Average live weight of ewes is 40 kg, fleece-cuts average 3.5 kg and lambs marked average 40%.

This chapter integrates the results of three experiments aimed at improving the productivity of tropical sheep by both genetic and husbandry procedures.

METHODS AND RESULTS

(a) Breeding for lamb survival

Three strains of Merino rams were joined to 1,200 indigenous ewes for one oestrous cycle. Ewes were synchronized with 0.15 mg of stilboestrol and joined in the second cycle after injection. Rams were representatives of indigenous animals (locally bred for longer than 10 generations), transient animals (locally bred for 2-3 generations) and introduced animals (South Australian Merinos).

At an average gestational age of 125 days, ewes were pregnancy tested (Pratt and Hopkins, 1975). No real difference in conception rate occurred between sires (Table 1). Pregnant ewes were divided into the three sire groups and placed in equal sized paddocks with similar amounts of shade and water. Biomass of pastures was in excess of 2,000 kg/ha, this being considered more than adequate at the stocking rate of one sheep to 5 ha. Average maximum and minimum temperatures during the last six weeks of pregnancy and the first four weeks of lambing were 33.6°C and 19.2°C respectively. This temperature range constitutes mild conditions for the tropics. At an average age of four weeks the progeny of the three groups were weighed and survival rates were recorded. Significant differences occurred between the three groups (Table 1).

TABLE 1

REPRODUCTIVE PERFORMANCES OF INDIGENOUS, TRANSIENT AND INTRODUCED SIRE STRAINS

Ram strain	Conception rate (%)	Progeny	
		Survival (%)	Live wt (kg)
Indigenous	58	61 † *	7.9 †
Transient	59	71 †	8.1
Introduced	58	80 † *	8.4 †

Lamb weights recorded at mean age one month
† $p<0.05$
* $p<0.01$

(b) Breeding for diversification

Greasy fleece weights and mature live weights of indigenous and introduced rams and ewes were compared. Introduced sheep were allowed a one year acclimatization period before the commencement of the experiment. The measurements were made under normal paddock conditions when good seasons prevailed. The ram measurements were taken from those animals selected for the sire evaluation study. The introduced ewes were also South Australian Merinos however they were of a different stud origin. The results show significant differences ($p<0.05$) between indigenous and introduced ewes and rams (Table 2).

TABLE 2

GREASY FLEECE WEIGHTS (GFW) AND MATURE LIVE WEIGHTS FOR TWO MERINO STRAINS

Strain	♀ GFW (kg)	♂ GFW (kg)	♀ Live wt. (kg)	♂ Live wt (kg)
Indigenous	3.50	2.24*	40	51
Introduced	4.27	2.70*	45	60

* GFW for seven months wool growth only
Introduced animals had significantly higher fleece weights and live weights ($p<0.05$)

(c) *Supplementation for lamb survival*

Practical aspects of improving lamb survival as a collateral husbandry measure to animal breeding programmes were investigated. Urea was used to improve the nutritional status of lambing ewes. A pen study was designed to compare the growth rate of lambs born to ewes fed an ad lib. basal diet of pelleted pasture hay (5.5% CP) or the basal diet containing 10 g urea per kg ration. Twenty control and 20 treated ewes were introduced to pens two weeks before expected parturition. Measurements were continued until three weeks post-partum.

A significant improvement ($p<0.01$) was measured in the growth rate of lambs in the treated group. In fact these animals were 48% heavier than the control lambs at three weeks of age.

In a follow up field study 600 pregnant ewes were divided into four groups and run in four half-square-mile paddocks when mild environmental conditions prevailed. Two groups of ewes each received urea at the rate of 1 g/l in the drinking water. Lamb weights and survival rates were recorded three weeks after the last expected birth.

An improvement in the survival and growth rate of lambs (4% and 12% respectively) occurred in the supplemented groups. The improvement in lamb growth rate was significant ($p<0.05$).

DISCUSSION

The low survival rate of newborn lambs in this environment is *the* major cause of reproductive wastage. If lamb survival could be increased then local producers would be in a position to implement breeding programmes and cull sheep on production performance; a strategy which is currently unavailable to them because of the low net reproductive rate. The results presented in Table 1 indicate that lamb survival may be significantly increased by pertinent genetic manipulations. It is likely that the indigenous lambs have a relatively poor ability to survive under even mild conditions. Conversely, introduced animals of higher fecundity (e.g. South Australian Merinos) may express this trait in terms of improved lamb survival. Evaluation of other strains of introduced animals of high fecundity is a logical progression of this study. The judicious use of such strains may have a desirable impact on the productivity of existing indigenous flocks. However, such use would need to embrace collateral considerations of the environmental physiology of the introduced strains, the ways in which husbandry strategies could temper the rigours of the tropical environment, and the genetic stability and wool quality of the strain evolved.

The future market value of wool and mutton must be regarded as unpredictable. The growing demand for mutton by South-East Asian, Middle East and local mining town markets has prompted an investigation into the feasibility of developing dual-purpose animals in tropical Queensland.

The plane of nutrition and the geographical situation of the area means that it is well placed to provide lean hogget carcasses of approximately 20 kg. The dual-purpose tropical sheep may offer producers in this area a type of diversification necessary to enhance their future viability. The ever spiralling costs of production exert a more profound influence on tropical sheep raising enterprises where the efficiency of present production is lower than that of more temperate areas. The results from Tables 1 and 2 suggest that the development of a dual-purpose animal is possible through further genetic manipulations of Merino strains. The initial studies also indicate that it might be possible to effect a concomitant improvement in lamb survival and wool growth. The perils of propagating introduced species without due regard to studies in environmental physiology may however subsequently reveal themselves in the form of low productivity and even higher mortality rates when harsh conditions prevail in the area. The attributes of the indigenous Merino to survive in these conditions is a pertinent reminder of the hazards which confront the injudicious use of introduced strains in a breeding programme.

The success of a breeding programme depends very largely on the net reproductive rate of the flock. Husbandry techniques aimed at improving lamb survival in this environment are therefore important collateral considerations. The data presented in the results indicates the value of providing urea to pregnant and lactating ewes on a poor plane of nutrition. The implementation of such a strategy could therefore be regarded as an integral part of the development of breeding programmes outlined in this chapter.

The data presented in this chapter are largely preliminary in nature. They do however serve to highlight the possible options which are open to research workers and producers alike in their efforts to improve the efficiency of production of tropical sheep.

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THE INFLUENCE OF PARASITES ON SELECTION PARAMETERS IN SHEEP

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SUMMARY

Four years of detailed experimentation has shown that commonly practised levels of parasite control may not enable sheep to express fully, their true characteristics and potential.

Under conditions which favour the parasite, mortalities can seriously reduce the selection potential in a breeding flock. Furthermore, an adverse effect on body size, the ratio of primary to secondary follicles and total greasy wool production resulting from parasitism in the first year of life can be permanent and result in the culling, on an objective measurement basis, of some individuals which may otherwise have found their way into the flock.

The effect of four different levels of parasitism on total wool production, fibre diameter, staple length, yield, tenderness and wool manufacturing qualities indicates the degree of variation from the inherent potential which can result.

This chapter does not attempt to answer the question as to whether it is desirable or not, to select sheep under conditions where the effect of parasites is suppressed, or in areas where parasite damage is minimal. It aims to report the nature and extent of change which can occur in parameters normally taken into account in selection.

INTRODUCTION

It is not unusual for rams to be bred and selected in one environment and used in another environment. The stud can be located in a winter rainfall area and the flock in a dominant summer rainfall location. Similarly, there can be interchange between dry and wet environments.

Selection using various parameters can occur under conditions where there has been minimal exposure or stress from parasites of various species imposed on the population.

This chapter does not attempt to answer the question as to whether it is vironment of the flock or elsewhere but aims to document the nature and extent of the effect of parasites on some of the parameters commonly used in selection. Furthermore, the evidence will suggest the nature of the differences which might appear in a tableland flock based on a stud located in a minimal parasite damage situation when sub-optimum levels of parasite control are practised.

MATERIALS AND METHODS

The data presented in this chapter originated from an experiment conducted at Clover Park, the Applied Rural Research Station of Merck Sharp & Dohme (Australia) Pty. Limited, near Hamilton in the Western District of Victoria. The sheep were fine-woolled Merinos of local origin and were first selected from a flock of 550, discarding 150 which included firstly the wrinkly and atypical-woolled sheep and then similar numbers of the heaviest and lightest sheep in the flock. In January 1972, the 400 five to seven month old wethers were randomized on liveweight rank order to 16 paddocks of 1.56 hectares. Four paddocks of 25 sheep were subjected to each of four parasite control programmes based on the broad spectrum anthelmintic, thiabendazole. After 331 days, the 16 groups were put into one mob and run together under identical management, during 1973 and 1974.

(a) *Parasite Control Programmes*

Four programes designed to permit four levels of helminthiasis were used. These were:

SUPPRESSIVE — Eleven drenches, given monthly to minimize continuing re-infection.

PREVENTIVE — Three drenches, given on a pre-planned calendar basis in January, (at the start of the trial), and in July and September.

CURATIVE — Treatment when there was a visual indication of parasite damage. Drenches were given in April, July and October.

SALVAGE — Only individual clinically affected sheep were treated to avert death.

(b) *Management and Measurements*

Except for parasite control, all sheep were managed in the same way and were vaccinated, jetted and injected with testosterone paste to minimize disease other than helminthiasis. A uniform stocking rate was maintained in all paddocks during 1972 by adding replacement sheep when deaths occurred.

At shearing, the fleece and belly-wool were weighed together to give total greasy fleece weight and later the skirted fleece was weighed separately. Individual mid-side samples were taken to determine yield, fibre diameter, staple length, tenderness and for classification of each fleece into Australian Wool Corporation (A.W.C.) types. Skirtings, pieces and belly-wool were aggregated separately on a replicate basis, weighed and sampled for yield and A.W.C. type determinations.

In 1972, live weights and parasitological data were collected at monthly intervals. Later, during 1973 and 1974 when the sheep were running as one flock, these data were collected at less frequent intervals. At the conclusion of the trial, 20 sheep from the original Suppressive and Salvage regimes were selected at random and mid-side skin sections taken. Body size measurements were also made on all the surviving sheep in the same two contrasting groups.

RESULTS

Live weights, greasy wool production and changes in sheep numbers are shown in Table 1 a, b and c.

TABLE 1

LIVE WEIGHTS (kg); GREASY WOOL PRODUCTION (kg) AND SHEEP NUMBERS

		PARASITE CONTROL PROGRAMME			
		Suppressive	Preventive	Curative	Salvage
(a)	Live weights				
	22. 1.72	21.3	21.4	21.4	21.3
	5.12.72	43.9	40.9	39.7	33.6
	16.11.73	58.0	57.0	57.4	54.3
	29.11.74	59.1	59.6	59.4	57.2
(b)	Greasy wool weight				
	1972	3.59	3.11	2.90	2.46
	1973	5.32	5.27	5.38	4.92
	1974	5.00	4.73	4.95	4.95
(c)	Sheep numbers				
	22 1.72	100	100	100	100
	5.12.72	99	96	91	82
	16.11.73	96	96	91	82
	29.11.74	95	95	91	82

The effect of the four parasite control programmes on wool quality and characteristics is shown in Table 2.

TABLE 2

WOOL QUALITY AND CHARACTERISTICS IN 1972

	PARASITE CONTROL PROGRAMME			
	Suppressive	Preventive	Curative	Salvage
Clean scoured yield (%)	73.3	71.8	71.7	74.6
Fibre fineness (microns)	17.8	17.2	17.0	16.6
Crimps per inch	16.2	16.7	17.0	18.1
Staple length (cm)	8.8	8.5	8.4	7.8
Sound fleeces (%)	96.0	78.1	70.3	65.4
Actual break (%)	0.0	4.2	3.3	12.3
1976 value (AWC minimum reserve price) ($)	6.92	5.81	5.40	4.86

Wool production is a strongly inherited character in sheep (Jackson *et al*, 1975) and is an important parameter used in selection in Merino flocks. The effect of four programmes of parasite control on the distribution of greasy fleece weights of young sheep has been shown in Figure 1. It is clear that there is not a uniform effect through the flock which decreases fleece weight proportionately, but rather, a sorting out of levels of susceptibility or ability to avoid infection. The histogram changes from the more classic type distribution to a multimodal battleship formation.

The skin sections and body measurements taken after two years of common management showed a trend towards a persisting decreased ratio of secondary to primary follicles from severe helminthiasis in the weaner year, but this was not significant from the 20 sections examined (Table 3). The decreased mean fibre diameter in the salvage programme sheep was significant and medullated fibres were also seen in these sheep, but not with the suppressive programme. All the body measurements indicated that helminthiasis in the weaner year had resulted in some permanent stunting, but none of the differences were found to be significant.

TABLE 3

SKIN HISTOLOGY AND BODY MEASUREMENTS OF THE SHEEP FROM THE SUPPRESSIVE AND SALVAGE PROGRAMMES IN FEBRUARY 1975

		PARASITE CONTROL PROGRAMME		
		Suppressive		Salvage
(a)	*Skin histology*			
	No. of sheep	20		20
	Secondary/primary follicle ratio	24.9	N.S.	23.8
	Mean fibre diameter (microns)	19.4	P<0.05	18.5
	Primary/secondary fibre diameter ratio	0.98	N.S.	0.99
	Medullation (%)	0		0.04
(b)	*Body measurements (mm)*			
	No. of sheep	95		82
	Chest depth	312.60	N.S.	305.90
	Hind cannon bone length	216.34	N.S.	214.11
	Pelvis width	176.49	N.S.	176.38
	Pelvis length	231.49	N.S.	228.94

DISCUSSION

At the end of 1972, substantial differences in live weight had developed between sheep on the different parasite control programmes. Similarly, there was an increase of 1.13 kg or 45.9% in wool production for the year during which the Suppressive programme was used. The other programmes gave less dramatic results but there was still a potential of 0.48 kg greasy wool above the production from a three drench programme commonly practised in the area.

Wool from the four treatment programmes was processed to the stage of combed top and showed significant increases in noil and card loss as the level of parasite damage increased (Lipson and Bacon-Hall, 1976). In the combed top, mean fibre length decreased; "neps" which create problems with the cloth making machinery and in the dyeing processes were also substantially increased.

When the economics of intensive parasite control were examined and the costs of labour, materials and mortalities estimated, the gross margin was still increasing to the highest level of the Suppressive programme (Johnstone *et al*, 1976).

During the second year, when all sheep were given identical treatment, the two intermediate programmes caught up substantially in body weight and wool production, but the Salvage group still lagged behind. By 1974, the gap had substantially closed for both wool production and body weight. In considering the compensatory gain which had occurred, the higher mortality eliminating some of the smaller sheep in the less intensive programmes may have biased the results in their favour. It is of interest to note also, that whereas the wool yields for the Salvage programme were the highest in 1972 (Table 2), in 1974 they were lowest; namely 73.3 for the Suppressive programme and 71.2 for the Salvage groups in 1974. This suggests that some of the compensatory gain in greasy fleece weight may have come from fleece constituents other than wool.

The body measurements of the Suppressive and Salvage groups also indicated a trend towards a permanent stunting from helminthiasis in the weaner year, but these differences were not statistically significant.

These results show that parasites can have an effect on several of the parameters used in the selection of Merino sheep. Selection of breeding stock for studs and for commercial flocks takes place most frequently in sheep between 12 and 18 months of age and the effects of any helminthiasis would still be evident at that time.

In the case of greasy fleece weight, the effect of parasites is not merely to reduce fleece weights proportionally, but differential susceptibility to infection and to the parasite effect results in a skewed and protracted distribution of fleece weights.

Fibre diameters are also important, particularly in the selection of stud rams, as this character is strongly inherited. In this parameter, there can be a decrease by one micrometre in the mean fibre diameter of a group of sheep subjected to helminthiasis. The difference would be greater in individual sheep. Under similar conditions, mean staple length can decrease by one centimetre. The effects on the secondary to primary follicle ratio and on body

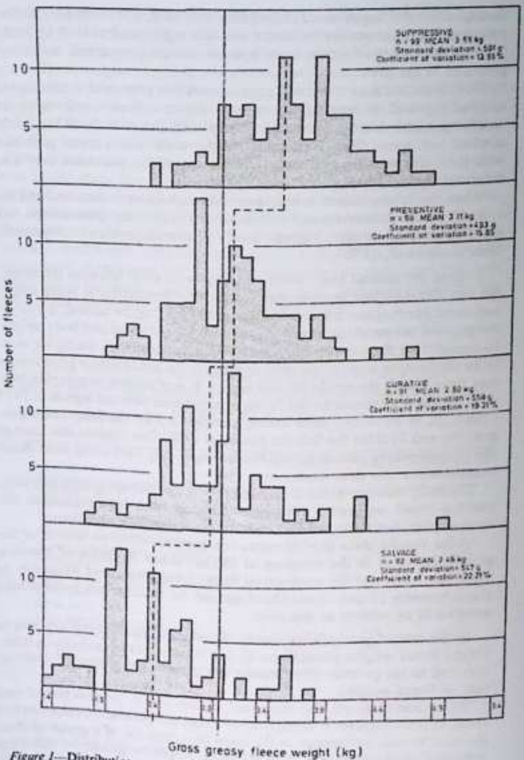

Figure 1—Distribution pattern of greasy fleece weights in Merino wether weaners on four parasite control programmes in 1972. (Growth period 331 days; mean all sheep 3.04 kg).

size were marginal and while they suggested trends in the direction of fewer secondary follicles and smaller sheep following helminthiasis, these trends were not found to be significant.

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GENETIC IMPROVEMENTS OF FERTILITY AND FLY RESISTANCE

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INTRODUCTION

The traditional procedure in developing sheep breeding plans is to estimate genetic parameters in the population needing improvement and sometimes to provide a check on these estimates by establishing selection flocks. This approach has proved to be completely adequate in developing breeding plans for the improvement of characters such as wool production traits.

A new sheep breeding research programme has recently commenced at Trangie Agricultural Research Station in which this traditional approach has not been followed. Description of this programme is given, attempts are made to explain and justify the procedure adopted and some of the early results which have been achieved are presented.

BACKGROUND TO EXPERIMENT

The aim of the research programme is to develop approaches to improve reproductive performance, and resistance to fleece rot and body strike. Using a traditional approach, the character under selection would be scored or measured on potential breeding stock and then those animals which meet this need (that is, have a high level of fertility, high resistance to fly strike etc.) would be selected. However, with the characters currently under discussion, this approach has limitations.

Selection for reproductive performance is hampered by the sex-limited nature of the trait, and by the limited and discrete range of possible states an animal may have (for example, born as a single or twin, a ewe having 0, 1 or 2 lambs). The discrete nature of the trait is probably partly responsible for the low heritability of fertility characters.

Fleece rot and fly strike tend also to be discrete characters in that an animal either has the conditions or not. Additionally, the incidence of these characters within a flock is very much influenced by climatic factors, especially rainfall. Thus, in many years the incidence of either condition is very low so that selection within a flock is not continuous and relatively ineffective in most environments.

It is therefore hoped to uncover other characters which will enable more rapid improvement to be made in reproductive performance, and fleece rot and fly strike resistance, than with direct selection for these latter characters. These other characters must show considerable variation, have a high heritability and, most importantly, have a high genetic correlation with the traits needing improvement.

EXPERIMENTAL PLAN

Separate flocks of Merinos, sampled from all Merino strains and the principal stud lines within these strains, were purchased in 1974. Fifteen flocks of 100 ewes each were formed in this way and the first complete drop of lambs were born in August-September 1975. It is on these progeny and subsequent drops of lambs that intensive measurement and recording will begin.

By assembling such a wide sample of the Australian Merino it will be possible to apply the results to all strains instead of the traditional approach of working with only one strain and extrapolating to other strains. However, the major reason for the wide sampling is to magnify the variation among sheep for the various characters under consideration, and thus improve the chances of detecting genetic correlations which would be of interest in a breeding programme. This consideration is extremely important in the exploratory stage of a programme where many such possibly correlated traits may have to be looked at, and where some of these measures are expensive and/or difficult to measure.

To overcome these problems, genetic correlations between flocks of sheep will be examined in the hope that these will indicate the likely magnitude of size of the correlation within these flocks. For example in order to estimate genetic correlations within a flock with a reasonable degree of accuracy, one may need to measure all possibly correlated characters on 500 to 1,000 animals, which could be a time-consuming and expensive procedure. However, if such within-flock correlations were mirrored by between-flock correlations then with the 15 flocks, a sample of 15-20 sheep per flock may provide equally reliable information.

The real point of this approach is to use estimates of between-flock genetic correlations as a screen to choose characters which, if correlated highly with reproductive performance of flystrike resistance within flocks, could provide a valuable adjunct or alternative selection criterion in an improvement programme.

The degree of agreement between within-flock and between-flock estimate of genetic correlations is critical. In Table 1 available estimates for the Australian Merino are summarized. It must be appreciated that many of the between-flock correlations shown have large standard errors. The following general points may be made with regard to the agreement between the sets of estimates:

(i) The agreement in sign between the within- and between-flock estimates is good, with the exception of correlations involving body weight and fibre density. Such discrepancies could reflect selection in the development of the different strains and flocks, or the introduction of genes from another breed (for example, a British longwool breed) in the initial development of the medium and strong wool strains of Merino.

(ii) The magnitude of the between-flock correlations is at least equal to, and in most cases greater than the magnitude of the within-flock correlations.

(iii) In general, where sizeable correlations exist within flocks, they are more noticeable as between-flock correlations.

TABLE 1

GENETIC CORRELATIONS ESTIMATED BETWEEN AND WITHIN MERINO FLOCKS

Characters correlated		Genetic Correlations Between flocks[A]	Within flocks[B] 1	2	3	4
GFW*	Yield	0.40(0.38)	−0.09	−0.05		0.06
	CFW	0.97(0.03)	0.80	0.65		0.82
	Staple length	0.98(0.03)	0.29	−0.02		0.70
	CPI	−0.90(0.07)	−0.20	−0.56		−0.87
	Fibre diameter	0.73(0.18)	0.13			0.19
	Fibre density	−0.89(0.12)	0.20			
	Body weight	0.92(0.12)	0.26	−0.11		0.20
Yield	CFW	0.63(0.28)	0.53	0.56		0.64
	Staple length	0.23(0.45)	0.36	0.63		0.54
	CPI	−0.22(0.47)	−0.54	−0.49		−0.47
	Fibre diameter	−0.17(0.49)	0.12			0.03
	Fibre density	−0.21(0.51)	0.15			
	Body weight	0.80(0.28)	0.09	−0.08		0.11
CFW**	Staple length	0.90(0.10)	0.46	0.39	0.37	0.89
	CPI	−0.83(0.12)	−0.53	−0.53	−0.22	−0.96
	Fibre diameter	0.57(0.28)	0.16		0.24	0.16
	Fibre density	−0.83(0.20)	0.30		0.14	
	Body weight	1.01(0.15)	0.27	−0.12		0.33
Staple length	CPI	−0.92(0.06)	−0.54	−0.34	−0.54	−0.75
	Fibre diameter	0.82(0.13)	0.03		0.44	−0.11
	Fibre density	−0.94(0.07)	−0.22		−0.36	
	Body weight	0.81(0.16)	−0.06	−0.26		0.01
CPI*†	Fibre diameter	−0.93(0.07)	−0.10		−0.17	−0.17
	Fibre density	1.01(0.04)	−0.13		0.06	
	Body weight	−0.81(0.16)	0.07	0.05		0.15
Fibre diameter	Fibre density	−0.98(0.03)	−0.63		−0.70	
	Body weight	0.56(0.32)	0.12			0.00
Fibre density	Body weight	−0.74(0.20)	−0.20			

Sources: A Jackson and James (1970)
B1 Brown and Turner (1963)
2 Morley (1955)
3 Schinckel (1958)
4 Beattie (1962)

* Greasy fleece weight
** Clean fleece weight
*† Crimps per inch

RESULTS AND DISCUSSION

At this stage, little information has been collected in the programme. The base ewes were joined in 1975 and the proportion of ewes bearing multiples, and the proportion of lambs dying between birth and weaning are presented for each flock in Table 2. Since these base ewes were purchased and not born and reared together, caution is required in interpreting the results.

The 1975 drop progeny experienced heavy rain associated with severe blowfly activity in February 1976. The proportion of animals struck and the proportion of animals affected by fleece rot for each flock is also shown in Table 2. In a comparison of Merino strains in their resistance to fleece rot, Dunlop and Hayman (1958) ranked the strains as fine-wool, medium non-Peppin, medium Peppin and strong-wool in descending order of resistance. A similar pattern can also be discerned from these data, although individual flocks within each strain vary considerably in terms of resistance.

TABLE 2

FLOCK MEANS FOR COMPONENTS OF REPRODUCTIVE PERFORMANCE AND SUSCEPTIBILITY TO BODY STRIKE AND FLEECE ROT

Flock		Per cent* multiple birth	Per cent** lambs dead	Per cent*** lambs struck	Per cent*** lamb fleece rot
Fine-wool	1	48	22	13	23
	2	15	24	4	4
	3	45	33	17	37
	4	33	52	2	8
Medium Non-	151	19	11	25	
Peppin	2	56	30	20	54
Medium Peppin	1	57	25	29	59
	2	29	28	6	30
	3	42	36	3	13
	4	30	41	37	54
	5	3	14	27	64
	6	3	30	14	32
	7	8	19	36	39
	8	71	25	10	39
Strong-wool		21	26	33	67

* percentage of ewes lambing
** percentage of all lambs born
*** percentage of lambs alive

In attempting to correlate, say, litter size with another character, ewes could only be classified into two categories on a within-flock basis, that is bearing singles or multiples. However, on a between-flock basis it is obvious that there is a wide distribution in the proportion of multiple-bearing ewes allowing a correlation to be generated using 15 classifications, that is each flock mean. Similarly, lambs were either struck or not struck by flies on a within-flock basis. But the mean proportion of animals struck in each flock illustrates the wide variation that exists for between-flock correlations.

In conclusion, the approach being used here does appear to magnify among sheep variation and should allow a large number of characters to be screened in terms of their usefulness as alternative selection criteria for the improvement of reproductive performance and resistance to blowfly strike in Merino sheep.

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PROBLEMS IN THE USE OF EXOTIC GENOTYPES

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SUMMARY

Some of the problems encountered in the importation and evaluation of exotic genotypes are discussed. Available methods of choosing breeds and of sampling them are considered and evaluation procedures after importation are examined.

Although new genotypes may be found to have major advantages they are also likely to display disadvantages of one kind or another. The exploitation of such genotypes presents a new set of challenging problems. There may be a need to evolve appropriate husbandry systems particularly when producing lambs from pasture with marked seasonal constraints.

Consideration needs to be given to the problem of multiplying exotic genotypes and securing investment in its further improvement. The introduction and evaluation of new breeding stocks is likely to be a continuing feature of animal breeding.

INTRODUCTION

The general principles underlying the use of breed resources as a means of genetic improvement have been reviewed by Dickerson 1969 and are discussed by Carter in the present edition. The intention of this chapter is to use some limited experience of experimentation with a few exotic genotypes to consider some of the specific problems which can arise.

CHOICE OF BREEDS

The initial choice of genotypes for importation depends on the acquisition of information from a variety of sources. While there are extensive world lists of breeds in for example Mason 1969, it is rather rare to find well documented accounts of sheep breeds although these may be available for some developed countries. It is possible for breeds represented in small numbers to escape such description and we have, for example, an interesting prolific breed such as the D'man from Morocco only being reported recently (Bouix and Kadiri 1974). This does not happen only in more remote areas of the world as is instanced by the description given by Bekedam (1971) of the Flemish breed found as a relic in the Netherlands. The attention now being paid to genetic conservation is likely to make such examples rather rare in the future and so would make the appearance of hitherto unreported breeds an unlikely event. What seems more probable is that increased knowledge about recognized breeds will reveal possibilities for their exploitation which did not become apparent until their features were better described.

Comparative performance figures are rare and in many instances it is necessary to make inferences from results in different environments without any breeds in common to provide a yardstick for comparisons. In the field of pig breeding a start has been made in Europe with the distribution of one stock of pigs to act as a common control against which other breeds might be assessed (King *et al.* 1976). The use of this technique in sheep is still in the future, but improvements in the freezing of fertilized ova, coupled with ova transplantation would make it feasible.

SAMPLING OF BREEDS

The problems of sampling a breed weigh very heavily on some would-be importers. Often veterinary considerations may restrict the choice of animals so that this question becomes academic but, given freedom of action, should an attempt be made to obtain a random sample or alternatively animals selected by certain criteria? The use of a random sample implies that one wishes to make some pronouncements about the performance of the breed as a whole. This approach is perhaps somewhat naive in supposing that, at the end of the evaluation procedure, breeders will wish to import additional animals when they already have some representatives of that breed, or that veterinary conditions will still allow an import to take place.

Given that there are performance data on which selection can be made, the purchase of animals for importation is a once and for all opportunity for selection which probably should not be bypassed. Since future actions will, however, depend upon conclusions reached upon this particular sample of the breed, precautions should be taken to ensure an adequate sample size (especially of males) so that replacement breeding stock can be produced without inbreeding complications.

EVALUATION PROCEDURES

A great deal of attention needs to be paid to the form of testing used in the evaluation of exotic genotypes. This is not easy if only because the most appropriate form of test will depend upon the way in which the breed is to be exploited and this in turn will depend upon its characteristics which may only be revealed in the testing process itself. The ways in which new genotypes will be used can be classified as: use as pure-breds, use in a cross or as part of a new synthetic population. Because the permutations of possible crosses will be large and the possible ingredients of synthetics also likely to be numerous, there will be a strong inducement to make many assessments on the basis of pure-bred performance. This will undoubtedly be useful but there may be a real danger if the pure-bred is poorly adapted to the new environment in which it finds itself whereas its crosses do show adequate adaptation and therefore perform relatively very much better. Examples of this are the performance of the Border Leicester in Australia (McGuirk 1967) and probably also the East Friesian in Britain both of which show high mortality as pure-breds. On the other hand, cross-breeding tests will be more informative if both pure-bred parents can be included so that a direct measure of heterosis is possible. While many predictions to a first order of approximation can be made neglecting the phenomenon of heterosis there are occasions in which it is very marked. In general the litter sizes of cross-bred ewes of the Finnish Landrace with a variety of breeds could have been predicted from a knowledge of the parental litter sizes. In other reproductive traits the situation has been very different. For example, Land, Russell and Donald (1974) reporting on crosses of the Finnish Landrace with the Tasmanian Merino found that 94% of cross-bred lambs mated to lamb at one year of age did so, thus resembling the Finnish parent whereas only 5% of the Merinos lambed.

FURTHER PROBLEMS IN EXPLOITATION

The testing process, whatever form it takes, will provide additional characterization of the imported breed and confirmation or otherwise of those particular merits which prompted its importation. In the case of the Finnish Landrace the prolificacy of the breed was rapidly confirmed. What was not anticipated was that the combination of low milk yield (Crowley and McGloughlin 1972) and a relatively small body size would combine with the size reduction inherent in multiple births to give very low growth rates. This disadvantage coupled with a poor carcass quality by conventional standards has resulted in the Finnish Landrace being rejected by the sheep farming community in Britain. It is to be hoped that this judgment is premature in that the extra prolificacy is a real asset, not readily achieved by within-breed selection. Further attempts have been made to exploit the breed in a variety of different ways. Crosses of the Finn and Dorset Horn do find favour for intensive lamb production but this is only a very small and specialized part of the industry in Britain. For use in grassland systems, encouraging results have been obtained using the Finnish Landrace x Border Leicester as a crossing sire in place of the Border Leicester, and an extract of the report by Deeble and Barker (1976) is given in Table 1. The records derive from a field trial involving about 1,200 ewes.

The Finn/Border Leicester crosses produced a bigger lamb crop, particularly when lambing at one year of age and although the individual weights of their lambs were smaller the disadvantage was not great when measured at 10 weeks of age.

Since the maternal contribution to the early growth of the lamb is known to be important, pilot experiments were also carried out with crosses of the Finnish Landrace and the East Friesian milk breed. These trials evolved

TABLE 1

PERFORMANCE OF FINN × BORDER LEICESTER (F/BL) AND BORDER LEICESTER (BL) CROSS EWES

Lambing at	1 year		2 years		3 and 4 years	
	F/BL	BL	F/BL	BL	F/BL	BL
Ewes lambed per 100 ewes mated	72.6	60.0	92.0	90.9	91.2	90.1
Lambs born per 100 ewes mated	95.9	69.8	178.5	160.8	192.0	175.0
Lambs reared per 100 ewes mated	72.2	51.2	143.0	127.7	149.5	131.3
Lamb wt. at birth (kg):						
Singles	3.7	4.2	4.6	5.0	4.6	5.1
Multiples	2.8	3.3	3.3	3.8	3.7	4.2
Lamb wt. at 10 weeks (kg):						
Singles	22.5	23.7	23.7	25.2	23.3	24.7
Multiples	17.4	19.5	19.4	20.9	20.7	22.0

TABLE 2

COMPARISON OF ABRO DAM LINE AND BORDER LEICESTER CROSSES

	Ewe Type	
	Dam Line × Blackface	Border Leicester × Blackface
All ewes		
wt. (kg)	53	60
fertility 1 yr old %	69	48
2 and 3 yr old %	95	95
Ewes lambing		
% assisted	15	28
No. born alive	1.83	1.63
No. at 8 weeks	1.72	1.58
Lamb performance		
Birth wt. (kg)	3.3	3.8
8-week wt. (kg)	19	20
age at slaughter* (days)	170	165
killing-out %	44.0	43.5
carcass score (1-7 points)	3.2	3.2

* Adjusted to same litter size.

into the creation of a new synthetic Dam line, also intended for use in crossing. The genetic contributions to this line were Finnish Landrace 47%, East Friesian 24%, Border Leicester 17% and Dorset Horn 12%. The results are now available from crosses of this ABRO Dam Line in comparison with a Border Leicester cross and are summarized in Table 2. The performance records have been obtained in an experimental flock of 600 ewes lambing at 1, 2 and 3 years of age.

The cross-bred ewes from the Dam line were smaller than the conventional Border Leicester cross-bred but produced and weaned more lambs particularly in their first lamb crop. A disadvantage in growth rate remained but by existing standards there was no difference in carcass grading of the lambs.

Despite an attempt to produce a crossing sire for use in a conventional manner, it turns out that changes in husbandry practices would be necessary to take full advantage of the new synthetic genotype. Because these sheep are smaller a higher stocking rate seems appropriate and to take advantage of early sexual precocity mating to lamb at one year of age also seems desirable. Consideration of the detailed economics consequent on changes in growth genotype and husbandry practices reveals a rather complex situation. No doubt linear programming methods could be employed to arrive at an optimum situation but reasons for the apparent conservatism of breeders soon become apparent. The moral of this is that with a farming system which attempts to utilize the seasonal growth of grass, no genetic change is likely to be simple and will therefore bear detailed examination of all the factors involved in the sheep production system.

MULTIPLICATION AND IMPROVEMENT OF EXOTIC GENOTYPES

Consideration also needs to be given to the ways in which introduced stock will be multiplied and further improved for the benefit of the industry as a whole. For species with a low reproductive rate, such as the sheep, the existing investment of breeders in their present stock is considerable. Suggestions for change may involve considerable redeployment of capital which may not be easily achieved in the breeding industry where margins are traditionally low. The problem of financing further improvement is a continuing one and experience in Britain would suggest that companies find it difficult to recoup the costs of a genetic programme in sheep. Because importation costs are also high there will often be commercial pressures to realize the investment which has already been made without further provision for the future.

CONCLUDING REMARKS

Experience of the recent boom in exotic cattle breeds may suggest that the importation of exotic genotypes is a passing phase which perhaps recurs at intervals. I would like to suggest instead that the evaluation of exotic genotypes should be a continuous process. The emergence of new markets for different products will provide new opportunities in the future. This factor coupled with improved methods of controlling animal disease will, in the long term, make the international movement of stock that much easier and developments in the ability to store both semen and fertilized ova in the frozen state should reduce transport costs. With progress in the characterization of individual breeds there is likely to be increased emphasis on evaluation of strains within the breed and the emergence of breeding groups will in turn call for measurement of differences between their products. Although adaptations of particular breeds to local environments will slow down the rate of breed substitution, further identification of the critical features in such adaptation should in turn lead to further rationalization.

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EXPLOITATION OF EXOTIC GENOTYPES

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SUMMARY

New breeds could be used to replace existing breeds, to contribute desired qualities in synthesizing new breeds or strains, or to cross with local breeds in stratified or rotational cross-breeding systems. Information on general and specific combining abilities for both offspring and maternal traits is needed to decide optimal utilization strategies.

Sound choice of breeds for importation demands clear definition of breeding goals and assessment of the genetic merit for important production traits of overseas relative to local breeds. The limitations of overseas performance information and the desirability of international co-operation in breed comparison studies are pointed out.

Local testing of new breeds is essential to determine their improvement potential and to guide effective utilization. Progeny test comparison of exotic versus local sires over native ewes provides a satisfactory initial screening, subject to adequacy of numbers and of genetic sampling.

Brief mention is made of alternative importation procedures and of the importance of animal health safeguards.

Investment appraisal of livestock importation involves balancing costs, including testing resources and disease risks, against present and future benefits through genetic improvement, increased flexibility and indirect stimuli to higher production. Rapid initial evaluation under experimental conditions should be followed by controlled on-farm testing and demonstration before general release to the industry.

Present New Zealand experience is discussed in terms of improvement needs for sheep production, nomination of promising overseas breeds, animal health and quarantine considerations and importation procedures. An experimental importation in 1972 comprised Finn, Oxford Down, East Friesian and German White Headed Mutton sheep from Britain and Ireland. Early performance of the pure-breds is summarized and the initial evaluation programme described. Likely future outcomes and developments are indicated.

It is concluded that the controlled introduction and testing of new breeds chosen to meet specific improvement needs should constitute a sound national investment.

INTRODUCTION

Traditional acceptance of and implicit faith in established breeds have in the past two decades been shaken by the "exotic revolution". Likewise cross-breeding is almost attaining respectability in the pure-breeding citadels of yesterday. Yet far from being novel, the introduction and crossing of breeds have been basic ingredients in the evolution of animal production in most regions. How many present sheep industries rely on truly indigenous races? And how many improved modern breeds are strictly "pure"? For present purposes exotic will be defined as a breed or strain for which commercial stock are not, or have only recently become, locally available. "Genotype" will refer to any specific breed or cross.

The resurgence of interest in new breeds has been stimulated by the need for more efficient production, particularly in the face of changing markets and conditions and increased farm costs; by greater awareness of the merits of other races through performance recording and better communication; and by technical advances in disease control and semen storage permitting readier interchange of genetic material. Whereas formerly choice of the breeds imported was largely fortuitous, confined to those familiar and available to the human migrants, the possibility now exists for more rational selection among a far wider range of breeds. The success of the plant breeder in exploiting exotic genotype is surely a challenge to the animal improver.

The evaluation, conservation and utilization of breeds have been under close scrutiny by the United Nations Food and Agriculture Organization, with particular reference to the needs of developing countries. General principles and procedures were discussed by an expert panel (FAO 1967). Subsequent studies have concerned cattle, pigs, poultry and breed conservation, but not specifically sheep. Aspects of exotic livestock importation as an improvement strategy were considered by Carter (1970, 1975). Importation and potential uses of new sheep breeds in relation to local industry needs have been discussed by Boylan (1968) in USA, Rae and Wickham (1970) and Carter (1972) in New Zealand, Turner (1971) and Australia Animal Production Committee (1976) in Australia.

PURPOSES

Introduction of new sheep breeds can serve the following purposes:—

- produce a new product, e.g. lambskin fur or milk for cheese
- exploit a new environment such as desert, tropical or mountain areas, or for environmental conservation itself, e.g. heather sheep
- meet a changing market e.g. heavier weight lamb, coarser or finer wool
- better exploit a changing environment or management system e.g. improved hill country or intensive husbandry with more frequent lambing

- improve production under existing marketing and farming conditions
- provide a wider range of genetic material for research study.

Non-genetic benefits could include profitable re-export and psychological stimulus to betterment of local breeds.

Although emphasis in this paper will be on genetic improvement of present production, it should be remembered that genetic diversity confers powerful flexibility to meet changing future market requirements and production systems.

The basis of genetic improvement in a population is increased frequency of favourable genes. The primary agent in such change is selection, which can operate both within and between breeds. As pointed out by Dickerson (1973) breed differences can be exploited very rapidly and as accurately as the differences are evaluated. The expression of genetic potential is influenced also by the way in which genes are combined, which can to some extent be controlled by the mating system. The contribution of exotic breeds to livestock improvement is thus seen to be dependent firstly upon their genetic superiority over existing stock for desirable productive traits, secondly upon the extent to which they may "nick" with local breeds and thirdly upon the breeding system adopted.

METHODS OF UTILIZATION

New breeds can be utilized to improve productive efficiency in four main ways:—

1. To replace existing breeds, as in the early change from Merino to Romney flocks in New Zealand.
2. To contribute desirable qualities in a cross-bred foundation stock for subsequent interbreeding to form new "synthetic" breeds or strains, past examples being development of the Corriedale, Poll Dorset and Drysdale.
3. As crossing sires to produce superior commercial progeny (not used to breed replacements) in a stratified or "tiered" cross-breeding system, exemplified by mating prolific sire breeds with hardy local ewes to produce fat lamb dams.
4. As component breeds in a rotational cross-breeding programme designed to exploit hybrid vigour, a procedure successfully applied in pig and poultry breeding.

In practice all these methods involve some degree of cross-breeding, breed substitution itself being most rapidly effected by "grading-up". The theoretical basis of cross-breeding has been greatly elucidated in recent years, applications to livestock improvement being discussed by Dickerson (1973). Dickerson (1969) defined the parameters needed to determine optimal breed utilization strategies and outlined appropriate experimental designs. Operational and economic implications of alternative breeding systems were considered by Robertson (1971) and Hill (1971), who stressed the importance of considering the potential for future selection improvement as well as short-term gains. Statistical and sampling aspects of breed evaluation have been studied by Hill (1974a) and Jansen (1974). Timon (1974) discussed sheep breed evaluation and breeding strategies, citing experimental comparisons in Ireland as examples.

In general terms, choice among alternative breeds and breeding systems requires information on additive or directly transmissible genetic breed differences (general combining ability) and on heterosis in breed crosses (specific combining ability), for both individual (offspring) and maternal traits. As pointed out by Moav (1966) continued crossing to combine desired but different qualities of two breeds may be more profitable than interbreeding the cross, even in the absence of hybrid vigour for economically important component traits. This applies particularly in combining superior maternal and individual performance traits of different breeds in situations, common in the sheep industry, where dam overhead costs are high and where genetic antagonisms militate against effective joint selection for maternal and individual attributes. High levels of heterosis are the only justification for recurrent cyclical crossing among breeds of similar productive merit. Heterosis can also contribute to successful stratified crossbreeding and to breed synthesis.

CHOICE OF BREEDS

Sound decision on importation itself and on choice of breeds demands clear definition of breeding goals, adequate description of the performance potential of existing stock, and prediction of the genetic merit for important productive traits of overseas relative to local breeds. The appropriate breeding goal should be to maximize product value relative to total input costs, but allowing for likely future production and marketing trends. Obviously the emphasis on different sheep production traits will vary according to the nature of the enterprise and the farming conditions. In the harshest environments, ability of the ewe to survive and reproduce with a minimum of shepherding and to clip an acceptable weight and quality of wool is of prime importance. At the opposite extreme, intensive feeding systems demand high fertility, growth rate and voluntary feed intakes and perhaps a long breeding period, with wool production of secondary importance.

Choice among candidate breeds for importation is necessarily guided by available overseas performance information. It is unfortunately true however that few countries have yet fully quantified the performance attributes of their own established breeds. A cardinal requirement here is comparative assessment of breeds treated alike. Replication of the comparisons over a range of farming conditions will widen the generality of the conclusions and provide useful information on the importance of genotype x environment interactions. Comparative evaluation is vastly more difficult among breeds farmed in different countries under quite different management systems, particularly in the absence of commercial flock recording information. A strong plea is made for international co-ordination of research aimed at comparing sheep breeds and crosses. This could be achieved on the one hand by including common breeds and if possible comparable production systems in trials in different countries, and on the other by standardisation of recording procedures and criteria, for example including fleece information even when this is not locally important.

LOCAL TESTING

Because of possible genotype x environment interactions, breed performance rankings overseas, even if accurately known, might not reflect productive merit under different conditions. Likewise combining ability established in crosses with overseas breeds may not accurately predict advantages in crossing with different local breeds because of specific genotype x genotype interactions. Local testing of new breeds is therefore essential to determine their improvement potential and to guide effective utilization.

The consensus of present evidence suggests that for the main productive traits in sheep and considering the wide spectrum of breeds potentially available, breed differences in general combining ability are likely to be of greater practical importance than in specific combining ability or heterosis A noteworthy exception to this general statement is environmental adaptability. This is particularly relevant in comparisons of introduced pure breeds with local stock. The ability of animals to adapt, over time, to diverse conditions is well testified by the ubiquity of the Merino, the lowland lamb-producing prowess of the hardy Scottish Blackface and the New Zealand hill country performance of the erstwhile Romney Marsh. But in the short term, change to an alien environment can seriously prejudice performance comparison of a new breed relative to established stock. Poor overall performance of the Border Leicester in comparative trials both in Australia and France can be cited as an example; in both cases however crosses with local stock performed creditably, resulting in high apparent levels of heterosis in productivity due simply to better adaptation of the crosses than of the "exotic" purebred. Perhaps the salient lesson here is that, in practice, the performance of crosses should be compared with that of the "better" parent rather than the parental average (in assessing overall productive merit).

The test evaluation of exotic breeds should clearly relate to the purpose for which they are imported. In seeking improved terminal sire breeds for lamb production, assessment of first-cross progeny out of local ewes for survival, growth and carcass traits would be appropriate. Improvement of the breeding ewe on the other hand demands appraisal of a much broader range of traits, some of which are expressed only in the female and are subject to large maternal and possibly heterotic effects. Initial evaluation based on comparative performance for all economically important traits of crosses with native ewes, relative to contemporary local pure-breds and crosses, should serve as a screening process to identify the more promising breeds. If performance of an exotic cross is not materially superior to that of locally derived stock, the breed in question may be dismissed as unlikely to contribute to productive improvement. If it is superior, subsequent effective utilization of the breed may then require further testing to determine additive genetic and hybrid vigour components of individual and maternal performance.

Estimation of heterosis and maternal effects is facilitated when all breeds are represented by pure-bred females, permitting derivation of reciprocal crosses. The needed information can alternatively be obtained from the generation and performance comparison of first crosses, inter-bred crosses and back-crosses, based on local ewes and requiring use only of males of the exotic breeds. Although this procedure is more time-consuming and demands greater experimental resources, it may be preferable in overcoming the problem of poor adaptation of imported pure breeds and in yielding results more directly applicable to breed utilization in the industry. Whichever testing method is adopted, the importance of adequate numbers and adequate genetic sampling needs emphasis.

IMPORTATION PROCEDURES

Carter (1975) discussed alternative methods of importing new genetic material, numbers of animals needed for satisfactory establishment of breed and animal health implications. He concluded that introduction of about 30 pregnant ewes per breed would permit most efficient use of limited importation and quarantine resources in establishing new sheep breeds. Perfection of embryo storage techniques may however favour future transport of fertilized ova *in vitro* rather than *in vivo*. Disease prevention is of obvious importance not only in protecting existing livestock industries but also in some cases in safeguarding market outlets.

COSTS AND BENEFITS

The value of importation and use of new breeds must be assessed in relation to alternative methods of improvement, in particular selection within or among, and cross-breeding with, existing breeds. For sound decision making such assessment must cover costs as well as benefits. Much study has recently been given (Moav 1973; Hill 1974b; Cunningham 1974) to the cost-effectiveness of alternative breeding policies, taking into account the different times at which expenditure is incurred and benefits are realized by commercial discounting procedures.

Benefits from importation will depend primarily on the actual superiority of the exotic over local breeds and this can be accurately determined only on the basis of local testing. The main cost components relate firstly to direct purchase and importation; secondly to necessary testing and development; and thirdly to quarantine requirements and potential animal health hazards. The risk of introduction of disease cannot readily be quantified nor can it be dismissed, but it should surely be minimal with modern advances in veterinary science and technology.

INDUSTRY APPLICATION

The advantages from introduction of superior breeds will accrue only as they are effectively utilized in the industry. The desirability of rapid dissemination and use of new breeds must however be offset against the need for adequate testing to ensure that they are in fact superior and to guide their most efficient use.

Some degree of control by Government or appropriate national organization over importation, testing and distribution of new breeds is considered necessary in the interests of national livestock improvement. It is important that breeds and animals imported be soundly chosen and that numbers are sufficient to permit effective subsequent multiplication and selection. In most situations experimental evaluation will provide more rapid and accurate information on relative breed or cross-bred performance than will on-farm testing, and will thus expedite initial screening of new breeds. Experimental findings should however be checked by field tests covering a wide range of commercial environments. Convincing demonstration of the productive superiority of new breeds or derived crosses will undoubtedly promote their acceptance and use by the industry.

An appropriate procedure would be conditional release, following initial experimental testing, of rams of "promising" breeds or crosses to co-operating breeders, the conditions including an undertaking to provide valid progeny test information on the rams in comparison with local sires. The outcome of such field testing, together with the further experimental information available, would then determine appropriate policies for dissemination and use of the new breeds in the industry.

NEW ZEALAND EXPERIENCE

The principles and problems of controlled livestock importation are illustrated by recent experience in New Zealand, whose economic well-being is closely dependent on the production and export of animal products. Recognizing the potential benefits from exotic breeds, yet mindful of the paramount need to avoid introducing animal diseases, Government established a small but high-security quarantine station on Somes Island, in Wellington Harbour. The specific purpose was to permit experimental importation of promising breeds in order to assess their potential contribution to improving productivity.

The predominant sheep breed (70%) is the Romney, unexcelled for weight of fleece produced per kilogram live weight, well adapted to a very wide range of farming environments and a satisfactory fat lamb dam in many conditions. General improvement in pasture and animal management, increasing value of meat relative to wool and change in market demand towards heavier carcasses have however highlighted the urgent need for greater prolificacy and the desirability of increased lamb growth and ewe milk production. The Cheviot and the Border Leicester, crossed with the Romney to form the Perendale and the Coopworth, have improved lambing performance in many environments. Selection within these breeds as well as the Romney itself is contributing further gains, albeit slow.

In considering choice of overseas sheep breeds, primary emphasis was for the above reasons given to importation of "high fertility" genes. Attention has been paid also to growth rate, milk yield, wool production and avoidance of pigmented fleeces. The breeds nominated as the most likely, on available evidence, to contribute to improvement of productivity in New Zealand flocks were the Finnish Landrace or Finn (Finland), East Friesian (Germany), Texel (Holland), Bleu de Maine (France), White Headed Mutton (Germany) and Oxford Down (United Kingdom). For each breed it was planned to introduce 30-40 unrelated ewes in lamb to a wide genetic range of sires.

The geneticist proposes, the veterinarian disposes! Practical choice of species and of sources, and consequently to some extent of breeds, for importation must necessarily be subject to animal health considerations. For veterinary reasons, experimental importation of cattle took precedence over sheep despite greater estimated potential advantages from introducing new sheep breeds. Likewise animal health factors dictated Britain and Ireland as the source of the only experimental sheep introduction to date, and required that all animals be at least four years of age. The capacity of the Quarantine Station limited the consignment to 110 sheep.

Of the breeds nominated, adequate samples could be obtained only of the Finn and the Oxford. A small number of German White Headed Mutton and East Friesian was however included to permit preliminary local testing. Animals were very carefully selected on the basis of pedigree and performance background and of course animal health clearance. The ewes were mated to rams which had also been carefully screened.

A total of 99 ewes and 10 rams finally reached Somes Island in December 1972. The ewes lambed in February-March and were mated with the imported rams to lamb again in September-October 1973. They and their progeny were than transferred to a second quarantine location, Mana Island, off Wellington's west coast. Of 200 hectare, this island permits the grazing of sheep but is an exposed and difficult environment. Provision of shelter and supplementary concentrate feeding have been necessary for the imported pure-breds, whose performance cannot therefore be properly compared with the large experimental flock on Mana of Romney ewes and derived crosses.

TABLE 1

NEW ZEALAND SHEEP IMPORTATION: PURE-BRED PERFORMANCE

Breed	Finn	East Friesian	White Headed Mutton	Oxford	Romney
Ewes (rams) imported	46(4)	5(1)	8(2)	40(3)	
Litter size—Somes	2.7	2.5	1.9	1.8	
Weaning %—Somes	240	230	190	130	
—Mana	175	175	80	115	90
—Progeny*	140	130	70	80	75
Live weight ranking	100	120	140	150	120
Fleece weight ranking	100	140	210	190	250
Fibre diameter (μ)	25	30	35	33	32

* New Zealand-born pure-bred ewes, lambing at Mana at 1½-2½ years of age.

The performance to date of the exotic pure-breds, summarized in Table 1, must be interpreted with caution, firstly because of the small numbers, particularly of the East Friesian and White Headed Mutton breeds, and secondly because of the very atypical conditions under which they have been managed. Results for the Romneys are shown merely as a rough guide. Under the largely indoor management at Somes, litter size and weaning percentage of the four imported breeds were broadly in line with reported overseas figures. Transfer to Mana resulted in a sharp drop in weaning percentage due mainly to lower fertility (particularly the White Headed Mutton) and higher lamb losses, but with some reduction also in litter size. Relative rankings for live weight, greasy fleece weight and fibre diameter (at hogget shearing) are also as expected, except perhaps for the comparatively high wool production of the Oxford. The apparent superior wool production of the Romney over the much heavier White Headed Mutton is of interest.

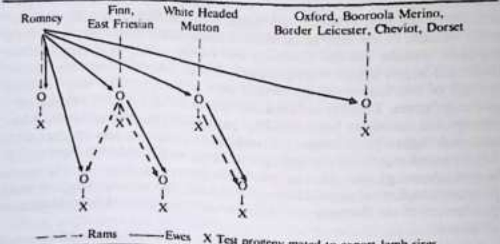
Collaborative research on these imported pure-breds is involving many scientific disciplines—genetics, physiology, behaviour, wool metrology and biochemistry. An initial aim in the programme is rapid multiplication of the pure-breds to expedite their future research and commercial use. By mating in 1976 the numbers of breeding ewes (2-tooth and older) had increased four-fold for the Finn, two-fold for the Oxford and at intermediate levels for the other two breeds. Superfoetation of the imported females and embryo transplantation to Romney host ewes is being explored as a means to augment natural increase in numbers. Animal health requirements stipulate that the imported animals themselves may never leave Mana and their progeny may not be released for industry use before 1979.

Because of small numbers of exotic pure-breds and their poor adaptation, already apparent, to New Zealand pastoral farming conditions, initial evaluation of these imported breeds will be based on performance assessment of their crosses with Romney ewes, relative to crosses sired by the local Border Leicester, Cheviot and Dorset breeds and to the straight Romney. The recent availability from Australia* of rams of the reputedly highly prolific Booroola Merino strain has permitted inclusion of this breed in the comparisons.

The design of the first phase in the evaluation trials is illustrated in Table 2. The aim is to generate and compare progeny out of Romney ewes by the nine sire breeds together with interbred Finn, East Friesian and White Headed Mutton crosses and Finn and East Friesian backcrosses to the Romney.

TABLE 2

NEW ZEALAND SHEEP IMPORTATION:
MATING DESIGN FOR EVALUATION PROGRAMME



*Sheep can be imported to New Zealand from certain "approved" areas in Australia.

All progeny will be assessed for survival, growth and wool production; major emphasis will however attach to the reproductive and weaning performance of the females over four or more lambings. Each of the 14 breed types compared will be represented by 150-200 ewes, mated to Down rams when not required to generate further test progeny. The second stage of the programme will develop and test breed combinations and breeding systems designed to exploit the merits of those breeds shown to produce superior cross-bred progeny.

The generation of exotic and local crosses was initiated at Mana in 1974 but obviously limited by available stock carrying resources. An unexpected early finding has been the good lamb growth of the Finn x Romney cross, superior not only to the Romney itself but also to the Border Leicester and Cheviot crosses. Of interest also is the strong mating preference of Finn, East Friesian and White Headed Mutton rams for ewes of their own breed versus Romney ewes. The resulting lower apparent fertility of Romney ewes mated to exotic relative to Romney sires was partially offset by better survival of the cross-bred lambs.

In 1976 the Romney ewes, in lamb to exotic sires, and the available cross-bred progeny were transferred to a third "sub-quarantine" mainland property to join a comparable group of Romney ewes in lamb to local or Booroola sires. This property, with a carrying capacity of about 5,000 ewes plus replacement stock, will henceforward be the main test location until general release of the stock is permitted in 1979 or 1980.

One, perhaps fortunate, consequence of the long overall quarantine period is that useful performance information on the exotic breeds and crosses will be available before they can be released to the industry. Although the testing will still not be complete, and will relate to only one effective environment, it should at least indicate the likely merits of the imported breeds and how they might best be utilized. Continued research and development will clearly be necessary—and rewarding—to ensure most effective utilization of both exotic and established breeds.

The prospects for real productive improvement are indeed exciting, particularly in terms of more efficient and profitable lamb production. An infusion of 25 percent Finnish or East Friesian "blood" should lift lambing percentage of the Romney by 35%, corresponding to about 40 years intensive selection for fertility. This could be rapidly achieved by wide use of half-bred Finn or East Friesian rams. Through judicious choice of the other component in this half-bred ram, for example Border Leicester or Oxford Down, the derived quarter-bred Finn or East Friesian sheep could substantially surpass the present lamb production performance of the Romney while yet retaining its versatility and wool production efficiency.

CONCLUSION

In the quest for more efficient sheep production we cannot afford to ignore the potential contribution of new breeds. Wise selection in relation to national improvement needs is the key to success, both in choice of imported breeds and in promoting subsequent genetic improvement. The introduction of exotic breeds may be expected to provide a challenge and a stimulus to existing breeders. New breeds, to succeed, must adapt to local conditions; for full exploitation of their potential, farmers also may need to adapt and to modify their husbandry practices. The costs of importation and testing may be great but the potential benefits, both direct and indirect, should amply justify the investment.

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A CROSS-BREEDING EXPERIMENT WITH FINNISH LANDRACE, ILE DE FRANCE AND TEXEL. SOME PRELIMINARY RESULTS

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SUMMARY

A cross-breeding experiment with Finnish Landrace (FF), Ile de France (IF) and Texel (TS and TC) is outlined. The Finnish Landrace is chosen for prolificacy and length of breeding season, the Ile de France for length of breeding season and carcass quality and the Texel (TS) for growth and carcass quality. The Texel Control line is the reference for the traditional system.

The aim of the whole project is to investigate under grassland farm conditions the improvement in both biological and economical terms of the efficiency of the three-way cross (TS×IF×FF) submitted to a system of 3 lambings in 2 years, compared with the traditional system of one lambing per year (TC). In this chapter only the preliminary results of some characteristics of the crosses are briefly mentioned and discussed.

INTRODUCTION

The profitability of the sheep industry in Holland as in most West-European countries depends largely on the number of lambs and the weight and the quality of their carcasses produced per ewe per year. The Texel breed is almost the only breed in the Netherlands. This originally Dutch breed is mostly kept in small flocks of about 50 breeding ewes on dairy farms with permanent grassland. They lamb once a year in spring. Under these conditions the breed produces a lamb with a rather unique slaughter quality. A breed comparison has indicated that the Texel breed can be ranked among the best breeds in this respect (More O'Ferrall, 1974). Observations on commercial farms have revealed that the lamb production is 1.4-1.6 lambs weaned per ewe lambed (Sturkenboom, 1971).

The quickest lamb production improvement can be obtained by the use of prolific breeds in cross-breeding programmes (Moav, 1966; Nitter and Jacubec, 1970 and Dickerson, 1973).

These programmes demonstrate that in a three-way cross the breed differences in both maternal and individual performance, the maternal heterosis in the cross-bred ewe and the individual heterosis in the terminal slaughter lamb are utilized completely. Furthermore, the lamb production can be improved when the "dam" breeds or cross-bred ewes have an extended breeding season, so that lambing is possible at 8 month invervals (Dickerson, 1973). So a highly profitable three-way cross could very likely be obtained by crossing first a very prolific, light breed with a meat type breed. Both breeds should have an extended breeding season. The F_1 ewe, which should combine good prolificacy and frequent lambings (at 8 month invervals) with moderate mature weight and slaughter quality, should be mated to a ram of a meat-type breed with excellent slaughter characteristics. The aim of this project is to investigate if such a three-way cross could be promising for the Dutch sheep industry. Results of the comparison of the pure-breds are described by Visscher (1974). In this chapter some preliminary results of cross-breeding will be presented and discussed.

MATERIAL AND METHODS

(a) Breeds and mating types

The project was started in 1971 with the acquisition of Finnish Landrace as a very prolific light breed and the Ile de France as a meat type breed. Both breeds have an extended breeding season. For the reason mentioned before a Texel Selection line (TS) is involved as sire breed. A Texel Control line (TC) is used as a reference line for the traditional lamb production system. In respect to prolificacy the foundation stock of both Finnish Landrace (FF) and Ile de France (IF) comes from the top half of the original populations (Visscher, 1974). Each line is bred as a self-contained flock of about 60 ewes and 10-12 rams. The mating system is based on avoidance of full-sib and half-sib matings. The choice of sires for the next generation is done within sires. A short generation interval is maintained by using young rams (6 months of age) for breeding as soon as possible and by a ewe replacement of about 30%.

After three years of adaptation, multiplication and evaluation of the pure-bred lines the reciprocal crosses between FF and IF line were made during two consecutive years with a total of 6 mating periods (Figure 1 phase I) in order to estimate heterosis, differences between breeds and reciprocal crosses. In order to get as many F_1-females as soon as possible the ewes were submitted to an intensive lambing system with 8 month intervals. So most of the ewes in the mating periods 1,3 and 5 were the same ewes. The same was true for the ewes in the mating periods 2, 4 and 6. Before the first and second mating period they were randomly divided in two groups: pure breeding vs. cross-breeding. If a ewe produced a pure-bred litter the next litter was a cross-bred one and the reverse. This is done in order to get as much genetic variation out of the available animals as possible. Before each mating period each group was randomly divided in 10-12 subgroups.

In phase II (Figure 1) the cross-bred females and pure-bred contemporaries will be submitted to an intensive lambing system with 8 month intervals with a maximum of 4 litters per ewe. The TS and TC ewes will produce one lambing per year. The numbers of females involved are approximate numbers.

Figure 1—Experimental design for "Schoonoord" cross-breeding project.

Phase I	Females					
	Finnish Landrace (FF)			Ile de France (IF)		
Mating period Males	1 Aug/Sep	2 Dec/Jan	3 Apr/May	4 Aug/Sep	5 Dec/Jan	6 Apr/May
12 Finish Landrace '74/'75	19	17*	13	18	12*	18
12 Finnish Landrace '75/'76	17	13	12	17	13	18
10 Ile de France '74/'75	15	15*	12	19	13*	17
10 Ile de France '75/'76	21	15	14	17	11	17
	* ½ year old females					
Phase II	Females					
Males	FF×FF	FF×IF	IF×IF	IF×FF	TS	TC
10 Texel Selection	90	55	60	80	60	
10 Texel Control						60

(b) *Expected composition of the mean of the mating types*

Under the assumption that the environmental contribution to each mean is the same in each mating period the means of the four different mating types of phase I have the following composition:

breed of sire	×	breed of dam	: composition of mean
FF	×	FF	: $a_{FF}+p_{FF}+m_{FF}+e$
FF	×	IF	: $\frac{1}{2}a_{FF}+\frac{1}{2}a_{IF}+p_{FF}+m_{IF}+h_{1,2}+e$
IF	×	FF	: $\frac{1}{2}a_{IF}+\frac{1}{2}a_{FF}+p_{IF}+m_{FF}+h_{2,1}+e$
IF	×	IF	: $a_{IF}+p_{IF}+m_{IF}+e$

where a = average additive breed contribution
p = paternal contribution
m = maternal contribution
$h_{1,2}$ and $h_{2,1}$ = heterosis contribution
e = environmental contribution

For each trait it is possible to estimate from these means

(1) the heterosis $\frac{h_{1,2}+h_{2,1}}{2}=\frac{(FF\times IF+IF\times FF)-(FF\times FF+IF\times IF)}{2}$

(2) the difference between reciprocal crosses, if $h_{1,2}=h_{2,1}$ and $p_{IF}=p_{FF}$, is namely: $FF\times IF-IF\times FF=m_{IF}-m_{FF}$

(3) the difference between sire breeds is namely: $(IF\times IF+IF\times FF)-(FF\times FF+FF\times IF)=a_{IF}-a_{FF}+p_{IF}-p_{FF}$

The means of the first four mating types of phase 2 (Fig. 1) have the following composition under the assumption that the environmental contribution to each mean is the same in each mating period:

breed of sire	×	breed of dam	: composition of mean
TS	×	FF	: $\frac{1}{2}a_{TS}+\frac{1}{2}a_{FF}+p_{TS}+m_{FF}+h_{3,1}+e$
TS	×	FF×IF	: $\frac{1}{2}a_{TS}+\frac{1}{4}a_{FF}+\frac{1}{4}a_{IF}+p_{TS}+\frac{1}{2}m_{FF}+\frac{1}{2}m_{IF}+h_m+\frac{1}{2}h_{3,1}+\frac{1}{2}h_{3,2}+e$
TS	×	IF×FF	: $\frac{1}{2}a_{TS}+\frac{1}{4}a_{IF}+\frac{1}{4}a_{FF}+p_{TS}+\frac{1}{2}m_{IF}+\frac{1}{2}m_{FF}+h_m+\frac{1}{2}h_{3,1}+\frac{1}{2}h_{3,2}+e$
TS	×	IF	: $\frac{1}{2}a_{TS}+\frac{1}{2}a_{IF}+p_{TS}+m_{IF}+h_{3,2}+e$

where a = average additive breed contribution

p = paternal contribution

m = maternal contribution

h_m = heterosis contribution of dam

$h_{3,1}$ and $h_{3,2}$ = heterosis contribution of individual

e = environmental contribution

From these means it is possible to estimate for each trait the maternal heterosis

$$h_m=\frac{(TS\times(FF\times IF)+TS\times(IF\times FF)-(TS\times FF+TS\times IF)}{2}$$

With this four mating types it is not possible to make an estimate for $h_{3,1}$ and $h_{3,2}$. Therefore it is necessary to make reciprocal crosses between TS and FF and between TS and IF.

(c) Experimental procedure

All animals are kept together in a single flock on the experimental farm "'t Gen" of the Research Institute of Animal Husbandry "Schoonoord". The mating periods are 34 days except the springmating period which is 51 days. Vasectomised FF-rams run continuously with the ewes from 17 days before the beginning of the mating period till the end of the mating period.

The heat control of the ewes is carried out twice daily. Ewes in heat are handmated. The animals are kept on pasture for most time of the year. Fig. 2 gives some details about the management system of both ewes and lambs. Ewes housed indoors are fed with ad lib. hay and concentrates according to the requirements for weight, stage of pregnancy and expected litter size or lactation. Lambs fattened indoors are fed with ad lib. hay and concentrates. The lambs are weighed at regular intervals till slaughter weight. The aim is to slaughter the lambs at a constant carcass weight of 22 kg. Therefore lambs from the pasture are slaughtered at a weight of about 47 kg. Lambs fattened indoors are slaughtered at a live weight of about 45 kg. Slaughtering occurs after a twelve hours period of fasting. Slaughter quality is determined by applying a method of classification of fleshiness and fat covering. This classification system is adapted from the beef classification system used in this institute (de Boer and Nijeboer, 1973). It has a scale from 1 to 6 and each class is divided in three subclasses. For fat covering the optimum class is about 2.67. For fleshiness the highest score is the best.

Figure 2—Management system

	LAMBING PERIOD			
	JAN/FEB	MARCH/APR	MAY/JUNE	SEP/OCT
PERIOD PREGNANT EWES HOUSED BEFORE LAMBING	about 2 months	about 2 months	about 1 week	about 1 week
PERIOD LACTATING EWES HOUSED AFTER LAMBING	2 months	1 week	1 week	2 months
LAMBS FATTENED AFTER WEANING (PASTURE/ INDOORS)	pasture	pasture	pasture	indoors
PERIOD OF ADDITIONAL CONCENTRATE FEEDING AFTER WEANING	first 50 days	first 50 days	till slaughter weight	till slaughter weight (ad lib.)

RESULTS AND DISCUSSION

(*a*) *Reproductive performance of pure-bred dams (phase I)*

Table 1 shows the original data from which the heterosis effects as well as the differences between the reciprocal crosses and between the sire breeds are calculated (Table 2). As Table 2 shows the heterosis contribution to the percentage ewes lambed per 100 ewes mated is only positive in two out of

TABLE 1

REPRODUCTIVE PERFORMANCE (PHASE 1)

Sire breed		FF	FF	FF	FF	FF	FF	IF	IF	IF	IF	IF	IF
Dam breed		FF	FF	FF	IF	IF	IF	IF	IF	IF	FF	FF	FF
Lambing period		Jan/ Feb	May/ June	Sep/ Oct	Jan/ Feb	May/ June	Sep/ Oct	Jan/ Feb	May/ June	Sep/ Oct	Jan/ Feb	May/ June	Sep/ Oct
Ewes exposed	'75	19	17*	13	18	12*	18	19	13*	17	15	15*	12
	'76	17	13	12	17	13	18	17	12	17	21	15	14
Percentage mated	'75	84	94*	85	100	100*	17	100	85*	47	80	100*	92
	'76	82	100	—	100	100	—	100	92	—	81	100	—
Percentage lambed (of those mated)	'75	94	100*	72	78	78*	67	100	91*	75	83	87*	100
	'76	86	92	—	100	69	—	100	73	—	100	80	—
Ave. litter size	'75	3.40	2.25*	3.13	2.00	1.20*	2.00	2.32	1.10*	1.33	3.20	2.46*	3.18
	'76	3.08	3.67	—	2.18	2.00	—	2.12	2.13	—	3.12	3.42	—
Percentage dead (within 24 hours)	'75	3.9	8.3*	16.0	3.6	0.0*	0.0	6.8	9.0*	0.0	18.8	15.6*	8.5
	'76	10.8	4.6	—	2.7	5.6	—	2.8	23.5	—	1.9	12.2	—

* ewes about 1 year at lambing.

TABLE 2

HETEROSIS, DIFFERENCE BETWEEN SIRE BREEDS AND RECIPROCAL CROSSES (PHASE 1)

		Heterosis			Difference between* reciprocal crosses			Difference between* sire breeds		
Lambing period		Jan Feb	May June	Sep Oct	Jan Feb	May June	Sep Oct	Jan Feb	May June	Sep Oct
Percentage lambed	'75	-16.5	-13	+10	-5	-11	-33	+11	0	+36
	'76	+7.0	-0	—	0	-11	—	+14	-8	—
Ave. litter size	'75	-0.26	+0.16	+0.36	-1.20	-1.26	-1.18	+0.12	+0.11	-0.62
	'76	+0.10	-0.19	—	-0.94	-1.42	—	-0.02	-0.12	—
Percentage born dead (within 24 hrs)	'75	+5.9	-0.9	-3.8	-15.2	-15.6	-8.5	+18.1	+16.3	-7.5
	'76	-4.5	-5.2	—	+0.8	-6.6	—	-8.8	+25.5	

* + means IF > FF; − means FF > IF.

five lambing periods, the average litter size in three out of five. The percentage lambs born dead is less in dams carrying cross-bred lambs. The differences between reciprocal crosses indicate that the FF-dams conceive better in almost every mating period. As could be expected the difference in the average litter size is consistently in favour of the FF-line. In four out of five lambing periods the difference in the percentage of lambs born dead is in favour of the IF-dams.

The data concerning the difference between sire breeds suggest that IF sired dams conceive better than FF sired dams. In three out of five lambing periods the viability of FF sired lambs is clearly better, in two lambing periods it is worse than IF sired lambs. As expected the difference in litter size between the two sire breeds is about zero in most lambing periods.

(6) *Growth and carcass traits (phase I)*

In Table 3 the growth and carcass traits of the first three lambing periods are summarized. The trait "growth from 10-50 days" is chosen as an estimate for the milk production of the ewe. In order to estimate the milk production for the different mating types the dams reared not more than two lambs. When more than two lambs per litter were born these extra lambs were artificially reared. After weaning from the bucket the treatment was the same as for dam-reared lambs. This partly explains the difference in

TABLE 3

GROWTH AND CARCASS TRAITS (PHASE I)

Sire & Dam breeds		FF×FF			FF×IF			IF×IF			IF×FF		
Lambing period		Jan/ Feb	May/ June	Sep/ Oct	Jan/ Feb	May/ June	Sep/ Oct	Jan/ Feb	May/ June	Sep/ Oct	Jan/ Feb	May/ June	Sep/ Oct
Traits (males only)													
Growth from 10-50 days (g/day)	n	16	14	10	13	6	1	16	5	2	10	9	10
	$\bar{x}$	228	260	261	300	373	315	294	422	302	252	263	313
	Sx	65	32	32	82	38	—	79	27	26	29	28	71
Slaughter age (days)	n	13	18	13	14	7	1	9	4	2	12	12	18
	$\bar{x}$	197.5	216.6	161.8	155.5	151.3	127	177.9	165.8	127	165.5	202.4	143.3
	Sx	32.2	23.0	14.6	10.7	5.7	—	33.0	37.1	1.4	10.7	30.0	12.9
Warm carcass weight (kg)	$\bar{x}$	21.2	22.5	22.7	22.8	23.6	23.5	21.7	22.6	23.3	21.4	23.5	23.8
	Sx	1.0	1.9	1.1	1.6	1.0	—	1.1	1.8	3.3	1.1	1.1	1.5
Net gain (g/day)		107.3	103.9	140.3	146.6	156.0	185	122	136.3	183.5	129.3	116.1	166.1
Carcass yield %	$\bar{x}$	48.9	51.9	51.4	48.9	51.7	51.1	48.1	49.9	51.0	48.7	52.3	53.2
	Sx	1.4	2.1	1.6	1.4	1.5		2.1	2.1	0.9	1.6	1.6	1.6
Fleshiness (score 1-6)	$\bar{x}$	1.87	1.64	2.23	2.88	3.05	3.00	3.22	3.24	3.66	2.69	2.72	3.02
	Sx	0.28	0.24	0.28	0.25	0.23	—	0.33	0.17	0.47	0.36	0.30	0.24
Fatcovering (score 1-6)	$\bar{x}$	2.82	2.14	2.89	2.47	2.52	3.00	2.63	2.75	3.00	2.63	2.83	3.25
	Sx	0.57	0.28	0.39	0.43	0.18	—	0.42	0.32	0.0	0.66	0.44	0.24
Percentage of lambs (male and female) that reached slaughter weight													
Actual number in brackets		93.9 (46)	80.6 (29)	80.0 (25)	96.4 (27)	100 (11)	100 (4)	86.4 (38)	90.9 (10)	87.5 (7)	81.3 (26)	81.3 (26)	85.7 (30)

TABLE 4

HETEROSIS, MATERNAL AND SIRE BREED EFFECTS (PHASE I)

	Heterosis in F_1			Difference between* reciprocal crosses			Difference between* sire breeds		
Lambing period	Jan Feb	May June	Sep Oct	Jan Feb	May June	Sep Oct	Jan Feb	May June	Sep Oct
Traits									
Males only									
Growth 10-50 days (g/day)	+30	-46	+65	+48	+110	+2	+18	+52	+39
Net gain (g/day)	+46.6	+31.9	+27.3	+17.3	+39.3	+18.9	-2.6	-7.5	+24.3
Carcass yield (%)	+0.6	+2.2	+1.9	+0.2	-0.6	-2.1	-1.0	-1.4	+1.7
Fleshiness (score 1-6)	+0.48	+0.89	+0.13	+0.19	+0.33	-0.02	+1.16	+1.27	+1.45
Fatcovering (score 1-6)	-0.35	+0.46	+0.36	-0.16	-0.31	-0.25	-0.03	+0.92	+0.36
Percentage of lambs that reached slaughter weight									
(male and female)	-2.6	+9.8	+18.2	+15.1	+18.7	+14.3	-22.6	-8.4	-6.8

* + means IF > FF; – means FF > IF.

number of lambs involved in the growth and carcass traits. The other part of the explanation comes from the fact that pure-bred ram lambs were used as sires to produce the next generation. Net gain is defined as the ratio between the mean carcass weight in grams and the mean slaughter age.

From Table 4 it can be seen that the heterosis in the cross-bred is consistently positive for net gain, carcass yield and fleshiness. For growth from 10-50 days of age there are quite large differences in heterosis between the lambing periods. The same could hold true for fat covering because under the more intensive systems the cross-bred seems to produce more fat than the pure-bred. The heterosis in viability expressed as the percentage of lambs that reach slaughter weight is only positive in the last two lambing periods.

For growth from 10-50 days, net gain, fat covering and percentage of lambs that reach slaughter weight the difference between the two reciprocal crosses is consistently in favour of the IF dams. This is probably due to their smaller litter size (higher birth weight) and their higher milk production so that their progeny grow faster and have less fat at slaughter weight. As expected the difference between the two sire breeds for fleshiness is in favour of the meaty IF sire. The viability expressed as the percentage of lambs reaching slaughter weight is in favour of the FF sired lambs.

(c) *Reproductive performance of cross-bred ewes (phase 2)*

The reproductive performance of the first two lambing periods of the two types of cross-bred ewes and their pure-bred contemporaries are shown in Table 5. Of two mating types only very few ewes were available in the second lambing period. This makes the estimate of the maternal heterosis from this lambing period less reliable. Despite this, Table 6 shows that the maternal heterosis for all traits is similar in both lambing periods and positive. Except for the percentage of lambs born dead which has a negative value. The maternal heterosis in the percentage ewes lambed of those mated is quite substantial. This holds to a much lesser extent for the percentage of ewes mated and for the litter size.

TABLE 5

REPRODUCTIVE PERFORMANCE (PHASE 2)

Sire breed Dam breed	TS FF×FF		TS IF×FF		TS IF×IF		TS FF×IF	
Lambing period	March April	May June	March April	May June	March April	May June	March April	May June
Traits (age at lambing)	1	1	1	1	1	1	1	1
Ewes exposed to the ram	22	23	13	15	18	3	13	4
Percentage mated	95	96	100	93	94	67	100	75
Percentage lambed of those mated	81	86	100	87	71	50	92	100
Ave. litter size (dead + alive)	2.41	2.74	2.15	1.69	1.58	1.00	2.08	2.33
Percentage dead (within 24 hrs)	9.8	21.2	7.1	4.5	5.3	0.0	12.0	28.6

TABLE 6

MATERNAL HETEROSIS

Lambing period	March/April	May/June
Percentage of ewes mated	+5.5	+5.0
Percentage lambed (of those mated)	+20	+25.5
Ave. littersize	+0.12	+0.14
Percentage born dead (within 24 hours)	+2.0*	+6.0*

* + sign indicates increased % born dead (see text).

Calculated from the percentage ewes lambed of those exposed to the ram in each lambing period of pure breeding of phase 1, the mean lambing frequency of Finnish Landrace and Ile de France ewes is respectively 1.14 and 1.03 per year. If in the cross-bred the maternal heterosis for this trait is consistently about 20% as the first results suggest, a lambing frequency of 1.3 should be obtainable. With a lambing interval of 8 months the theoretical maximum lambing frequency is 1.5 per year. The lambing frequency in the Texel breed is about 0.9. If there is no substantial maternal heterosis in litter size the average litter size of the mature cross-bred will be about 2.6 lambs, which is the mean of the average litter size of FF-line (3.2) and IF-line (2.0). With estimated losses of about 20% the number of weaned lambs per litter will be about 2.1 lambs. So a cross-bred ewe could produce about (1.3 × 2.1 =) 2.73 lamb carcasses a year. In the traditional system of the Texel breed this is about (0.9 × 1.6 =) 1.44 lamb carcasses. This means about a doubling of the biological efficiency of lamb meat production with breeding measures only.

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THE NEED FOR DUAL-PURPOSE SHEEP

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INTRODUCTION

In Australia the total number of sheep is more than ten times the human population and the export of surplus production of the grazing industry has always made a major contribution to the national economy. Variability in price in response to economic factors, political and technological changes, and seasonal conditions are a feature of export markets and, in the case of meat which is perishable and has high storage costs, these problems are accentuated.

Despite this it has been possible to recognize long term trends influencing the production of meat and also in respect of the demand for meat in importing countries. A number of organizations have studied these trends and have published projections of future demand and supply indicating likely surpluses or shortfalls for various categories of meat.

These reports are reviewed to indicate the likely future markets for sheep meats and the consequences and opportunities for the Australian grazing industry. The implications for priorities of objectives in genetic improvement of sheep and appropriate genetic means to achieve these are discussed.

PROJECTED SUPPLY AND DEMAND

The Food and Agriculture Organization of the United Nations has a continuing programme of projecting future trends and checking the resulting estimates against the outcome, and a well established methodology has been developed.

In 1971 F.A.O. released projections for the world supply and demand for all meats up to 1980. With respect to red meats they concluded that the combined exportable supplies of the surplus producing countries would probably still be below likely effective import requirements. The export surplus and import demand and consequent balance are set out in Table 1.

In 1974 F.A.O. undertook a major revision of the 1971 projection in which more up to date production statistics and improved techniques were used (Table 1). This supported the conclusions of the earlier projection. It is significant that surpluses in Australia and New Zealand constitute 85% of the projected supply of exports in this study.

In 1975 F.A.O. published a summary of selected national meat production and demand outlook studies. These estimates of production and con-

TABLE 1

PROJECTIONS OF TOTAL WORLD EXPORT AND IMPORT REQUIREMENTS FOR RED MEATS AND BALANCE* FOR 1980 ('000 TONS)

Projection	Beef and veal				Mutton and lamb			
	Export Surplus	Import Demand	Balance ±	% of export	Export Surplus	Import Demand	Balance ±	% of export
FAO 1971 [1]	4,179	5,823	-1,650	-40	1,086	1,687	-601	-58
FAO 1974 [2]	4,453	5,536	-1,083	-24	2,110	2,566	-456	-22
FAO 1975 [3]	5,343	4,986	+420	+8	1,307	2,332	-1,025	-73

* Balance: - denotes shortfall; + denotes surplus
[1] "F.A.O. Meat Production and Demand Projections to 1980"
[2] "Review of the F.A.O. Meat Production and Demand Projections to 1980"
[3] "Summary of selected national meat production and demand outlook studies"

sumption prepared by the major beef and sheep meat production and consuming countries were used to revise the balance of world trade as projected by F.A.O. in 1974 (Table 1). The difference between these estimates and those projected by F.A.O. in 1974 was largely due to the decline in sheep numbers in exporting countries in the period 1970 to 1973 in response to very depressed wool prices which was not taken into account in the F.A.O. study.

In this series of studies succeeding estimates indicate greater shortfalls for sheep meats and smaller shortfalls for beef. However there is little change in the estimated shortfall for red meats so that the original conclusions continue to be supported in general.

The above considerations do not take account of the 1973-74 changes in world prices for petroleum and consequent effects on the affluence and capacity to pay for imports of the oil rich countries in the Middle East.

A study by the West Australian Department of Agriculture (Neil personal communication) estimated that the demand for sheep meats in Middle East countries would reach 500,000 tons (including live sheep) by 1980, but the basis of the estimate is not stated. This is about 30% higher than the most recent estimate by F.A.O. for these countries. If it proved correct it would further increase the projected deficit in 1980.

In the event, by 1980 the strong requirement for imports of sheepmeats relative to the projected export supplies could be expected to increase prices and encourage production until the export surplus matches the import demand. Thus, prices for sheep meats can be expected to rise and may approximate to those for beef as they have done in the past when supplies of sheep meats have been limited.

FACTORS AFFECTING TURN-OFF

New price relations amongst red meats are likely to influence the ratio of returns from wool and meat in sheep enterprises and hence the economic basis of existing priorities for genetic change in sheep.

In particular a higher priority is likely to apply to factors affecting the turn-off of animals for slaughter from the flock. Marshall (1973,1974) concluded that an increase in the proportion of breeding ewes was necessary in order for turn-off to increase whilst maintaining a steady population. However true this may be, it is likely that the sex composition of the flock will vary as a result of culling policies with respect to aged ewes, surplus young ewes and prime wethers, rather than as the result of a deliberate decision to change the proportion of breeding ewes in the flock.

We have used a simple mathematical model of flock structure—involving essentially similar assumptions to those described by Egan *et al.* (1972) but including a weighting of 1 ewe = 1.25 wethers = 1.25 yearling sheep to maintain comparable stocking rates—to investigate the effects of increased fertility and growth rate upon turn-off and sex composition. Table 2 presents some generalized results.

TABLE 2

CALCULATED EFFECT OF LAMBING % AND SLAUGHTER AGE OF WETHERS, UPON TURN-OFF AND SEX COMPOSITION

Lambing %	Age of wethers at slaughter years	*Turn-off	Ewes in flock %
Normal	3½	†100	38
Normal	2½	119	44
+15%	3½	107	34
+15%	2½	128	40
+30%	1½	173	47

† Base = 100

$$\text{*Turn-off} = \frac{\text{total sales}}{\text{flock size}}$$

The calculations suggest that the response of turn-off to increased fertility is limited by the need to reduce the proportion of breeding ewes to enable the additional young sheep to be maintained on the property until slaughter age. However, the full benefit of a higher reproduction rate can be realized if a concurrent improvement in growth rate permits the sale of young wethers for slaughter earlier than was previously possible. It may also be seen that the flock structure is essentially established by these factors. Calculations by Egan *et al.* (1972) suggest that wool production will remain fairly constant over the range of structures described in the table.

OBJECTIVES AND MEANS FOR GENETIC CHANGE

Acceptance of the probability of changes in the future demand for sheep meats indicated by the projections in Table 1 may justify changes of emphasis in the goals for genetic change. When objectives for genetic improvement are expanded to embrace factors which influence turn-off throughtout the industry, and carcass quality in major sectors, a larger number of characteristics are involved than the few which serve when increased wool production is the major objective. Specifically these may include fecundity, survival of lambs from multiple births, milk production and post-weaning growth rate. Other characteristics related to carcass quality such as fat depth in relation to carcass weight may assume a higher priority of specific markets are to be satisfied (Suiter 1976).

Avenues for improvement in meat production include changes in the base wool producing breed, the Merino, to increase the turn-off of wether sheep, changes in cross-breeding systems for lamb production, and the development of dual purpose breeds or crosses for producing apparel quality wool plus lamb or young wether mutton in the wheat/sheep or high rainfall zones.

(i) Meat production from Merino woolgrowing areas

There is sufficient evidence both in the literature and in the sheep industries of overseas countries, to suggest that it is possible to develop mutton qualities without prejudice to the range of qualities of wool produced within Australian apparel wool breeds. From a review of the literature Turner (1972) concluded that insofar as fleeceweight, meat and milk are concerned, there are no strong negative genetic correlations to prevent concurrent selection for all three. Furthermore, the Merino, which by virtue of its quality wool will probably continue to be the dominant breed type in Australia, has been shown to be responsive to selection for weaning weight (Pattie 1966), bodyweight (Turner, Brooker and Dolling 1970) and fecundity (Turner 1969).

The hierarchical structure of the Merino stud industry provides valuable resource of genetic material which might be better utilized to increase meat production. While within strain selection for a large number of characters can only lead to slow rates of improvement in individual characters, commercial producers have the opportunities for both between strain selection and for developing systematic cross-breeding systems if worthwhile amounts of heterosis can be shown to exist. This in turn could lead to the identification of a small number of appropriate genetic goals capable of being achieved by selection within ram breeding flocks.

(ii) Lamb production systems

The Merino is also the base for a highly efficient stratified cross-breeding system which has evolved for prime lamb production based on the Border

Leicester × Merino ewe. Whilst the efficiency of this system has been confirmed (Matthews 1920; Miller and McHugh 1955; McGuirk 1967) it has several deficiencies in that it is not self replacing and the supply of suitable lines is variable, the wool has a high fibre diameter and hence lower value, and the breeding season is limited.

There is a need to examine alternate systems for lamb production, particularly as future export markets may require less fat and heavier carcass weights than those produced at present. Terril and Sidwell (1975) demonstrated that multiple cross ewes in a continuous breeding system which could be self replacing would lead to substantial improvement in efficiency. Likewise a programme at the Animal Breeding Research Organization at Edinburgh which is showing considerable promise involves the development of a new breed from a gene pool including Finnish Landrace, East Friesland, Border Leicester and Dorset Horn.

(*iii*) *Dual-purpose breeds or cross-bred sheep*

A major contribution to meat production can come from producers of apparel quality wool in the more favoured environments by the development of true dual-purpose types of sheep capable of producing quality wool and lamb or young wether mutton with satisfactory carcass characteristics for potential markets.

The only well established Australian efforts at developing dual-purpose sheep are represented by the Corriedale and Polwarth, both breeds evolving from a Merino and Lincoln ancestry. Most comparisons of the meat production of these breeds have been based solely on the weight and grade of prime lamb produced. Both the Corriedale (McGuirk and Scarlett 1966) and the Corriedale × Merino (Miller and McHugh 1955; Simms and Webb 1945) were shown to be superior to the Polwarth and the South Australian Merino but all were inferior to the Border Leicester × Merino.

In the Peppin Merino and Corriedale crosses, Iwan *et al.* (1971) have reported moderate levels of heterosis for reproduction rate and lamb growth rate. However, although heterosis for weight of lamb weaned per ewe joined was 10-11%, production of the cross-breds did not exceed that of the pure Corriedales. The final evaluation of this work must await the analysis of wool production data.

By contrast in South Africa recent attempts at developing dual-purpose breeds have been more successful (Hofmeyr 1976). The Dohne Merino, derived from crosses between the German Mutton Merino and the South African Merino appears to have increased reproduction by 20%, improved growth, and maintained wool weight and quality.

Since in Australia mating plans of a dual purpose nature (Comeback, Corriedale and Merino crossed with British breed rams) in the sheep/wheat and high rainfall zones involve more than 25% of the ewes mated, there is an urgent need for specific work in this area.

THE IMPLICATIONS FOR RESEARCH

Research programmes require a substantial time between inception and completion so that aims should be related to future rather than present needs of the industry. After considering the effects of recognizable trends in supply and demand for sheep meats and in the absence of comparable projections for wool, it appears that research programmes should relate to an industry in which more exportable sheep meats are required, together with the continuing production of apparel quality wool.

Because of the wide range of objectives which would need to be sought if meat production from sheep is to be substantially increased, selection within breeds can be expected to achieve only very slow rates of progress. A change in emphasis to other means of genetic improvement is imperative if Australia is to accept the challenge of future markets for sheep meats.

There is an urgent need for much more work in the comparison of breeds, strains and crosses, the examination of the variation between breeds and strains and the relations between productive characters across a range of breeds. Taylor (1972) has discussed the potential use of between breed variation for genetic improvement with respect to cattle. Results need to be interpreted in terms of their effects on flock structure for the important environments to provide a basis for new production systems.

It is clear from the foregoing that the importation of new genotypes could play a vital role, particularly with respect to breeds with valuable fleeces and high fertility and growth or with superior survival of lambs. Because so many characteristics are involved the need and role of new breeds should be established before they are widely distributed to the industry.

Research in these terms will not only produce knowledge of existing and imported breeds and the means of combining them to best advantage, it will produce prototypes of new synthetic breeds. The projects could become the basis for the dissemination of new breeds to the industry by using A.I. The Coopworth and Drysdale in New Zealand and the Dohne Merino in South Africa are successful examples of this approach.

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23

DEVELOPMENT OF THE GROMARK — A NEW HIGH PERFORMANCE DUAL-PURPOSE SHEEP BREED

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SUMMARY

A fixed half-bred of the Border Leicester and Corriedale breeds has been selected for live weight, twinning, wool and to a limited extent reduced fat since 1965 on fertilized natural pasture in northern New South Wales.

The average live weight of rams is: weaning (adjusted) 35 kg, yearling 61 kg, 2 year old 90 kg. Yearling rams grow 450 g of 30μm diameter average wool per month with a low level of hairy birth coat and hairy britch. Ewes rear approximately 100% lambs. Sheep are hardy with little body strike, a minimum of lambing trouble and have a quiet temperament. The use of objective measurement of production characters coupled with final selection on appearance has produced a breed that should compete with cross-breds.

INTRODUCTION

During recent years in New South Wales prime lamb production has become more firmly established on the cross-breeding system with a significant reduction in the number of sheep in self-replacing dual-purpose flocks (A.B.S. 1976.)

In the 1950s attempts were made to form a dual-purpose breed from the popular first-cross Border Leicester-Merino but these projects appear to have lapsed. Since then the trend has been to develop meat types growing wool of a spinning count of 60^S (23μm diameter) and finer. This approach was endorsed by the report of an expert panel (Animal Production Committee 1970).

The Gromark project was commenced in 1965 with the object of developing a dual-purpose breed with the emphasis firmly on meat production. Another aim was to strongly apply selection pressure for production characters in a commercial situation.

The genetic principles employed in this development have been documented by Turner and Young (1969) and Dolling (1970) and have been summarized by Victoria Department of Agriculture (1974).

The project has been conducted on aerially fertilized natural pasture hill country adjoining the city of Tamworth on the north-west slopes of New South Wales. Rainfall averages 650 mm per annum with a summer incidence. Pastures are predominantly summer growing native perennial grasses in conjunction with winter growing naturalized annual legumes of *Trifolium spp.* and *Medicago spp.* Grass seed infestation from *Aristida sp.* and *Stipa sp.* is a feature of the environment.

BREEDING PLAN

430 Corriedale ewes from an old established flock on the northern tablelands of N.S.W. were joined to 12 stud quality Border Leicester rams. The rams which were mainly twin or triplet born represented many of the leading blood lines in the eastern states and were selected from sub-strains that expressed large size and prolificacy. Following the first cross the sheep have been inter-bred to fix them at the half-bred level.

The breeding flock consists of 400 ewes with three sire lines each using two or three rams in a syndicate mating for no more than two seasons. This should have kept inbreeding to a reasonable level and may have allowed some natural selection for libido in rams.

Characters selected for improvement in order of importance have been:

Live weight
Twinning (prolificacy)
Wool (weight and quality)

Little attention has been given to carcase quality except for the use of the scanogram to measure fat depth on the 1973 ram drop as yearlings. Rams showing the higher fat measurement (>4 mm) were rejected. Body shape has been allowed to emerge naturally and has moved towards the longer, leggier and presumably leaner type.

Live weight was chosen as the top priority character for improvement because:—

It did not require detailed recording of ewes.

It has a moderate heritability at weaning and high heritability at the yearling stage (Turner and Young (1969)).

It has a positive genetic correlation with reproductive rate (Turner and Young (1969)).

Large size of breed means that a lamb carries less fat at a given weight than smaller breeds (Searle and Griffiths (1976)).

Hardiness and easy care features have been built into the selection programme.

Deliberate selection for finer wool has not been considered a worthwhile use of available selection pressure in a breed of this type. Judged by price differentials per μm diameter in recent years it would not lead to a worthwhile increase in monetary return. It would also tend to move the wool type into the zone of fleece rot susceptibility which would go against the easy care aspects of the breed (Henderson 1968).

SELECTION METHOD

Direct selection methods have been used mainly on rams to apply pressure to the chosen characters. Marketing principles dictate that the breed must maintain an attractive appearance and this has been achieved by selecting acceptable types from the highest production grades for use as sires.

Rams are individually ear tagged at birth, and the date, type of birth and age of dam recorded. Tag colour is used to indicate sire line. Actual birth weights are not recorded but estimates of 5 kg for singles and 4 kg for twins are used in calculating liveweight gains per day.

Rams are weighed unshorn at weaning (approximately 4½ months) and adjusted for age, type of birth and age of dam. They are again weighed at yearling stage (approximately 14 months) immediately after shearing and greasy fleece weight at this second shearing is recorded. The rams are then graded for type of birth (S=single, T=twin, Tr=triplet), each of the live weights and greasy fleece weight.

Independent gradings of the production characters are given as follows:—

Top 20%	A grade=potential stud
next 30%	B grade=potential selected flock
remainder	C grade=flock

Rams are downgraded for visual faults but are never upgraded for visual excellence. The majority of rams used have graded T.A.A.B. (twin, A grade adjusted live weight at weaning, A grade live weight as yearling and at least B grade greasy fleece weight).

RESULTS AND DISCUSSION

The following production levels have been achieved on fertilized natural pasture without the aid of improved pastures or supplementary feeding.

Ram lambs (weaning, average age 4½ months)

Live wt. Singles av. 35 kg=liveweight gain per day 225 g
Twins av. 28 kg=liveweight gain per day 180 g

Yearling rams (14 months old) most of drop retained.

Liveweight (off-shears) average 61 kg, range 54-73 kg.
Greasy fleece production averages 0.45 kg per month.
Fibre diameter average 30μm, range 28-33μm.
Scanogram fat depth 12th rib adjusted to 68 kg liveweight, average 3.2 mm, range 1-7 mm.

2 year old rams (sires and reserves)

Live weight (immediately after shearing) 80-100 kg.
Greasy fleece weight 6 to 7 kg, length 12-15 cm.

Ewes

With unsupervised lambings ewes rear approximately 100% lambs, although with supervised lambings 64% of ram lambs tagged at birth ex mature ewes are twins. Few triplets are produced.

Wool averages about 50^s spinning count (30 μm diameter) and may have fined up slightly due to a preference for a more compact staple tip. There is a very low level of hairy birth coat and hairy britch.

Some indication of the limitations of the environment are illustrated by the large difference in the live weight of singles and twins at weaning and the rarity of triplets although many twins are produced. Even under sub-optimal conditions the live weight gain for this breed compares reasonably well with the general average performance of 230 g live weight gain per day for prime lambs in Australasia (Tribe and Coles 1966: Kirton 1974). The overall performance of the sheep under the conditions imposed indicates an excellent result under more favourable circumstances.

The good growth rate of the breed is a desirable feature to complement higher lambing percentages, marketing at heavier weights and mating of ewe lambs. The large mature size should also enable the production of leaner carcases and attract buyers of rams and breeding ewes as it reduces the cash costs of running a given biomass per hectare.

The general fitness and resilience to adverse conditions and the low level of body strike and lambing trouble should reduce husbandry costs. Being very plain bodied the sheep lends itself to the use of mechanized shearing devices. The quiet and tractable temperament means that the sheep are easy to work and handle.

By rigorous selection for production characters a breed has been produced that should increase production and at the same time reduce costs. As a self-contained breed it should compare favourably with cross-breeding at least for the production of prime lamb dams. With changes in markets and methods of marketing the pure-bred Gromark lamb may compete with the specialized terminal sire breeds.

The Gromark is similar in concept to the Coopworth breed in New Zealand which is a fixed half-bred of Border Leicester and Romney breeds. The Coopworth is slightly stronger in the wool having a spinning count of 46^s-50^s (35-30 μm diameter) and the main selection pressure has been applied to prolificacy and considerable attention is also given to fleece weight and live weight at weaning (Coopworth Flock Book 1972).

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GROWTH OF DISSECTIBLE FAT IN THE MERINO

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SUMMARY

A study of the growth and partition of dissectible fat was carried out on pasture reared Peppin Merino sheep. The weight of dissectible fat in the internal, intermuscular, and subcutaneous fat depots was recorded for sheep slaughtered at intervals from birth to almost three years of age.

The relative percentage growth of the major fat depots, internal, intermuscular, and subcutaneous depots, and the partition of fat between these three depots is presented.

INTRODUCTION

The important role of fat in its effects on carcass composition, evaluation by the meat trade and on profitability has been recognized and well documented. Butterfield (1963) showed that selection had no effect on the proportional distribution of muscle in a beef carcass, and Seebeck (1968) found only minor difference in muscle distribution between sheep breeds. It seemed logical then, that for further advances in the production of a carcass, the growth and partition of fat should be studied, as fat would appear to be the tissue to be most amenable to alteration by selection.

MATERIALS AND METHOD

Animals of the same age were selected randomly, weighed and slaughtered without prior fasting. Twenty-six ewes, 26 wethers, i.e. males castrated at birth, and 31 rams were killed at specific ages from birth to almost three years of age.

The pelt and gut contents were weighed and subtracted from the live weight to obtain a pelt-free empty body weight (PFEBWt).

The kidney fat and the fat depots of the abdominal (omental, mesenteric and pelvic) and thoracic cavities (mediastinal fat and coronary fat) were weighed during the dressing procedure. The carcasses were then deep frozen, transported to the dissecting laboratory and kept frozen until required. After thawing the carcasses were halved by soft siding (Walker, 1961), and the left side dissected within 36 hours.

Subcutaneous fat was defined as fat superficial to the plane of the muscles but included the fat beneath the *cutaneous trunci m.* (*panniculus adiposus m.*). Muscles were removed individually, the fat removed from their surfaces was recorded as intermuscular fat. Individual muscle weights were also recorded.

The growth rate of the fat depots is expressed as the proportion of the final weight reached at the specified intervals, and is called the relative percentage growth. It is a modification of the method used by Wilson (1954). This method of presenting the data allows the growth between any two consecutive stages to be examined but has the disadvantage that statistical analyses or predictions cannot be applied. An allometric examination and statistical comparisons have been recorded elsewhere (Warren, 1974).

The mean weight of fat in each major depot at each slaughter interval is expressed as a percentage of the mean total dissectible fat weight. These percentage figures indicate the partitioning of the total fat between the major depots.

RESULTS

Results are presented in the tables below, Tables I to 6.

The results bearing an asterisk are from sheep from the same flock, killed at the same time but derived from a study by Lohse (1971). They were used in order to gain more information on the changes that appeared to occur during early post-natal life and for which there is little corroborative evidence in the literature for Merino sheep.

TABLE I

RELATIVE PERCENTAGE GROWTH OF SUBCUTANEOUS FAT

	Ewes			Wethers			Rams		
Age (Days)	N =	Mean PFEB Wt.	Relative %age growth	N =	Mean PFEB Wt.	Relative %age growth	N =	Mean PFEB Wt.	Relative %age growth
0	6	3.179	0.1	8	3.44	0.2	6	3.398	0.2
7	2	3.941	0.7	5	4.63	0.8	3	4.412	0.5
18	3	6.604	7.1	3	5.42	2.3	3	6.629	4.5
28*	1	9.730	2.6	2	8.361	3.5	2	7.967	2.6
84	2	17.65	26.5						
110	3	16.69	17.6	3	15.02	23.1	3	15.80	24.4
180	4	18.00	24.2	4	18.62	26.6	5	18.24	22.2
365	3	15.05	7.4	4	18.18	13.1	5	20.03	17.6
730	2	25.05	32.1	2	22.71	22.6	2	22.43	10.6
1010	2	28.09	100.0	3	33.57	100.0	4	39.44	100.0
	Final SC fat wt. (g) 2619			Final SC fat wt. (g) 2698			Final SC fat wt. (g) 2485		

* from Lohse (1971)

TABLE 2

RELATIVE PERCENTAGE GROWTH OF INTERMUSCULAR FAT

	Ewes			Wethers			Rams		
Age (Days)	N =	Mean PFEB Wt.	Relative %age growth	N =	Mean PFEB Wt.	Relative %age growth	N =	Mean PFEB Wt.	Relative %age growth
0	6	3.179	1.7	8	3.44	1.5	6	3.398	1.7
7	2	3.941	5.2	5	4.63	3.7	3	4.412	3.0
18	3	6.604	8.8	3	5.42	3.2	3	6.629	7.7
28*	1	9.730	6.0	2	8.361	5.1	2	7.967	5.3
84	2	17.65	34.8						
110	3	16.69	28.4	3	15.02	31.0	3	15.80	32.2
180	4	18.00	42.2	4	18.62	38.3	5	18.24	34.7
365	3	15.05	19.8	4	18.18	19.9	5	20.03	22.8
730	2	25.05	46.4	2	22.71	33.2	2	22.43	18.2
1010	2	28.09	100.0	3	33.57	100.0	4	39.44	100.0
	Final IEM fat wt. (g) 2189			Final IEM fat wt. (g) 2698			Final IEM fat wt. (g) 2465		

* from Lohse (1971)

TABLE 3

RELATIVE PERCENTAGE GROWTH OF INTERNAL FAT

	Ewes			Wethers			Rams		
Age (Days)	N =	Mean PFEB Wt.	Relative %age growth	N =	Mean PFEB Wt.	Relative %age growth	N =	Mean PFEB Wt.	Relative %age growth
0	6	3.179	1.0	6	3.44	1.2	6	3.398	1.3
7	2	3.941	2.5	2	4.63	2.1	3	4.412	1.6
18	3	6.604	4.4	3	5.42	2.1	3	6.629	4.15
28*	1	9.730	4.4	1	8.361	5.3	2	7.967	4.5
84	2	17.65	20.2						
110	3	16.69	15.2	3	15.02	21.9	3	15.80	18.2
180	4	18.00	24.8	4	18.62	24.3	5	18.24	25.3
365	3	15.05	11.3	3	18.18	17.1	5	20.03	15.0
730	2	25.05	33.1	2	22.71	22.4	2	22.43	17.9
1010	2	28.09	100.0	2	33.57	100.0	4	39.44	100.0
	Final int. fat wt. (g) 3367			Final int. fat wt. (g) 3319			Final int. fat wt. (g) 2743		

* from Lohse (1971)

TABLE 4

THE PARTITION OF DISSECTIBLE FAT IN MERINO EWES

Age (Days)	N	Mean PFEB Wt. (kg)	Mean SC* (g)	Mean IEM** (g)	Mean Int.*+ (g)	Total Fat (g)	Percentage of total fat % SC	% IEM	% Int.
0	6	3.179	3.0	36.6	34.7	74	4.0	49.2	46.7
7	2	3.941	18.5	114	84.2	216	8.5	52.5	38.9
18	3	6.604	187	193	149	529	35.3	36.5	28.2
28+	1	9.730	69.4	131	149	350	19.8	37.5	42.7
84	2	17.65	694	761	680	2135	32.4	35.6	32.0
110	3	16.69	462	622	513	1598	28.9	39.0	32.1
180	4	18.00	635	923	835	2393	26.5	38.6	34.9
365	3	15.05	193	433	381	1007	19.1	43.0	37.9
730	2	25.05	842	1015	1115	3072	27.0	36.3	36.3
1010	2	28.09	2619	2189	3367	8176	32.0	26.8	41.2

* SC = subcutaneous fat
** IEM = intermuscular fat
*+ Int. = internal depot fat
+ from Lohse (1971)

TABLE 5

THE PARTITION OF DISSECTIBLE FAT IN MERINO WETHERS

Age (Days)	N	Mean PFEB Wt. (kg)	Mean SC* (g)	Mean IEM** (g)	Mean Int.*+ (g)	Total Fat (g)	Percentage of total fat % SC	% IEM	% Int.
0	8	3.44	5.0	41.0	39.5	85	5.8	47.9	46.2
7	5	4.63	21.8	100	70.5	192	11.3	52.0	36.7
18	3	5.42	62.6	85.4	70.6	223	28.1	40.2	31.7
28+	2	8.361	95.3	136	177	409	23.3	33.4	43.3
110	3	15.02	625	836	728	2189	28.5	38.2	33.3
180	4	18.62	717	1034	806	2558	28.4	40.4	33.2
365	4	18.18	354	537	568	1460	24.3	36.8	38.9
730	2	22.71	609	896	742	2247	27.1	39.8	33.0
1010	3	33.57	2758	2698	3319	8875	31.2	31.5	37.3

* SC = subcutaneous fat
** IEM = intermuscular fat
*+ Int. = internal depot fat
+ from Lohse (1971)

TABLE 6

THE PARTITION OF DISSECTIBLE FAT IN MERINO RAMS

							Percentage of total fat		
Age (Days)	N =	Mean PFEB Wt.	Mean SC*	Mean IEM**	Mean Int.*+	Total Fat	% SC	% IEM	% Int.
		(kg)	(g)	(g)	(g)	(g)			
0	6	3.398	5.2	43.0	38.0	86	6.0	49.9	44.1
7	3	4.412	12.0	74.0	64.8	150	8.0	48.9	43.1
18	3	6.629	112	189	123	424	26.5	44.6	28.9
28+ 84	2	7.967	63.6	130	124	318	20.0	40.9	39.1
110	3	15.80	607	793	500	1903	32.0	41.7	26.3
180	5	18.24	551	857	695	2203	25.0	43.4	31.6
365	5	20.03	438	561	411	1411	31.1	39.8	29.1
730	2	22.43	263	448	490	1201	21.9	37.3	40.8
1010	4	39.4	2485	2465	2743	7693	32.3	32.0	35.7

* SC = subcutaneous fat
** IEM = intermuscular fat
*+ Int. dep. = internal depot fat
\+ from Lohse (1971)

DISCUSSION

(a) Relative percentage growth of dissectible fat

At birth, in the lambs examined there was a very small amount of subcutaneous fat. Of those lambs dissected at birth, 50% had less than 2 g, 40% less than 6 g, and the remainder between 6 g and 13 g of subcutaneous fat. When fat occurred it occurred most commonly on the flank and shoulder regions.

Between birth and 18 days the subcutaneous fat showed a greater relative increase in weight in relation to its weight at birth than did the intermuscular or internal fat. However, the absolute increase in fat weight in all three depots was similar.

This greater relative increase in subcutaneous fat in the first 18 days is reflected in the figures for the partition of fat, with the proportion of the total fat occurring in the subcutaneous depot increasing rapidly. The biological impetus for the redistribution of the total dissectible fat could be that the subcutaneous fat acts as an insulating mechanism before the fleece has grown sufficiently to take over this role, and thus aids in maintaining a thermal homeostasis.

The seasonal fluctuations in available pasture and other factors affecting growth are reflected in the data by the fluctuations in body weight. The subcutaneous and intermuscular fat were more severely affected by a body weight loss than the internal fat.

At the same age the relative percentage growth values for intermuscular fat were higher than those for subcutaneous fat within the same sex except for the final slaughter weight. This indicates that the subcutaneous fat is later maturing than the intermuscular fat. However, to use the term later maturing may be misleading in the light of its overall growth pattern.

By plotting the relative percentage growth values obtained from the data in this experiment against the PFEBWt it appeared that the point at which the rapid deposition of subcutaneous fat began was at approximately 16 kg PFEBWt for ewes, 18.6 kg for wethers and 22 kg for rams.

For the intermuscular fat, the stage at which rapid fat deposition began was at a slightly higher body weight. However at these weights the intermuscular fat had reached a much greater proportion of the weight recorded at the final slaughter stage.

The individual fat depots composing the total internal fat fell into three distinct groups with regard to their growth. However as the omental and kidney fat depots contained most of the internal fat only these depots shall be considered. It is pertinent to state that, before the stage of accelerated growth of these depots they contained 51% of total internal fat in the rams and wethers, and 63% in the ewes. At the final slaughter stage they contained 71%, 85% and 78% of the total internal fat for the rams, wethers and ewes respectively.

With those internal fat depots under consideration in this paper the PFEBWt at which rapid fattening occurred appeared to vary between the sexes. It occurred earlier in the ewes than in the wethers and later again in the rams. Although the difference between the wethers and rams was not as great as between the wethers and the ewes.

When all three fat depots are considered it was estimated that the rapid fattening stage began when the ewes had reached 58%, the wethers 55% and the rams 68% of the final muscle weight measured. The PFEBWt at which this occurred were between 16.7 and 18 kg for ewes, 18-22 kg for wethers and at or in excess of 22.5 kg for rams. The sexes show the same relative order of magnitude in their body weights in this respect as Berg and Fukuhara (pers. comm.) found in cattle. The weight at which rapid fattening began in the wethers concurs well with the weight for transition from a prefattening to a fattening stage of growth demonstrated by Searle and Griffiths (1975) in a similar strain of Merino.

(b) Partition of dissectible fat

Subcutaneous fat was much the smallest depot at birth, however, by 18 days it had achieved the proportion of the total depot about which it fluctuated until the last stage of the study. In the period from 180 days to 365 days, when the ewes lost 12% of their body weight and the wethers body weight remained static, the subcutaneous fat was more severely affected than the intermuscular or internal depot fat and fell as a proportion of the total dissectible fat.

At birth, and seven days for all "sexes", the intermuscular fat contained the highest proportion of the dissectible fat. From this point it showed a fluctuating decline with increasing age and body weight.

The internal depot fat was at its maximum as a proportion of the total dissectible fat at birth, then fell rapidly to 18 days of age, when it formed 28%, 32% and 29% of the total dissectible fat for ewes, wethers and rams respectively. From this point it showed a slow but fluctuating increase through to the oldest animals, where it formed on the average over the three sexes, 38% of the total dissectible fat.

As the subcutaneous fat is more sensitive to an inadequate nutritional level than the intermuscular fat or internal fat, the partition of fat between the major fat depots is altered by weight loss. Thus it would be expected in animals which have not suffered a weight loss, the weight of subcutaneous fat would exceed that of the intermuscular fat at a lighter body weight than in those animals which had not suffered a weight loss.

The data suggests that the partition of fat between the subcutaneous and intermuscular regions occurred in three phases. The early phases during which the subcutaneous fat underwent a rapid growth relative to the intermuscular fat was concluded by about the eighteenth day after birth. From about 18 days until rapid fattening commenced, the ratio remained stable at about .75 : 1, except for the period of weight loss. This, the second phase, it is postulated, is the period when muscle growth is taking precedence over the growth of fat. The third stage is concurrent when the rapid fattening and the proportion of dissectible fat in the subcutaneous fat depot increases, that in the intermuscular depot decreases, while the internal fat shows an increase over the proportion at 180 days.

During the triphasic changes in the relative percentage of subcutaneous and intermuscular fat of the total dissectible fat the percentage of internal fat also changed. During the first phase up to 18 days the internal fat fell from about 46% to 30%, with a concomitant increase of subcutaneous fat (Tables 3-6). The internal fat then slowly increased its proportional contribution to the total fat, apparently unaffected by the seasonal weight loss of the sheep.

CONCLUSION

The results obtained are in agreement with Searle and Graham (1972) in defining a phasic growth pattern for the growth of fat. However with the techniques used in this study a triphasic growth pattern was postulated as opposed to the four phases of Searle and Graham. There is close concurrence with the results of Searle and Griffiths (1975) in the live weight at which rapid fattening began.

The results of this study suggest that for a lean carcass not only should an animal have a high mature body weight but it should also have a high mature muscle weight.

In the Merino strain under study a large proportion of the dissectible fat occurs in commercially valueless regions and an area for improvement would be to attempt to shift more of the internal fat into or onto the carcass. In view of the high and independent heritability of the various fat depots demonstrated in other species (Duniec *et al.*, 1961), this should be possible as techniques are available for estimating fat cover.

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THE THEORY BEHIND BREEDING SCHEMES

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SUMMARY

In the traditional stud hierarchy, gene flow is essentially from elite studs through multiplier studs to the general population. Long term responses are thus governed by the rate of progress in the elite studs, selection at lower levels of the hierarchy affecting only the genetic gap between levels. If the sire breeding nucleus is opened to gene inflow from lower levels, there are two main effects. First, the genetic gains from selection at lower levels are introduced to the nucleus, and can be passed from the nucleus to the whole population. Second, by the regular introduction of less closely related individuals to the nucleus, the rate of inbreeding is reduced.

The increased rate of genetic gain through opening the nucleus is only appreciable when about 50% or more of females are needed for replacements, and may then be 10% to 15% greater than in a closed nucleus. The best structure then is to have about 10% of the population in the nucleus, about half of the nucleus female replacements introduced from outside, and all surplus females born in the nucleus used for breeding in the other flocks. However, these values may be varied considerably without much effect on genetic gains. The rate of inbreeding in an open nucleus will usually be about half of that in a closed nucleus of the same size. This may be of value in small nucleus systems, but is of negligible importance in large scale schemes.

INTRODUCTION

Genetic responses to selection within populations of domestic animals are usually not very rapid, and in the slower breeding species such as sheep may take some time to spread through the population. For these reasons, the costs of running a selection programme may not be justified if they have to be recouped by the increased productivity of the flock in which selection is practised. However, this problem may be overcome if selection is carried out in special flocks (studs) so that the costs of obtaining genetic improvement are spread over the increased production of all animals using the studs as the source of superior genes. In fact, not only is this the common pattern in the livestock industries, but there is usually a further structure, with elite studs at the apex of a pyramid, acting as a source of breeding stock to a layer of multiplier studs, which in turn pass on genetic improvements to the commercial producers. This pattern acts to multiply many fold the increased production resulting from a given genetic gain at the top of the pyramid. The structure of the Australian Merino breed was described in these terms by Short and Carter (1955).

In such a system, the direction of gene flow is essentially from the apex of the pyramid to the base, and the result of this is that the long term rate of genetic change in the whole breed is that of the genetic sources at the top of the pyramid. The effects of selection carried out at lower levels of the hierarchy are in the long run only to determine how far apart genetically the different levels of the hierarchy are. The rate at which this long term situation is approached depends on the rates of gene flow between the levels. The effects of such a hierarchy on breed improvement were recently summarized by Bichard (1971).

OPEN NUCLEUS SYSTEMS

In recent years there has been a great expansion of interest in a different structure, usually practised in the context of co-operative group breeding schemes. However, the structure could in principle be applied in other contexts, such as on a single property, or indeed it could be adopted by the traditional stud hierarchy. Therefore the structure will be referred to here by the more general name, open nucleus breeding system. The characteristic of this system is that the sire breeding nucleus is not closed, so that gene flow occurs not only from apex to base of the pyramid, but also in the reverse direction, from the base to the nucleus. Normally, in group breeding schemes, only females are transferred from the base to the nucleus, but this is not a necessary restriction, at least in theory. If open nucleus systems are used in the traditional hierarchy, there may well be transfer of males from daughter studs to parent studs. However, only transfer of females from base to nucleus will be given detailed consideration in this chapter, since in group schemes sire selection in the base will be impracticable for managerial reasons in most cases. The rates of genetic gain which can be obtained by opening the nucleus to females from the base have been discussed by Jackson and Turner (1972) for an Australian Merino system, and by Rae (1974) for New Zealand Romneys, and in both cases optimal structures for such a system have been sought. A somewhat different approach has been taken by James (in press) who attempted a theoretical analysis in more general terms.

The essential effect of opening the nucleus on the rate of genetic gain is that because genes now flow from base to nucleus as well as from nucleus to base, any genetic gains made in the base by selection of base replacements will contribute also to genetic gains made in the nucleus, the extent to which this happens being dependent on the rate of gene flow from base to nucleus. So compared with a closed nucleus, an open nucleus has two sources of long term gain, of unequal magnitude.

If we compare the two possibilities of either closing or opening the nucleus after it is established, we see that the difference in mean breeding value of nucleus replacements in the two systems arises because in the open nucleus female replacements come partly from the base, and therefore can be very highly selected compared with the replacements which would otherwise have to be chosen from within the closed nucleus. But since the mean breeding value of the base is lower than that of the nucleus, this genetic difference offsets to some extent the expected genetic superiority of the females from the base due to their being highly selected. Making optimum use of base females in the nucleus thus involves balancing these two factors in the best way possible. Looked at in this way, the problem becomes one of choosing nucleus female replacements whose expected breeding values are as high as possible, and the cut-off points in nucleus and base should be chosen so as to have equal expected breeding values. For selection on a character with heritability h^2, this is equivalent to adding A/h^2 to the phenotypic value of each nucleus born female, where A is the mean breeding value difference between nucleus and base, and then selecting the best females on these adjusted values as nucleus replacements. (To allow for any environmental differences the phenotypic values should be taken as deviations from the corresponding means). The only problem is in knowing A, which may vary in the early stages of the programme before settling down to its long term value. If it is assumed that A will be relatively constant then it is possible to work out theoretically what the selection cut-off points should be in nucleus and base, and from tables of the normal distribution convert this to proportions selected from nucleus and base, which is a more convenient method, since comparisons need only be made on a within flock basis.

The optimum fraction of the population to be used in the nucleus can be considered in a similar way. The smaller the fraction of the population in the nucleus, the more intensely can females be selected from the base as nucleus replacements, and so the greater will be their genetic superiority over the mean of the base. On the other hand, as the nucleus size decreases the sires for use in the base must be selected from among a smaller number of males born in the nucleus, and so their genetic superiority over the mean of the nucleus decreases. The result will be that this tends to increase the genetic gap between nucleus and base, and thus negate the beneficial effect of the more intense selection of females. The average genetic value of female replacements for the nucleus will be greatest when the nucleus size is chosen so as to give the best balance between these opposing forces. The choice of nucleus size may then be regarded as a problem of balancing some loss of genetic gain on the sires-of-dams path against an increase of genetic gain along the dams-of-sires path.

RATES OF GENETIC GAIN

Equations which can be used to predict the consequences of open nucleus systems have been worked out (James, unpublished data). For instance, the steady rate of gain when the system settles down, G^*, is given by the following equation.

$$G^* = \frac{(1+y)C_N + xC_B}{(1+y)l_N + xl_B} \qquad (1)$$

In this equation x is the fraction of breeding females in the nucleus which were born in the base, y is the fraction of base breeding females which were born in the nucleus, and l_N and l_B are the average ages of parents in nucleus and base respectively. C_N and C_B are the genetic selection differentials in nucleus and base, measured from the means of the groups in which selected animals were born. In selecting for a trait with heritability h^2, the genetic selection differentials are h^2 times the phenotypic ones. If A^* denotes the stable difference in mean breeding value between nucleus and base, then

$$A^* = \frac{2(l_B C_N - l_N C_B)}{(1+y)l_N + xl_B} \qquad (2)$$

The genetic selection differentials are averages and can be calculated as follows. Let D_{MN} be the genetic superiority of males selected as nucleus sires over the mean of all males born in the nucleus, D_{FN} be the genetic superiority of nucleus-born females selected as nucleus dams over the mean of all nucleus-born females, and d_{FN} be the genetic superiority of base-born females selected as nucleus dams over the mean of all base-born females. Then

$$C_N = \tfrac{1}{2}(D_{MN} + (1-x)\,D_{FN} + xd_{FN}) \qquad (3)$$

Let D_{MB} be the genetic superiority of rams selected as base sires over the mean of all nucleus-born rams, D_{FB} be the genetic superiority of nucleus-born ewes selected as base dams over the mean of all nucleus-born ewes, and d_{FB} be the genetic superiority of base-born ewes selected as base dams over the mean of all base-born ewes. Then

$$C_B = \tfrac{1}{2}(D_{MB} + yD_{FB} + (1-y)d_{FB}) \qquad (4)$$

Thus C_N and C_B can be calculated, as can l_N and l_B from the vital statistics, so that for any proposed nucleus breeding plan, we can work out its consequences for ultimate rate of genetic gain and the genetic gap between nucleus and base.

It may be helpful to show how equations (1) to (4) are applied, and this is done using the example shown in Figure 1 of Jackson and Turner (1972). In this system there is a nucleus of 20 rams and 1000 ewes with 2 ram and 4 ewe age groups. The base has 400 rams of 3 age groups and 20,000 ewes of 5 age groups. The lambing rates are 70% in the nucleus and 74% in the base. Half the nucleus ewe replacements come from the base and all surplus nucleus-born ewes are used as base dams, so $x=0.5$. Since 125 nucleus ewe replacements are selected from the 350 nucleus-born ewes, the other 225 are used as base ewe replacements, so $y = 225/4{,}000 = 0.05625$.

The best 10 rams are selected as nucleus replacements from 350 born each year, giving $D_{MN} = 2.289$ (in units of $h^2\sigma$). Also 133 base rams are replaced yearly, so in all 143 of 350 are selected, giving a selection differential 0.949. Then since $\frac{10}{143} D_{MN} + \frac{133}{143} D_{MB} = 0.949$ we find $D_{MB} = 0.848$.

The best 125 out of 350 nucleus-born ewes are selected as nucleus dams, giving $D_{FN} = 1.045$. Since the other 225 are used as base dams $125 D_{FN} + 225 D_{FB} = 0$, since the mean deviation for the whole group is zero. Thus $D_{FB} = -0.580$. The best 125 out of 7400 base-born ewes are selected as nucleus dams, giving $d_{FN} = 2.482$. Since 225 base ewe replacements are nucleus-born, the other 3775 are base-born, and in all $3775 + 125 = 3900$ base-born ewes are selected, with a differential of 0.755, from the 7400. Then since $125 d_{FN} + 3775 d_{FB} = 3900(0.755)$, we find $d_{FB} = 0.698$. Then

$$C_N = \tfrac{1}{2}(2.289 + (0.5)(1.045) + (0.5)(2.482)) = 2.026$$

$$C_B = \tfrac{1}{2}(0.848 + (0.056)(-0.580) + (0.944)(0.698)) = 0.737$$

The average ages of sires are 2.5 years in the nucleus and 3 years in the base. From age-specific fecundities in Table 2 of Jackson and Turner (1972) the average ages of dams are 3.72 years in the nucleus and 4.28 years in the base. Then $l_N = 3.11$ years and $l_B = 3.64$ years. Thus

$$G^* = \frac{(1.056)(2.026) + (0.5)(0.737)}{(1.056)(3.11) + (0.5)(3.64)} = 0.49$$

and

$$A^* = \frac{2((3.64)(2.026) - (3.11)(0.737))}{(1.056)(3.11) + (0.5)(3.64)} = 1.99$$

To find an optimum breeding plan we have to repeat the calculations for a range of values of the different variables and find that combination which gives the best results. Clearly, given the number of variables involved, this may be a rather tedious operation.

For this reason, a fairly general survey was carried out, using a slightly simpler model (namely, assuming generations do not overlap) in order to get ideas on when an open nucleus system gives appreciably greater gains than does a comparable closed nucleus system, and to what extent the optimum structure of the scheme depends on variations in the basic parameters. The detailed results are to be published elsewhere, but the general conclusions are as follows.

First, by looking at optimum schemes for different combinations of selection intensities in males and females, it was found that the advantage of opening the nucleus was not very great unless the fraction of females born needed for breeding was about 50% or more. If the selection intensity in females is 20% then the best that can be done by opening the nucleus is to increase the rate of gain by about 5% of that attainable in a closed nucleus. On the other hand, if the selection intensity in females is 50% to 80%, then an open nucleus may give genetic gains 10% to 15% greater than can be obtained in a closed nucleus. The selection intensity in males does not greatly affect these results, though the gains are slightly greater, for a given female selection intensity, when a smaller fraction of males is selected. The selection intensities which favour opening the nucleus are of course those common in sheep and beef cattle breeding.

Under these conditions (1% to 2% of males needed for breeding, 40% to 80% of females needed for breeding) the ultimate rate of genetic gain was greatest when about 10% of the whole population was in the nucleus, when about 40% to 50% of the nucleus female replacements were introduced from the base, and when all nucleus born females not needed as replacements in the nucleus were used as replacements in the base. However, the rate of gain was not very sensitive to changes in these parameters. For example, if 1% of males born and 80% of females born are needed as replacements, less than 10% of the *extra* gain obtained by opening the nucleus is lost by varying the nucleus size between 4% and 20% of the whole population, by varying the fraction of nucleus female replacements introduced from the base between 30% and 70%, or by using all or none of the surplus nucleus-born females as replacements in the base. Since the extra gain is only 15% of the total, such variations would reduce the total rate of gain by only 1% to 2%. There is therefore plenty of scope for varying these parameters for practical reasons without losing much potential for genetic gain. This is perhaps not surprising, since the effect of opening the nucleus is not great, though undeniably valuable.

RATES OF INBREEDING

In the same paper a method of calculating the effect of opening the nucleus on the rate of inbreeding was developed. It is not proposed to discuss the method here, since it involves matrix algebra and is a little complicated. However, a brief summary of the main conclusions can be given. The introduction of breeding animals from outside into the nucleus reduces the average degree of relationship between nucleus sires and dams below the value it would have in a closed nucleus of the same size, and therefore results in a lower rate of inbreeding. The parameter with the greatest effect is x, the rate of introduction of genes into the nucleus. When $x = 1$, and all nucleus dams are introduced, the effective size of the nucleus is about twice that of a closed nucleus of the same size. Most of the increase in effective size of the population is achieved by raising x from zero (i.e. a closed nucleus) to 0.5, rather than by raising x from 0.5 to 1. Thus, very roughly, we can say that an open nucleus in which about half the female replacements are introduced from the base would have about twice the effective size of a closed nucleus of the same actual size. Since it would have about twice the effective size, it would have about half the rate of inbreeding. This is so over a wide range of values of the relative size of nucleus and base. For instance, a closed nucleus of 25 sires and 400 dams used each generation would have an effective size of 95, and thus an inbreeding rate of about 0.5% per generation. An open nucleus with $x=0.5$, $y=0$, when the base used 100 sires and 1600 dams per generation, would have an effective size of 208, while if the base were five times as large (500 sires, 8000 dams) the effective size of the population would be 219. In these cases the rate of inbreeding would be about 1% every 4 generations. In systems as large as this, inbreeding is a very minor consideration. Only in much smaller systems would the inbreeding effect be worth taking into account in designing the system. It should be noted that the size of the nucleus rather than the size of the whole system is the important feature in relation to inbreeding.

OTHER CONSIDERATIONS

In planning a nucleus system, the long term features are determined only by the procedures adopted for selection and transfer of breeding stock, as can be seen from equations (1) to (4). The initial conditions, namely the source of foundation stock and the way in which foundation stock are distributed between nucleus and base, have no influence on either the final rate of genetic gain, or on the genetic gap between nucleus and base. But this does not mean that they are unimportant. The initial level of breeding value will determine the base line above which gains are made, and a system which starts x units ahead in breeding value can expect to stay x units ahead in breeding value. So the average genetic value of the foundation stock should be as high as practicable. It is intuitively reasonable, and can be proved mathematically, that the best available animals in the foundation stock should be placed in the nucleus, because this leads to the most rapid gains in the early years of operation. This is because the passage of genes from nucleus to base is used to lift the base towards the level of the nucleus, and the higher the level of breeding value in the nucleus, the greater the lift given to the base. However, it must be remembered that the overall level of the whole population at the beginning is not altered by allocation of animals to nucleus or base, and that although by very intense initial selection a highly superior nucleus may be established, this genetic differential in the nucleus will be only partly passed on to the next generation of the base.

Nevertheless, it will be worth seeking the best possible genotypes for the nucleus, and in a co-operative group scheme there may be some advantage in looking for superior foundation stock in other flocks. The question of whether to use highly selected individuals from many flocks or to choose foundation animals from one genetically superior flock cannot be answered in general. An answer depends on how many flocks are available and on the relative magnitude of between-flock and within-flock genetic variation. This question has been discussed by James (1966) and Jackson and James (1970). Usually it would seem best to select from several flocks, especially as this would be expected to increase the genetic variability available for selection. However, the decision must be made in the light of individual circumstances.

A variety of questions about organization and its genetic effects can be answered quickly using equations (1) to (4). In the example, we can ask if it is worth using the cast-for-age rams from the nucleus in the base, replacing some of the rams 2 years younger which would be used otherwise. These rams have a genetic differential 2.286 over the mean of their own drop, but compared with the drop 2 years later this is reduced by (2)(0.49) to 1.306. These would replace the worst 10 of 143 selected under the scheme described above. These 10 would have an expected genetic differential of 0.269, so if they were replaced by the older nucleus rams the genetic mean of the base rams would be increased by $\frac{10}{133}$ (1.306−0.269)=0.078 and since half of this would be passed on to their progeny, the gap between nucleus and base would be reduced by about 0.04 $h^2\sigma$. The optimum operating conditions would be slightly altered, as would the rate of genetic gain. If this were the only change made, the rate of gain would be increased to 0.495$h^2\sigma$ while A^* would be reduced to 1.95$h^2\sigma$, as can be checked by substitution in the equations. These are of course comparatively small changes.

DISCUSSION

In the preceding sections attempts have been made to show the important features of nucleus breeding schemes and how their genetic effects may be calculated. There have also been discussions of operating conditions which give greatest genetic gains in the steady phase. However, these are not necessarily the economically best conditions. In particular, since the rate of genetic gains is not very sensitive to variation in the parameters, these may well be varied in order to produce a significant cost reduction with only a negligible change in genetic gains. For instance the size of the nucleus may be halved with very little effect on genetic gains, but costs of the nucleus would be greatly reduced. However, the economic optimization of a scheme will depend on many factors specific to the particular situation, and cannot be profitably discussed here.

Though the equations given here are quite general, the numerical results discussed have all been based on the assumption of individual selection for a continuously distributed trait. This has made it possible to ignore heritability, since all responses are proportional to heritability. If such methods as progeny testing are considered, further parameters such as numbers of sires tested, and relative usage of proven and untested sires need to be considered. Again, it is probably best that these be considered in the context of specific schemes.

It is possible that open nucleus systems may be somewhat more valuable for all-or-none traits which are rare. It is well known that the effective heritability of such traits is low, but increases as the trait becomes more common, and then falls again. If a large scale screening is carried out to initiate the nucleus, the level of incidence may be raised enough to make a significant improvement in effective heritability. However, there might then be little advantage to keeping the nucleus open.

Perhaps it is worth reiterating the basic principles on which a nucleus breeding scheme should be based. Considering all replacements, male and female, regardless of their place of use, it is clearly best that selection should be on estimated breeding value, taking into account any genetic differences between their places of origin. This will maximize the mean breeding value of the whole of the next generation, which will not be affected by the mating pattern adopted. Setting aside a sire-breeding nucleus enables the best sires and dams to be mated, so that in the progeny the sires will be selected from a group with an above average mean, and the problem to be solved is to find the best balance between this effect and the reduced selection intensity involved in selecting sires from a small fraction of all males born. There will be some further complications if we allow for genetic differences between age groups, but the general principles will not be affected.

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THE PROMOTION OF BREEDING SCHEMES AMONG STUD BREEDERS

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SUMMARY

The entrenched hierarchical structure of the stud sheep industry has closed the parent studs to new genetic material. This structure and traditional selection based on visual appraisal has slowed or even halted genetic progress over the last 30 to 40 years. Renewed progress in stud and commercial flocks depends on the wider adoption of appropriate breeding schemes based on objective measurement in flocks large enough for adequate genetic progress.

To break the hold of traditional methods, we need firstly to identify those social and economic forces in the industry which tend to maintain the *status quo*, and to recognize the influence on producers' decision-making of groups such as stock and station agents, sheep and wool classers, bankers and consultants. At the same time, it will be necessary to create an awareness of the need for change in all sections of the industry. This is best done by demonstrating the superiority of commercial sheep bred on objective criteria over those bred by traditional methods—by demonstrating the economic benefits of breeding for production rather than for blood.

Changes in breeding methods will almost certainly produce social problems for some individuals and sections of the industry. These possibilities must be foreseen and extension must attempt to minimize the problems of adjustment.

To date too few people have been charged with the task of promoting the adoption of recommended breeding programmes and these have not always had adequate training and experience in sheep breeding or in extension. We need to expand the training of appropriate personnel.

INTRODUCTION

The hierarchical structure of the stud Merino sheep industry has been described by Short and Carter (1955); this structure provides an efficient method for disseminating changes, both good and bad, that may be made in the parent studs (Pattie, 1973). Bichard (1971) has examined the rate of dissemination of genetic improvement in such a structure and shown there is a lag of approximately two generations between tiers of the hierarchy when average males are sold to the next layer. The lag will be more or less if below or above average males are transferred.

McGuirk (1976) has stated that permanent genetic improvement in commercial flocks of Merinos is entirely dependent on selection policies adopted in the stud; as pointed out by Pattie (1973), however, the parent studs are closed to introduction of new genetic material and so breeders have restricted genetic variation with which to work.

The importance of promoting breeding schemes amongst stud breeders has been stressed by Pattie (1973) who states "A search for ways in which the present system, so rigidly closed by tradition, could be modified to allow introduction of new genotypes and the use of scientific breeding methods would seem to be a most urgent project at present facing the Merino and other breed societies".

In this chapter the extension methods which have been used in promoting breeding schemes will be discussed; a model communicating innovations described by Rogers and Shoemaker (1971) is used to categorize these extension efforts and to comment on the effectiveness of these approaches.

METHODS AND MATERIALS

Rogers and Shoemaker (1971) describe four basic stages in the Innovation-Decision Process:—

- Knowledge — the individual is exposed to the innovation's existence and gains some understanding of how it functions.
- Persuasion — the individual forms a favourable or unfavourable attitude towards the innovation.
- Decision — the individual engages in activities which lead to a choice to adopt or reject the innovation.
- Confirmation — the individual seeks reinforcement for the innovation-decision he has made, but he may reverse his previous decision if exposed to conflicting messages about the innovation.

This model has been used to study thirteen cases, in Australia and overseas, in which the author has been involved in the promotion of breeding schemes. Key factors in these case studies are shown in Table 1 under the stages of the Innovation-Decision Process. The factors listed are those considered important in the extension of breeding schemes and are not the results of in-depth sociological surveys.

RESULTS AND DISCUSSION

While recognizing that evaluation of these case studies is by no means a detailed sociological study of the way in which the innovation-decision process works in the sheep industry, it does provide a basis on which the promotion of breeding plans can be considered in a general way and allow a discussion of solutions to the problem described by Pattie (1973).

It can be seen from Table 1 that the means by which individuals gain knowledge of breeding schemes are diverse. The traditional extension methods of breeding schools, bulletins, press and radio have not always been as effective as might be expected. Other means such as hogget competitions used as teaching aids, satisfaction from breeding schemes with cattle, and the influence of farm consultants, woolbuyers and successful breeders using these recommendations have also influenced the spread of knowledge about breeding schemes. The prestige of organizations in developing countries like FAO, has hastened acceptance of new information promoted by their experts.

TABLE 1

KEY FACTORS IN THE PROMOTION OF BREEDING SCHEMES

Stage of innovation decision process	Key factors	
Knowledge	Hogget competitions	Mass media-radio
	Breeding schools	Beef recording scheme
	Wool buyers	Australian Merino Society
	Farm consultants	An Accountant
	Extension bulletins	Visit existing schemes
	FAO sheep raising project	
Persuasion	Visits to schemes in operation	Exercises in selecting rams on measurement
	Visits to studs and satisfied clients using measurement	Contact with author
Decision	Compared progeny of rams from 3 sources	
	Compared crosses of ewes and progeny.	
	Decided to establish "control" flock	
	Compared nucleus progeny with remainder	
Confirmation	Full adoption of schemes (7)	
	Recently commenced (2)	
	Interest waning (2)	
	Opposition by sheep classer (2)	

Experience has shown that encouraging interested breeders to visit schemes in operation and discuss them on a producer level is a worthwhile extension activity. Sheep breeders seem to react more favourably when breeding schemes are on their own or local flocks. They are less receptive to demonstrations on government research centres. This clearly indicates the need for establishing demonstration flocks with co-operators. Breeders using these schemes are some of the most effective extension agents.

In two of the four cases studied in which interest is either waning or has ceased, professional sheepclassers have played an influential role in presenting conflicting information and attitudes. Many sheepclassers see these breeding schemes as a threat to their livelihood and extension officers must recognize this fact. Indeed officers should try to work with and through professional sheepclassers who are widely accepted in the industry.

Breeders in these case studies were motivated by low returns, the unavailability of rams of the quality required at a price they could afford to pay, and high labour inputs. They might have been interested if sound economic assessments had been available in an understandable form. Indeed there is a need for articles such as those by Thatcher and Napier (1976), Napier and Jones (1976), and Spriggs (1975) to be published as extension material for use by extension officers in the field.

(a) Extension activities

The key factors listed in Table 1 suggest areas in which extension activity should be expanded.

(1) Demonstration flocks should be established in the local area. Utilize co-operators using objective measurement to promote breeding schemes.

(2) At hogget competitions and sheep classing demonstrations used as teaching aids get people to estimate fleece and/or body weight. Then shear and weigh the wool and body as a check on accuracy or lack of it.

(3) Write bulletins on breeding plans and budgets with step by step procedures, e.g. Clark and Bennett (1973), Jefferies (1976), and Turner (1973).

(4) Economic articles must be widely promoted, but at present they exist in research publications such as Hill (1974) little understood by laymen.

(5) Schools should be organized to train breeders and sheepclassers in principles of breeding and schemes which could be promoted Australia-wide.

(6) Alternative roles will be required for people whose professional activities would be curtailed by the introduction of scientific breeding schemes. For example, sheepclassers could become salesmen for studs using objective measurement.

(7) Schools for stock agents have been held at least in Tasmania and Western Australia. These could be expanded to reach all those engaged in selling stud stock and in ram selection.

(8) Liaison with wool testing laboratories to help interpret objective measurement results to the breeder as an aid to ram selection.

(9) Co-operation with breed societies, such as the Poll Dorset production competitions (Stafford and Dolling 1975), helps to promote measurement among breeders.

There would be a greater chance of acceptance by sheep breeders if they could see less of a threat and more of the economic, labour and management advantages of the proposed changes in breeding plans for themselves and the industry as a whole. For example, there is less work in managing a nucleus flock than a complex family system.

(b) Extension personnel

It appears that the most effective extension officers in sheep breeding are those with a good academic training in genetics, and wide experience in breeding projects under the guidance of recognized geneticists on properties locally, interstate and overseas. Schools and workshops on genetics supported by work with co-operating breeders to train the officer to handle the practical problems associated with sheep breeding. This sort of experience helps officers to keep their feet on the ground.

More officers need to be trained to work in this field. There are only one or two specialist extension officers working on sheep breeding in each State.

(c) Sociological Surveys

There is an urgent need for sociological data on why producers have not accepted recommended breeding plans. This data needs to be collected from those for and against change as well as other members of the strong social structure in the stud industry. This information could then be used to help design more effective Extension Programmes.

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SOCIOLOGICAL, ECONOMIC, BUSINESS AND GENETIC ASPECTS OF SHEEP GROUP BREEDING SCHEMES

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SUMMARY

The birth and development of sheep group breeding schemes represents a major departure from the established selection, business and sociological patterns long accepted within the industry. This is the first large scale adoption of research results announced 20 years ago and expensively extended in the interim. Geneticists had not previously considered group breeding and currently a research gap exists on the potential gains between starting and the steady state. Close ties between farmers and researchers, a management oriented extension service, and open Government support have given New Zealand a sound basis for group breeding. In Australia group breeding schemes have grown largely neglected by the huge organization designed to assist the wool industry. Group breeding has caught the imagination of farmers and is already a major force for genetic and general change. Groups are likely to continue to increase and producer inspired vertical integration within the industry has already started. The traditional sheep industry, the advice of scientists and the development of group breeding are reviewed in the light of sociological, economic business and genetic factors of importance. The need for a sound legal and financial basis for a long term investment in animal breeding is covered and the likely future development of group breeding schemes discussed.

INTRODUCTION

In 1976 the author was granted a three-month fellowship by the Australian Agricultural Council to study livestock group breeding schemes in New Zealand and Australia. This involved visiting many of the groups and research workers, accountants and extension officers involved in various aspects of group breeding schemes.

In 1967 the first schemes began in New Zealand and Australia and have expanded rapidly. New Zealand now has 27 sheep and 7 cattle groups while the major Australian sheep group has 420 members and 1.25 million ewes representing 10% of the Western Australian and 3% of the Australian Merino ewes joined to Merino rams. A description of the findings of the fellowship follows with specific reference to sociological, economic, business and genetic aspects.

THE TRADITIONAL SYSTEM

(a) The Business of Ram Breeding

The rapid increase in the number of farmers joining group breeding schemes (GBS) during the last six years represents a major departure from established business and sociological patterns long accepted within the sheep industry. Within Australia most Merino sheep men rigidly adhere to a single blood line within the three tier system of parent studs, daughter studs and commercial flocks. Flock rams are bought from a stud during an annual visit on a fee scale set by the parent studs. In many cases the stud classer assists in choosing the rams and annually culls the maiden flock ewes and thus plays a key role in maintaining the close business association between flock and stud.

(b) The Notion of Quality

Preservation of and progress in sheep quality have been in the hands of the studs, studmasters being well paid and respected for their acknowledged skills in this area. It has been calculated that in terms of genetic gain a two-generation advantage is held by parent studs over daughter studs and by daughter studs over commercial flocks, (assuming that genetic progress is being made). As only less desirable rams are sold down through the ranks a hierarchy of quality exists. Quality assessment is a visual-tactile skill taught superficially through such systems as the annual show and jackeroo training but ultimately inherited by studmasters and some classers. Studs are the authority on and repository of sheep quality.

(c) The Social Organization

From the pinnacle of the 23-parent studs unfolds a well defined social organization. The functions are divided among ram breeders, multipliers and users who co-operate to produce wool and improve its quantity and quality. From the top level flow not only the genes but also the concept of quality. This value transmission takes place in many ways but forms the pivot on which the present sheep industry depends. Many of the present sheep breeders and their fathers were trained as jackeroos on the parent studs so both by education and family example the studs notion of quality is reinforced. Assent is annually renewed at the visit to collect the rams, a major social outing and one in which many wives participate, enjoying the hospitality of the studmaster and his wife. The commercial sheep breeder and his peer group are socially tied to the stud and all trust, accept and practise the stud's notion of quality. The country and State shows and the media coverage of sheep champions chosen by the visual assessment of studmasters completes the national acceptance of the traditional system.

While many facets of agriculture have been recently moving towards a more "urban" organization of specialization, stricter differentiation and professionalisation of jobs, these forms have long existed in the sheep industry. Assessment of quality is a professional skill held tightly by the sheep classers who through classing the maiden ewes and selecting the rams for the flock owner completely control genetic progress. Such a stable social organization controlled by the parent studs and the professional sheep classers is well able to resist change and generally has done so.

In recognition of the apparent contribution being made to improving the quality of the Merino sheep the government decided not to sub-divide the large stud properties for soldier settlement. This decision helped keep the stud owners in a position of wealth, power and prestige which reached its peak following the 1950s wool boom. This was the time (1955) chosen by scientists to announce to the Merino sheep industry that the very basis of selection used in the studs was wrong. Twenty years of repetition has done little to improve the acceptability of the message which was unacceptable within the sociological organization and threatened the economic position of the rulers. Economic recession has reduced the wealth of the studs but until the advent of GBS their power and prestige in the sheep industry remained unchallenged.

SCIENTIFIC RESULTS

Following research on sheep selection methods scientists claimed that much faster improvement could be made in characters of economic importance by the use of objective measurement. Fleece weight and quality were the first characters examined but the potentials for progress in many others, particularly reproductive rate, have since been defined. For major reviews see Turner 1969, Dun and Eastoe 1970. From 1955 onwards (CSIRO 1955) an extension programme was undertaken to bring about the adoption of selection on fleece measurement. Turner (1973) stated that the campaign to influence stud breeders was generally unsuccessful and today only two major daughter studs in N.S.W. are said to be using fleece measurement effectively.

Scientific recommendations conflicted with traditional selection procedures and the accepted notion of quality. In the face of these new findings sheepmen turned to their professional advisers on matters of quality, the classers, who dismissed the scientists' claims. The classers maintained that they could pick by eye heavy cutting sheep; scientists had ignored the many other factors essential in a "quality" sheep and anyhow non-sheepmen couldn't possibly give sound sheep advice. Most sheepmen accepted this as it agreed with their own feelings.

Selection on fleece weight was not a completely new concept and the work of Mr C. Euston Young in the 1930s in Queensland stimulated scientists to research the benefits of this method (Turner 1973). Austin (1904) states that the "Wanganeila" rams were selected on clean fleece weight from

1878 onwards. The breakthrough made by both men was lost when traditional classing methods took over with their passing.

ADOPTION OF MODERN SELECTION METHODS

The major extension effort for twenty years to sell selection on fleece weight has had some success but mostly at the flock level. Department of Agriculture sheep officers were able to explain the potential benefits of selection on fleece weight and some flock owners agreed to select maiden ewes on greasy fleece weight. Following the work of Morley (1955) larger commercial flock owners were encouraged to form their own ram breeding nuclei within their flocks. Management difficulties at a time of low sheep profitability have led many innovators to revert to the traditional system. A few nucleus breeders have survived and now sell rams. Sheep extension officers have usually only been accepted as advisers on sheep quality by fringe members of the traditional social organization. Their comparative youth, lack of acceptable social background and regular replacement makes them poor competition for the stud classer. Farmers who took up fleece weighing met opposition from leaders and peers, their sheep showed no visual response and rams selected on fleece weight were unavailable. Most returned to the fold.

DEVELOPMENT OF GROUP BREEDING SCHEMES

For GBSs to be as widely accepted as they have been there must have existed a number of ram buyers dissatisfied with the quality of rams available. This feeling is partly generated by the widely publicized results of scientific research and partly by a lack of any visual or measured progress in sheep quality over many years. Organizing this feeling required the presence of an acceptable catalyst person to spark the idea and an organized social unit within which to speak and from which could come the first GBS members. The first two men (Parker 1970 and Shepherd 1975) who thought up the GBS concept were stud masters of medium sized studs, convinced by scientists about selection on measurement, acceptable to sheepmen, and able to speak and convince some of their group of ram buying clients. Such a break with tradition is helped by a degree of economic independence from possible repercussions. A climate of innovation in the farming community is also important because if farmers have made one break with tradition they more easily make the next. This is particularly evident in Western Australia where many new-land farmers left their fathers in the eastern states and adopted a whole new farming technology. In New Zealand GBSs have been particularly successful within the new sheep breeds where the first innovation was the decision to drop Romneys.

Successful catalysts may have a range of backgrounds but must be acceptable, have an audience and be able to convince a proportion of members of the genetic and economic benefits of selection on measurement and the promotion of superior ewes. Farmer catalysts must be established leaders capable of convincing members of their peer group to join the scheme. The other common catalysts are farm management consultants who convince a group of their existing clients to form a group. Once started and organized the forces within the group are self sustaining and non-farmer members are unnecessary and undesirable in any position of dominance.

Major departure from an accepted "norm" within a group usually brings alienation because it is a challenge to those in power; in this case both economically and socially. For the ordinary farmer, success of the new system demonstrates that he made the wrong decision in not joining the scheme and so he would prefer to see it fail. Sons have been strongly opposed by their fathers who see their own prestige and life's work in terms of the ongoing success and standing of the family farm. Such pressure is hard to resist in a close farming family where knowledge, values and assets are all inherited. Stud opposition to GBSs has been strong with expulsion from breed societies of early innovators. This excommunication was followed by social isolation of both the farmer and his wife from the former social organization of stud breeders and ram buyers. Opposition made starting a GBS difficult but has helped keep members together, firmed their resolve to succeed and helped publicise their ideas.

The promotion of top flock ewes is a very appealing concept for ordinary members who feel they are making a personal contribution to progress in the sheep industry. This satisfaction is often demonstrated in a renewed interest in the sheep enterprise and an improvement in management standards and general innovative drive.

Within the founding group not only must the members be acceptable to one another but the quality of the sheep in the individual flocks must also be acceptable. Members who consider their sheep are superior or different are reluctant to pool them. Many groups insist on assessing the acceptability of any new applicant and inspecting his flock to maintain harmonious relations within the group.

FACTORS IMPORTANT IN THE ESTABLISHMENT OF A GBS

Economic and business aspects have tended to be neglected in the enthusiasm of forming a GBS, but a sound economic and business base is essential for a long term venture such as animal breeding. GBSs start with the accepted aim of improving the economic productivity of the sheep. Thus, drawing up the selection programme is a natural first undertaking. The mechanics of the selection programme need to be clear so that both members and nucleus manager understand and efficiently carry out their work. In New Zealand members started by contributing all twinning maidens into the nucleus and entry requirements have slowly expanded. Geneticists have given some suggestions on optimal flock structure in the steady state (Jackson and Turner 1972; Rae 1974) but no precise guidance exists for the build-up years. It is known that the initial screening of a large number of ewes gives a valuable leap forward in genetic progress. Progress in the early years is then heavily dependent on the genetic merit of the foundation sires chosen for the first two joinings.

For farmers considering forming a group breeding scheme a benefit-cost analysis is necessary to weigh the increased costs of measurement and transport plus the formation costs against the value of the extra wool produced in unknown quantities until the steady state is reached. From initial screening, it is four years before the first ram is available and ten years before the flock contains at least all FIs, so at the flock level benefits only come slowly.

Some work has been published on the economic benefits of selection (Spriggs 1975; McGuirk 1976) but sufficient data is not yet available to examine the economic benefits of GBSs. Few of the present schemes have attempted a feasibility study before commencement. And almost all owe their success to ram sales rather than major gains in productivity although this is now being demonstrated in some. While precise genetic gains during the build-up phase are unknown, reasonable data exist for the steady state situation and economic estimates can at least be based on this. Benefits and costs must be related to both the member and the nucleus manager. Calculations indicate that assuming no sale of rams to non-members, the saving in ram costs covers the costs of measurement and gives some extra return to the nucleus manager. Establishment costs can only be covered in the long term by ram sales or rises in productivity. It is worth noting that with a potential annual gain in fleece weight of 2% and an 18% inflation rate and a static wool price one has to be a believer in survival economics to start a GBS. The nucleus manager is the key to the success of most GBSs so his appointment is vitally important. Group recognition of him as a top sheep manager and good visual judge of sheep is important. Many managers previously ran studs and usually have the desired qualities. If they are also community leaders then this personal acceptability lends acceptability to the sheep and since early flock progress is slow the nucleus ewes and particularly the rams for members must be fed so that they look like stud sheep. Members need visual proof that they have made the right decision. A sound legal structure is essential in such a long term undertaking to protect the members investment and set out acceptable financial and working arrangements. Three major decisions govern the legal structure of any GBS. These involve the ownership of the nucleus sheep, control within the group and distribution of rewards. Sheep ownership may rest with the original contributor, nucleus manager or a corporate body such as proprietary limited company or co-operative.Rules must be formulated to cover distribution of the assets if the group disbands. Control usually starts with an elected committee which provides the officers of any corporate body that may be formed. When nucleus managers own the sheep the committee has only an advisory role with reduced powers. Distribution of rewards depends on the ownership structure, the simplest being for the nucleus manager to retain the profits after distributing 1 ram per 5 ewes contributed. Where individuals retain ownership the nucleus manager is paid an agistment fee designed to give him a profit approximately 50% greater than his commercial sheep return as a reward for his extra time, and managerial skill. Corporate bodies must devise a payment system which generously rewards the nucleus manager, who takes the major responsibility in the GBS, and profits are then distributed on a share basis which is usually equal.

While many groups enthusiastically sell the co-operation by gentlemen's agreement concept, many prefer to ensure their place and investment in the group with a documented legal and business structure. This helps stabilize and organize the original idea and cements the commitment of all members.

FACTORS IMPORTANT IN THE ONGOING SUCCESS OF GBSs

The long term viability of GBSs once the enthusiasm and newness have worn off, requires rather different factors from those which start them. Support and encouragement no longer come from advisers or scientists who, having contributed their ideas, leave the farmers to get on with the job. Support must come from within the group itself. Meetings to work out legal, business and selection programs, at which each member needs to feel he is making a contribution, help keep the group together while the slow business of breeding gets underway. Newsletters and perhaps visits to other GBSs help fill in the 3-4 year lag period before the first rams are available. Comradeship and peer group support from within the GBS have overcome the high drop out rate among farmers taking up fleece measurements. This support is important in living with the added management problems, the opposition of neighbours and friends and the long wait while genetic gains materialise at the flock level.

A new enthusiasm arises when visual and economic improvement can be positively demonstrated and this phase has been reached in groups in New Zealand and Western Australia. At this stage the fence-sitting neighbours join or buy rams and the members go out and publicise the proven wisdom of their early stand and thereby enlist new members. The two founding groups have risen from a start of about 10 members to 100 and 420 ram buying clients respectively. The need to believe that progress is being made is important if the GBS is to survive. Methods to demonstrate progress need devising; the progeny test every 10 years using frozen semen from the top rams is the most accurate. Financial rewards from genetic progress sufficient to cover formation and annual costs have been made in many New Zealand groups where lambing percentage has risen 40% and selection for easy care sheep has reduced labour requirements. A more obvious reward has been the profit from the sale of surplus rams to new members and commercial buyers. Increased profits for the manager and members are the ultimate proof of the original idea and that genetic progress is being made.

THE FUTURE OF GBSs

A new stable social organization with a new value system is developing around the present GBSs. Assistance in value transmission in terms of sheep quality is given through the agricultural colleges and universities who teach future farmers. The acceptability and social position of members tends to change once a scheme proves its success and this is acknowledged by outsiders wishing to buy rams or by an increasing membership with original members holding the dominant position. The GBS mirrors the stud system in terms of social strata but with democratic rather than dictatorial rule. GBS leaders with their reinforced confidence and wider contacts among rural, research, and marketing people, tend to rise as leaders in other spheres. The growth of GBS into major commercial ram sellers in direct opposition to the studs will continue. This success has led in New Zealand to the formation of stud GBSs and a partial change to selection on measured characters by many individual studs. Changes in the Australian stud system will be very slow because increases in wool production are less obvious than improvements in reproduction rate and because sheep quality assessment is in the hands of a small professional class. The Western Australian group with 1.25 million ewes and 420 members, convinced of their progress and improved returns, is likely to increase membership rapidly. This group has sufficient production to completely supply a major woollen mill and will probably vertically integrate its whole operation. In New Zealand one GBS bought a small wool store to interlot wool and now owns a wool scour and are 25% shareholders in a spinning mill. An exciting future for GBS seems assured. They have overcome the opposition of the traditional study system and demonstrated a co-operative and innovative skill not thought to exist in the farming community. If the wool production industry is to survive it will probably need to follow the trends set by such other agricultural products as pigs and poultry. This will involve a revolution in wool handling and vertical integration of the industry. In New Zealand a close association exists between Universities, Agricultural Colleges, extension workers, and farmers, all aided by a Government heavily dependent on rural export earnings. Government support of livestock improvement is obvious in the early development of a computerized sheep selection plan and encouragement of GBS by people at all levels. The Government has given further aid by taking a 25% holding in the farmer initiated spinning mill. In Australia attitudes in the extension service range from interest to opposition. No effective association exists in the chain between researchers and farmers. In Australia, agricultural research appears to be done for the sake of Science whereas in New Zealand it appears to be done for the sake of farmers. Active encouragement of vertical integration is essential if commercial opposition is to be neutralized. GBSs have made the breakthrough advocated by scientists twenty years ago and have made a major contribution to improving the earning capacity of the Australian sheep industry, however assistance is apparently withheld at all levels in case the stud industry objects. GBS now have a sound social and financial base, contain considerable innovative and leadership skill and are market oriented. Vertical integration is now possible and with this they will assume a position of dominance in the wool industry and survive where others will not.

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ADVANTAGES OF GROUP BREEDING SCHEMES

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Livestock breeding groups were first established in New Zealand in 1967. They were formed by people who realized that in every large flock or herd, there is a small number of very high-performing animals. The basis of a group breeding scheme is to be able to identify these animals on several properties, and bring them into a central nucleus where they are mated to animals of similar high performance. The male offspring are used in the contributing flocks or herds, and hence improve them genetically.

Traditional livestock breeding has a structure which can be represented by a triangle. At the apex are the stud breeders. Below these are the flock ram or run bull breeders, or propagators, and at the base are the commercial farmers. The stud animals at the top are registered and no unregistered animals can enter the registered flocks or herds. The only movement of stock is downward, involving sires. Because of this, high-performing females are scattered throughout the triangle. Development of the breed, however, and any increase in performance throughout the industry is limited to the progress of the group of breeders at the apex.

The more modern breed societies allow for the identification of high-performing females, regardless of their position in the triangle, and encourage their use in the apex for the breeding of sires. Thus there is a movement of stock in both directions; high-performance females moving up, and high-performance-tested sires moving up and down.

The establishment of group breeding schemes allows for the screening of very large numbers of ewes at the base of the triangle for the purpose of identifying high-performing females, and so the progress that can be made is further maximized.

It should be pointed out at this stage, that animal improvement in the future is unlikely to be confined only to group breeding, and that there will continue to be a place for individual breeders, provided they operate reasonably large flocks or herds, and use modern recording techniques to the fullest extent. Furthermore, the industry as a whole, would be best served if a balance is maintained between individual breeders, and group breeders. There are, however, several advantages to group breeding which should be mentioned.

Genetic Advantages

Because of the large numbers of animals being screened to find the highest producers, only the very best need enter the central nucleus. In many cases each member of the group runs a nucleus within his own flock or herd, where females coming in from the screened commercial section are bred and recorded. It is only the best of these females which enter the central nucleus each year, and then only after careful selection and scrutiny for structural soundness and freedom from important faults.

Many of the advantages arising from group breeding are as follows:

(1) Animals coming into the central nucleus by this means have been tested under practical farm conditions, where their offspring will later perform.

(2) Records are taken for traits of commercial and economic value, and selections are based on these records, subject to health and established standards of soundness.

(3) Replacement sires for the co-operating farms come mostly from the nucleus unit, so the improvements are quickly spread throughout the group.

(4) A rapid generation turnover of breeding stock can be maintained.

(5) There can be an avoidance of inbreeding which may arise with small breeding units.

(6) There is likely to be a continuity in breeding objectives over the years, giving improvement in traits of commercial importance.

(7) By joining together with other breeders, a breeder can benefit from a co-ordinated policy, from pooled experience, from shared facilities, and from the improvements achieved.

Other Advantages

Because of its size and potential, a breeding group has an identity greater than that of an individual breeder. This helps in getting the breeding group, and the commercial goals it stands for better known among farmers. In the past it has often been difficult for a breeder who has improved his stock to obtain a financial reward for his efforts, because he had little impact on the market. With a co-operative venture, more can be spent on promotion and advertising, and the improved stock can be better identified and marketed. Farmers can be more confident of the standards attained, continuity of supply, and the performance of the stock they buy.

The economies of scale of operation can be applied to large-scale group schemes without loss of accuracy or standards of overall excellence of the sires produced.

The group will have a common set of breeding goals, of recording systems, and breeding methods. These will be agreed upon, only after much discussion, argument, and negotiation among group members. A common agreed policy is likely to be more sound, convincing and effective than a series of different plans of independent breeders.

Because of their size and co-operative nature, group breeding schemes can act as a focus for advisory, technical and other aids to breed improvement, and obtaining the advice of a geneticist on breeding methods is more feasible with a group. Groups may also be able to exercise more influence than the individual breeder, in political and commercial circles.

Groups are in a good position to give technical advice and services to farmers using their stock, just as large commercial companies do, and in practise, such follow-up services and liaison with farmers, and the feedback from their reactions and experience with the improved stock, may be crucial to the success and future of breeding groups.

Results from Breeding Groups

Figures giving reliable information on progress being obtained in breeding groups are not readily available because of the short time that groups have been in existence, and because scientifically-controlled tests have not been undertaken.

The New Zealand Romney Development Group is one of the oldest groups and some comparative figures are available on two-tooth ewe performance.

On the property at Wairunga where the central nucleus of the group is located, the central nucleus sheep are mixed in, for management reasons, with the Wairunga flock.

The results presented in Table 1 concern the lambing performance of two-tooth ewes in the central nucleus which are the progeny of contributed ewes screened from members' flocks. The performance of these ewes, which in most cases have been recorded for one generation only, is compared in six successive years with that of two-tooth ewes born in the Wairunga flock in each of the same years. It should be mentioned that the ewes in the Wairunga flock have been on an intensive, within-flock selection programme for lamb production for 20 years.

TABLE 1

LAMBING PERFORMANCE OF TWO-TOOTH EWES IN THE CENTRAL NUCLEUS

	1970	1971	1972	1973	1974	1975	Av.
No. nucleus two-tooths mated	6	43	58	86	87	113	65
% docked	116.7	111.6	134.5	124.7	116.1	129.4	122.2
Wairunga two-tooths mated	376	305	251	227	216	212	264
% docked	93.5	114.1	115.5	116.3	106.5	112.8	109.8
Margin for central nucleus %	+23.2	−2.5	+19.0	+8.6	+9.6	+16.6	+12.4

Table 2

FULL BREAKDOWN OF LAMBING PERFORMANCE IN TWO-TOOTH EWES

	Nucleus Flock 2-tooths						Wairunga 2-tooths					
YEAR	1970	1971	1972	1973	1974	1975	1970	1971	1972	1973	1974	1975
NO EWES MATED	6	43	58	86	87	113	367	305	251	227	216	212
EWE PERFORMANCE												
% reared lambs	83.3	83.7	88.0	91.3	81.6	90.3	73.0	87.2	85.7	85.9	82.4	85.4
% lost all lambs	16.7	11.6	8.6	8.2	14.9	5.3	14.7	7.2	10.7	10.1	13.0	7.1
% barren	0.0	0.0	1.7	2.5	2.3	4.4	10.6	4.9	3.2	3.1	4.6	7.5
% deaths, tupping/lambing	0.0	4.7	1.7	0.0	1.2	0.0	1.7	0.7	0.4	0.9	0.0	0.0
% Ewes assisted at lambing	0.0	0.0	0.0	1.2	0.0	1.8	0.0	1.0	0.4	0.0	0.5	2.5
Lambing												
% lambs born/Ewes mated	150.0	130.2	153.4	140.7	140.2	139.4	118.3	140.7	138.2	137.0	133.8	128.1
Proportion singles/total lambs born	33.3	39.0	27.0	39.5	37.7	38.2	48.8	37.3	41.2	40.2	43.3	43.8
Proportion twins/total lambs born	66.7	61.0	69.6	57.9	62.3	57.9	49.8	54.1	54.1	59.8	54.7	58.2
Proportion triplets/total lambs born	0.0	0.0	3.4	2.6	0.0	3.9	1.4	7.7	3.5	0.0	2.0	0.0
Proportion quads/total lambs born	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.2	0.0	0.0	0.0
% Lambs docked/ewes mated	116.7	111.6	134.5	124.7	116.1	129.4	93.2	114.3	115.3	116.3	106.5	112.8

Table 1 shows that the two-tooth progeny of the contributed ewes have docked an average of 12.4% more lambs over the six-year period than the two-tooth progeny of the intensively-selected Wairunga ewes. In one year the Wairunga two-tooths performed better than the two-tooths from the screened ewes, but by only 2.5%. The ewes of the central nucleus and those of the Wairunga flock have at all times been run as one mob and mated randomly to the same rams. The full details of the performance of the two groups are given in Table 2.

Structure of Breeding Groups

To operate effectively, groups must have a formalized structure. The form and organization of group-breeding schemes varies widely between groups, reflecting their different origins, and the needs and facilities of each group. Several types of organization are in use at present, such as the private company, Industrial and Provident Society, Partnership, Incorporated Society, or simply a gentleman's agreement. In some cases ownership of the stock in the nucleus remains in the hands of the contributors, in others the company or Society, and in some cases, the nucleus is owned and operated by one member of the group.

The long-term success of breeding groups, however, will depend largely on the effectiveness of their organization, and the more formal structures will give the best guarantee of long-term success.

Conclusion

It is confidently believed that livestock breeeding groups will continue to evolve and develop, as circumstances dictate, and that, by being able to maximise the advantages of modern animal breeding methods, they will play a major role in the development of the livestock industries in most sheep and cattle raising countries.

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THE AUSTRALIAN MERINO SOCIETY NUCLEUS BREEDING SCHEME

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INTRODUCTION

The Australian Merino Society, as it is currently structured, was not the result of a predetermined Breeding Plan. Quite the opposite. It actually evolved to meet a need—and once one need was satisfied, quite often another developed, requiring further adaptations and innovations.

As more and more people became involved, decision making was, of necessity, spread to make use of many people's talents. Today over 500 sheep breeders and several associated, interested, non-rural people, have a viable, functional and democratic process of combining several disciplines, not the least of which include Wool Testing Laboratories, Agricultural Colleges, Research Institutions, Farm Management Consultants, etc., in an attempt to maximize returns from genetics, nutrition, management and marketing.

The relatively simple process of breeding rams for sale—under a system whereby a sheep, once it had a piece of Blue Paper saying who bred it, immediately inherited some mystical superiority, which alone qualified it to be a superior animal—namely a stud animal, did not encourage change.

Once measurement for production became the hallmark of qualification, certain problems appeared in the "ram breeding" business. The first and foremost being the relatively small differences between the supplier and the supplied. It soon became all too clear that there were equally good ewes in the clients' flocks as there were in the Stud. It also became all too apparent that it was almost a national sin not to be using this superior genetic material. As it stood, the vast number of superior ewes running in ordinary farmers' flocks around the countryside, breeding wethers and flock ewes, were contributing nothing to the nation's genetic progress in sheep production.

Once sheep men were made aware of this situation they readily joined together and isolated their superior ewes into a common Central Nucleus to breed their ram requirements. As a prelude to this rather dramatic change in sheep breeding, certain background criteria need to be understood in order to evaluate the reasonably successful establishment of such an active group of people.

HISTORY

The Parent Flock, which was eventually to be the basis of the Central Nucleus, had been a Registered Merino Stud, established in 1943 and supplying by 1960, up to 1,000 rams annually to the industry. This Stud had been classed along traditional lines, until 1953, when fleece weighing commenced on the reserve 1½ year old rams. This policy continued until 1957, when all 1½ year old ewes were fleece weighed. By 1960, with Stud ewes at 4,000 head, artificial insemination was commenced, using superior sires selected on fleece weight criteria alone.

The use of AI was continued for seven years. Body weight and average fibre diameter as additional factors were used from 1962 onwards. During the early and mid-60s, distribution curves of fleece weight ranking and body weight ranking were drawn annually, and progress measured for increasing productivity at the top end of the scale. By 1966, through co-operation with daughter flocks, it was found, by simple progeny testing, that a few elite sires were emerging in the daughter flocks which were virtually equal to sires available from the Parent Stud. It was then realized by the Studmaster that it would be necessary to

1. increase the size of the gene pool,
2. make use of the selection differential of the few elite females in daughter flocks,

if the past rate of progress was to be maintained.

From this thinking emerged the co-operative breeding plan now employed.

BREEDING PLAN STRUCTURE

Once motivated, wool growers have to be given a concrete and concise as well as a practical, simple and functional breeding plan, which all can follow and take part in.

The actual breeding plan became more sophisticated as the actual size of the enterprise grew. The dramatic growth of the Society must be appreciated in order to understand some of the basics behind the criteria used in selection.

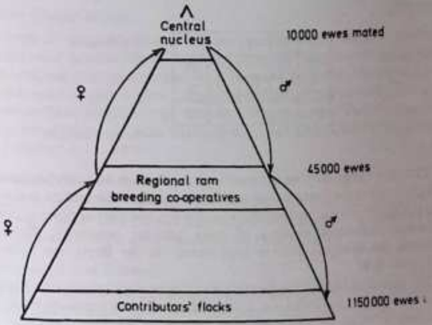
The table below portrays the annual progression of selection pressure applied through the Central Nucleus Flock which was operated on a two-tier system until 1971: i.e. daughter flocks returned the top ½% of maiden ewe progeny direct to Central Nucleus, which used these superior ewes for breeding rams which were supplied direct to contributors, after culling on objective as well as subjective factors.

Year	*Number of ewes mated from which ewe progeny were selected*	*Number of maiden ewes contributed to C.N.*
1967	: 20,000	20
1968	100,000	100
1969	350,000	400
1970	500,000	700
1971	700,000	800
1972	800,000	900
1973	900,000	720
1974	1,000,000	750
1975	1,100,000	800
1976	1,200,000	800 (anticipated)

From 1971 onwards, a three-tier system was developed with the establishment of regional ram breeding co-operatives which were used as screening sub-flocks to the Central Nucleus. Currently there are 30 such co-operatives operating throughout Western Australia and 2 in South Australia. A further 3-4 are planned for 1977.

Initially, via the ram breeding co-operative flocks, which desirably service 30-40 farmer contributors and up to 50,000 ewes (one has over 60,000), the top ½% of maiden ewe progeny from *each contributor's* flock was sent to Central Nucleus, and the next 2% in ranking order were screened off to the ram breeding flock. This operated for 1971 and 1972.

The Three-Tier Breeding System 1971-77



From 1973 onwards, ewes to Central Nucleus came only from the ram breeding flocks, the number of maiden ewes contributed being equal in number to 2% of the total ram-breeding ewes mated at each co-operative.

Farmer contributors gave maiden ewes equal in number to 1% of their total ewes mated, to their respective ram breeding co-operatives. The co-operatives receive top ranking sires from Central Nucleus and in turn supply top ranking sires bred in each co-operative flock to original contributors.

Ram breeding co-operative managers are usually chosen for their knowledge of genetics, husbandry and managerial skills, as well as acceptability by group members.

SELECTION CRITERIA

Prior to any selection, a decision on what to select for, is a necessary prerequisite.

The changing emphasis of selection criteria has been largely influenced by industry demand. Development of Persian Gulf markets for live shipping wethers of over 60 kilograms liveweight from Western Australia, led to increased emphasis on bodyweight in the late 1960s and early 1970s. Wool industry emphasis shifting from subjective to objective appraisal in the last few years, has led to a closer look at trade requirements and what is obtainable from competitive fibres.

Thus, from 1963/70 selection criteria were based solely on a fleece weight/body weight index, using a pundit square grid method of isolation of desirable sires and dams, with an upper limit on average fibre diameter on rams only.

Fleece Weight (FW)					
4	41	42	43	44	— Top Progeny
3	31	32	33	34	
2	21	22	23	24	
1	11	12	13	14	
	1	2	3	4	— Body Weight (BW)

This was really only an arithmetical expression of superimposed distribution curves for fleece weight and body weight. It should be pointed out that culling for normal undesirable visual traits was part of normal practice.

Because individual ranking of ewes became necessary, from 1970 onwards, the selection criteria were based on the Berryman formula of F.W. × 10 + B.W.

The reasoning behind this formula was to give equal economic loading to wool and meat in the index, i.e. historically wool has normally been worth ten times in value per unit more than mutton in Western Australia.

With the advent of more sophisticated methods of measuring the physical characters of wool it became necessary to quantify the more important of these, and to try to assess their relevance in a breeding plan.

Before deciding on which characters should or should not be subjected to selection, it is necessary to ascertain

1. whether the character is measurable,
2. whether the character is heritable.

This required further refinement into characters which are controlled by the environment and characters which are influenced by genetics.

FACTORS OF GENETIC ORIGIN

What effect do such characteristics as:

(i) clean fleece weight,
(ii) tensile fibre strength,
(iii) average fibre diameter,
(iv) range in fibre diameter (i.e. coefficient of variation),
(v) ratio of number of secondary follicles to number of primary follicles,
(vi) ratio of diameter of secondary follicles to diameter of primary follicles,
(vii) average fibre length,

have on

(a) processing—e.g. topmaking and spinning?
(b) fabric quality?

(i) Clean Fleece Weight

"Research in the CSIRO and elsewhere has shown that it is possible to increase wool production by selecting sheep for fleece weight rather than the conventional procedure which is influenced by staple crimp. We have found such wool to give higher top and noil yields, better combing tear and greater mean fibre length of top, leading to stronger yarn, than the conventionally selected control." (Dr. M. Lipson, former Chief CSIRO Division of Textile Industry.)

(ii) Tensile Fibre Strength

Tensile strength has obvious importance and although environment plays a major role, Dr. Lipson has shown that there is "increased yarn strength with wool from sheep selected on fleeceweight".

(iii) Average Fibre Diameter

(a) B.A.E. reports show a high correlation between price paid for greasy wool and average fibre diameter (other things being equal).

(b) Dr. Lipson has shown "for fabrics of identical structure, fibre diameter is the major factor affecting handle of wool"

(c) Fibre diameter is recognized as the most important physical attribute of raw apparel wool in terms of the fabric into which it may be processed (Dunlop and McMahon, 1974).

(iv) Range in Fibre Diameter

This is a function of variation from four different sources, each contributing differently to the total.

Source of variation	*Percentage of total variance*
Between sheep	20
Between sites over the sheep	10
Between fibres within sites	66
Between points along the fibre	4
	100

Measurements have shown that for a single staple of wool, with an average diameter of say 23 microns, the actual range can be as low as 10 microns, or as high as 40 microns and higher.

Most evidence to date has shown that variations in fibre diameter have little or no effect on either wool processing or the final product. It is the average figure that is of importance.

The fibres at the coarse end of the range (e.g. fibres exceeding 28 microns) are known to the trade as "coarse edge". Professor K.J. Whitely of the University of N.S.W. has as recently as June 1976, stated "the available technical evidence shows there is no good reason why the serious breeder should concern himself with the coarse fringe at this time".

In order to readily understand the full significance of these larger diameter fibres in a normal staple of wool, let us look at a few specific examples. In tests on samples of wool from six different rams, the following results were obtained from A.W.T.A. Melbourne.

Ram No.	*Mean Fibre Diameter*	*% Fibres exceeding 28 microns*	*Range in Diameter from finest to strongest*
1	23.0	4.6	18 microns
2	23.0	10.6	30 microns
3	23.0	13.3	32 microns
4	23.0	18.5	40 microns
5	21.5	13.0	30 microns
6	20.0	6.0	28 microns

It is quite difficult to comprehend how, if trade says 21 micron wool is better than 22 micron wool, and 22 micron wool is better than 23, and so on, meaning of course that one or two microns make all the difference to the price they pay, as per the following price schedule, that someone can say

AUSTRALIAN AVERAGE WOOL PRICES
19 Micron to 30 Micron Cents Per kg Clean
and Differential Per Micron

Selling Season	19M	21M	23M	25M	27M	30M
1964/65	224	207	192	178	171	226
1965/66	234	213	201	191	181	176
1966/67	229	209	199	180	168	150
1967/68	235	208	179	150	136	103
1968/69	244	218	184	150	132	118
1969/70	228	187	162	139	119	99
1970/71	174	140	123	115	106	99
1971/72	161	153	145	130	126	119
1972/73	419	371	360	338	317	292
1973/74	405	356	336	308	279	237
Average Price	255.3	226.2	208.1	187.9	173.5	161.9
Differential						
C per kg	29.1	18.1	20.2	14.4	11.6	
C per Micron	14.55	9.05	10.1	7.2	3.9	

that ram sample 1 (above), with 4.6% fibres greater than 28 microns and a range in diameter of 18 microns, performs exactly the same as sample 4 with 18.5% fibres over 28 microns and a range of 40 microns. Similarly, for ram No. 5, this wool (other things being equal) should bring more money than ram No. 1, yet it has 8.4% more fibres over 28 microns than No. 1. Ram No. 6 would be classed as a fine wool even though it had 1.4% more fibres over 28 microns than No. 1 and a range of 28 microns compared to 18 microns.

What do some processors have to say about this?

On a recent visit to wool processing complexes in five different countries, the opportunity was taken to seek information from as wide a spectrum of the industry as possible. Some of the information obtained is summarized.

(a) Woollen mill No. 1 in the U.K.

This mill processes only top quality fine wools from Australia. The managing director stated that average fibre diameter contributed only some 70% towards the variable known as "handle" and that 30% was due to other factors. Upon testing a number of "tops" taken at random from the best hand-picked top quality mill-run, no fibres exceeding 28 microns could be found.

(b) Woollen mill No. 2 in the U.K.

This mill stated they did not agree with the Australian statement concerning variation in fibre diameter and that they supplied "tops" conforming to a specification which was as follows:

No more than $3\frac{1}{2}\%$ fibres exceeding 30 microns in a 21 micron top
No more than 7 % fibres exceeding 30 microns in a 23 micron top
No more than 15 % fibres exceeding 30 microns in a 25 micron top

They also stated that if they exceeded these limits, their customers, the spinners, would be on the phone in half an hour asking "What is wrong with this top? We are having trouble with "ends down".

Before we rush to conclusions and say either our advice in Australia is wrong or that the processors don't know what they are doing, let us have a rational look at the situation.

What sort of information has been available to the spinner over the years?

1. Average fibre diameter.
2. Average top fibre length.

He has never had access to information (or only at a high cost) regarding variation in fibre diameter. As new and more rapid methods of recording individual fibre diameter become available, we find topmakers are now starting to produce tops which conform to more stringent limits and are actually starting to measure fibre diameter range as a normal practice. It was found that at least one topmaker was not actually quoting this information to spinner clients (only average fibre diameter). Because they are now starting to control this coarse edge, they are able to supply their clients with a better product as far as speed of processing is concerned, and they know full well that until their competitors do likewise, their top will perform better. Once this starts to happen it becomes

1. highly competitive, and then
2. eventually accepted as the norm.

(c) Spinning mill No. 3

Spinners try to produce as much yarn (that is, spin down to as fine a yarn as possible) in as short a time as possible. In the past, spinners had a highly labour-intensive industry, but in keeping with most other industries, capital is slowly replacing labour.

The spinners have covered themselves by not spinning down to limits, but stopping short with the yarn having a greater number of fibres in cross section than the theoretical limit to which it could have been reduced. Each time they tried to speed up the spinning process, they had trouble with breakages. Woollen mills were visited where wool was being processed at only 80% of the speed of synthetic yarn. Over the centuries, the spinners have learnt to live with wool and its imperfections and have devised machinery to do just this. Average Merino wool has certain characteristics, e.g. "coarse edge", and no one really worried about it. In fact, the final report on objective measurement of wool in Australia by the specially appointed Objective Measurment Committee of the Australian Wool Board in October 1972 came out with the profound statement that "variations in fibre diameter of sound fleeces grown within Merino flocks have been found to fall well within acceptable commercial limits".

Of course they do, because the acceptable commercial limits were set to suit the Merino clip, and not vice versa. Why? Because if the limits were set any tighter, there would not be enough wool to process!

In a recent paper delivered by a director of a large woollen mill it was pointed out how very significant a small excessive percentage of coarse fibre becomes, and that it would seem, therefore, that the traditional habit of spinning well above (in terms of numbers of fibres in cross section) the theoretical limit spinners have been protecting themselves against imperfections or shortcomings in wool fibre and not maximizing productivity.

It would appear from overseas evidence that we should at least be paying some attention to the "coarse edge" and giving it some consideration in our selection criteria.

(v) Ratio of number of secondary follicles to number of primary follicles

Research has shown that fleeces from flocks selected for high Clean Fleece Weight, process better. Also, as CFW increases, so does the S/P ratio. Is there a correlation?

Quoting from Dr. I. Fairnie's address to the W.A. branch of A.S.A.P. in 1973 "High S/P ratios are also correlated with fibre uniformity, i.e., low fibre diameter variation".

(vi) Ratio of diameter of secondary follicles to diameter of primary follicles

Selection of sheep with little differences in diameter between secondary and primary follicles would also reduce fibre variation (Ryder and Stephenson 1968). This also confirms the work of H.B. Carter who has previously shown a direct relationship between coefficient of fibre diameter variation and ratio of diameter of primary to secondary fibres.

(vii) Average fibre length

"In general, increased fibre length tends to improve spinnability and strength of the resultant yarn, although there are limits beyond which problems can occur in drawing" and "we have observed increased yarn strength with wool from sheep selected on fleece weight, which is due to the greater mean fibre length of such wool, compared with that of conventionally selected controls". (Dr. M. Lipson).

So much for factors of genetic origin.

FACTORS OF ENVIRONMENTAL ORIGIN

Is there anything we can do in our selection programme which may be of benefit in the areas where the environment has influence on our wool?

1. Fibre diameter variation along the fibre.

Which animals show the greatest degree of along-fibre diameter variation? Are they the ones with a wide variation in follicle size—not only within the primary group and within the secondary group, but between these groups?

2. Dust penetration and the subsequent yield loss as excess noil in topmaking.

Is this also due to wide variation in fibre diameter; is it a function of the amount of wax in the wool, and could it be related to S/P ratio?

3. Fleece rot—is this also related to S/P ratio, yield, suint, diameter, etc.

There are quite a number of factors which have not been really related to variables like the environment and processing losses. Future research may show up new areas where animal breeders, in this case the Merino ram breeder, may be able to select to help the processor more profitably handle his fibre.

With these thoughts in mind, it should be possible to devise a breeding plan based on trade requirements and breeders' profitability.

The Breeding plan incorporates

1. rams selected by an index.
2. artificial insemination.

The current ram selection index for body weight and fleece characteristics is:

$$\frac{W}{D^2} + BW + S/P - 2\text{ S.D. fibre diameter}$$
$$- 2\text{ S.D. follicle diameter} - 10\frac{dp}{ds} - 2 \times \%\text{ suint}$$

where:
W = clean wool weight for 12 months × 1,000.
D = average fibre diameter.
S/P = secondary follicle/primary follicle ratio.

S.D. fibre diam. = standard deviation of individual fibre diameters.

S.D. follicle diam. = standard deviation of individual follicle diameters

$$\frac{dp}{ds} = \frac{\text{diameter of primary follicles}}{\text{diameter of secondary follicles}}$$

B W = body weight.

The only other selection factor is efficiency of food conversion. Once rams have been selected according to the above index, the 30 top ranking ones are placed in individual feed pens and maintained at zero body weight change, i.e. kept on a maintenance diet for 90 to 100 days. At the completion of this period, the amount of clean wool produced is divided by the amount of food eaten, and animals are thus ranked for efficiency of conversion of food to wool.

This value is then added to the index to give a final ranking. The highest performing rams then go into the A.I. programme.

PROGRESS OF ARTIFICIAL INSEMINATION

Initially, Central Nucleus and a few ram breeding co-operatives used A.I. It was later extended to include the flock members at the third level of the co-operatives.

Year	*Ewes Inseminated*
1973	19,300
1974	39,200
1975	63,000
1976	?

MARKETING

Once an organized, controlled and performance-tested breeding plan is implemented, the way is then open to produce large lines of a predictable product, e.g. sufficient to supply the total requirements of a mill with, for example, 1,000 bales of wool per week.

Spinners have one basic requirement—a continuous supply of an extremely uniform and predictable top. The whole design of the topmaking process is based around one basic function—to present as nearly as possible, a perfectly uniform top.

Under a large scale Group Breeding Scheme, strictly but democratically controlled, the possibilities for producing large scale uniform products become much more a reality.

Conversely, the demands of a Breeding Plan designed to cover these ambitious goals, may be beyond the resources, the abilities and the ambitions of individuals operating alone, and much organized, professional and joint effort may be required. Whatever the emotional and self-interested screams and yells of traditional Merino stud breeders, the cold hard facts of life are such, that small, isolated and intensely jealous ram breeding enterprises may just not be able to keep up with industry demands.

FUTURE

The Australian Merino Society looks to the future with confidence and a faith built on logic, measurement, assurance and last but not least—trust. Members believe they have a destiny—one which is controllable, constructive and highly creative. They know where they are heading and it will take a lot to stop them. They are indeed a dedicated group of animal breeders.

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STUD MERINO BREEDING

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If one takes a look at the Australian Stud Merino breeding industry, one will find that it is made up of hundreds of individuals operating under an accepted set of breeding principles, but at the same time doing very much "their own thing".

Some have stayed strictly within a major bloodline, others have fused one or more bloodlines, some have scrapped one bloodline and changed to another.

Some breed stud sheep to sell to other studs, some breed to sell only to flock owners and others—about 40%—breed to provide their own flock ram requirements.

On a different theme, some breeders go in for measurement, others use some, and yet others, none. One must add that measurement is not new to the stud industry. Austin has described studs using objective measurement principles well before the turn of the century.

At the Deniliquin Show in 1874 washed wool weights were used as a judging criterion.

ATTITUDES TO CHANGE

Stud men have rarely been hasty however to adopt major changes in contradiction to practical experience.

The great depth of experience going back to John McArthur, Samuel Marsden and others in the late 1860s, underlies much of this caution.

The word Merino in Spanish signifies "fugitive without a regular home".

The fine woolled flocks that had the run of the Spanish country-side for centuries were known as the "Ovegas Merino" travelling sheep.

The Merino was unique to Spain and the much sought after fine wool produced by the Spaniards brought great wealth to the Nobility and the Church that owned the various cabanas or flocks. These flocks developed individual characteristics through differing environmental and management factors that became relatively fixed over the centuries by random breeding from within.

The most famous of the Cabanas were the Escurial or royal flocks, the Negretti, the Infantata, the Paula and the Guadalupe and collectively they founded the great Merino flocks of the world.

The sequence of events leading to this began in 1765 with the Elector of Hanover receiving a gift of 300 Escurials from the King of Spain. Later in 1786 the King of France received 400 Infantatas thus founding the famous flock that exists to this day at the Royal Farm, Rambouillet. The English King George III received Negrettis to establish the Royal flock at Kew in 1791.

Captain Waterhouse later brought the first Merinos into Australia in 1798 which were Escurials from South Africa.

In the USA, Colonel Humphries initiated what was to become the famous Vermont strain with the importation in 1808 of 100 Infantata Merinos.

The Napoleonic war in 1809 destroyed the Merino industry in Spain. The old Cabanas were either sold or slaughtered. Many went to the USA, others mostly Paulas were shipped to England and the balance driven overland by Napoleon to France and Central Europe.

From 1810 onwards the Merino scene shifted to Europe, the USA, and Australia.

In England such great interest was shown in Merino breeding during this period that in 1811 the world's first Merino Society was formed with Sir Joseph Banks as president. Demonstrating that there is little that is new under the sun.

By the early eighteen hundreds the centre for stud Merino breeding was Saxony. The Merino sheep industry had developed to such an extent that in 1802, of the fourteen million sheep on the German side of the Rhine, four million were Merino.

The methodical Germans, had by this time much improved the yields and bodyweights from those of the original Spanish sheep, and the famous Electoral, Steiger and Gadegast flocks of Saxony and Lichnowski of Silesia were to become the foundation blood of the Australian stud industry.

Our industry in Australia began as mentioned earlier, with the introduction by Captain Waterhouse of Escurials from the South African flock of Colonel Gordon.

These sheep led to the development of Australia's two original studs, Camden owned by Colonel McArthur and Burrundulla by the Cox family, Captain W.A. Cox having purchased the Merinos from Waterhouse on his leaving the colony.

McArthur subsequently purchased Negrettis from George III's flock at Kew in 1804. He also pioneered the introduction of Merinos from Saxony. Some of his first importations from the Electoral flock in 1812, were sent on to James Cox of "Clarendon", Tasmania, who was a son of W.E. Cox, of "Burrundulla".

"Clarendon" thus became the first of the famous studs to evolve in that State.

By 1830 there were 10 Merino studs in N.S.W. and 7 in Tasmania, all were based on Merinos imported direct from Saxony, such as was William Riley's famous Raby Stud in 1824.

Others were founded on Camden or Burrundulla ewes and rams, imported from Saxony.

The Saxons reigned supreme in Australia until 1860. The sheepmen concentrated on fineness and purity of fibre. Tasmanian, Victorian and Mudgee studs dominated the ram breeding scene.

The studs provided the flock rams and most stud rams were imported from Saxony with a few known as "Anglo Merinos" from England.

Towards the end of that period the French Rambouillet made its first appearance.

The climatic restrictions applying to fine wool Merinos, mainly in the newly developed plain country of N.S.W. led the Peppin Brothers George and Fred to seek to produce a long stapled, broader woolled sheep that would thrive under much wider environmental conditions and cut more wool. The Peppins founded their stud in 1861 with the purchase of Rambouillet rams which included the sire "Emporer". The premier family that resulted from crossing this ram with Cannally and selected station bred ewes; plus the later establishment of and cross mating with the "Warrior" family founded by the imported Vermont ram "Grimes", led to the development by these remarkable breeders of the now famous Peppin blood.

While the above-mentioned long wool Rambouillet/Vermont cross sheep were under development at Wanganella, significant developments had already begun in South Australia. As early as 1841 John Murray at Mt. Crawford took steps to establish what subsequently became known as the Murray blood. From the original flock consisting of Camden blood ewes and another 100 ewes mated to Tasmanian rams, the famous Murray blood was evolved from continuous selection and breeding from within for over 130 years.

The Mount Crawford sheep were the foundation of many South Australian studs that evolved with the emphasis on strong wool.

It was from such flocks that the Australian strong and medium wool Merino as we know it today evolved.

What type of sheep that went into the original mix, will never be known, except that there is understood to have been an infusion of English Leicester cross from the ewe side to broaden the wool and give more size to the Saxon.

The breeding methods used have changed little to this day and go back to Robert Bakewell. They may be summarized as linebreeding, heavy culling, firm conviction on type and consistency in selection.

Such disciplines, plus an element of luck in the quality of the genetic material that came their way, rewarded a number of breeders with a medium strong wool Merino suited to the arid Australian pastoral conditions. It is from these flocks (but a relative handful of the hundreds that never made the distance) that the great parent studs were evolved as we know them today.

These new Peppin and South Australian strains had barely begun to filter through the existing Australian flock, when the Vermont invasion swept through the established Saxon studs.

THE VERMONT "INVASION"

It began in 1884 when Patrick McFarland brought in "Matchless" from the USA. Weighing over 200 lbs and carrying a fleece of 28 lbs (albeit a yield of only 8 lbs scoured). His purchase was emulated by Samuel McCaughey, then Australia's largest flock owner. These men felt the New Vermont sheep would be the answer to their search for larger sheep, with heavier fleeces than on the Saxons at the time.

The first crosses were a marked improvement. However, instead of judicious infusion of the new blood, they went for broke. "The more wrinkles and grease the better," became the standard and most of Australia's major Merino studs of the period rushed to jump on the bandwagon of the foolish new fashion.

The New Vermonts were most dissimilar to the "Grimes" of the 20 years before. They were a product of American expediency in that they had been developed with excessive wrinkles and excessive grease to fill bales.

The American woolgrower sold his wool on the farm to private buyers at a district price. Quality therefore did not matter, quantity did and the New Vermont filled the bill.

The effect of the New Vermont on Australia's Merino industry was disastrous.

The Vermont breeders introduced extreme corrective mating, grease, wrinkles, and accentuated the growing problem of primary fibres. Wool quality and constitution suffered and the great drought of 1902 marked the end of the Vermont era in Australia.

Australian woolgrowers from then on looked to the Peppins, the Murrays and a few other studs that had resisted the Vermont craze for their breeding base.

These studs continued to line breed their sheep and by 1936 had largely "fixed" the Australian Merino type that still stands today.

Australia's Vermont era served as a lesson to our studs not to hasten into major change.

THE SCIENTIFIC ERA

The next major changes to stud breeding practice were suggested in the late 1950s by two scientists, Dr. Dun from the N.S.W. Department of Agriculture and Dr. Newton Turner from CSIRO.

Having successfully contributed to the elimination of Australia's greatest rural problem, the rabbit, with the discovery of myxomatosis, the CSIRO was naturally an organization held in great esteem by the man on the land.

Thus when Drs. Dun and Newton Turner expressed doubts on the ability of the stud industry to service effectively the needs of the flock owner, their views had to be taken very seriously.

What upset the Merino stud men was the proposal by these scientists that studs should forget what the sheep looked like and go by measurement alone.

No doubt the intention of these scientists was to achieve an improvement in the rate of gain of wool production.

But to the stud breeder it appeared that they had totally disregarded his ability as a Merino breeder and as a business man who had to work within a fiercely competitive marketing framework.

Whereas the scientific disclosures of the late 1950s and early 1960s got a cool reception from the stud industry, they were seized upon by various opportunists who saw the chance to "knock" the stud system.

CO-OPERATIVE BREEDING

That leads me of course to the Australian Merino Society whose founder, Mr. Jim Shepherd is a contributor to this book.

Mr. Shepherd has indicated that the rams that have been used over the Central Nucleus ewes are from his Bungaree stud.

He also indicated that the progeny of the nucleus ewes are inferior to the stud Bungaree progeny born on the same farm and run under the same conditions.

I could suggest that the whole system would work better if the Central Nucleus was scrapped and Bungaree ram hoggetts were used in place of these apparently inferior Central Nucleus-born rams.

But I would be guilty of the same lack of insight that scientists have been displaying. I would be forgetting that ram breeding is a business.

The Australian Merino Society ram breeding business functions in a way that is quite different from the stud breeding business.

Their ewe contribution system is an integral part of their ram marketing because the contribution of ewes leads to an involved and committed clientele.

The A.M.S. must be seen for what it is—an extremely effective marketing system based on co-operative emotionalism.

BUSINESS BASIS

Since 1960 the Australian Stud Merino industry has learnt to live with scientists—and they more and more so with the professional sheep breeders.

With the passing of every year, through their own work with the sheep, and their contact with commercial flocks, scientists' increasing experience draws them to the desirable situation of having more and more in common with the Merino studmaster. They have come to realize the stud Merino industry is complex and that there is more to it than breeding methods alone.

It is a highly competitive, laissez-faire industry where marketing and public relations play a major role. Like any business, it can only exist if it makes a profit.

It is just as valid for a sheepbreeder to market his offering in show condition as it is the used car dealer to polish his cars or the supermarket to place the milk at the back of the shop!

They do these things for sound business reasons.

Science has the great advantage of objectivity. Herein lies its usefulness to our industry: to pry and probe, experiment, to disseminate information and be the fire engine for emergency research. We see that as their role in the ball game, but not that of calling the shots.

Self-appointed experts have been wrong in the past no matter what the field, and too much is at stake for breeders to blindly follow any "Pied Piper" of science.

However, breeders would be similarly foolish to ignore science.

It is acknowledged that science has largely been behind all the progress in agriculture in response to needs that have arisen with the passage of time. In Australia, where would we be today without myxomatosis, trace elements, vaccines, organophosphates, fertilizers, the mules operation, new pasture species and the broad spectrum drench—most of which are great contributions by science.

Objective measurement likewise, fills a need that has arisen in the sheepbreeding industry.

There are simply not enough subjective experts to get around a national flock of 150 million sheep. They are also expensive—yet a discipline must be imposed on flock management if the national flock standard is to come close to that of the Merino studs.

The time is fast approaching where sheep that cut less than the national average of about 4 kg will not be worth shearing.

Science's guidelines of culling with the use of scales in the shearing shed in conjunction with the woolclasser, is a very effective answer to this problem. A great side benefit also is that the method *involves* the flock owner, which makes him more conscious of how his flock performs and results in greater interest, leading to better management.

With the encouragement of the various State departments of agriculture, many stud breeders use objective measurement for sire selection—and as a marketing aid. Experience has shown that though micron indicators are prone to variation due to environmental changes and age of the sheep, they do indicate the position of the animal in relation to the average. Measured clean fleece weight is of significance with sire selection and has great influence on what sires a breeder decides to keep and what to sell.

Most important of all, such information serves the studmaster as his record of progress (or otherwise) over the years.

It is important to enumerate the objectives and current breeding practice as it applies in the stud Merino breeding industry of Australia today.

In 1975 there were over 2.5 million stud Merino sheep in Australia belonging to 1,623 registered studs, which in turn delivered to flock owners over a quarter of a million rams in that year.

These stud flocks may be generally grouped into four distinctive bloodlines.

The Saxon (17-20 micron) the Peppin (20-22 micron) Collinsville (21-23 micron) and the Bungaree (23-25).

AUSTRALIAN BLOODLINES

The bloodlines occupy sections of the Merino wool micron spectrum and the latter ones were evolved from the Saxon to meet the specific needs of various environments, roughly in the order of their severity.

Accordingly, the Saxon is found in areas of high rainfall and mountain conditions, mainly in Victoria, Tasmania and the "Divide" country of N.S.W.

The Peppin and Collinsville serve the more favoured pastoral and agricultural regions and the Bungaree in areas of greater stress from low rainfall and where the annual summer drought is longest.

The Australian Merino flock register exists as a record of the background of the various Merino bloodlines and strains as well as a history of the studs involved. It also functions as security for the investment and asset value of pedigree sheep and as a patent record of the performance of those that are successful.

Generally studs develop to become strains within bloodlines from which families are formed through line breeding and then outcrossing with parallel families developed either from within the stud or with purchases from other studs.

The performance of studs varies considerably depending on the quality of genetic material with which they started and from subsequent purchases. The skills involved with general management and selection procedures also contribute to variation between studs.

The responsibility of the studs is to set a standard of excellence that directly relates to economic importance and to aim for bloodlines that breed true to type.

This is an extremely tall order, but constant perseverance in this direction has enabled a great number of studs to market rams that their clients know from experience will breed according to their like.

For a stud the key to the exercise is to develop or acquire sires of desirable phenotype that are relatively homozygous for desirable attributes. This takes time, effort, perseverance, talent and money, plus more than a grain or two of luck.

Having on progeny test found such an animal, a family within the blood can be developed and concentrated by line breeding (herein lies great scope for A.I.). This together with heavy culling and perseverance with type leads to the goal of all stud breeders—to reduce ancestry and genetic scatter to a minimum and produce a strain of Merino that breeds uniformly for the characteristics they are seeking and that will in turn pass such characteristics on to the flock owner.

It is to this area that genetics gives a commonsense interpretation of some of the more difficult problems of animal breeding. For example Mendelism gives the explanation why animals of similar appearance do not necessarily breed true. Only subsequent breeding performance will decide what genes the creature is carrying. Similarly it explains why the performance of similar strains may vary so greatly, also, why crossed strains tend to breed back to ancestral strains.

It certainly explains why uniformity can only be achieved by line breeding and the use of tested sires which in turn requires so much consistency and patience. It underlines the importance of a sire that performs genetically. They are comparatively rare, and extremely valuable animals and when they occur the objective must be their widest possible use. Here again science can render great assistance with the practicality of semen storage.

REALIZING ON POTENTIAL

At this stage it may be appropriate to inject a little controversy with a declaration that closed parent studs have gone about as far as they can go with Merino sheep breeding. After all, many of the British breeds of sheep have changed very little since 1830 and like the internal combustion engine the situation at the top end of our stud flocks has largely matured. On that plane the breeder's major job is to maintain the levels that have been achieved. Stud and flock situations that are trailing must catch up to the potential of the leaders. This is possible and what a giant stride it would be in itself.

It is all very well to work for better production figures for dairy cattle, laying hens etc., because any environmental deficiencies can be artificially remedied. They are not expected to have to survive in a drought. We do not want to develop a Merino that needs assistance at the first sign of adversity. It is this area that can give rise for concern with current practice in our industry.

The tremendous competition that exists is driving more and more of our studmasters into artificial environments which could lead to strains being developed that will not perform in the natural environment.

STUD CRITERIA

To conclude one must explain what are believed to be the desirable characteristics that stud breeders aim for in breeding.

One such characteristic still used by the studmaster but for which he is often roundly criticized is constitution.

Constitution, of course means carriage and outlook—the subjective assessment of the animal's ability to thrive and produce thrifty stock. Body weight measurement is a good guide to constitution, as unthrifty animals weigh less than the average. However, it remains for the subjective assessment to weed out off-type sheep that would pass on bodyweight, but fail in skeletal shape, hocks or dropped pasterns to name but a few.

Having passed the constitution, the conformation hurdle, the sheep unlike most other animals is only half way there. It must pass in covering as well.

Desirable wool characteristics are fleece weight, length of staple, style, staple formation, yield, evenness of covering, and absence of any coloured fibre.

It is the strict adherence of the studmasters of Australia over the years to standards set for covering on Merino sheep that has won Australia its premier place in the world as a producer of quality wool. Australian wool stands out in the world's market place for its handle, spinnability, yield, and its absence of coloured fibre.

The first thing the stud breeder has instilled in him during his apprenticeship is the importance of how to "read wool that is warm and living on the sheep's back". The remarkable coincidence is that what the studmaster looks for is also what the wool user wants despite the average breeder's lack of knowledge of the end user's needs.

What the studmaster seeks is a bulky covering of wool that experience has taught will resist the ravages of the environment. This is a wool that has to be "stiff" to resist weathering and dirt penetration.

To be "stiff" it has to have a well defined crimp. The greater the development of this crimp definition the greater the apparent bulk of the fleece. This assists the surface of the fleece to remain sealed.

Hand in glove with definition comes handle which among other things indicates that sufficient wax is present to protect the fibre all the way up to the tip and also contributes to the sealing of the surface of the fleece.

Handle is also the assessment of the degree of softness and elasticity. Any deviation towards poor handle is rejected by the studmaster as a breeding fault.

Lock, the other important stud criterion is the subjective indicator of the number of fibres per unit area of the skin. Experience has shown that better lock or staple formation leads to improved fleece weight and structure.

With such a fleece structure as has been indicated, the minimum amount of yolk is needed to service the fleece. Experience again has shown that excessive yolk attracts the blowfly and lowers the thriftiness of the animal.

The result is that well bred wool in Australia is a gutsy high yielding product of great style, handle and colour throughout the micron range, and generally spins better than crimp indicates.

To many scientists these criteria are outmoded, but should still be the subject of further research.

Scientific evidence still contradicts actual wool buying practice as spinners in both the U.K. and Japan have indicated.

The question that remains is: "Can a stud breeder afford to deviate from these traditional principles without irrefutable evidence that these principles are wrong?"

Or is it a safer alternative to maintain the status quo and at the same time, use objective measurement as an aid to selecting higher performing animals?

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