I. INTRODUCTION

Wool is divided into two broad classes, apparel-wool and carpet-wool, produced by different breeds. The aim of selection is to improve production, and within each class four main steps are followed in developing a programme:

a) Defining production,
b) Estimating parameters for the characteristics defined,
c) Formulating breeding plans, and checking by experiment,
d) Investigating physiological differences between sheep differing genetically in wool production, so as to improve selection criteria or provide a basis for developing improved sheep types.

The definition will include not only quantity and quality of wool itself, but other characteristics important for the welfare of the flock, such as reproduction rate. The list, however, should be as short as possible.

The four stages will be discussed separately for apparel-wool and carpet-wool.

II. APPAREL-WOOL

a) DEFINING PRODUCTION

(i) Wool quantity

Weight of clean wool per head is the simplest measure of quantity. Efficiency (output per unit of input, whether of feed or cost) is also important. Research
has shown that sheep producing more wool per head are also producing more per unit of feed (for review see TURNER and YOUNG*, 1969, Chapter 13; CLARK et al, 1965; HAMILTON and LANGLEDS, 1969; SAVILLE and ROBARDS, 1972). «Easy care» features to reduce labour costs have also been investigated in some countries. Selection in these cases is for sheep with less wool on the face (to reduce eye-clipping) and, if Merinos, with less skin wrinkle (to reduce maintenance and increase reproduction rate, DUN, 1964).

High wool weight per head from sheep with medium to open faces (and plainer bodies if Merinos) is the selection criterion. For final selection of rams, the cost of estimating percent clean yield and clean wool weight is justified, but for ewes, and preliminary ram selection, greasy weight is in general sufficiently accurate (see correlation, Table 3).

(ii) Wool quality

Quality is defined mainly through market requirements. Apparel-wool may be sold on world or local markets, or used locally. Local requirements may need to be considered individually, but research over the last 15-20 years has clarified those for world markets.

Until recently, wool for sale has been classified by «count» or «quality number», intended as a guide to average fibre diameter but based in many countries on staple crimp frequency. Crimp is now known to be unreliable as a guide to diameter (see Table 3; TURNER and YOUNG, 1969, Chapter 1; Bureau of Agricultural Economics 1970; Australian Wool Board, 1973; DUNLOP and MCMANON, 1974). Processing trials and manufacturing experience have shown that average fibre diameter is overwhelmingly the most important processing characteristic, crimp being unimportant except in special cases (see reviews above).

The Australian Wool Board in 1969 appointed an Objective Measurement Policy Committee (OMPC) to investigate sale of wool on measurement instead of appraisal. This involved:

1. Determining what characteristics should be measured.
2. Developing more rapid and cheaper measuring techniques.
3. Establishing sampling methods and determining where in the wool-selling procedure samples should be taken.

Some wool in Australia is now being sold on measured sample, but the eventual aim is sale of all Australian wool by description only.

The Final Report of the OMPC (Australian Wool Board 1973) listed the following characteristics as important in processing:

1. Average fibre diameter (of overwhelming importance),
2. Fibre length,
3. Post-scouring colour (whiteness),
4. Freedom from pigmented fibres,

* Reviews are quoted where available, and papers not included in the review are listed in addition.
5. Characteristics influencing processing costs and losses:

(i) Percent clean yield,
(ii) Vegetable matter content (particularly of certain types),
(iii) Tenderness (reduction of diameter at point(s) along the fibre),
(iv) Fibre damage, due to fleece rot (bacterial damage causing staining, fibre breakage or cotting) or tip weathering (due to dust penetration or degradation through strong sunlight).

Characters (1) to (5i) will apply everywhere, but (5ii) to (5iv) are more likely to be of concern in countries where sheep are at pasture all the year (e.g. Australia, New Zealand) than in those where animals are housed and fed for at least part of the year (e.g. Northern Europe, Canada).

The Report considered that variability of fibre diameter within individual Australian Merino flocks was within acceptable limits, while analyses of such within-flock variation found the most important contribution to come from differences between fibres within a staple. Where nutrition had changed markedly during the year, variation along the fibre was also important (Dunlop and McMahon, 1974). The chief worry for manufacturers appears to be the proportion of fibres with a large positive deviation from the average diameter. This proportion may need to be investigated further for some sheep types, but more critical processing experiments are required. Standards appear to have been fixed by measuring wools known to be acceptable, rather than by varying the proportions of fibres with high diameter and observing the effect on processing.

Average fibre diameter is the most important quality characteristic, but what diameter should be chosen? Results from Australian sales on measurement enabled Turner (1973) to study the regression of price on diameter for a number of price ranges, and to conclude that, for these ranges, increased wool weight, without any diameter change, would bring a greater economic return than decreased diameter, without any weight change, when clean weights were 4 Kg or less. With higher weights, relative economic return would depend on the fibre diameter of the flock under consideration.

Increased wool weight, with no diameter change, can be achieved by selecting rams on high clean wool weight, rejecting those with a diameter more than one standard deviation above the mean, and selecting ewes on greasy wool weight. Costs of estimating yield and diameter are currently too high to justify their measurement for ewes, except perhaps ewes in a top ram-breeding nucleus.

In Australia, 75 percent of the sheep population is Merino, and a further 22 percent part Merino. Medullated fibres («hair») are not a major problem. Such fibres may be present in larger proportions in other breeds and are undesirable in apparel wool, particularly when shed («kemp»).

(iii) Other characteristics

The most important of these is reproduction rate, which can be defined as number of lambs born (or weaned) per ewe joined (put to the ram). Standardization of definition is needed; number of lambs born per ewe lambing, or per ewe inseminated, gives no indication of the number of ewes which fail to lamb, or to

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come on heat. Lambs born per ewe joined gives a truer indication of reproduction rate for the flock.

Attention is paid by many breeders to characteristics called in Australia «faults»; some of these may be important, but should not be included in a selection programme unless their association with production has been objectively established.

Body weight need not be considered if wool is the main product, but body weight itself (or some function of it) may be included where meat is also important.

b) Estimating parameters

From (a), the characteristics for which parameters are required are:

Greasy wool weight
Clean wool weight
Average fibre diameter
Post-scouring colour
Percent clean yield
Face cover score
Skin wrinkle score (Merinos) \{ in some countries
Reproduction rate
Body weight (in some cases)

Areas of pigmented fibres which cover part or all of the body are in most cases controlled by genes at a single locus, but nothing is known of the inheritance of occasional pigmented fibres in white fleeces, though sheep with these may often be found (Kelley and Shaw, 1942).

Parameters are available for pre-scouring wool colour, but only one set for post-scouring colour; these are included in the tables.

Research is in progress to determine the characteristics associated with fleece protection during growth, but no clear answers are yet available. Quantity of wax is probably important, and selection may eventually be for an optimum percent clean yield in a given environment.

Fibre length is not included in the list. Its correlation with staple length is not high, and average fibre length in top or yarn is greatly influenced by processing technique. Selection for high clean wool weight has been shown to increase both staple length and number of fibres per unit skin area («density»), so consideration of these characteristics in addition to clean wool weight may not be necessary.

Tables 1-3 give estimates of repeatability, heritability and correlations for various breeds.

Crimp frequency has been included in Table 3, not because it should be considered in selection, but to present its correlation with production characteristics.

Gene × environment interactions for wool characteristics are unlikely to be important, except where genetic or environmental differences are very large (Dunlop, 1962).
c) Breeding plans

(i) Formulation

1. Repeatability and age at selection (Table 1)

The repeatability estimates for wool production characters are high enough for a single early record to be indicative of lifetime performance. The age of measurement will depend on the age at first mating, which should be as young as possible to ensure a short generation interval. In general, first mating is at $1\frac{1}{2}$ years, and selection will be on measurement at 12-16 months.

### TABLE 1

**Repeatability estimates**

**Apparel wool breeds - wool production**

(Measurements at 15-16 months and later ages)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Merino and allied breeds</th>
<th>Other breeds</th>
<th>References *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greasy wool weight ............</td>
<td>0.6 - 0.9 *</td>
<td>0.4 - 0.6 +</td>
<td>19 33 54 61 68 14 21 54 61 68</td>
</tr>
<tr>
<td>Clean wool weight .............</td>
<td>0.6 - 0.9</td>
<td>— **</td>
<td>19 33 54 61 68</td>
</tr>
<tr>
<td>Average fibre diameter .......</td>
<td>0.5 - 0.8</td>
<td>0.4 - 0.7</td>
<td>33 61 68 22 32</td>
</tr>
<tr>
<td>Post-scouring colour ..........</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Percent medullation ...........</td>
<td>—</td>
<td>0.5 - 0.7</td>
<td>—</td>
</tr>
<tr>
<td>Percent clean yield ...........</td>
<td>0.5 - 0.8</td>
<td>—</td>
<td>33 68 22 23</td>
</tr>
<tr>
<td>Face cover score ..............</td>
<td>0.4 - 0.9</td>
<td>0.8</td>
<td>19 68 13</td>
</tr>
<tr>
<td>Skin wrinkle score ............</td>
<td>0.4 - 0.7 +</td>
<td>× **</td>
<td>19 68 ×</td>
</tr>
</tbody>
</table>

* See bibliography at end of paper for numbered references.

** — No estimates.

*** × Not applicable.

* One lower estimate of 0.4 for Polish Merino (30), and one of 0.2 for other breeds (21).

Some environmental adjustments will be needed. If there has been no previous shearing, the wool-growing period will vary from animal to animal according to the length of the lambing season. Adjustments will be needed for this and may also be needed in some environments for type of birth (single or twin) and age of dam (young or adult). Even with a previous shearing, adjustments for maternal effects may be needed to avoid penalizing twins and progeny of young ewes.

In the case of rams, preliminary culling at an early age (e.g. weaning) may be an advantage. If data are available to make the environmental adjustments...
TABLE 3
PHENOTYPIC AND GENETIC CORRELATIONS
APPAREL WOOL BREEDS - WOOL PRODUCTION
(Wool and body measurements at 15-16 months, Reproduction rate at ages shown)

<table>
<thead>
<tr>
<th>Characteristics Correlated</th>
<th>Merino and allied breeds</th>
<th>Other breeds</th>
<th>Merino and allied breeds</th>
<th>Other breeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phenotypic</td>
<td>Genetic</td>
<td>Phenotypic</td>
<td>Genetic</td>
</tr>
<tr>
<td>Greasy wool weight and:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean wool weight . . .</td>
<td>+ 0.8 to + 0.9</td>
<td>+ 0.6 to + 1.0</td>
<td>-**</td>
<td>+ 0.9</td>
</tr>
<tr>
<td>Average fibre diameter.</td>
<td>+ 0.1 to + 0.4</td>
<td>+ 0.1 to + 0.5</td>
<td>+ 0.1</td>
<td>+ 0.2</td>
</tr>
<tr>
<td>Post-scouring colour...</td>
<td>+ 0.2</td>
<td>+ 0.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of crimps . . .</td>
<td>-0.2 to -0.4</td>
<td>-0.2 to -1.0</td>
<td>-</td>
<td>-0.4 to -0.5</td>
</tr>
<tr>
<td>Percent medullation...</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+ 0.3</td>
</tr>
<tr>
<td>Percent clean yield...</td>
<td>-0.1 to + 0.1</td>
<td>-0.2 to + 0.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Face cover score ....</td>
<td>-0.1 to 0</td>
<td>-0.1 to -0.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skin wrinkle score . .</td>
<td>+ 0.2 to + 0.4</td>
<td>0 to + 0.7</td>
<td>×***</td>
<td>×</td>
</tr>
<tr>
<td>Number of lambs born:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-year-old ewes . . .</td>
<td>-0.1 to 0</td>
<td>-0.5 to + 0.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>24-year-old ewes . . .</td>
<td>+ 0.1</td>
<td>+ 0.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Body weight . . . .</td>
<td>+ 0.2 to + 0.6</td>
<td>-0.3 to + 0.6</td>
<td>+ 0.3 to + 0.4</td>
<td>+ 0.2 to + 0.6</td>
</tr>
<tr>
<td>Clean wool weight and:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average fibre diameter.</td>
<td>0 to + 0.4</td>
<td>0 to + 0.4</td>
<td>+ 0.3</td>
<td>0 to + 0.2</td>
</tr>
<tr>
<td></td>
<td>2-year-old ewes</td>
<td>2-4-year-old ewes</td>
<td>Body weight</td>
<td>Average fibre diameter and:</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>-------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Number of crimps</td>
<td>-0.1 to 0</td>
<td>-0.9 to +0.3</td>
<td>+0.2 to +0.7</td>
<td>+0.1 to +0.7</td>
</tr>
<tr>
<td>Percent medullation</td>
<td>-0.2</td>
<td>-0.5</td>
<td>-0.8</td>
<td>-0.1</td>
</tr>
<tr>
<td>Percent clean yield</td>
<td>0.4 to +0.5</td>
<td>0 to +0.6</td>
<td>0.6</td>
<td>+0.1</td>
</tr>
<tr>
<td>Face cover score</td>
<td>0</td>
<td>-0.2</td>
<td>-0.3</td>
<td>+0.1</td>
</tr>
<tr>
<td>Skin wrinkle score</td>
<td>0.1 to +0.3</td>
<td>-0.4 to +0.1</td>
<td>+0.2</td>
<td>+0.1</td>
</tr>
</tbody>
</table>

* See bibliography.
++ No estimates.
*** Not applicable.
+ One value of +0.8 for Corriedales (51).
++ Estimates for the Romney (10) and some for the Rambouillet (48) are negative. The greasy wool weights used were for ewes in the breeding flock, and the influence of number of lambs on the ewes' fleece weight could generate a negative genetic correlation.
discussed above, fleece weight at weaning can be used for this. If such data are not available, preliminary culling can be done on wool follicle curvature, scored on vertical skin selections [see Section d]).

2. Heritability and mass selection (Table 2)

Heritability levels for wool characteristics measured at 12-16 months are high enough for selection on individual phenotype (i.e. mass selection) to be effective when the animals under selection have been reared together. Examination of relatives such as progeny or half-sibs is unnecessary except in special circumstances.

**TABLE 2**

**HERITABILITY ESTIMATES**

**APPEL WOOL BREEDS - WOOL PRODUCTION**

(Measurements at 12-16 months)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Merino and allied breeds</th>
<th>Other breeds</th>
<th>Merino and allied breeds</th>
<th>Other breeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greasy wool weight</td>
<td>0.2 - 0.8 *</td>
<td>0.3 - 0.7 *</td>
<td>2 5 8 9 33 48 14 20 21 34 38</td>
<td>5 4 6 1 6 9 42 43 45 5 4 6 1</td>
</tr>
<tr>
<td>Clean wool weight</td>
<td>0.2 - 0.6</td>
<td>— **</td>
<td>5 3 5 4 6 1 6 4 9 6 9</td>
<td>— —</td>
</tr>
<tr>
<td>Average fibre diameter</td>
<td>0.2 - 0.6</td>
<td>0.5 - 0.6 ++</td>
<td>33 5 2 5 4 6 1 6 9 2 2 3 4 3 8 5 4 6 1</td>
<td>5 4 6 1 6 9 4 4 5 4</td>
</tr>
<tr>
<td>Post-scouring colour</td>
<td>0.2</td>
<td>0.7</td>
<td>2 7</td>
<td>— —</td>
</tr>
<tr>
<td>Percent medullation</td>
<td>—</td>
<td>0.3 - 0.7</td>
<td>33 5 2 5 4 6 1 6 9 2 2 4 4 5 4</td>
<td></td>
</tr>
<tr>
<td>Percent clean yield</td>
<td>0.3 - 0.8</td>
<td>—</td>
<td>33 5 2 5 4 6 1 6 9 2 2 4 4 5 4</td>
<td></td>
</tr>
<tr>
<td>Face cover score</td>
<td>0.3 - 0.8</td>
<td>0.6</td>
<td>2 4 4 5 4 6 1 6 9 4 4 5 4</td>
<td></td>
</tr>
<tr>
<td>Skin wrinkle score</td>
<td>0.2 - 0.8</td>
<td>× ***</td>
<td>2 5 4 6 1 6 9</td>
<td>×</td>
</tr>
</tbody>
</table>

* See bibliography.
** — No estimates.
*** √ Not applicable.
* Values of 0.1 for Polwarth (33) and Norwegian breeds (22).
++ One value of 0 for Romney (34).

Progeny tests, for example, would be recommended:
— When rams were to be introduced from an outside source whose genetic level was unknown,
— When a few rams were to be used widely with artificial insemination.

Observations on female relatives are needed when selecting rams for reproduction rate: dams' records are most efficient, and save time in the selection of both rams and ewes.
3. Relevance of genetic correlations (Table 3)

**Greasy and clean wool weight.**—This correlation is high enough to justify the use of greasy weight for ewe selection and preliminary ram selection, yields being obtained only for rams with the highest greasy weights.

**Crimp frequency and average fibre diameter.**—The phenotypic correlation is low, ranging from \(-0.1\) to \(-0.3\) for Merinos, and \(-0.4\) for Corriedales.

**Clean or greasy wool weight and wool quality.**—The correlation of wool weight with crimp frequency is high and negative, while the correlation with fibre diameter is positive but small. Changing from assessment of quality on crimp to measurement of fibre diameter will increase the rate of genetic progress through selection, particularly for Merinos. The high negative genetic correlation with crimp will slow progress if crimp has to be maintained, but diameter can be maintained without sacrificing much progress in wool weight.

**Clean or greasy weight and reproduction rate.**—This is an important correlation, since it indicates the ease of improving both characteristics simultaneously. Estimates vary from small negative to zero. All except one of the negative estimates are based on fleece weights of ewes in the breeding flock, which are themselves influenced by lambing performance, so generating a negative genetic correlation, as both characteristics are heritable.

4. Breeding structure

In countries with well-developed sheep industries, the classic breeding structure is in layers. A top layer of supposedly superior animals produces sires for general flocks, and there may be an intermediate layer drawing males from the top in order to multiply their numbers. This system is frequently «closed» (with downward flow of males but no upward flow of females), but may be partly «open» (with downward flow of males and upward flow of females).

The rate of genetic gain in the top layer establishes the rate for the whole system. It is therefore important that this top layer should be making the greatest possible genetic gain—which means selecting on characteristics of importance, and using measurement.

Dissatisfaction with, and lack of knowledge about, exact selection methods in the top layer of Australian and New Zealand studs has led to two developments:

- Establishment of nuclei in large flocks for the production of home-bred rams, selected on measurement.
- Establishment of «co-operative breeding schemes», in which superior females are contributed by a number of flocks to form a central ram-breeding nucleus, which then supplies rams to the co-operators.

**Richard** (1971) analysed rates of gain and genetic differences between layers in a closed system, while **Jackson and Turner** (1972), investigated some aspects of partly open co-operative schemes, and showed that rates of gain could be increased by 16 percent if half the annual ewe replacements in the nucleus came from within itself, half continuing to come from the co-operating flocks.

Co-operative schemes could be of value in countries where flocks are small and of low productivity. Selection within flocks in such cases would be of little
value. Genetic gains would be greater if each of a number of small flocks contributed a few superior animals to a co-operative ram-breeding nucleus.

(ii) Checking with selection experiments

Australian sheep breeders have been urged for many years to use breeding plans based on measurement, and confirmatory results of their value are available from Merino selection experiments begun in the 1950's and later. These are of two types—single-character selection to confirm predictions of response, and selection for wool quantity and quality.

1. Single-character selection

*Clean wool weight alone.*—There have been 4 experiments with selection for high clean wool weight. Marked direct response occurred in two (DUNLOP, unpublished, up to 7 percent per annum), medium response in a third (TURNER, BROOKER and DOLLING, 1970) and no response in the fourth, after the initial gain due to selection of the base parents (SAVILLE and ROBARDS, 1972). Selection for low clean wool weight in paired groups for the last two experiments showed continuing response.

Crimp frequency fell in all groups selected for high clean wool weight, and rose in the low weight groups, though there were not always corresponding changes in diameter.

*Average fibre diameter.*—In one experiment, groups selected for high and low diameter have become markedly different, with little difference in clean wool weight or staple length, and only a slight difference in crimp frequency (TURNER, BROOKER and DOLLING, 1970).

*Percent clean yield.*—In one experiment, groups selected for high and low percent clean yield differ markedly in yield, and in the same direction for clean weight (TURNER, BROOKER and DOLLING, 1970). The main component of the yield difference is the wax content (TURNER, unpublished).

*Incidence of multiple births.*—Two groups have been selected for high and one for low incidence. Response has been marked, especially in one of the two high lines. There is no marked downward trend in differences in clean wool weight between the high and low lines (TURNER, 1972).

In a similar experiment with the NZ Romney, a control group was included. Both high and low lines had average fleece weights below the control, and though the low line fleece weight was above that in the high the difference was small and not significant (CLARKE, 1972).

2. Selection for wool quantity and quality

*High clean wool weight with diameter maintained.*—In one selected group (S) wool weight rose initially by 2.5 percent per annum. Response slackened during a drought period, then returned to 2.5 percent per annum when conditions improved. There was no change in average fibre diameter, although crimp frequency fell, and no downward trend in number of lambs weaned per ewe joined (TURNER, DOLLING and KENNEDY, 1968; TURNER, MCKAY and GUINANE, 1972, and TURNER, unpublished).
**High clean wool weight with crimp maintained.**—In a second group (MS) run with S, selection was for high clean wool weight, but after the first 8 years diameter maintenance was changed to crimp maintenance. Response initially was at 2.5 percent per annum, as in the S group; response since the change has been variable, the average wool weight increase being only 1 percent per annum (Turner, unpublished). The same low increase was obtained in a second experiment where crimp was maintained (Dun and Eastone, 1970).

d) **Physiological investigations**

Some examples of this approach will suffice.

(i) **Skin characteristics**

Examination of vertical skin sections for Merinos has shown that wool follicle structure can be scored according to degree of curvature (Nay, 1974) and that such scoring can be done as early as at weaning (Nay, Jackson and Turner, in preparation). Highly curved follicles are associated with greasier wool of lower weight, shorter staple and higher crimp frequency, though not necessarily finer diameter. Early preliminary culling of rams on degree of curvature can be done at weaning, though final selection later on clean wool weight and fibre diameter is recommended.

The possibility is being investigated of further improvement in production by selection on wool weight, with diameter maintained, among animals with straight or only slightly curved follicles.

(ii) **Association of hormone levels with reproduction rate**

Marked differences in the blood level of luteinizing hormone have been found between lambs 30 days old in the groups selected for high and low incidence of multiple births. The possibility of using this for early diagnosis of fecund animals is being investigated. The differences occur in lambs of both sexes, so direct selection of rams might be possible (Bindon and Turner, 1974).

III. **CARPET-WOOL**

a) **Defining production**

Carpets are traditionally made from wool of high diameter and containing a proportion of medullated fibres. In some countries blends of two types of wool are used, one of which comes from «true» carpet-wool breeds, while the other comes from the coarser apparel-wool breeds (e.g. N. Z. Romney), and contains less medullation or none at all.
The percentages of the two types in blends vary from country to country, probably according to availability and cost. For example:

<table>
<thead>
<tr>
<th>Traditional carpet-making countries</th>
<th>Carpet-wool</th>
<th>Coarse-apparel wool</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i.e., Iran)</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Great Britain</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Australia</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>United States</td>
<td>30</td>
<td>70</td>
</tr>
</tbody>
</table>

Specifications for optimal fibre diameter and percentage medullation do not exist. Burns, Johnston, and Chen (1940) stated some, but they were merely obtained by measuring wools traditionally used for carpets. This is a starting-point only; such measurements should be followed by processing trials and wear tests with varying fibre diameters and percentages of medullated fibres. Some tests of this kind are now in progress, and may yield concrete information. In the meantime, the opinion of manufacturers can be accepted, namely that the main role of medullation is to lower costs by providing more «cover».

(i) Wool quantity

In the absence of specific experiments on efficiency of food conversion in carpet breeds, it may be assumed that clean weight per head will be the main criterion of quantity.

(ii) Wool quality

The main components are high fibre diameter and «resilience», with no clear criterion for measuring the latter. Average diameter, staple length, presence of medullation and absence of kemp are requirements. Pigmented or yellowish fibres are still acceptable, though at lower prices; as the use of the tufting technique increases, displacing weaving, the demand for white wool will be greater.

Presumably fibre damage is as important with carpet-wool as with apparel-wool. One great problem is the bright yellow stain which occurs during heavy monsoonal rain in some areas.

b) Estimating parameters

From (a), the characteristics for which parameters are required are:

- Greasy wool weight.
- Clean wool weight.
- Average fibre diameter (high preferred).
Presence of medullation (but exact amount not clearly specified).
Absence of kemp.
White fleeces fetch a higher price, but pigmented or yellow fleeces still accepted.
Staple length
Body weight.
Reproduction rate.

Body weight and reproduction rate are even more important than with apparel-wool breeds, as meat is usually the main product, wool and sometimes milk being secondary.

Few estimates of phenotypic and genetic parameters have been published for carpet-wool; those which have been fall within the ranges given for apparel-wool (see references under carpet-wool). For the moment, the available estimates can be assumed to apply, though it is to be hoped that more work will be done on the carpet breeds themselves.

c) BREEDING PLANS

(i) Formulation

The plans suggested for apparel-wool should apply to carpet-wool breeds. Since carpet breed flocks are small in many countries where no formal structure exists to supply rams, the establishment of central ram-breeding nuclei would be an advantage. These could be established by some central organization (Government or private), or co-operatively by flock owners.

(ii) Checking by experiment

There are references in the literature to selection experiments in various places, but no published results. It is hoped that information might emerge in the discussions at this Conference.

SUMMARY

Wool can be divided into two broad classes, apparel-wool and carpet-wool. The paper stresses the need for defining production clearly in terms of market requirements, which certainly differ for the two wool types, and may also vary according to the market.

The world marker for apparel wool has fairly clear-cut definitions of requirements, average fibre diameter being the most important single processing characteristic. Staple crimp frequency, formerly used as a guide to diameter, is an unreliable one, and is of no importance itself except in special cases. Sale of wool on measured diameter is now the aim for the Australian market, and measured diameter should now replace quality number for assessing wool quality in selecting rams. This will lead to faster gains in wool weight under selection,
because a high negative genetic correlation between weight and crimp retards progress when crimp is being maintained.

Reproduction rate is of importance in any flock, and body weight may have to be included if meat production is also being considered.

Estimates of genetic parameters are given. Heritability levels are high, and if crimp is no longer used to assess quality, there are no antagonistic genetic correlations. Results of successful selection to increase apparel-wool production are described.

Requirements for carpet-wool are not so well defined. High diameter is required, and a percentage of medullation is acceptable because it lowers cost, but no optimal percentage has been determined. Genetic parameters are scarce. As those for apparel-wool breeds are all similar, it seems reasonable to extrapolate their values to carpet breeds until estimates for the latter are available.

RESUME

La laine se répartit en les deux catégories laine cardée et laine à matelas. Cette étude insiste sur le besoin de délimiter avec précision la production par rapport au marché lainier qui peut différencier entre les deux catégories.

Les caractéristiques du marché mondial de laine cardée se définissent avec précision. Le diamètre moyen de la fibre lainière est la caractéristique textile la plus importante. Le frisage de mèche est un indicateur inconstant du diamètre et n'a pas lui-même d'importance. En Australie nous désirons d'établir le marché lainier et la sélection génétique des béliers sur le diamètre mesuré de la fibre.

En cette sélection le poids de laine se développerait plus rapidement en raison de la corrélation génétique négative et élevée entre le poids et le frisage de laine qui retard le progrès en la sélection établit sur le frisage seulement.

Le taux de reproduction est toujours important et il faut que l'on a ègard au poids vif quand la production de viande est contemplée.

Des valeurs de paramètres génétiques sont présentées. Les coefficients d'heritabilité sont élevées et à défaut d'utiliser le frisage d'évaluer la qualité lainière, il n'y a pas des corrélations génétiques et negatives. Les résultats montrent que la sélection de développer la production de laine cardée est favorisée par le succès.

Les exigences textiles de laine à matelas ne se définissent pas bien. Il y a besoin du diamètre élevé et une proportion des fibres avec médullaire est avantageux pour réduire le coût. On ne connait pas ce proportion précise. Les paramètres génétiques ne sont pas nombreuses. Avant qu'elles se manifestent il paraît raisonnable d'extrapoler les paramètres génétiques des moutons à laine fine aux moutons à laine croisée jarreuse.

ZUSAMMENFASSUNG

Die Wolle kann in Zwei breite Klassen getrennt werden, Kleiderwolle und Teppichwolle. Die Abhandlung betont das Bedürfniss für eine klare Begriffsbestimmung der Produktion, da die Marktforderungen gewiss für diese zwei Typen unterschiedlich sind, und können sich also, dem Markte entsprechend, ändern.

Die Fortpflanzungsraten ist in jeder Herde wichtig und das Körpergewicht sollte auch erwogen werden, falls die Fleischproduktion also mitzubetrachten wäre.


BIBLIOGRAPHY

A) APPAREL-WOOL AND GENERAL REFERENCES


B) CARPET-WOOL


