ORGANIZATION OF ON-FARM BREEDING PLANS FOR BEEF CATTLE

R.G. BEILHARZ*

Summary

The steps for deriving an optimum breeding plan for any particular breeding situation are described. They comprise definition of background and aims, definition of traits to be considered, a list of estimates of genetic parameters for these traits, the appropriate method of improvement suggested by these estimates for each trait, a reconciliation of these separate demands into one overall plan, and the testing and possible modification of this breeding plan.

The breeding plan for the beef herd at the Mt. Derrimut field station is described as an example suggested by the application of these steps. This plan comprises cyclical crossbreeding involving the three breeds Angus, Hereford and Friesian. Artificial insemination is used. The crossbreeding is expected to improve all traits of reproduction. Selection for growth rate among replacement heifers occurs also.

The National Beef Recording Scheme is described. It is an aid to on-farm breeding plans which will be more effective if guided by advisers. Two recently initiated breeding plans, in which co-ordinated groups of breeders utilise the National Beef Recording Scheme, are discussed. These plans depend mainly on selection for growth rate although there is no reason why more traits should not also be improved, particularly if uniform carcass evaluation is introduced.

Plans such as these should, in theory, lead to significant improvement in growth rates and, hence, in turn-off of beef. Possible impairment of reproduction through inbreeding or through too rapid a response in the single trait of growth rate, are discussed.

I. INTRODUCTION

If the conclusions of quantitative genetics are applied rationally and systematically, it should be possible to develop the optimum breeding plan for any livestock breeding situation. This plan will vary from farm to farm, depending on the circumstances of each farm. In this paper a series of steps is presented, which, if applied systematically, should lead to a workable breeding plan for any particular situation. A plan developed for a herd of 30 breeding cows at the Mount Derrimut field station is discussed as an example. A discussion of several other plans being attempted on farms in south eastern Australia follows and completes the paper.

II. STEPS FOR DERIVING A BREEDING PLAN

(a) Definition of Background

Both breeder and genetic adviser must together clearly define the aims of the breeding plan (e.g. production of stock for slaughter at a certain age, or of reproductive-stud-stock, etc.). They must also clearly define the

* School of Agriculture and Forestry, University of Melbourne, Parkville, Victoria, 3052, Australia.
resources available in land, personnel and facilities, and the sort of data that can be collected. If yards, scales and access to computers are not available, a simple plan might be all that can be undertaken. Alternatively, one might decide to provide yards and scales.

(b) Definition of Traits

Each trait that may have to be considered must be defined so that it can be measured. Secondly, it must be clearly established for each trait what its economic contribution will be.

Measurement is essential, although it may sometimes be difficult. If necessary a subjective scale of values, as consistent as possible, must be used, as e.g. for "temperament". One cannot, rationally, breed for a trait that is not measurable in some way.

The economic contribution of traits should be estimated for the particular situation for which the breeding plan is being developed. Thus, high prices for veal are quite irrelevant to a breeding situation in which the sole turn off is from 2-1/2 year old bullocks and old cows.

One should summarise the definition of traits by placing all traits considered into an order of importance for the particular situation being discussed. This is necessary in order to limit the number of traits to be improved. The fewer other traits are considered, the more progress can be made in any particular trait.

(c) List of Estimates of Genetic Parameters

For each trait in the order of importance above, estimates of heritability, estimates of heterosis (response to crossbreeding), and estimates of genetic correlations with other traits must be listed. This information should be provided by the genetic adviser from the literature. For the common traits of interest in cattle breeding such estimates exist. In general, traits concerned with reproduction have low heritability but show some heterosis. Traits concerned with growth have medium heritabilities (0.1-0.3) but show little heterosis, except when confounded with heterosis in a maternal effect. Carcass traits tend to have high heritabilities (> or = 0.3) and no heterosis.

(d) Appropriate Method of Improvement for Each Trait

From quantitative genetics we know that traits of medium or high heritability are improved most rapidly by selection on the basis of the individual phenotype. For traits of low to medium heritability selection on family average, or within-family selection, are most appropriate. The choice between the two alternatives depends on the reasons for the lowered heritability. If family members all experience the same environment, which is different from that of other families, within-family selection is appropriate. Another reason for preferring within-family selection is to reduce rate of inbreeding. Sometimes the nature of the trait forces the use of variations of family selection, such as selection of surviving family members after the slaughter and measurement of a randomly selected group of sibs, or selection on progeny test. Obviously, for traits, showing substantial heterosis, outbreeding or crossbreeding are required.

If none of these methods seem suitable (e.g. for a trait with a low estimate for heritability and low heterosis) no significant genetic improvement can be expected. Such traits should be excluded from the breeding programme. They must be improved by modifying the environment.
At this point only the 3 or 4 most important traits, that are capable of genetic improvement, and that are not mutually strongly positively correlated, should be considered further.

(e) Synthesis of Overall Breeding Plan

The separate demands of the remaining important traits must be reconciled into an overall breeding plan. This is the point where selection indices for combining the various traits to be selected must be calculated, or independent culling levels set. One may also have to combine the requirements of selection for some traits with cross-breeding for others. There may be other constraints imposed by the background. For example, a stud breeder may not be willing to crossbreed.

(f) Tests of the Synthesized Breeding Plan

At this stage, for breeding plans that involve closing of herds, the rate of inbreeding should be estimated. As a rule of thumb I suggest that the "increment" of inbreeding ($\Delta F$, Falconer 1961) should be no greater than 1% per generation as calculated by $\Delta F = \frac{1}{2N_e} - \frac{1}{8N_m} + \frac{1}{8N_f}$ where

$N_e$ = effective population size;
$N_m$ = number of breeding males; and
$N_f$ = number of breeding females.

With effective selection the real rate of inbreeding will, of course, be higher than is indicated by this formula.

If $\Delta F$ is found to be higher than 1% per generation a system of breeding families, with systematic movement of males between families should be considered. Alternatively, periodic opening of the breeding plan may have to occur. One may wish to avoid introducing outside stock, if systematic application of a breeding plan has already resulted in significant improvement.

Other tests at this stage involve Checks on the estimated requirements of labour and facilities. One should also calculate expected progress in the breeding plan and compare its value with expected costs. Such practical considerations may force further modifications onto the breeding plan.

III. EXAMPLE OF A PRACTICAL BREEDING PLAN

At the Mount Derrimut field station of the University of Melbourne it was possible to start a herd of 30 breeding beef cows in 1970. Through a grant from the Rural Credits Development fund a set of yards including a cattle scale was erected and 30 yearling heifers bought. The small herd size is merely one of the factors that must be taken into account. The steps set out in II. above were applied as follows.

(a) Definition of Background

The background is one of interest in the collection of data on all aspects of performance of the cattle and also on economic evaluation of beef production. The aim is to sell steers and surplus heifers at from 8 to 18 months of age depending on market prices and pasture conditions on the field station. There will also be cull cows for sale. The stock are sold for slaughter.

The traits considered economically important are fertility and survival, mothering ability as indicated by weaning weight or growth to weaning, and growth rate to slaughter age.
(b) Definition of Traits

There are various ways of defining fertility and survival. For example one can combine both aspects in the measure: Percentage of calves weaned per cow mated as a result of a limited mating season. Maternal ability and pre-weaning growth are confounded in measures such as weaning weight or average daily gain to weaning (adjusted to age and sex of calf and age of dam, as required). The fact that maternal performance and pre-weaning growth are confounded in one measure does not matter, as long as the measure is sufficiently heritable to respond to selection. Post-weaning gain is measured over a period of several months after weaning.

Reproduction was considered to be the most important trait followed by growth to weaning. As the slaughter age may vary, post-weaning growth was considered less important.

(c) List of Estimates of Genetic Parameters

There are few estimates on genetic parameters of reproductive traits in beef cattle in Australia. However, we can utilise the generally accepted principle that traits concerned with reproduction are poorly heritable but respond to heterosis. Pattie (1973) states that cross-breeding plans, based on overseas research, are practised in Australia to utilise the superior reproductive performance of crossbred females. Wiltbank et al. (1966) found significant heterosis on age at puberty such that crossbred heifers (between Hereford, Angus and Shorthorns) were younger by 20 to 27 days at puberty, after allowing for an effect of heterosis on growth rate. In the same breeds Gaines et al. (1966) found a 10% advantage in number of calves weaned from crossbred matings even though all cows used were purebreds. They expected a further gain to result when cows were crossbreds. Again with the same breeds, Gregory et al. (1965) and Gregory et al. (1966) found significant effects of heterosis in pre-weaning and post-weaning growth traits. Clearly it is reasonable to expect reproduction, however measured, to be significantly improved by crossbreeding. If the separate effects (i) of earlier puberty and increased calving percentage resulting from use of crossbred cows, (ii) of increased survival of crossbred calves, (iii) of increased 'growth to weaning, and (iv) of increased post-weaning growth are added, one may expect perhaps a 20% improvement in turn off of liveweight to result from a system of continuous crossbreeding.

Estimates of heritability of about 0.25 are available in Australia for growth rate to weaning (Pattie 1973). No estimates are available for post-weaning growth but we can safely expect heritability to be higher than for growth to weaning.

(d) Appropriate Method of Improvement for Each Trait

Clearly, crossbreeding is appropriate for improving reproduction. Selection on own phenotype is appropriate for pre- and post-weaning growth.

(e) Synthesis of Overall Breeding Plan

The breeding plan adopted to accommodate these requirements was a continual crossbreeding plan which started with 10 purebred cows of each of the Angus, Hereford and Friesian breeds. The Angus cows were inseminated with Hereford semen, the Hereford cows with Friesian semen, and the Friesian cows with Angus semen. The first calves were born in 1972. These crossbred calves have been mated in 1973 and will produce their first calves in 1974.
The management of the crossbreeding scheme is simple. Each cow is eartagged with a colour that denotes the semen with which she must be inseminated throughout her life. The crossbred heifers resulting from any particular breed of semen replace the purebred cows of the same breed. Thus a calf that is from an Angus cow by Hereford semen replaces a Hereford cow. It will thus, in turn, be inseminated with Friesian semen.

Selection for growth rate will be imposed on top of the crossbreeding scheme. Infertile cows are culled. Within any group of crossbreds only the fastest growing heifers will be kept. Because of infertility in the original purebreds we have retained all crossbred heifers from the first calf drop.

(f) Tests of the Synthesized Breeding Plan

Although there is no control herd for comparison, the considerations of III(c) suggest that a substantial average improvement in turn off of liveweight should occur rapidly, as purebred cows are replaced by crossbreds. This is, of course, a result which can only be maintained thereafter. We expect selection of growth rates to give us a slow but continuing response in the future. As we are utilising semen from A.I. centres we largely depend on the selection of bulls done for A.I. centres for the amount of response we will get in growth rate. Should any breed of semen turn out to give consistently poor results it will be easy to substitute another breed. Ideally, more research is needed on which breeds give the largest amount of heterosis in 3-breed cycles.

IV. OTHER BREEDING PLANS

Although the breeding plan outlined above suggested that crossbreeding will provide a rapid and significant benefit, crossbreeding has so far not been widely utilised in beef cattle breeding in southern Australia, except as a stage in grading up to new breeds through an insemination programme. I suggest that this is because reproduction (fertility and survival) is not so readily seen as contributing to economic return, as in a species with large litters such as pigs. Most commercial pig breeding programmes in Australia, the U.S.A. and the U.K. involve crossbreeding.

In Australia there has, to date, been no uniform system of appraisal of carcass quality. Hence, it has not been possible to include effective selection for traits related to this in breeding plans. Thus, Australian beef cattle breeding plans based on performance records have, in practice, been based mainly on selection for growth rates.

Resulting from recommendations of an expert panel (Rendel et al. 1968) the National Beef Recording Scheme, using computer facilities at the University of New England, was launched in 1972. Many on-farm breeding plans now utilise this scheme.

In this scheme reproductive performance, growth rate and carcass merit are identified as the traits of economic importance. Actual records taken for each herd may include all of the following. Identification, sex, breed, date of birth, sire and dam for each animal; mating records (bull, mating period and bodyweight) for each cow; calving records (pregnancy diagnosis, identification of calf, birth date, sex, single or twin, birthweight); calf performance (weight of calf at about 200 days of age, condition and grade of calf, weight and condition of dam); and growth after weaning (date, weight, condition and grade at the beginning and end of a test period starting after calves have recovered from weaning). Provision is made for future inclusion of carcass data. The computer calculates rates of gain to 200 days, or post-weaning,
and adjusts gain to 200 days for age of dam. It provides summaries in which
calf gains, pre- and post-weaning are expressed in relation to the average
of the group (herd). Dams and sires are evaluated on their calves' average
growth rates. To the extent that the assumptions and corrections used in the
computer programmes are reasonable, one gets a sound comparison of the animals
used in any herd. Breeders are urged to utilise this information in selecting
replacement sires and breeding cows. Clearly this scheme helps to evaluate
individuals, sires or dams. The breeder must still decide how to use these
records, whether to close his herd, whether and where to purchase replacement
sires, whether to crossbreed, etc. Clearly, this scheme will be of most
use when accompanied by a sympathetic extension service.

Various schemes utilising the facilities of the National Beef
Recording Scheme have recently been started to co-ordinate breeding plans on a
larger scale. These schemes aim at more effective improvement by providing
larger populations with which to work and, as a consequence, achieving higher
selection differentials. It appears that at least initially, these schemes
will be basing their improvement largely on selection for rapid growth rate
which is expected also to improve milking ability through pre-weaning growth.

One example is the Sire Evaluation Programme of the Beef Improvement
Association of Australia. This scheme is available for each breed of beef
cattle and utilises artificial insemination. The crux of the scheme for 'each
breed is the use of semen of a particular bull, the reference sire, in many
herds (U.S.D.A. Extension Service 1972). Reference sires will be bulls
"outstanding" in performance. This has two benefits. More breeders will be
induced to co-operate and take systematic records for a defined purpose, and a
significantly large proportion of the stock in co-operating herds will be the
progeny of an "outstanding" bull. At the time of writing initial reference
sires have been named for the Hereford and Angus breeds.

In the scheme sufficient semen is supplied to get about 20 progeny
of the reference sire in each herd. Breeders are urged to choose the cows for
insemination in such a way as to eliminate bias. The remaining cows of each
herd are mated, in similarly chosen single-sire group(s), to the breeder's own
bull(s). The traits of the progeny of each breeder's bull(s) are compared
against a standard of 100 for the same traits of the progeny of the reference
sire. Ease of calving will also be recorded for the calves resulting from each
bull. Appropriate corrections will be applied to allow for different numbers
in the progeny groups. Clearly, a rapid comparison of weights or growth rates
becomes available for progeny of a large number of bulls in any breed in an
area such as south-eastern Australia. Because of genotype environment
interaction, it would be unwise to use the same reference sire in northern and
southern Australia. Clearly, also, it will be easy to incorporate carcass
traits as soon as uniform carcass assessment becomes routine. One can even see
how, over a longer test interval, traits of fertility of female progeny can be
compared.

The Beef Improvement Association hopes in this way to identify
outstanding sires from a large population of selected bulls. Such bulls will then
be used as future reference sires. Although reference sires will be registered
(purebred) animals initially, it is conceivable that unregistered bulls, though
not crossbreds, may in future be used as reference sires. There is nothing in the
scheme preventing individual breeders from using non-registered cattle.

A second example of a co-ordinated breeding plan is the Sirebank
Herefords Scheme which started in northern Victoria in 1973. This scheme
comprises 8 herds with a total of about 6,000 breeding cows and yearling heifers.
The size of individual herds ranges from 200 to 2,500 females.
A nucleus herd of 240 cows was selected by taking, on average, the best 5 to 6% of cows from each breeding group in the co-operating herds. Actual proportions selected were modified by considering past selection and the desire to rapidly reach an equilibrium age structure. The criteria of selection were rearing and mothering ability as judged by performance (i.e. growth) of their first one or two calves. This nucleus herd will have 100 yearling heifers associated with it and is expected to yield 210 calves per year.

The bulls for this nucleus herd were the best 9 bulls from a post-weaning growth test of 2,500 bulls. This bull test was conducted by the Victorian Commercial Hereford Breeders Group whose members comprise most of the members of Sirebank Herefords. The bulls were selected for entry to the post-weaning test on the basis of pre-weaning growth rate. When the scheme is fully operative, the nucleus herd will require 11 bulls, with half being replaced each year.

The nucleus herd will supply bulls, hopefully of merit, to the 8 base herds. In the first few years because of strict culling these bulls will not satisfy base herd replacement requirements completely. Some bulls for the base herds will have to be chosen from the base herds.

Each year some yearling heifers chosen from the base herds, presumably on their own growth rate, will be compared with the 100 yearling heifers of the nucleus herd. Comparison will be on performance (i.e. growth) of the first calf. It is expected that 10 to 30% of the replacements moving into the nucleus herd will come from the base herds. This procedure will keep the genetic base wide, and is expected to realise the achievement of a large selection differential.

This scheme is not a closed breeding plan. It will, in future, also utilise the Hereford reference sire of the Beef Improvement Association. If the reference sire is judged to be superior, more of his semen will be used than is required for testing. Other outstanding bulls found by comparison with a reference sire, in other herds, may also be used.

Clearly, this scheme relies on intense selection pressures being applied but again basically in growth rate. Concentration of effort in the nucleus herd will also increase accuracy of selection. By selecting females on calving performance animals with low fertility will be kept out of the nucleus herd. There is no reason why merit cannot be judged on a combination (e.g. by selection index) of several traits. This is intended in the future.

V. GENERAL DISCUSSION

In theory, both examples of co-operative schemes outlined should result in significant improvement in performance, particularly in the characters emphasised in selection. The extent to which actual improvement will take place will depend on numbers of animals becoming available for breeding and on the accuracy of the assumptions and corrections being built into the computer programmes.

As reproduction is not expected to respond to selection one does not expect any great improvement in this regard. It is even possible that in the long term reproduction may deteriorate.

Mayr (1970) points out that the genotype of a population is a single interdependent genetic system. Strong one-directional selection experiments, particularly for single traits, typically show correlated responses which frequently involve impaired reproduction.
Inbreeding is a second possible cause for future impairment of reproduction. It is not difficult to see a system widely using single reference sires rapidly narrowing the genetic base of the herds co-operating with the Beef Improvement Association. The more successful the scheme, i.e. the more accurate and well publicised the choice of best bull for future reference sire, the greater will be the probability that subsequent reference sires will be sons of a past reference sire. In any case, within 10 years a significant proportion of all breeding females in co-operating herds will be daughters of quite a small number of reference sires.

Possible depressing effects on reproduction may not manifest themselves for 10 years. We should nevertheless start now to plan to avoid them. 'In the long term, inbreeding can be avoided most readily by closing the large populations co-operating in schemes such as discussed above. Several large but closed populations, i.e. with different reference sires, being bred in similar directions, should allow breeding to occur for an indefinite time without danger. One may use pedigrees within each population to avoid inbreeding.

If any population does show a depression, a small amount of semen may be obtained from one of the other populations that are up to then unrelated. Danger exists only if all cattle populations in southern Australia (and those in New Zealand, the U.K. and Canada, etc.) become related by frequent exchange of semen between them.

With regard to depression in reproduction resulting from too rapid a response in growth rate, it is quite possible that the numerous inefficiencies always found in large co-operative schemes will slow progress sufficiently for there to be no problem. If not, attention to more traits, or relaxation of selection differentials may be required.

VI. ACKNOWLEDGEMENTS

Messrs. J. Arnott, R. Carrall and H. Hopkins supplied details of the National Beef Recording Scheme and the Beef Improvement Association. I am particularly indebted to Mr. I. Hopkins for details of the Sirebank Hereford Scheme and for many discussions of the various cattle breeding schemes being practised in Victoria.

VII. REFERENCES