

New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](http://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for [commercial purposes](#).

NoDerivatives — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

How relevant are current and emerging genetic technologies to the beef breeding cow?

H.T. BLAIR AND D.J. GARRICK

Department of Animal Science, Massey University, Palmerston North, New Zealand.

ABSTRACT

The genetic merit of stock in the commercial sector of the beef breeding herds is dependent on the rate of genetic gain in nucleus herds and the length of delay it takes to transfer this genetic gain to commercial herds. This paper states the factors controlling the rate of genetic gain and genetic lag and examines the impact of current and future technologies on these factors. The setting of selection objectives and opportunities for crossbreeding in New Zealand beef breeding herds are also mentioned briefly.

The maximum theoretical rate of genetic gain in beef cattle herds is about $3.4\sigma_T$ (genetic standard deviations). Current technologies should allow a rate of gain of about $0.25\sigma_T$ but results from New Zealand beef cattle selection experiments suggest that the actual rate achieved in the industry is unlikely to exceed $0.1\sigma_T$. It is suggested that many new technologies becoming available will either have little impact on the rate of genetic gain or will be too expensive to apply in New Zealand's extensive beef cattle industry. Opportunities will exist for nucleus breeders who are prepared to cooperate with each other giving them a larger pool of breeding cows.

The most likely genetic lag using current practices is about 10 years in the New Zealand beef cattle industry. By generating replacement females from only young parents and by accessing sires of above average genetic merit, it should be possible to reduce genetic lag to about 1 year.

It is concluded that the New Zealand beef cattle industry could greatly enhance the rate of genetic gain and reduce the level of genetic lag through the application of existing technology. Furthermore, the establishment and application of sound selection objectives is an immediate priority.

Keywords: genetic gain; genetic lag; selection objectives.

INTRODUCTION

The farming units that constitute a livestock industry are typically structured in such a way that a small proportion constitute nucleus (also known as seed-stock or stud) units where within-breed selection is undertaken. Most animals are managed by farmers running commercial units who purchase animals (mainly sires) from nucleus breeders thereby importing genetic change. Sometimes these farmers utilise genetic differences between breeds by crossbreeding.

The direction of genetic change in the nucleus sector must be consistent with that required not only by farmers in the commercial sector but also by processors and retailers. Because most beef is produced by commercial farms, genetic gains arising in the nucleus need to be transferred rapidly to commercial units.

This paper will describe the factors that control the rate of genetic gain in the nucleus units and the level of genetic lag between the nucleus and commercial units. The current and future impact of various technologies such as animal identification, control of reproduction, trait measurement and, the capture, transfer and analysis of data will then be discussed in the context of genetic gain and genetic lag. Baker *et al.*, (1990) reviewed reproductive technologies and their impact on genetic gain.

SELECTION OBJECTIVES

A well-defined farming objective is prerequisite to strategic (long-term), tactical (medium-term) and operational (short-term) planning. Decisions regarding, for example, replacement of fences, purchase of new machinery or selection

of new breeding stock should all be compatible with the farming objective. A critical step in strategic planning for livestock managers is to establish a selection (or breeding) objective. The selection objective includes a list of traits that contribute to the satisfaction (primarily economic) the farmer derives from owning the stock. Traits in the list should be accompanied by an estimate of their relative importance. While most recent scientific writings have focused on profitability or productivity as being the objective of animal improvement, it should be recognised that farmer "satisfaction" with the animals in their herd might require that some non-production traits receive attention in the selection objective. The setting of selection objectives should involve input from nucleus breeders, commercial farmers, consumers, retailers, processors and scientists. This seldom occurs in practice.

Selection objectives in New Zealand

Most breed societies describe an "ideal animal" which tends to focus on conformation traits as a means of satisfaction rather than on traits affecting profitability via production. The first formal reporting of beef cattle selection objectives in the New Zealand industry are contained in an article on selection priorities of 7 out of 8 beef cattle group breeding schemes existing in New Zealand in the late 1970s (Dodd *et al.*, 1982). Nicoll and Johnson (1986) reported the post-1976 selection objective for the (then) Department of Lands and Survey (now Landcorp) herds in the central North Island region. Nicoll and Morris (1993) commented on the genetic trends achieved through the application of selection towards this objective. No other readily accessible reports of selection objectives for beef

cattle in New Zealand are known to the authors. However, examination of prices paid for bulls sold at the New Zealand Beef Bull Sale Week in Palmerston North in 1992 and 1993 (Blair and Garrick, unpublished data) and in Australia (Robinson *et al.*, 1992), would suggest that weight at sale controlled some 50% or more of the variation in sale price of bulls. Current selection objectives in the New Zealand beef breeding industry seem to be based primarily on liveweights with the exception of Landcorp whose objective includes a maternal component.

There is need to define selection objectives for the New Zealand beef cattle industry. While some scientifically acceptable objectives have been published (Rae and Barton, 1970; Clifford and McDonald, 1972; Morris, 1980; Newman *et al.*, 1992), there is little evidence of these being widely implemented by the industry. Selection objectives must be devised in such a way that all sectors of the industry feel comfortable with them to ensure their widespread adoption.

UTILISING BREED DIFFERENCES

The question of which breed mix to use can be a complex issue depending on personal likes and dislikes as much as the relative performance of the various beef cattle breeds. Common breeding policies in commercial beef cattle production include purebreeding, rotational crossing (e.g. Angus with Hereford; crossbred females retained for breeding) and, specific crossing (e.g. Angus dam with Simmental bull; sell all crossbred progeny). Baker *et al.*, (1982) provided examples of how crossbreeding might be implemented to enhance farm output of beef and concluded that there were substantial financial rewards to commercial farmers if crossbreeding was incorporated into the farming system.

A 1987 survey of beef cattle in New Zealand (Anon 1987) showed that of the 1.098 million breeding cows for which a breed or breed cross was specified, about 67% were purebred and another 24% were Angus x Hereford, 1% Angus x Friesian and 2% Hereford x Friesian crosses. Similar proportions were shown for steers and non-breeding bulls and for breeding cows. However, the beef breeding bull class was dominated by purebred animals (81%) with Angus x Hereford bulls contributing only 7% of the numbers. A conservative estimate suggests about 70,000 cows would need to be committed to the nucleus tier to produce the 55,000 purebred bulls that are used each year (3 years average use, 40% culling, 85% animals reared to sale). Therefore, there are likely to be about 670,000 purebred beef breeding cows and 360,000 crossbred breeding cows, respectively, in the commercial sector. That is, about 65% of cows are not contributing maternal heterosis to the commercial sector. Furthermore, the production of 344,000 and 173,000 purebred Angus and Hereford steers and non-breeding bulls, respectively, would suggest there is an immediate opportunity to further increase the use of crossbreeding in the beef cattle industry.

FACTORS DETERMINING RATE OF GENETIC GAIN AND GENETIC LAG

The rate of genetic change per year ($\Delta G/\text{yr}$) that will be generated in the nucleus herd depends on four factors: the genetic standard deviation (σ_T) for the objective (T), intensity

of selection (\bar{i}), accuracy of selection or correlation between the objective and the index (I) being used for selection (r_{TI}) and the generation interval (L); according to the following equation:

$$\Delta G/\text{yr} = (\sigma_T \bar{i} r_{TI})/L$$

In an ideal world, with marketing skills aside, the nucleus breeder with the greatest rate of genetic change for the commercial farmer's objective would be in a superior position relative to competing nucleus breeders. If \bar{i} and r_{TI} are set to theoretical limits (3.44 and 1.0, respectively), and L to its minimum (1.0), a limit of about $3.4\sigma_T$ is obtained. This gives a benchmark against which the impact of current and future technologies can be assessed.

By consistently buying sires from one nucleus breeder, the commercial producer's herd will, within 2 or 3 generations (e.g. 8 to 15 years for beef cattle), achieve the same rate of genetic gain as the nucleus herd (Garrick, 1993). Beyond this time, the average genetic merit of the commercial herd will be inferior to that in the nucleus herd as predicted, approximately, by the following equation:

$$\text{Genetic lag} = 2 \times L \times \Delta G/\text{year}$$

That is, the genetic merit of the commercial producers herd is twice the generation interval (say, $2 \times 5 = 10$ years for beef cattle) behind that of the nucleus unit. On average, the commercial unit in 1994 would have the merit of the nucleus in 1984. This lag can be reduced by selecting the above average bulls from the nucleus, by reducing the generation interval of the commercial herd and, undertaking whatever selection is feasible amongst the females of the commercial herd. In theory, with advances in reproductive technologies (particularly cloning), the genetic lag could be eliminated. Under this scenario, there would be no distinction between the genetic merit of nucleus and commercial stock.

CURRENT TECHNOLOGIES

Rate of genetic gain

Consider the sequence in which events requiring decisions take place on the farm using the birth of a new generation as a starting point. Virtually all stock in the nucleus sector of the beef cattle industry are pedigree recorded around birth and identified with a permanent tag. This operation allows performance records on ancestors or relatives to assist in estimating breeding values. The inclusion of such records will improve the accuracy of selection (r_{TI}) and can reduce the generation interval if selection decisions can be made at an earlier age than would otherwise be possible. If information from relatives is not used and if inbreeding is not of concern, tagging at birth is not necessary.

The next event is to measure those characters that are being used to predict genetic merit for traits in the objective. Characters typically measured include one or several liveweights between birth and 24 months of age. Consistent with the poorly defined selection objectives for New Zealand beef cattle, it appears that few characters other than liveweight are currently being incorporated into genetic assessment by most nucleus breeders. Landcorp's breeding scheme (Nicoll and Johnson, 1986) also records numbers of calves born and weaned to assist in predicting the lifetime productivity of

cows. Ultrasonic fat depths, an ultrasonic eye muscle area and scrotal circumference are measured for many of the bulls presented for sale at the New Zealand Beef Bull Sale Week. These ultrasonic assessments can assist in predicting the lean content of carcasses while scrotal circumference is a useful predictor of bull serving capacity and daughter reproductive rate. If these characters assist in predicting genetic merit for traits in the objective, their collection may be cost effective.

The observed measurement of an animal reflects its phenotype, the sum of the genetic and environmental influences. The value of the measurement is when it is compared to assessments on other animals in the same environment. Measurements made on animals in the absence of contemporaries provide little or no useful information as to the animal's genetic merit. As a consequence, the ultrasonic and scrotal circumference measurements taken at the Beef Bull Sale Week would seem to have limited utility, since only the bulls that are offered for sale are being assessed. That is, there are no (few) herd mates against which they can be compared.

The characters which are assessed and the method by which the character is measured will impact on the accuracy of selection and the generation interval. The greater the amount of information collected and the greater the accuracy with which characters are measured, the larger the value of r_{TT} . However, if the animal misses a breeding cycle to allow the collection of the information, the longer the generation interval. Therefore, r_{TT} and L must be balanced to ensure genetic gain per year is optimised.

At the time of measurement, consideration must be given to the means of recording the data. In some situations, the data may never be physically recorded, the breeder simply relying on memory to provide the means through which selection will be undertaken. A majority of breeders store the data by recording it on sheets or cards while a smaller number capture the data electronically either through the use of a connection between the digital readout equipment and a computer or by entering the data directly into a computer. All methods of data recording suffer from some deficiency; where many animals and/or several characters are involved, relying on memory alone will be unsatisfactory; dirt or moisture can lead to written figures being difficult to read and, computer files can be corrupted. Any errors in data recording/reading will reduce the rate of genetic gain through a reduced r_{TT} . However, while affecting selection of individual animals, these are likely to be of only minor effect from the long-term population viewpoint.

The raw data will require some manipulation to allow the ranking of available animals for selection. If only one character (say a liveweight) is recorded and no information from ancestors or relatives is to be used, the available stock can simply be ranked on that character and the required number selected. However, it is more common to have measurements on several characters, to adjust for effects such as dam age and age at measurement and for the objective to consist of several traits. In this situation, more complex manipulations of the data are required to predict Breeding Values (BVs) and some form of index which combines these predicted BVs into a single score on which the animals can be ranked. Until recently, those nucleus breeders requiring this service utilised Beefplan. However, the last two years

have seen the major Breed Societies shifting their data processing to Breedplan software marketed by the Agricultural Business Research Institute (ABRI) at Armidale (Rickards, 1992). This system generates BVs for the liveweight characters currently being recorded by New Zealand breeders. However, Breedplan does not currently produce BVs for an objective specified by the breeder nor does it combine these BVs with their relative economic values to arrive at a single score or index. However, there is an attempt to provide breeders with a package that will assist them in designing a customised objective (Barwick *et al.*, 1992).

The current analytical technique of choice for generating BVs is Best Linear Unbiased Prediction (BLUP) (Garrick, 1991). The use of BLUP will maximise r_{TT} compared with other linear unbiased methods and in some situations, will optimise the generation interval.

Upon receiving a listing of the animals with their estimated breeding values and/or selection index values, the breeder should then choose the top animals as replacements in the herd. This task is simple if the selection objective has been clearly stated and reflected in the BV processing. To enable a short generation interval to be maintained, nucleus breeders should be mating both bulls and heifers at 15 months of age. The number of animals selected will dictate the selection intensity (\bar{i}). The smaller the number chosen, the larger the value of \bar{i} , the faster the rate of genetic gain. For those nucleus herds using natural mating, there will be few options available for manipulating selection intensity. However, for breeders able or prepared to use AI, there is an opportunity to greatly increase selection intensity. While AI is currently used in the beef cattle breeding industry, it is typically to get access to sires unobtainable through natural mating such as those from overseas. Providing these sires are genetically superior in those traits that constitute the selection objective, their widespread use will increase the selection intensity. However, because of the cost of AI (provision of facilities, oestrous synchronisation, possibly a reduced conception rate, etc) and the cost of semen itself, it is not typical for widespread usage to occur. As a consequence, these nucleus herds act as a multiplier tier (Garrick, 1993) between the overseas stud and the New Zealand commercial farmer. This may still provide a genetic advantage to the New Zealand commercial farmer but is dependent on the sire being sufficiently genetically superior for the correct objective. International comparisons of sires are only now becoming possible as genetic linkages are generated across countries.

The use of Multiple Ovulation and Embryo Transfer (MOET) to increase selection intensity for females has not been widely used by beef cattle breeders in New Zealand. MOET has been used to rapidly multiply rare genotypes especially the "exotic" breeds.

Given the above technologies, the potential $\Delta G/\text{yr}$ in the beef cattle industry should be about $0.25\sigma_T$ ($\bar{i} = 1.35$; $r_{TT} = 0.6$ and $L = 3.25$). This assumes nucleus herds are breeding independently of each other and that the selection objective is clearly established. However, beef cattle selection experiments in New Zealand have shown a genetic gain of only about $0.1\sigma_T$ (Nicoll and Morris, 1993) and, it is unlikely that the actual $\Delta G/\text{yr}$ in the New Zealand beef cattle industry is better than this.

Sire purchases

Genetically-related decisions on commercial farms are required at four levels:

1. what breed mix is to be used (crossbred dams, females from a dam line, terminal sires, etc.),
2. which nucleus breeder bulls are to be purchased from,
3. which bulls from within that nucleus are to be purchased and,
4. which females will be selected within the commercial herd.

Choosing between sire sources. If a stud is chosen that is making no genetic gain, there will be no gain in the commercial herd. The commercial farmer should be aiming to purchase from a stud with substantial genetic gain. A problem confronting most breeders in the commercial tier is deciding where to purchase their breeding sires or semen (or females, eggs or embryos). There are a variety of factors that cause this difficulty: not all animals presented for sale have an estimate of their genetic merit made available to the buyer; there are different terms used to describe genetic merit (breeding value, breeding index, expected progeny difference, index); the estimates of genetic merit may not be comparable between different farms, companies or countries and, when animals are presented for sale there is often a wide range of sizes even within a breed due to different rearing conditions (particularly between farms), which may influence buyers decisions. There are a variety of clues which the commercial farmer might use to help resolve this problem:

1. examination of breeder selection policies,
2. test matings within the buyer's farm,
3. central performance tests, and
4. sire referencing.

The following references provide further information on these topics: Clifford and McDonald (1972), test mating within farm and central performance tests; Wickham (1977), central performance tests; Hill (1981) central performance tests and sire referencing; Nimbkar and Wray (1991), sire referencing.

Central performance testing is costly, subject to carry-over effects from pretest environments and are not widely used in New Zealand. Test-matings within farm have been limited and likely involve too few sires and progeny per sire to be of great assistance. There is little evidence to show that commercial farmers are aware of the correct questions to ask a nucleus breeder about their selection policies to make sound decisions as to which nucleus to buy from. As a consequence, it would seem that there is a substantial opportunity for commercial farmers to enhance the genetic merit of the stock by greater discrimination amongst nucleus breeders.

Genetic lag

Choosing amongst sires. Given that proven sires are unlikely to be within the commercial breeder's budget (except through AI), it will be necessary to choose from amongst those young bulls not required for use in the nucleus. Clearly, these sires should be chosen on the basis of their genetic ranking for those traits identified as being important to the commercial farmer's objective. The genetic lag can be reduced by purchasing above average genetic merit young bulls.

Choosing females within the commercial herd. Selection of females in the commercial herd has the effect of reducing genetic lag between the nucleus and commercial herds. However, this requires that at least one character useful for predicting the selection objective can be assessed in the females. An obvious character would be liveweight however, selecting for larger breeding females may not be consistent with an objective that includes the cost of feed production (Newman *et al.*, 1992). Furthermore, if the commercial farmer is mating a proportion of cows to a terminal sire breed and selling all crossbred offspring (e.g. Baker, 1982) there may be too few replacement females on which to impose effective selection.

To encourage the rate at which the genetic advances made in the nucleus herd are expressed in the commercial herd, the males and females in the commercial herd should be as young as possible. This has to be balanced with the reality of: the cost of buying bulls; maximum maternal performance of cows not being reached until about 5 years of age; the cost of rearing replacement females to the time they produce saleable offspring (currently a minimum of 2.5 years). Both of these objectives can be achieved by mating young cows to generate replacement females and crossbreeding older cows to produce animals for slaughter.

Use of reproductive technologies. While the AI and MOET reproductive technologies can in theory be used to reduce the genetic lag between nucleus and commercial herds, there is not yet widespread use of these techniques by commercial farmers in New Zealand. Both techniques allow a higher reproductive rate of individual animals enabling progeny in excess of nucleus requirements to be farmed for commercial purposes.

FUTURE TECHNOLOGIES

Rate of genetic gain

The identification of calves for pedigree purposes will likely see at least two developments in the future. Electronic eartags have been shown to work but have a disadvantage in terms of cost per unit (Jordan and Schaare, 1990). Although some errors in tag reading will be avoided, the main benefit will be in labour saving at the time of character measurement. The uptake of this technology will require the cost of the tag to be less than the amount saved in labour charges.

The use of DNA fingerprinting in human forensic medicine and criminal law is already well established. DNA hoofprinting will eventually occur in all animal industries. The advantage of DNA hoofprinting will be accurate pedigree identification and hence a larger r_{TT} . Currently, blood-typing can provide the same service in the beef cattle industry. In situations where pedigree recording is difficult or impossible (for example, group matings or mixed semen), DNA fingerprinting will likely have a role to play depending on the laboratory cost of the process. Where pedigree recording is already feasible by tagging at birth or mothering-up, the additional accuracy gained must be considered against the cost of the parentage test. If the primary motivation for pedigree recording is to use ancestry information, it is likely the gains in accuracy will be too small to justify DNA

hoofprinting unless the expected costs are markedly reduced. The r_{TI} based on ancestry for most beef cattle nucleus herds is likely to be in the range of 0.4 to 0.5 (equivalent to a reliability between 0.16 and 0.25). Some errors in identification will slightly reduce the r_{TI} on a herd basis. The more critical issue is that selection based on pedigree information alone in the beef cattle industry is not particularly accurate and should therefore be supplemented with information recorded on the individual itself or, if available, its progeny.

With the better definition of selection objectives and technology advances, the characters actually measured on each animal will change in the future. First, greater account of fat distribution and colour in the carcass may be important for the Asian market. In vivo measures of these traits will likely involve ultrasonic assessment of fat distribution (Deland *et al.*, 1992) and plasma levels of β -carotene for fat colour (Yang *et al.*, 1992). Second, the efficiency with which feed grown is utilised to produce saleable animals will likely become more recognised for its importance to beef cattle farmers (Newman *et al.*, 1992). The effect of feed efficiency on farm profitability is already widely recognised in intensive animal industries such as poultry and pig production and to a lesser extent in dairying.

New developments will also affect the characters that will be measured. Two types of characters for which research is already well advanced in at least some farm animal species are Physiological Indicator Traits (PITs) and DNA markers (Marker Assisted Selection; MAS). To date little research has been directed towards PITs for beef cattle breeding in New Zealand. However, it is likely that the underlying physiological mechanisms will be similar for the various farm animal species such that research based on sheep and dairy cattle (e.g. Blair *et al.*, 1990) may well be applicable to beef cattle. MAS (e.g. Mackinnon, 1992), whereby DNA is digested with endonucleases and associations determined between the resulting segments of DNA (called RFLPs, VNTRs, minisatellites or microsatellites) and traits of importance in beef cattle, is the subject of intense research in North America and Australia. One of the first requirements of MAS is the generation of a library of markers well distributed along the entire genome. Development of these markers requires a substantial financial input (e.g. Womack, 1993). New Zealand will be able to benefit from this research albeit at a cost as the MAS associations may well be patented. Furthermore, with a nucleus of about 70,000 cows in the beef cattle industry, establishment of linkage relationships between the DNA markers and traits of interest will be expensive. If current estimates of about \$10 per DNA marker are correct, it could cost up to \$2000 per cow in the nucleus or up to \$140 million if the entire nucleus is included. In contrast, these costs are markedly reduced in the dairy industry because of the much smaller number of cows actively involved in breeding bulls for progeny test i.e., the cost per cow may not be different but the number of cows needed to be tested is much reduced.

The effect of both PITs and MAS will be to increase r_{TI} , increase the selection intensity and/or decrease the generation interval. It is unlikely that PITs or MAS will be used on their own but rather, they will be coordinated along with physical measurements on the animal itself or its progeny. Both techniques will be useful for the early screening of potential replacement stock allowing existing procedures

(e.g. progeny testing) to be applied to a smaller number of animals. As research into MAS continues, the discovery of genes with major effects on traits of importance is likely. For example a gene probe already exists for the horn gene (Georges *et al.*, 1993) in cattle making the production of polled lines more simple than with traditional breeding techniques. The potential also exists for identification of undesirable genes such as mannosidosis. There are already a number of gene probes available for undesirable conditions in dairy cattle (Robinson and Shanks, 1994). However, breeders must be careful not to waste excessive selection intensity by trying to remove all undesirable genes in a breed. Because the genes are associated with undesirable phenotypic conditions, they already tend to be at a low frequency and can probably be ignored. As with any technology, the cost of PITs and MAS must be balanced against the expected returns from improved genetic gain in the selection objective.

DNA technology will eventually allow genetic variation to be manipulated (Clark *et al.*, 1990; Pursel and Rexroad, 1993). The production of so-called transgenic animals by genetic engineering will allow manipulation of existing genes within a species, introduction of genes from other species or incorporation of entirely new DNA sequences into the animal's genome. While manipulation of existing traits of economic importance is obviously of interest, use of animals as pharmaceutical factories probably has more appeal in chickens, sheep and dairy cattle than in beef cattle. The manipulation of the genome of farm animals by these new techniques will undoubtedly receive public debate during the next decade. If this debate results in an unfavourable opinion of this technology by consumers, relevant livestock industries will have to give serious consideration as to whether exports markets might be adversely affected.

The proportion of breeders who electronically capture data will increase as the technologies become more accepted. However, financial benefit will accrue through labour savings with little impact on genetic gain.

The recent surge in usage of Breedplan by New Zealand beef breed societies means that much of the data collected in New Zealand are being analysed using statistical procedures that are near optimal for the production of BVs. The developments required for the future in this area are first, the formulation of appropriate selection objectives so BVs can be combined into an index for selection purposes. Second, an improved usage of these indices by both nucleus breeders and commercial farmers in selecting replacement breeding stock is required.

The use of reproductive technologies such as AI, MOET, sexed semen and cloning (Baker *et al.*, 1990) for the production of the next generation of animals is unlikely to increase in the beef cattle industry in the near future unless their cost of implementation is markedly reduced. For example if it were possible to extend the life of sperm in the cow reproductive tract to say 14 days, up to two-thirds of the cows could conceive without the need for oestrous synchronisation. The utilisation of AI in nucleus herds would likely be increased through the better definition of selection objectives so that stud-masters could accurately identify the value of high genetic merit sires. Furthermore, a more cooperative structure amongst herds with common selection objectives would

enable the real benefits of increased selection intensity achievable via AI to be realised through the increased number of cows being serviced.

It is difficult to predict how these technological advances are going to impact on the rate of genetic gain since each technology can potentially affect more than one of the four components of the genetic gain formula. However, wider use of high genetic merit sires (providing the selection objective is clearly known) should be encouraged by Breed Societies. This requires the use of across herd rankings and coordination of selection programmes amongst contributing herds.

Sire purchases

Choosing between sire sources. The only new technology in the immediate future that will assist the commercial farmer in discriminating between sire sources is MAS. The use of DNA markers will be independent of environmental effects thereby making these types of BVs comparable across herds and years. However, there will be at least two problems associated with this technology. First, MAS relies on associations or linkages between the DNA marker and traits of economic importance. These associations may not be the same in every family and, may be quite different for genetic material derived from other countries. Second, genotype by environment interactions may well dictate that some DNA markers are only useful in some environments.

Substantial benefits in discriminating between sire sources could be had simply from application of existing knowledge/technology. However, the beef cattle industry must show a commitment in wanting to use this information and it may require some changes in industry structure (such as the wider use of proven sires and the generation of greater genetic linkages between herds) to make the best use of technologies such as sire referencing.

Genetic lag

Choosing amongst sires. There is probably little to be gained for individual commercial farmers from being able to more accurately select sires within a stud. Assuming that the new information is available to all potential buyers, the commercial farmer will be hampered more by the price they are prepared to pay for a bull rather than the accuracy of the BVs. However, if AI becomes widespread in commercial herds, access to high genetic merit sires would become a reality for a greater number of herds.

Choosing females within the commercial herd. On commercial farms where more heifers are reared to the time of selection than are required, PITs and MAS may offer an opportunity for more accurate selection (increased r_{IT}) without the need for pedigree recording. However, they are unlikely to be cost effective until being widely applied in the dairy and plant breeding industries.

Use of new reproductive technologies. Artificial insemination, MOET and cloning all have the potential to reduce genetic lag to the commercial herd by making animals of higher genetic superiority available. The application of these techniques will be dependent on cost and farmer perceptions with the same concerns as discussed in the current and future genetic gain sections being true for genetic lag.

A combination of reduced generation interval in the commercial herd (retain female replacements only from young parents) and access to high genetic merit sires has the potential to reduce genetic lag from the current 10 years to about 1 year.

CONCLUSIONS

The application of existing technologies in the New Zealand beef cattle industry has the potential to increase the rate of genetic gain by at least 150%. However, the ability of nucleus breeders to achieve this goal is severely hampered by poor definition of selection objectives. Given the scientific literature on this subject, there has to be real concern at the effectiveness of transferring current knowledge to practitioners in the industry.

The current level of genetic lag could be reduced from about 10 years to about 7 years if commercial breeders were to keep replacement females only from young parents. If AI becomes practical for extensive commercial beef cattle farmers, access to high genetic merit sires would allow a further reduction in the genetic lag to about 1 year.

Developments in reproductive and DNA technologies are likely to be of limited benefit unless their costs can be markedly reduced. Alternatively, cooperative ventures amongst a number of nucleus breeders with similar objectives may allow the costs of these technologies to be spread over a larger number of animals than is currently possible with the small nucleus herd sizes.

REFERENCES

- Anon. 1987. Beef cattle numbers by age, sex, breeds and county at 30 June 1987. New Zealand Department of Statistics.
- Baker, R.L. 1982. The place of crossbreeding in beef cattle improvement. *Proceedings of the World Congress on Sheep and Beef Cattle Breeding* 2:193-208.
- Baker, R.L.; Shannon, P.; Garrick, D.J.; Blair, H.T.; Wickham, B.W. 1990. The future impact of new opportunities in reproductive physiology and molecular biology on genetic improvement programmes. *Proceedings of the New Zealand Society of Animal Production* 50:197-210.
- Barwick, S.A.; Fuchs, W.; Davis, G.P.; Hammond, K. 1992. A breeding objective and selection index package for use with Breedplan. *Proceedings of the Australian Association of Animal Breeding and Genetics* 10:565-568.
- Blair, H.T.; McCutcheon, S.N.; Mackenzie, D.D.S. 1990. Physiological predictors of genetic merit. *Proceedings of the Australian Association of Animal Breeding and Genetics* 8:133-142.
- Clark, A.J.; Archibald, A.L.; McClenaghan, M.; Simons, J.P.; Whitelaw, C.B.A.; Wilmut, I. 1990. The germline manipulation of livestock: Progress during the past 5 years. *Proceedings of the New Zealand Society of Animal Production* 50:167-180.
- Clifford, H.J.; McDonald, M.F. 1972. Beef Cattle Improvement through Performance Recording and Selection. Eds. New Zealand Society of Animal Production. Occasional Publication No. 1.
- Deland, M.P.B.; Hebbeman, B.K. 1992. Sequential scanning of crossbred feedlot steers. *Proceedings of the Australian Association of Animal Breeding and Genetics* 10:388-391.
- Dodd, C.J.; Milligan, K.E.; Wickham, B.W. 1982. An overview of New Zealand group breeding schemes. *Proceedings of the World Congress on Sheep and Beef Cattle Breeding* 2:103-112.
- Garrick, D.J. 1991. Best linear unbiased prediction for across-flock/year breeding values. *Proceedings of the New Zealand Society of Animal Production* 51:411-416.
- Garrick, D.J. 1993. The importance of industry structure. In: *Proceedings of the A.L. Rae Symposium on Animal Breeding and Genetics*. Ed

- H.T. Blair & S.N. McCutcheon. Massey University, New Zealand. pp110-119.
- Georges, M.; Drinkwater, R.; King, T.; Mishra, A.; Moore, S.; Nielsen, D.; Sargeant, L.; Sorensen, A.; Steele, M.; Zhao, X.; Womack, J.; Hetzel, J. 1993. Microsatellite mapping of a gene affecting horn development in *Bos taurus*. *Nature Genetics* 4:206-210.
- Hill, W.G. 1981. Assessment of breeding values in selection programs. *Proceedings of the Australian Association of Animal Breeding and Genetics* 2:227-236.
- Jordan, R.B.; Schaare, P.N. 1990. Measurement technologies and their impact on animal production. *Proceedings of the Australian Association of Animal Breeding and Genetics* 8:25-36.
- Mackinnon, M.J. 1992. Use of genetic markers in genetic improvement programmes. *Proceedings of the Australian Association of Animal Breeding and Genetics* 10:245-251.
- Morris, C.A. 1980. Some benefits and costs of genetic improvement in New Zealand's sheep and beef cattle industry. *New Zealand Journal of Experimental Agriculture* 8:331-340.
- Newman, S.; Morris, C.A.; Baker, R.L.; Nicoll, G.B. 1992. Genetic improvement of beef cattle in New Zealand: breeding objectives. *Livestock Production Science* 32:111-130.
- Nicoll, G.B.; Johnson, D.L. 1986. Selection applied in the Angus breeding scheme of the New Zealand Land Development and Management Corporation. *Proceedings of the third World Congress on Genetics Applied to Livestock Production* 9:413-418.
- Nicoll, G.B.; Morris, C.A. 1993. Lessons from New Zealand beef cattle selection experiments. In: *Proceedings of the A.L. Rae Symposium on Animal Breeding and Genetics*. Ed H.T. Blair & S.N. McCutcheon. Massey University, New Zealand. pp69-87.
- Nimbkar, C.; Wray, N. 1991. An investigation of the use of sire referencing in genetic improvement in beef cattle. *Animal Production* 52:567(ab-abstract).
- Pursel, V.G.; Rexroad, C.E. 1993. Status of research with transgenic farm animals. *Journal of Animal Science* 71(Suppl. 3):10-19.
- Rae, A.L.; Barton, R.A. 1970. Selection objectives and methods of measuring merit on beef cattle. In: *New Zealand Beef Production, Processing and Marketing*. Ed A.G. Campbell. New Zealand Institute of Agricultural Science. pp 101-112.
- Rickards, P.A. 1992. The Australian seedstock industry - what it has to offer the world. *Proceedings of the Australian Association of Animal Breeding and Genetics* 10:14-20.
- Robinson, D.L.; Fenwick, J.R.; McDonald, C.A. 1992. The relationship between objective measurements and the price paid for beef bulls. *Proceedings of the Australian Association of Animal Breeding and Genetics* 10:353-356.
- Robinson, J.L.; Shanks, R.D. 1994. Prevalence of two inherited disorders in US Holstein cattle. *Proceedings of the New Zealand Society of Animal Production* 54: 35-38.
- Wickham, B.W. 1977. The relationship between central test station performance and subsequent progeny performance for growth traits of Hereford bulls. *Proceedings of the New Zealand Society of Animal Production* 37:89-95.
- Womack, J.E. 1993. The goals and status of the bovine gene map. *Journal of Dairy Science* 76:1199-1203.
- Yang, A.; Larsen, T.W.; Tume, R.K. 1992. Carotenoid and retinol concentrations in serum, adipose tissue and liver and carotenoid transport in sheep, goats and cattle. *Australian Journal of Agricultural Research* 43:1809-1817.