Issues in genetic improvement of deer

Peter Fennessy

A number of issues need to be considered in any discussion of the prospects and approaches to genetic improvement of deer in New Zealand. The main issues relate to future market prospects, the important traits, the gene pool available, genetics of the traits and a consideration of options.

Products

Venison is the major product of the New Zealand deer industry accounting for over 75% of the export revenue. There is also a substantial internal market to the hotel and restaurant trade. The main attributes required by the product in the market are leanness, tenderness and consistency. While the market for chilled venison (often sold under the Cervena™ brand) is growing, the major market is for frozen venison, mainly into Europe.

The same venison quality attributes of leanness, tenderness and consistency are likely to be required in the future. However, there is likely to be an increasing demand for product from animals of defined health status and which have had little in the way of exogenous health treatments and which have been reared on pasture under natural conditions with a keen regard for the welfare of both the animal and the environment.

The velvet antler market is currently centered on Korea, where it is an important part of the traditional medicine business. The current market features a premium for size without sacrificing quality assessed in terms of shape and calcification. While it seems that this premium market will continue to be important, other factors will come into play in the smaller antler segment including velvet antler quality. This is expected to become more important as the medicinal value of velvet antler becomes better researched and more widely known. However, defining such quality factors is not yet feasible although a high lipid content and a low calcium content are likely to be important. Other co-products (hides, tails, semen) find a ready market but they are unlikely to become major considerations for genetic improvement in the near future.

Productivity and flexibility of production systems are also high on the priority list in any consideration of genetic improvement. Individual animal productivity is a major determinant of the profitability of any farming enterprise. Flexibility is also critically important as markets can change much more quickly than a genetically-based biological system where the lag between the initial breeding decision and meeting a market with product in commercial quantities could be 10 years. Consequently devising systems which have an inherent flexibility is very important. Flexibility covers such aspects as timing of slaughter, weight at slaughter and health. While flexibility can be influenced greatly by genetics, much of the flexibility of any system comes from how the system is managed.

Hence aspects such as pasture management, and health and welfare of the animals are vitally important. Flexibility will be considered in greater detail later in the paper.

Breeding objectives to identifying traits

The discussion above highlights the major factors to be considered in developing a breeding objective for breeders of stags for venison producers. The situation is much less clear for velvet antler producers although an objective focussed on a rapid rate of velvet antler growth would likely be the most appropriate.

The breeding objective ideally should be described in economic terms. While the relative values of venison lean and fat would be derived, there are no basic genetic data to provide the initial information. Since net profit per unit of inputs (pasture, etc) is the basic breeding objective, probably the best that can be achieved at present is to focus on carcass weight gain and efficiency of conversion of pasture to venison. Economic criteria should be added but as yet, such models have not been developed for NZ conditions although McManus and Thompson (1993) have considered such breeding objectives in the UK. However, simple biological models (Fennessy & Thompson 1988, 1989) have been described and currently a more sophisticated biological model is being developed Vetharaniam and McCall, pers comm). This will provide the basis for an economic model.

The principal components of productivity in the whole enterprise are the efficiency of feed conversion, reproductive rate and the mortality rate. In the absence of a good economic model, the cost side cannot be considered adequately. Therefore the traits to be considered reduce down to the rate of liveweight gain/weight for age and reproductive rate. In this respect, modelling studies have attempted to define the effect of changes in these parameters on the biological efficiency of the whole system (Fennessy and Thompson 1988, 1989). Thus Tables 1a and b present estimates of the change in efficiency as a result of changes in reproductive rate and the rate of growth due to hybridisation/crossbreeding.

Table 1a The effect of calving rate (% of hinds calving) on lifetime biological efficiency of the hind/calf unit (g carcass/MJ of ME)

Calving rate	Biological efficiency - slaughter at 63 weeks
100	2 92
98	2 89
95	2 85
90	2 78
85	2 70
80	2.62
75	2 53
70	2.44

Table 1b The calculated biological efficiency (g carcass/MJ ME) of hybridisation of different sub-species of red deer (as sire strain), across the basic red deer hind (as dam strain).

Mature live weight of parental strains (male/female)		Biological efficiency at 67 weeks
Sire strain	Dam strain	
200/100	200/100	2 97
300/160	200/100	3 29
400/220	200/100	3.55

Product quality traits are more difficult to define. However, the following aspects do merit consideration: fat content, meat to bone ratio, proportion of carcass in the high-priced cuts, tenderness and meat colour (relevant to changes of colour in retail situations). In other species, all of these traits are known to exhibit some genetic variation. However, whether the genetic variation within the deer gene pool is sufficient to make a genetic improvement programme worthwhile is not known. This reflects one of the major dilemmas for the New Zealand deer industry. The industry needs a system for data collection to enable data to be collected in the venison plants and from the market. Such data would provide the essential basis for an information system.

Disease resistance is the third major aspect to be considered in any discussion of genetic improvement. While farmed deer are remarkably healthy animals under New Zealand conditions, internal parasites, bovine tuberculosis and yersiniosis are all diseases which do have an economic impact. However in all cases practical schemes probably require genetic marker technology. Clearly this would be a major consideration requiring considerable investment.

Options - products and genetic improvement

Demand for venison features a seasonal pattern which tends to pay the highest prices per kg in the August to November period coupled with a very marked increase in the price per kg for carcasses over 50 or 55 kg. The growth rate (and growth pattern) of New Zealand red deer (NZR) is such that it is very difficult to achieve such slaughter weights at the yearling stage. The velvet antler market has parallels with the venison market in terms of requirements for larger products. The major velvet market in Korea pays the highest prices for the larger types of antler from the larger strains such as the Chinese malu (e.g. *C.e. xanthopygus*) or Siberian wapiti e.g. *C.e. maral, C.e. sibiranicus*). This demand for the larger antler types has also stimulated interest in methods to increase antler size. Consequently the dual demands for faster growth rates and larger antlers have generated pressure to develop breeding and management practices to achieve these aims. While there is potential for improved nutritional management the genetic route offers greater possibilities. Therefore the two breeding options for the New Zealand farmer are to genetically improve the NZR deer by selection within this strain (Fennessy 1982) or alternatively to hybridise NZR deer with larger strains or (sub)species such as Canadian wapiti (CW) (Fennessy and Pearse 1990).

Options - the gene pool

The red deer family is notable for its extraordinary diversity and the capacity of its members to hybridise with one another to produce fertile offspring. This capacity for hybridisation among the various subspecies of the red deer family (e.g. wapiti and European red deer) and with other related species (e.g. Père David's deer, *Elaphurus davidianus*) coupled with the genetic diversity now available within New Zealand offers considerable potential to increase the body and antler size of the basic NZR deer to better satisfy market requirements. The NZR deer, being predominantly of the *C.e. scoticus* subspecies, is small (average adult stags weigh about 200-220 kg and hinds weigh about 100-110 kg) compared with the larger European red deer or North American wapiti or elk subspecies. Consequently, hybridisation using a large male over the smaller NZR female can be expected to result in an increased efficiency (e.g. Fennessy and Thompson 1988, 1989). It will also offer greater flexibility in terms of the ability to meet venison market demands with a younger animal (i.e. to attain the required carcass weight at a younger age). Hybridisation will also likely increase antler size due to the positive allometric relationship between antler size and body weight within the red deer family (Huxley 1931; Schroder 1983).

Unfortunately there is a dearth of objective information on the comparative performance of the various strains/subspecies of red deer with the only information being that described by Fennessy (1992). However, there are more data for Canadian wapiti or elk (see Table 2) although even here it needs to be recognised that there are different subspecies which may be quite different in terms of relative growth rate. The wapiti hybrid data presented in Table 2 are notable for the lack of any improvement in growth rate with an increasing proportion of wapiti genes over 50% in males although there was some improvement in females. These data were collected some years ago and it is now apparent that the relatively poor performance of the ¾ and pure wapiti was due to the combined effects of subclinical internal parasitism probably coupled with copper deficiency (Waldrup and Mackintosh 1993).

Table 2. **Relative yearling live weights for New Zealand red deer, Canadian wapiti (or elk, CW) and their intermediate hybrids (from Fennessy and Pearse 1990, Fennessy 1992)**

	Relative yearling weights			
	Males		*Females*	
NZR	100	(108 kg mean)	100	(87 kg mean)
¼ CW/¾ NZR	117		122	
½ CW/½ NZR	141		150	
¾ CW/¼ NZR	142		159	
CW	141		165	

While the objective data on European strains of red deer are scarce, it seems that some of the larger strains are about 50% heavier than NZ red deer. This is similar in size to the elk x red F1 hybrid. Consequently the NZ red deer farmer has a number of options when considering genetic improvement. However, the fundamental option is that between selection within a strain or crossbreeding/hybridisation between strains or subspecies.

Selection or crossbreeding/hybridisation

The decision whether to select within a strain or hybridise between strains is an important one. The expected mature liveweights for progeny of a superior NZR stag are compared with the progeny of an average stag from a larger hybrid strain in Table 3. For the purposes of comparison, the hybrid strain is assumed to be 20% heavier than the NZR strain so that the selected superior sire within the NZR (i.e. a sire which is two standard deviations above average) is the same weight as the average hybrid. This demonstrates that the hybridisation option can be expected to produce markedly heavier progeny than even the intensively selected NZR sire. Although the first generation advantage to the hybridisation option is clearly apparent, there is then the question as to the options for utilisation of the hybrid females. Venison production is one option, but others include using the hybrid female as the base for generation of a larger hybrid by using an even larger sire strain over these hinds. In this respect, practical considerations mean that the sire strain should probably not be more than 50% larger than the female strain. For example, hybridisation of CW males with red deer females is not recommended in large scale commercial enterprises because of the increased managerial requirements during pregnancy necessary to minimise calving difficulties. However, use of ½ CW/½ NZR sires over NZR hinds is quite satisfactory (see Pearse 1992) and likewise CW sires over ¼ CW/¾ NZR hinds would also be expected to be quite appropriate.

Table 3 Comparison of (A) mature liveweights (kg) of parental strains and their adult progeny with the situation (B) in which a superior New Zealand red (NZR) sire, an average sire of a new different strain or a superior sire of the different strain is mated with NZR hinds The hybrid strain is 20% heavier at all ages than the NZR deer strain (from Fennessy 1993)

	Sire		Dam	Progeny	
	Weight	*Breeding[1] value*		*Male*	*Female*
(A) Parental strain (± phenotypic standard deviation, σ_p)					
NZR	220 ± 22	-	110 ± 11	220	110
"New strain"	264 ± 26	-	132 ± 13	264	132
(B) Selected sire x NZR hinds[2]					
Superior NZR	264 (+ 2σ_p)	17 6[3]	110	229	114
Average "new strain"	264 (average)	44.0[3]	110	242	121
Superior "new strain"	316 (+ 2σ_p)	64.8[3]	110	252	126

[1]Estimated breeding value relative to the NZR strain
[2]Assumes a heritability of 0 4 for mature liveweight within the NZR deer and within the hybrid strain, yearling liveweights would be around 55 and 80% of adult liveweights for males and females respectively, zero hybrid vigour is assumed in the progeny of the hybrid sires over NZR dams.

[3]Calculations	Estimated breeding values	=	0 4 * deviation from strain average
		=	0 4 * 44 = 17 6 kg
	Average new strain	=	EBV = new strain *mean* performance - NZR strain *mean* performance
		=	264 - 220 = 44 kg
	Superior new strain	=	EBV = strain effect (44 kg) + 0 4 * deviation from strain average (0 4 * 52 kg = 20 8 kg)

[4] Mating of these stags to average hinds' progeny performance

a Superior NZR sire to average hinds of NZR strain

EBV of progeny	=	EBV of 17 6 kg + EBV of 0)/2 = 818 kg
Expected average performance	=	strain average (220 kg)_ + EBV of progeny (818 kg)
	=	229 kg

b Average new strain sire to average hinds of NZR strain

EBV of progeny	=	(EBV of 44 kg + EBV of 0)/2 = 22 kg
Expected average performance	=	220 kg + 22 kg
	=	242 kg

c Superior sire of new strain to average hinds of NZR strain

EBV of progeny	=	(EBV of 64 8 kg + EBV of 0)/2 = 32 4 kg
Expected average performance	=	220 kg + 32 4 kg
	=	252 kg

Genetic parameters

Until recently there has been no information on genetic parameters for production traits in deer except for one paper with velvet weight in Chinese sika deer (Zhou and Wu 1979). However, van den Berg and Garrick (1997a, b) have analysed velvet antler and liveweight data collected from five farms in the South Island. Heritability of velvet antler weight ranged from 0.43 to 0.45 (± 0.09 to 0.12, SE) in 2-, 3- and 4 year old stags. The standard deviation of velvet antler weight increased with age (and velvet yield) with the coefficient of variation (CV) averaging around 22% for 2-, 3- and 4 year olds. Their standard deviations are markedly higher than those reported by Fennessy (1989) for a smaller data set from one property. Heritability coefficients for liveweight for 2- and 3 year old stags were 0.57 ± 0.11 (se) and 0.47 ± 0.12. The CV for stag liveweight was around 9%.

These estimates of genetic parameters indicate the potential for genetic improvement through selection and breeding within the NZ red deer. However, it is possible that these estimates are somewhat elevated because of the effect of 'crossbreeding' between strains of NZ red deer which occurred on farms through the 1970's and 1980's. The estimates are slightly higher than those used in the calculations in Table 3.

The future

Market requirements often change very rapidly while genetic improvement is a long slow process constrained by the biology of the animal in terms of its reproductive rate and genetic variation in the traits of interest. Thus in considering the potential for genetic improvement, an approach which allows flexibility in terms of the final products while improving the underlying productivity of the individual animal and the efficiency of the overall system is most appropriate. A hybrid-based system such as is developing in the New Zealand deer industry offers this possibility. In such a system the development of specialist sire and dam strains allows the breeders of the former to concentrate on product quality traits and on maintaining the flexibility to change rapidly in terms of the timing of production or product mix (e.g. in terms of carcass weight) required, while the breeders of the latter concentrate on productivity traits.

In hybridisation situations in which the sire strain is clearly superior to the dam strain for the desired character (e.g. growth rate), the genetic gain arises mainly from the between-strain difference (and possibly hybrid vigour), with the genetic merit of the individual sire relative to other individuals within its own strain playing a less important part. Therefore the potential for hybridisation to make major improvements in productivity means that there are numerous questions about the emphasis which should be placed on genetic improvement within a strain. This relates both to the development of a specialist dam strain based on the NZR and to the identification or the development/genetic improvement of appropriate specialist sire strains.

Consequently, in considering genetic improvement within the deer industry, the objective must be to improve product quality traits, flexibility, efficiency of production or other traits which might have a place in an industry structured around hybridisation. An integrated industry would utilise hybridisation to capitalise on the differences between strains as the main method for producing high quality venison or other specialist products, while also providing the opportunity for developing and utilising specialist dam strains. Therefore the specific immediate needs of the industry are comparative data on the terminal sire strains and definition of the objectives for a dam strain, and a performance recording and genetic evaluation system which will facilitate these developments.

Conclusion

While there are a range of options for genetic improvement of the New Zealand deer herd, the choices are not straightforward. The fundamental question, as to the role of within strain selection in a situation where crossbreeding/hybridisation options abound, remains.

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