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Genetic Improvement and Reproductive Control of Farmed Red Deer and Wapiti (*Cervus elaphus*)

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ABSTRACT: Farmed red deer are a recent domesticant that, aside from subspecies hybridisation, have been subjected to little genetic modification by man. However, the species exhibits useful variation in economic traits, some of which are highly heritable such that genetic progress can be easily achieved from mass selection. Whereas many breeders record performance details, few take advantage of modern techniques for analysing these records and ranking animals for selection or sale. The adoption of DNA technology for parentage recording is more advanced in the deer industry than other livestock sectors. Commercial venison and velvet producers exploit genetic improvement through sire selection and choice of strain (subspecies). A large variety of strains exist, and they vary markedly in their production characteristics. Deer farmers have been quick to realise the potential of assisted reproductive technologies (ART's) to improve the rate of genetic progress. However, while development and application of technologies such as AI and ET have been rapid, overall adoption has been at relatively low levels. Emerging ART's, including in vitro embryo production and cloning, hold considerable promise as powerful tools in breeding programmes. However, development is required to improve their overall efficiency.

The inherent summer lactation patterns of the red deer are often poorly aligned with pasture production seasonality, resulting in poor calf growth. Techniques used to advance the onset of seasonal breeding, and hence align lactation and feed production, so far have met with variable success. In the last decade it has become clear that the thyroid glands play a permissive role in the termination of the breeding season. As with other mammals, ablation of thyroid hormones results in persistent reproductive activity in red deer, indicating another potential mechanism for manipulating conception dates. Although destruction of thyroid tissue is an unlikely avenue, temporary and reversible suppression of thyroid gland secretion at a critical time each year is a possibility. This will require understanding of the mode of action of thyroid hormones on hypothalamic function. Present studies are focused on neurotransmitter pathways in hinds.

Key Words: Red Deer, Wapiti, Farming, Genetic Improvement, Reproductive Control

INTRODUCTION

The red deer (*Cervus elaphus*), represented by numerous subspecies distributed naturally across Europe, Asia and North America, is one of the newest ruminant domesticants in pastoral farming (Fletcher 1998). In New Zealand, where deer farming has rapidly attained the status of a mainstream animal industry, European red deer (spp. *scoticus, hippelaphus*), North American wapiti (spp. *nelsoni, roosevelti, manitobensis*) and their hybrids form the basis of an industry instigated only 30 years ago from the capture of wild stock. There are presently 2 million deer farmed across 4500 properties, generating an annual revenue of $NZ240 million from export of venison and velvet antler products (New Zealand Game Industry Board Statistics).

The domestication of red deer has presented unique opportunities and challenges to pastoral farmers. Their inherent "wildness" is itself both beneficial (e.g. low-intervention, "easy-care" management; natural disease resistance) and challenging (e.g. overcoming natural aversion to man as a predator), and highlights the fact that this is a species little influenced genetically by man to comfortably fit the rigorous confines of pastoral management systems. Reproductive seasonality is a case in point: genetically entrained and rigidly controlled summer birth seasonality has obvious adaptive significance to red deer in their natural northern hemisphere habitat, but results in misalignment of the high energy demands of lactating hinds with early spring feed production in most NZ pastoral systems (Asher *et al*, 1993a). How is this problem addressed?

In this compilation of review papers, various authors discuss trends in genetic improvement and reproductive manipulation of red deer (specifically in NZ, but with relevance elsewhere) to improve production opportunities and overcome production - limiting challenges.

GENETIC IMPROVEMENT OF FARMED DEER

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Deer farmers are confronted with a number of decisions that impact on the genetic merit and improvement of their farmed deer. These include the choice of species (e.g. red, sika, fallow), the choice of strains (e.g. among red deer, North American elk, Scottish, English, Hungarian, Danish, Yugoslavian), the mating structure (pure breeding vs. crossbreeding strategies) and the nature of within-strain improvement.

Within-strain improvement requires that animals are ranked for attributes of interest and this typically necessitates additional identification and measurement tasks in comparison to those required for commercial farming of deer. Most deer farmers prefer to concentrate on productive aspects of their farming operation and leave genetic improvement to a specialised sector of the industry dedicated to the production of sire stags.

This paper first addresses the genetic issues that are to be considered by commercial deer farmers and then considers some aspects of within-strain improvement that are principally the domain of stag breeders. The issues are presented in a New Zealand context, but the thought process that is followed applies to farmed deer in other countries.

Farming Goals

The first logical step in development of a breeding programme involves definition of the goal of the farming system. In the context of a deer farm, the goal may be described in a business framework, such as maximising net farm income. However, it is more common for the goal to be somewhat more specific, including limitations on the production circumstances, typically discriminating between venison, velvet or mixed venison and velvet production. For example, the goal might be to maximise the value of velvet antler produced per head, or to maximise profitably of venison production per hectare. In some circumstances, the goal might be limited to a particular strain of deer, such as maximising the production of venison from fallow deer. Farming goals should be well established prior to consideration of strains and strain improvement strategies.

Selection Objective

Given a defined farming goal, and knowledge of expected production and economic circumstances relevant to the farming operation, it should be possible to quantify the likely returns from the farm. Given a profit-related goal, this could be achieved by creating a bio-economic model of the farming system. The model could take the form of a described profit function (Skeritt and Amer; 1999), or a farm budget, perhaps developed on a spreadsheet. The required complexity of this modelling approach will vary according to the production circumstances (e.g. seasonal availability of pasture and other feeds) and economic circumstances (e.g. costs of supplementary feeding, returns for velvet and venison products of various grades).

A bio-economic model of the farming system can be employed in three ways to assist in the development of a breeding programme. First, the expected performance of alternative strains or crosses can be used to assess their performance. Second, the animal characteristics that contribute to costs or returns can be marginally altered, to quantify the impact of each trait on farm profit. This allows the economic values (EVs) of each trait to be assessed, providing guidance for within-strain improvement programmes. Third, modifying the expected costs and prices to reflect uncertainty of the future can allow assessment of the sensitivity of strain choice and EVs.

In practice, the development of a bio-economic model is often beyond the capability of individual farmers. While researchers possessing an integrative knowledge of biology are best suited to this task, useful bio-economic models cannot be developed in isolation of knowledge of farming practices and animal performance in a commercial environment. McManus (1993) developed a selection objective for red deer in UK production circumstances.

Industry Breeding Structure

Suppose an average deer farmer uses each sire for four seasons at a ratio of 1:60 hinds. Sire stags would therefore mate 240 breeding hinds in their lifetime. Given the sex ratio of offspring, a breeder of sire stags with 85% fawning would need to run 2/0.85=2.4 hinds to produce one male offspring. Allowing for only the best one in 4 stags being available for sale would suggest that some 10 hinds are required for sire breeding to meet the needs of 240 commercial hinds. The industry could therefore be structured with 10/240 = 4% hinds in sire breeding herds and 96% hinds in commercial herds. In order to achieve genetic improvement, the sire-breeding sector would need to be involved in performance and possibly pedigree recording. From a genetic viewpoint, there may be little need for performance recording in the commercial tier. The genetic advance created in the sire-breeding sector determines the rate of genetic progress achieved by the industry. Commercial farmers can exploit genetic advance in sire stags, and strain differences in performance, by nature of their mating systems.

Choice of Mating System and Source of Replacements

In some circumstances there is a conflict between the desired attributes of the dam and the desired attributes of the offspring. For example, fast growing, large offspring are likely to achieve higher venison returns than average animals, but large mature size dams are likely to have higher feed intakes and require lower winter stocking rates than average dams. In this case, it is often advantageous to use a different dam line and sire line, the dam line chosen for maternal attributes and the sire line chosen to produce desirable slaughter offspring. In circumstances where there is significant heterosis there may be advantage in recreating first-cross animals, rather than losing heterosis by interbreeding or backcrossing the hybrid animals. A tiered mating structure is a viable option in some farming circumstances, such as farming corporations that span several localities. However, it can complicate management on small farms, particularly if purchasing replacement females is not considered a viable option.

Management may be simplified in a self-replacing system with only a single strain. However, it is important to quantify the opportunity cost of such a strategy. This is readily achieved with a bio-economic model and estimates of strain effects, but in practice most decisions are made on the basis of subjective assessment.

Choice of Strain

In theory, the ranking of strains is a straightforward exercise given a bio-economic model and estimates of strain and heterotic effects for the relevant traits. Information on heterosis has been difficult to obtain because heterosis effects must be separated from strain effects. Multiple generations of measurements are often required because insufficient purebred females are available for one of the parental strains.

Experience in New Zealand has shown strains and species of deer span a considerable range in mature body weights and therefore growth rates, and differ markedly in their velvet antler productivity (Fennessy and Pearse, 1990; Pearse, 1992). However, other aspects such as temperament, susceptibility to parasites and mineral availability (e.g. copper) also need to be taken into account when choosing an appropriate strain. Many strong perceptions of strain strengths and weaknesses exist in the NZ deer industry, although often these vary dramatically depending on individual preferences and perceptions, and potentially detrimentally influenced by marketing efforts of individuals with strong commercial interests. Considerable mixing among strains has been, and is continuing to take place in NZ deer. Ignoring strain differences and heterosis effects in genetic evaluations, while theoretically sub-optimal, may be the only pragmatic solution to this problem.

Within-strain Selection through Performance Recording

The traits that influence the breeding goal and their relative importance will vary according to production and economic circumstances, and according to individual expectations for the future. A commercial producer considering buying sire stags would be well-advised to choose the breeder that has a similar breeding objective and can demonstrate that selection is being imposed on these economically important traits. Modern statistical procedures allow ready identification of genetic progress in recorded traits, but many breeders are yet to adopt this technology.

From the perspective of a sire breeder with a well-defined objective, the next step in the development of a breeding programme is to identify suitable selection criteria that allow progress to be achieved for the desired traits. Scientific and practical experience have demonstrated that both venison and velvet productivity can be readily modified by selection. Live weights and velvet antler weights are highly heritable and demonstrate considerable variation (McManus, 1993; Morris *et al*, 1992; van den Berg and Garrick, 1997). Some traits that influence returns may be primarily influenced by environmental factors and therefore not amenable to modification by genetic selection. Other characteristics may be expensive or otherwise problematic to measure (e.g. individual feed intake) or cannot be measured until late in life (e.g. longevity). For these traits, the sire breeder has to make carefully reasoned tradeoffs as to whether the cost and effort required for their measurement might be better directed towards traits more readily measured, but which still have a clear genetic relationship to the selection objective.

Relative to other livestock species, deer present more difficulties in parentage recording. Hinds tend to hide their fawns at the time of birth, so birthdate is not easily obtained without intensive recording. The impact of recording birthdate in deer is considered by Amer *et al*, (1999). A common practice is to "mother-up" fawns to hinds at a later date, once fawns are actively running with their dams. Some farmers maintain hinds in their single-sire mating groups until weaning, facilitating the recording of sire. Lack of pedigree information has little impact on high heritability traits such as velvet antler weight. However, it causes problems in low heritability traits or in traits where direct and maternal influences need to be distinguished, such as for weaning weight. Stag breeders are more comfortable basing their marketing on progeny guaranteed to be from icon sires with big industry reputations than on EBVs which they feel substitutes the supposedly important artistic job of visually judging the animal.

The Role of Molecular Genetics

In addition to using markers for parentage testing or parentage verification, strain specific markers are routinely used to quantify the proportion of elk genes in crossbred strains of red deer. Elk and elk crosses tend to have faster growth than strains of red deer but also differ in disease and behaviour attributes. Buyers prefer purchasing such animals with DNA-based objective information.

The advent of DNA technology has already revolutionised such recording and will see even greater adoption when DNA marker analysis becomes cheaper than at present allowing for routine parentage testing from multiple sire groups.

The use of DNA markers for marker-assisted selection offers promise, with some chromosome regions (known as QTL) having been identified from strain crosses involving inbred Pere-David deer (Fennessy and Mackintosh, 1992; Tate *et al*, 1995; Goosen *et al*, 1997). These QTL have yet to be validated for within-strain use but offers promise for future selection.

DEVELOPMENT AND APPLICATION OF ASSISTED REPRODUCTIVE TECHNOLOGIES

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The red deer industry in NZ has been quick to realise the potential impact of assisted reproductive technologies (ARTs) on the rate of genetic progress in breeding programmes. However, while the development and application of such technologies has been rapid, overall adoption has been at relatively low levels due to various industry infrastructure and economic reasons. Here we review established and emerging ARTs for red deer and wapiti that have implications for accelerating rates of genetic improvement.

Artificial insemination (AI)

Development of protocols for oestrous synchronisation, semen collection/cryopreservation and insemination of red deer and wapiti was spearheaded in the early 80's, and has been well described in the scientific literature (reviewed by Asher *et al*, 1993b). Present commercial practice for red deer involves:

i) Semen collection by electro-ejaculation of sedated stags. Various cryopreservation techniques

ii) Oestrous synchronisation with 12-14 days treatment with intravaginal CIDR devices followed by injection of 200-250 IU eCG.