GENETIC SELECTION AND RECORDING

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SUMMARY

Any programme of genetic improvement is primarily dependent on specifying the objectives. It is then a matter of choosing an appropriate character which is measurable and which will respond to selection.

The selection objective must be market related though it is recognised that genetic improvement is a long term investment and this can be difficult. Overall an appropriate objective is to improve the efficiency of conversion of grass to meat. In deer, this probably entails selection for weight or growth rate. The requirements for a successful scheme of genetic improvement include recording the pedigree of the animals and appropriate weights at different stages of the growth cycle.

INTRODUCTION

Modifying the genetics of farmed or domestic animals has been a feature of the development of many cultures over the past few thousand years. Hence we now have Great Danes and Dachshunds, Merinos and Coopworths, Thoroughbreds and Clydesdales. If all this history teaches us one thing it is simply that where there is a clear objective and animals are selected on the basis of a clearly defined objective performance, then the results are spectacular. The thoroughbred is a superb example. However, where the objectives are less clear and based on opinions, then the results are much less satisfactory. An example is selection based on the opinion that sheep with woolly heads must be growing more wool overall. It would be far more profitable to actually weigh and record the fleece weights.

There are a number of very important issues to consider in setting up any genetic selection and breeding programme:

* There must be a clear measurable objective.
* The character being selected for must be heritable.
* There must be variation for the desired character within the population.
* The more characters you select for, the less progress will be made in any one.

Therefore if a character is measurable, heritable and variable it is possible to make genetic progress by direct selection for the character you want to improve. (NB: The Appendix defines some of the terms used by geneticists and shows the method of calculation of expected genetic progress in response to selection for a particular trait, in this case velvet antler weight).

Direct selection for a character is the most useful approach. So if you are really interested in breeding stags for bigger antlers, then select for antler size. This is true even though antler size and body size are correlated - bigger, heavier stags on average have bigger antlers. Progress in improving antler size will be faster when selection is based on antlers rather than on body size. The point about correlated characters raises the next issue, namely to beware of the apparently correlated responses. These are the will o' the wisp effects which are here today and gone tomorrow. There is no ready example with deer but there is with sheep. In New Zealand, there is considerable interest in breeding leaner, meatier sheep. In some research flocks, there is a correlation between leanness and fecundity (lambs born per ewe) in that sheep from lean lines have more lambs while sheep from high fecundity lines are leaner. However, this association is not absolute - there are high fecundity lines of sheep which are not leaner. Therefore if you want leaner sheep, then select for leanness, not fecundity.

It is clearly apparent that the real problems come when the character you are interested in is not readily measurable in the live animal. Carcase fatness and killing out percentage are two examples. In these cases there is no alternative but to use indirect selection; that is to select for some character which is associated with the desired character. Alternatively the breeder could progeny test stags by single sire mating them to groups of hinds and comparing the progeny at slaughter.

OBJECTIVES

Defining the objectives clearly and simply is the most important step in setting up a programme of genetic improvement. While the principal objective of selection and breeding is to improve the profitability of an enterprise, such an objective is too imprecise to be useful. If the bottom line objective is profitability, then we have to produce something for which other people will pay a premium or we have to produce it more efficiently.

Objectives must be market related. However, a programme of genetic improvement in deer is a long term investment and anybody who has attempted to make long term market predictions about any product will appreciate the enormous difficulties that this entails. However, we have to make some attempts - eg, it is a good bet that the demand for lean meat will be much higher than that for fat meat but when it comes to a decision between red meat and white meat or between meat and vegetable protein, the situation becomes more difficult. Here it is the customers' perception that is all important, which highlights the importance of considering the market base for a product and the commitment of the marketers to devise profitable ways of selling the product.

If the real aim is to improve efficiency, then there are obvious problems. Efficiency is something which means different things to different people and it can be very difficult to measure. My own definition of biological efficiency is:

$$= \frac{\text{Product output}}{\text{Food intake}}$$

In this definition, an estimate of food intake is required. Under practical grazing conditions, this is virtually impossible and therefore indirect estimates of efficiency must be used as an alternative.

EFFICIENCY

For this paper, it is assumed that the objective is to genetically improve the efficiency of meat production from deer. Therefore the next step is to identify the characters or traits to be selected for. At this point, it is useful to look at the readily measurable productive characters likely to influence efficiency.

It is a fact of life that bigger animals tend to be metabolically more efficient. For example, a rat must eat more each day for its weight than a horse, simply because for its weight, the rat has a greater surface area and it is this surface area which is responsible for losing heat to the environment. In practice this means that a 200 kg deer would be expected to lose heat at only about 2.8 times the rate of a 50 kg deer even though it is four times the weight (Table 1). Clearly, this has repercussions in terms of the amount of feed required to maintain an animal. However, it is obvious that size isn't everything. Even among the red deer family, there are small sika in one environment and giant wapiti in another.

TABLE 1 - Relativities between weight and metabolic rate (where metabolic rate is proportional to weight to the power of 0.75; i.e. $MR \propto W^{0.75}$).

Weight (kg)	Relative weight	Relative metabolic rate
50	1.0	1.0
100	2.0	1.7
200	4.0	2.8
400	8.0	4.8

The difference in maintenance requirements (a function of the metabolic rate) means that the larger, heavier animal is more efficient than a smaller animal, all other factors being equal; however, in life all other things are seldom equal and therefore a thorough examination of each situation is necessary. For example, a female of 50 kg, which produces twins each year which reach a slaughter weight of 40 kg in six months, could be up to twice as efficient in terms of meat produced per unit of feed as a 500 kg female producing one offspring per year which reached 400 kg at two years of age. In addition to the reproductive rate and the relative growth rates of the offspring there are several other factors which need to be considered in comparisons of efficiency. These include the length of the productive life, ease and cost of management, susceptibility to disease and animal health costs and the requirements and costs of supplementary feed.

Efficiency can also be expressed in economic terms, where account is taken of both the income from product sold and the variable costs so that gross margins can be calculated:

$$\text{Gross margin} = \text{Income} - \text{variable costs}$$

In the calculation of gross margins there is no allowance for fixed costs which are considered to be the same in all such deer breeding enterprises involving a fixed area of land. Consequently the gross margin provides an indication of economic efficiency.

Therefore, some estimates of the impact of changes in such factors as the weight of animals or the reproductive rate on both biological efficiency (calculated as carcass output per unit of feed input) and economic efficiency (calculated as gross margins) are presented in Table 2. The estimates suggest that the changes in economic efficiency are markedly greater than the changes in biological efficiency.

TABLE 2 - Factors affecting efficiency of meat production in a herd of red deer, the expected response in biological efficiency or economic (gross margins) efficiency to changes in the factor, and the possible means of changing the factor (Fennessy 1982 and Fennessy unpublished).

Change in the factor	% Change in Efficiency		Means of changing the factor
	Biological	Economic	
10% in weight for age of the whole herd	2	9	Selection for weight within a herd or strain; change of strain/sub- species (eg, red deer to wapiti).
10% in weight of slaughter stock only, with no change in age at slaughter.	5	15	Hybridisation (eg, wapiti X red deer females); selection; management-altering calving season.
10% units in herd weaning rate (calves weaned per 100 hinds to stag)	6	19	Management-nutrition, survival; selection for twinning; management to increase twinning.
1% units in herd death rate	2	-	Management and disease control; selection; hybridisation.

From Table 2, it is apparent that there are numerous possible approaches to improving efficiency. In some cases, changes in management practice will be far more effective than any grandiose scheme of genetic improvement. For example, a better quality fence around a calving paddock can produce more dramatic effects on efficiency and profitability than several years of selection and breeding. This, of course, highlights the fact that genetic improvement is the approach you take after you have got the basics of management right.

In a meat production system, the most efficient approach towards improving efficiency will involve mating a genetically large male to a genetically small female, so long as there is little effect on the calving rate and the survival of progeny. This is evident from Table 2 where a 10% change in the weight of stock at slaughter with no change in age is about twice as effective as a 10% change in the weight of the whole herd. Consequently, this is the place for the wapiti and wapiti hybrid male - they are an example of a genetically larger male to mate to the genetically smaller red deer female. However, there are several other possible large male/small female systems with the deer available in New Zealand. The wapiti bull x red hind is the extreme example and a great deal of managerial skill is needed to achieve a satisfactory weaning rate. Therefore, if wapiti are to be used on anything but a small scale with intensive management, then the red hinds to which they are mated will need to be larger than the usual New Zealand red hind of about 100 kg. Although the hinds going to the wapiti male will be small in relation to the size of the male, they could still be large by current farm standards, averaging as much as 130 kg. To produce such megared hinds will require systematic mating programmes. Another option is to mate average New Zealand red hinds (about 100 kg) to wapiti x red hybrid stags or to some of the larger European red stags. The large male/small female system would just be operating at a different level.

EFFICIENCY, SIZE AND SELECTION

Red deer are the predominant species of deer in New Zealand making up about 84% of the total population. Therefore any programme of genetic improvement must involve the ordinary New Zealand red deer. However, red deer are members of an incredibly diverse group of cervids, ranging in size from the Japanese sika deer to the North American wapiti. The red deer is intermediate in size and can interbreed with other members of this group to produce fertile hybrids.

The potential to breed red deer of different sizes is evident from the hind weights listed in Table 3. This potential carries with it the temptation to breed deer simply for size. It is also possible to produce hybrids with other species closely related to the red deer, such as Pere David's deer, *Elaphurus davidianus*.

TABLE 3 - Female adult weights for members of the red deer group which can be interbreed to produce fertile hybrids.

	Adult female weight (kg)
New Zealand sika	75
New Zealand red	100
European red	100 - 150
Fiordland wapiti	170
Canadian wapiti	240

Since hybridisation across strains is the most efficient meat production system, the most obvious place for the ordinary New Zealand red deer is as a specialist dam line. Consequently, within the red deer we have to develop a method for selecting and producing a more efficient dam. Practically the most obvious way is through selection for weight at a given age. However, this is not straight forward because selection for weight alone at any age is virtually certain to result in an increased overall mature or adult size and consequently the average weight of the whole herd will increase.

Therefore, in attempting to produce a more efficient dam line with the emphasis on early growth rate, it may be possible to select for growth rate up to 15 months of age without having a major influence on mature size. One possible way to achieve this is to make some allowance for the rate of growth of an animal relative to its parents. For example, in comparing two daughters of the one sire in the same mob but out of different hinds, the one that at 15 months of age reaches 90% if its dam's mature liveweight is likely to be superior to that which reaches only 70% of its dam's weight at the same age. However, the use of such an approach using simple ratios is unlikely to be appropriate.

As outlined above, selection for some relative adjusted weight parameter rather than weight for age alone is probably the most useful criterion for improving efficiency. If the objective is just to produce a larger hind, such as a "megared", there are far simpler ways of doing this, than selecting within NZ red deer. The possibilities include using the female progeny of large European stags over New Zealand red hinds or the progeny of hybrid Canadian wapiti/NZ red stags over New Zealand red hinds.

PATTERN OF GROWTH

Having concluded that the most practical approach to improving efficiency in a deer herd is to select for weight it is necessary to look at the usual pattern of growth in red deer. The growth pattern to 15 months of age is characterised by several phases:

* intrauterine growth reflected in birth weight
* growth on milk reflected in weight at about 3-4 months
* growth during the autumn at 4-6 months of age (post-weaning)
* growth during the first winter from 6-9 months
* growth during spring and summer from 9-15 months

Thereafter for hinds, the growth pattern is largely a function of their reproductive status (and the season of the year) and of course the quantity and quality of feed offered. Under normal farm conditions, though, hinds will continue to gain some weight each year to reach a mature weight at about 4-6 years of age. Having attained puberty stags also develop an annual cycle of weight change, although this is usually very mild in the rising two year old stag. From 15-21 months (rut and winter), the young stag will maintain weight or lose very little weight if fed to appetite, while from 21-27 months (spring-summer), growth is rapid. The demands of the hormonal changes through the annual reproductive cycle then take over, characterised by low feed intakes and large weight losses over the rut followed by weight maintenance during the winter. Thereafter, annually over the spring-summer, the stag regains lost weight rapidly with some increase in pre-rut peak weight expected up to about 5-7 years of age.

SELECTION FOR GROWTH

From a practical viewpoint, the earlier the replacement breeding stock can be selected, the better. The milk feeding period is a critical phase of the young deer's life, with milk intake at this time having a major effect on weaning weight, and therefore a major potential influence on the animal's production in later life. In the short term, however, the real advantage in recording weaning weight is to select the most productive hinds, i.e. those that rear the best calves.

After the milk-feeding period, the period from 9-15 months of age can be regarded as the best opportunity to exploit the young deer's potential for growth. Potential growth rates are very high during this spring-summer period (as evidenced by indoor feeding trials with deer fed high quality diets to appetite) while under New Zealand pastoral conditions pasture growth is at its highest in spring. However, a distinction must be made between

* the animal's potential to grow (growth potential), and
* the actual growth rate,

since animals seldom achieve their potential for variety of reasons. The growth potential is determined largely by the animal's genetic make-up which influences its capacity to eat, the efficiency with which it utilises its feed, etc. In contrast, the actual growth rate is a function of the interactions between the animal's genetic make-up and external factors, especially the quality and quantity of feed available, climate and disease. Therefore, in practical terms this means that comparisons between animals must be made on a within-herd basis with all animals given the same opportunity to express their genetic potential.

Consequently, the weight at 15 months can be expected to provide a good indication of the animal's ability to express its genetic potential. However, as has been indicated previously, genetics alone do not tell the full story and a considerable proportion of the variability within a herd is not of genetic, but of environmental origin. Therefore, when the objective is to select for improved growth rates or weight for age, the important weights to be recorded are:

* weight at 3-4 months (usually weaning weights),
* weight at about 15 months,
* and for stags, the weight at 25-27 months.

In some cases, breeders are very interested in an estimate of mature liveweight. The best estimate is the winter lean weight taken in June following the rut when the stag will have lost virtually all of his body fat. This liveweight is far more relevant than the pre-rut liveweight which is greatly influenced by the quantities of excess fat and the actual timing of the measurement over this period when weight gain can be very rapid (this weight gain is partly due to water retention pre-rut).

Weaning Weight

It can be expected that the weaning weight of the calf will be a function of several factors in addition to the hind's milking or mothering ability.

For example, the age of the calf at weaning and its sex are likely to be important variables. As well, other factors which could influence the hind's milk production include her age and weight. Therefore, in trying to rank hinds in terms of their mothering ability, we endeavour to take account of these various factors. Although only a very few sets of farm records have been analysed to date, the following effects have been recorded within herds:

* Weaning weight of male calves is about 4-5 kg heavier than female calves (i.e. about 8-10%).

* Weaning weight increases by about 0.1-0.5 kg/kg hind weight.

* Weaning weight increases by about 0.25-0.4 kg/day of age at weaning when calves are weaned pre-rut.

* Calves reared by 2 year old hinds are about 8-10% lighter than calves out of older hinds, even at the same hind weight; a major part of this difference is probably due to the difference in birth date and hence age at weaning.

* The sire of the calf.

Practical Approaches

The various factors which can influence weaning weight indicate the important things to record, namely:

* Sire and dam of the calf
* Birth date
* Weight of dam
* Weaning weight and date

Consequently, a hind recording system requires that hinds be single sire mated, that the hind and her progeny be matched up, the birth date recorded and animals weighed.

Practically, the difficult areas are in the hind-calf pàiring and the date of birth. However, any recording-genetic improvement scheme is worse than useless unless the farmer can collect the information simply and accurately. Therefore several farmers have developed practical schemes (see Cowie 1985). With small mobs of quiet hinds, it is quite feasible to eartag calves soon after birth. At that time or soon after the tagged calves can be matched with their dams. With larger farms and larger mobs, though, there is the sheer problem of numbers. While hind-calf pairing can be simply done at any stage prior to about three months of age, recording birthdate is much more difficult. This gets back to the question of the real importance of birth date in terms of its influence on weaning weight. Although our analysis shows that it has quite an effect, it is probably adequate to sort hinds into approximate groups, each covering a calving span of about a week. If this is simply not feasible it is essential that at least late calves (second cycle) be identified. In this case, it is accepted that the ranking of hinds will be compromised by the difference in birth dates, although of course there is argument that the best hinds calve early anyway.

Elite Herds

The simplest way into a herd improvement programme is to select an elite group of hinds from within a single herd or from a group of herds. The problem lies in the selection of hinds for such an elite herd without recording all the animals.

One approach is to weigh all the calves at about three months of age and sort out the heaviest, and then to match up these calves with their dams. To minimise the effect of the various possible complications, it is best to work within sire mobs (so that all calves considered are by the same sire) and to deal with first calving hinds separately. The hinds could then be sorted further on the basis of those which have reared the heaviest calves relative to their own body weight, using the adjustment factors outlined earlier.

Complications

If a farmer wants to increase the average size and weight of his deer herd, the quickest way is to hybridise with wapiti or a larger (eg, selected European) strain of red deer. However, numerous factors may argue against this strategy and the decision is to then select the most efficient animals from within the herd. Therefore, this requires that somehow, there be an estimate of the animal's mature size in order to select that animal which is going to grow relatively faster. There is a considerable need for research in this area, but it seems that after allowing for differences between sires, that adjusting for the weight of the dam may be the most useful approach.

OTHER TRAITS

As indicated in Table 2, other than selection for weight, there are a number of other alternatives which could be expected to improve the efficiency of meat production. These include selection for earlier calving and selection for twinning. The principles are identical to those pertaining to selection for weight. However, the one additional crucial point is that if one is selecting for earlier calving, the hinds must be given the opportunity to calve much earlier than late November. An alternative here could involve indirect selection for those stags within a herd which clean their antlers early thus indicating that their testicular development is advanced compared with the rest of the herd. With selection for twinning, positive identification of genuine twins is essential to improve the chances of real genetic progress.

THE FUTURE

The whole area of recording schemes and schemes for genetic improvement in deer is one where there are likely to be considerable advances in the next few years. The information being collected through Deerplan (see Fennessy 1985) run by the New Zealand Deer Farmer's Association will be very useful in this respect.

FURTHER READING

Cowie, J. 1985. Practical deer recording and its benefits. The Deer Farmer (26), 38-39.

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APPENDIX

Definitions and calculation of expected progress

The purpose of a selection programme is first, to identify the genetically superior deer within the herd and then, second, to use these animals as breeding stock. With ongoing selection and breeding, each year's crop will be, on average, genetically superior to the previous year's crop for the character selected. In this section, selection for velvet antler weight will be used to illustrate the selection principles.

Using a selection programme will result in the genetic merit of the herd increasing year by year. The expected rate of increase can be calculated using the following equation:

$$\text{Genetic gain per year} = \frac{\text{Heritability x Selection differential}}{\text{Generation interval}}$$

Each of these terms will be considered in detail to illustrate the essential principles involved in improvements of velvet antler yield through selection.

However, the terms genotype and phenotype which are used frequently in discussions of genetic improvement must be explained. The genotype refers to the whole set of genes carried by the animal for a particular character or trait, such as antler growth. The phenotype of the animal is its actual production of this character. The set of genes the animal carries functions as a group in the expression of the phenotype.

For the purposes here it is assumed that the productive characters of deer are the result of the action of many genes and are not the consequences of only one or two genes. For a character such as velvet weight, the yields for individual stags would therefore be expected to be distributed around the mean. This appears to be the case with Figure 1 showing the velvet weight distribution for a group of 87 three-year-old stags. The mean velvet yield is 1.55 kg. It is the variation around this mean which provides the raw material for selection.

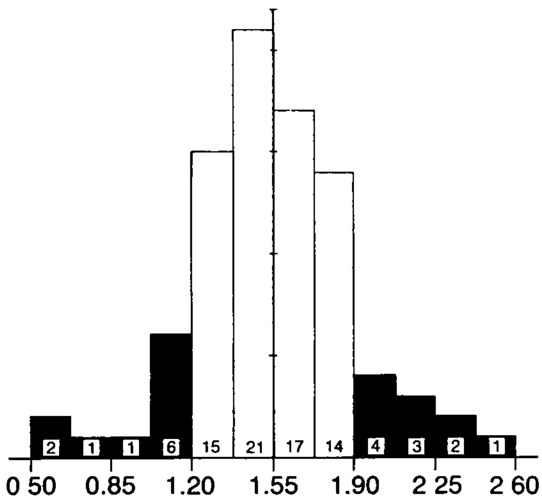

Fig 1 - Distribution of velvet antler weight in a herd of 87, 3 year old red stags with a mean yield of 1.55 ± 0.35 kg (from Fennessy 1982-3).

The standard deviation of velvet weight for the 87 stags of ± 0.35 kg indicates that two-thirds of the stags would be expected to have velvet weights between 1.20 and 1.90 kg (i.e. 1.55 ± 0.35), with about one-sixth of the group of stags yields greater than 1.90 kg.

The selection differential is the difference between the performance of the animals used for breeding and the herd average from which they came. Selection differentials are given in Table 1 and are applied to a group of 100 stags with a mean velvet yield of 1.55 ± 0.35 kg.

TABLE 4 - Selection differentials and average yields for sub-groups of stags selected from a total group with a mean velvet yield of 1.55 kg and a standard deviation of 0.35 kg.

Stags selected		Selection differential		Selected stags average yield kg
Proportion	Percentage	Relative	Actual (kg)	
1.00	100	-	-	1.55
0.90	90	0.20[1]	0.07	1.62
0.75	75	0.42	0.15	1.70
0.50	50	0.80	0.28	1.83
0.25	25	1.27	0.44	1.99
0.10	10	1.76	0.62	2.17
0.05	5	2.06	0.72	2.27
0.01	1	2.66	0.93	2.48

[1]Actual selection differential = standard deviation x relative sel. diff.
= 0.35 x 0.20
= 0.07 kg

It can be seen from Table 4 that if only a few stags are used for breeding they can be very highly selected. The top stag in a group of 100 is expected to be 2.66σ better than average. This would represent a yield of 2.48 kg of velvet antler for the top stag in such a group of 100 stags. However, if the top 25 per cent of stags were selected the yield would be on average only 1.27σ above the mean (i.e. a yield of 1.99 kg in Table 1).

In applying such selection differentials in practice, we would have to assume that the hinds used for breeding are just average, since at this stage in deer genetics it is not possible to put numbers on hinds who do not normally grow antlers. However, in the long term it will be possible to assign breeding values to hinds based on the performance of their male relatives.

The heritability (h^2) is the proportion of the variation in a particular trait within the herd which is of genetic origin. Some Chinese work on Meihualu (Sika deer) suggests that the heritability of velvet antler weight is about 0.35 (Zhou and Wu, 1979, Acta Genetica Sinica 6: 434). This means that about 35% of the variation in velvet antler production within the herd of stags of the same age is of genetic origin. The remainder of the variation, in this case 65%, is of environmental origin and would be due to factors such as the level of nutrition.

The generation interval is the average age of the parents when the progeny are born. In a deer herd in which the hind numbers are stable, the average age of the hinds will be about 8 years (hinds culled at 15 years of age or older). If only 3 year-old stags are used as sires, then the generation interval would be 5.5 years whereas if only 8 year-old stags are used, the generation interval would be 8 years.

Therefore, it is apparent that if only older stags are used or the herd is made up mainly of older hinds, then the generation interval will be longer and the potential rate of genetic gain reduced.

A good rate of genetic progress is dependent on a high selection differential. Since only a few stags are used in breeding compared with the number of hinds used, it follows that stags can be much more intensively selected. Therefore, they will contribute more to the selection differential than will the hind. Therefore, the top stags in the herd must be identified accurately so that they can be used for breeding.

The phenotypic deviation is the term used to describe this superiority. It is the difference between the mean for the herd and the animal in question. Stag 622 was the highest velvet producer in the group of 87 shown in Figure 1. With a yield of 2.60 kg his phenotypic deviation was 1.05 kg (2.60 kg minus 1.55 kg).

Examples of the effects of different breeding programmes on the expected rate of genetic progress which illustrate the important points made in this article are given in Table 5.

TABLE 5 - Expected annual rates of genetic gain in velvet antler yield from following different breeding plan[1].

Stags used	Heritability	Selection differential of stag (Table 4)	Generation interval (years)	Expected genetic gain (kg/year)
Top 1%	0.35	0.93 kg	5.5	0.03
	0.35	0.93	8	0.02
Average Stags	0.35	0	5.5	0
	0.35	0	8	0

[1] It is assumed that the hinds are average and that their selection differential is zero, eg, genetic gain = $\frac{0.35 \times 1/2\ (0.93)}{5.5} = 0.03$

Although the annual rate of improvement, which is the increased yield expected from this year's progeny compared with last year's, appears to be very small, the effect of 10 years of selection using only the top 1 per cent of stags compared with just average stags is substantial.

Using 1 per cent, the stags produced in 10 years time would be expected to be 0.30 kg higher in velvet antler yield than those produced if average stags had been used. Since this applies to each year of a stag's productive life, the benefit from selective breeding would amount to 2.4 kg during a productive lifespan of nine years (two to nine years of age). This is a substantial improvement for relatively little effort.