An Introduction to Linebreeding Alpacas

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Introduction

A breeding plan of some description is a necessity for every alpaca breeder that is serious about herd improvement. Without a plan, breeders will produce alpacas that are most likely, of the average quality, of the national herd. There will be the few exceptions that are either outstanding or very poor. However, relying on a random combination of genes leads to assorted results. A carefully considered breeding plan is a wise investment by reducing the odds on what genetic material is passed on to the next generation. At this point it is worth remembering that physical science is not an exact science. While total control is not obtainable, predictability may be increased through a scientific approach and a sound breeding plan.

Line breeding is common practice among most domesticated and indeed undomesticated animals throughout the world. There are even specific references in the Bible explaining how some races were established. A small number of alpaca breeders have ventured down the path of linebreeding, however, the topic linebreeding is relatively uncharted territory in the Australian Alpaca industry. This paper will attempt to provide an overview of the key considerations and implications for a linebreeding program.

The effect of linebreeding

By definition linebreeding is a concentration of the genes of a specific ancestor or ancestors through their appearance multiple times in a pedigree. Inbreeding is similar but involves the breeding of very close relatives. While the difference between linebreeding and inbreeding is highly debatable, for the purposes of this paper, linebreeding will be achieving an inbreeding coefficient no greater than 12.5%. Up to 25% inbreeding coefficient can be achieved by mating a sire back to his daughter or full sister to full brother. However, while I would consider this to be inbreeding, the difference between linebreeding and inbreeding is interpretation. In fact it can quite easily be argued that linebreeding is inbreeding, but to a lesser extent. Examples of inbreeding and linebreeding various animals such as dogs, cattle and horses are able to provide us with the benefit of years of experience and knowledge that we can apply to alpaca breeding programs.

The main aim or purpose of linebreeding is to develop consistency and uniformity within a herd or breed. Bill Robbins states, “Linebreeding is the system by which practically all lasting improvements in livestock have come about” [1]. This can be clearly observed within dog breeding where we now have many different types of dog that breed true to type, which probably all originated from a dog much like a wolf. In some cases livestock or animal breeders have developed a strain within a particular breed through linebreeding. By concentrating the genes of an ancestor or ancestors with specific recognizable traits it is possible to develop a strain within a breed that might one day be recognized as a breed itself. Suri and Huacaya alpacas which have clearly recognized standards may well be examples of this within the camelid family. Eric Hoffman states, “There is only one species of alpaca and the two coat types are often referred to as breeds” [2]. Linebreeding may be used like a tool in the breeder’s toolkit to stamp in particular traits and recognizable features that are of high priority to your breeding program. Whether it is a particular frame, fleece, or other distinguishing feature, linebreeding has the potential to set particular characteristics in a homozygous form to develop a strain within a breed that will show uniformity and consistency. An alpaca has 37 chromosome pairs, inheriting 37 from the dam and 37 from the sire. If the two genes an alpaca carries for a particular trait on a chromosome pair are the same it is said to be homozygous for that trait and will pass on that genetic information to its progeny. “Because inbreeding causes an increase in the proportion of like genes (good or bad, recessive or dominant), the inbred animal's reproductive cells will be more uniform in their genetic makeup. When this uniformity involves a relatively large number of dominant genes, the progeny of that individual will uniformly display the dominant characteristics of that parent”[3].

Every breeder should recognize the value of setting desirable characteristics by increasing homozygosity. Breeders should also beware of setting undesirable characteristics and this highlights the importance of selection and out crossing which will be explained in detail later.

Inbreeding coefficient

When attempting to fix desired traits through linebreeding it is useful to have an understanding of Galton's Law of ancestral heredity and Wright's inbreeding coefficient to fully appreciate ancestral influence.
Galton's ancestral law states that the two parents contribute between them on average half of the total genetic make up of the offspring, the four grand parents a quarter and great grand parents one eighth. Galton's Law recognizes and estimates the hereditary influences that are not expressed in an individual but are capable of being passed on to the next generation. An individual alpaca will pass on a different combination of genes to each offspring and therefore, while very useful in estimating genetic influence, Galton's Law is in fact an estimation of the proportional influence.

Table 1. Galton's Law expressed mathematically.

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Galton's Law expressed mathematically shows proportional genetic contribution.

From Table 1, it becomes clear that the influence of an outstanding great grand sire will have little influence. However, if the great grand sire appears in three or four of the four possible positions in the pedigree, his influence would be considerable.

Wright's inbreeding coefficient is a measure of pedigree relationship and estimates the probability that both genes of a pair in an individual are identical (homozygous) by decent.
For example;
Sire & daughter or full brother & full sister = 25%
Sire & granddaughter or brother & half sister = 12.5%
Aunt & nephew or uncle & niece = 12.5%
Full first cousins = 6.25%
Half first cousins = 3.125%
It is relatively easy to calculate the inbreeding coefficient of one ancestor which appears twice in a pedigree. The cumulative effect of multiple appearances in a pedigree by an ancestor or multiple ancestors has a far greater genetic influence and is more difficult to calculate.

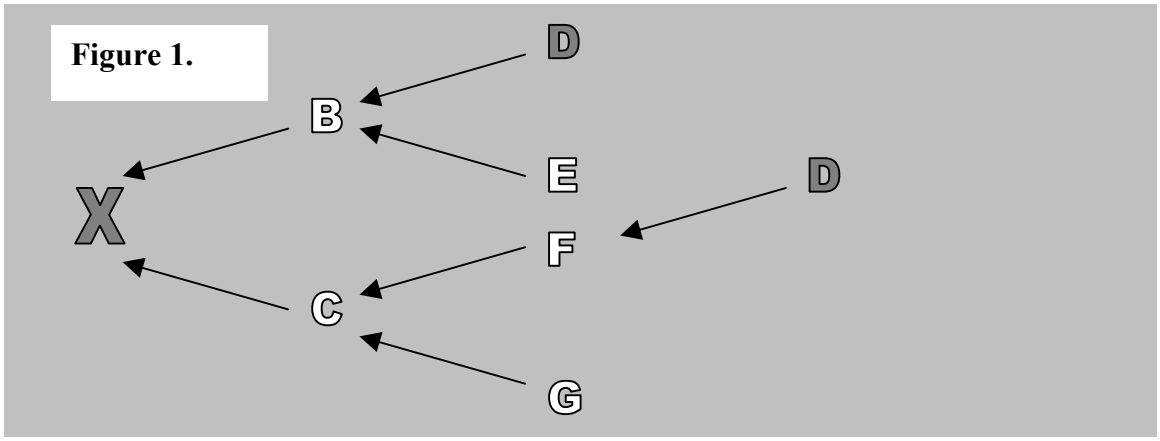
Wright's formula for inbreeding coefficient devised in 1922 is expressed as;

$$F_X = \sum [(1/2)^{n + n' + 1} (1 + F_A)]$$

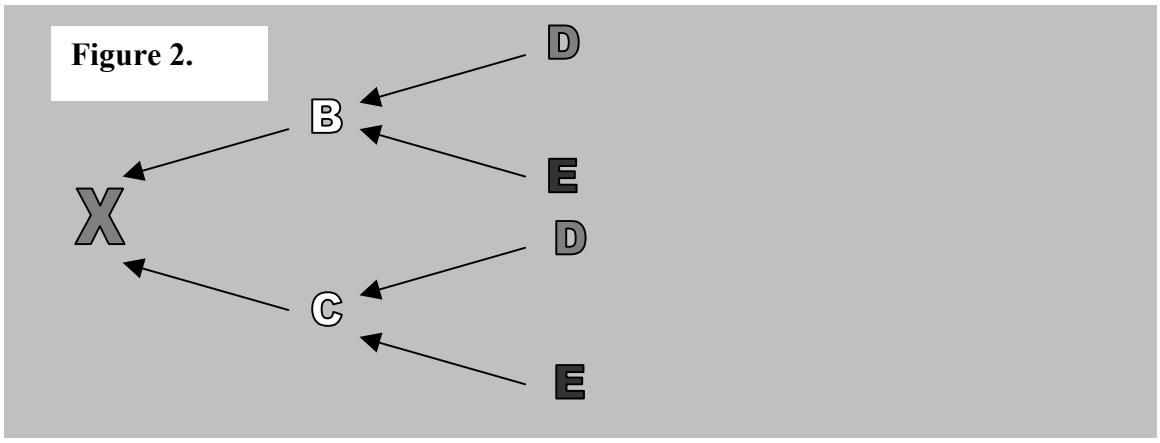
F_X = the inbreeding coefficient of animal X.
(1/2) = fraction of an individual alpacas genetic material that is passed on to its progeny.
n = the number of generations between animal B and the common ancestor.
n' = the number of generations between animal C and the common ancestor.
+1 = is added to n and n' to account for the additional generation between animal X and its parents.

F_A = the inbreeding coefficient of the common ancestor.

The following example demonstrates the use of the formula in use;



$\mathbf{F_X = \sum [(1/2)^{n+n'+1} (1 + F_A)]}$ $\mathbf{= \sum [(1/2)^{1+2+1} (1 + 0)]}$ $\mathbf{= 0.0625}$ $\mathbf{= 6.25\%}$ inbreeding coefficient



$\mathbf{F_X = \sum [(1/2)^{1+1+1} (1 + 0)] + [(1/2)^{1+1+1} (1 + 0)]}$ $\mathbf{= 0.25}$ $\mathbf{= 25\%}$ inbreeding coefficient

However, when calculating the inbreeding coefficient in Figure 2, if ancestor D already has an inbreeding coefficient of 0.125 or 12.5% then the calculations would be as follows;

$\mathbf{F_X = \sum [(1/2)^{1+1+1} (1 + 0.125)] + [(1/2)^{1+1+1} (1 + 0)]}$ $\mathbf{= 0.265}$ $\mathbf{= 26.5\%}$ inbreeding coefficient

In a practical sense this means alpaca X has 26.5% likelihood of carrying genes for a particular trait by decent from the common ancestor.

In this situation the use of pedigree tracking software that automatically calculates inbreeding coefficients quickly becomes very useful. By using appropriate software a breeder may identify and track the influence of various ancestors over dozens of generations. Some pedigree tracking software allows the recording of various features or traits. This is particularly useful, providing the breeder with the facility to easily identify and trace the influence or source of a particular trait (good or bad) within their herd.

Disadvantages of inbreeding

There are some obvious advantages and gains to be made through planned linebreeding. However it is the problems associated with severe inbreeding which deters some breeders from considering the role of linebreeding within their herd. The main disadvantages of inbreeding are; reducing the gene pool, decrease in hybrid vigor, inbreeding depression and the appearance of genetic faults. Reducing the gene pool is seen by some as an advantage and others as a disadvantage. On one hand the concentrating of specific genes is very useful in developing alpacas that are

uniform and consistent in appearance. On the other hand it could be argued that by concentrating specific genes, we are losing others that might have an important influence that we have not yet identified. Inbreeding depression or decreasing hybrid vigor can cause lack of fertility, higher mortality rates, smaller framed alpacas, congenital defects, reduced resistance to disease and infection. Genetic faults are possibly the biggest obstacle with inbreeding and are often cited as the reason some breeders steer clear of linebreeding. Recessive genes that are responsible for faults are either present or not present in a particular alpaca. However, except for sex linked genes, recessive genes must be present in duplicate (one from sire and one from dam) for the effect to be revealed. The practice of linebreeding will more likely reveal undesirable genes through visible faults exhibited in an alpaca. While many consider this to be a disadvantage, others would see this as an opportunity to identify alpacas that carry defective genes and remove them from the breeding program. A breeder could eventually create a strain that is free from that genetic defect. Through continual outcrossing, the expression of undesirable genes can be masked and faults or defect may be hidden in an alpaca's genetic make up and not visible in its phenotype. In this situation recessive, defective gene causing faults could be propagated in the carrier state and widely dispersed in the Australian alpaca population. With current research into alpaca DNA genome mapping, it may soon be possible to identify particular faulty genes in alpacas. The defective gene carrying alpaca could then be withdrawn from a breeding program. This DNA technology breakthrough could prove to be very useful to the linebreeder enabling screening of breeding stock at selection stage before recessive faulty genes can be spread.

Selection and culling

Selection has a major role to play in any breeding program and has great influence in future generations. It is usually not appropriate to choose a stud male for instance based on a superb fleece or fantastic conformation or a good looking head, in isolation to other traits. Decisions about selection and culling for a breeding program should be, as far as possible made based on analysis of data gained through objective measurement and in line with overall breeding goals. It is possible to place a value on particular traits that are important to your own breeding objectives and score each trait to determine an Estimated Breeding Value (EBV) for each alpaca in your program. The Across herd Genetic Evaluation program (AGE) can be a useful source of data when calculating EBVs. In calculating EBV's, it is important that they match your own breeding objective and include all traits that you identify to be important. In this way it is easier to measure improvement and make large genetic gains through appropriate selection. It is easy to be influenced by the success of currents fads, but to achieve uniformity within a herd a breeder must stick to breeding objectives and selection criteria.

It has been suggested that the phenotype (the genetic make up of an alpaca as shown or evident by its appearance) of an alpaca is the result of it genotype (the true genetic make up of an alpaca regardless of its outward visible appearance) and its environment (quality of feed, trace elements, climate conditions, etc, etc.)
P = G + E. In fact some would argue that; Phenotype = Genotype30% + Environment 70%.
Chris Tuckwell states, "Animals that have identical genetic merit can have divergent phenotypes. An animal's phenotype is predominantly (at least 60%) determined by its environment" [4].
If this is true, then how do you select animals for a breeding program when 70 % of what you see is in fact the product of the environment? A great number of breeders, including myself, have used particular stud males with no progeny and very limited pedigree, based on its outstanding phenotype. Sometimes a male will be highly prepotent for a particular trait and pass on that trait in the majority of cases. In other circumstances the male may be highly unpredictable throwing progeny of varying, conformation, colour or fleece style. By using a stud male with some degree of linebreeding a breeder is able to increase the odds of producing progeny that display the required traits. The pedigree data contained on the IAR database is a very valuable source of information that should be studied carefully and considered with other selection criteria.

Culling works hand in hand with selection in a breeding program and is equally important. Culling may be achieved through a number of means such as; not breeding from particular alpacas, using females that exhibit undesirable traits as recipients for embryo transfer recipients, castrating males that do not match breeding objectives, etc, ect. A breeder that is willing to remove animals from a breeding program that do not match the breeding objective will achieve whole herd genetic gain quickly. While the breeder that retains below standard animals in a breeding program compromises the rate of whole herd improvement. In some cases it may be prudent to split a group of females into two groups being "breeding seed stock" and "embryo recipients" in order to maximize whole herd genetic improvement.

Outcrossing / purpose and process

When a breeder is not happy with the alpaca they have produced outcrossing is frequently used to bring in different genes and reduce homozygosity. By breeding to an unrelated line new genes and new traits are immediately brought into the mix. The new genes can also increase hybrid vigor and address any areas affected by inbreeding depression in one generation. If your goal is to maintain consistency and uniformity it is a good idea to outcross to an unrelated line that also has some degree of linebreeding while also exhibiting the traits you desire. Uniformity within a herd can still be maintained when crossing two lines that have some degree of linebreeding, however, these uniform alpacas are unlikely to produce uniform and consistent progeny. Therefore it is important to either continue breeding back to the original line or continue with the new line to maintain uniformity and consistency in future generations.

Prepotency

Prepotency is a measure of the likelihood that an alpaca carries genes in a homozygous form and passes one on to each of the offspring. An example of this is a homozygous Suri male alpaca mated with a Huacaya dam to produce a Suri offspring. The Suri male would be considered to be highly prepotent in its ability to throw Suri progeny. An alpaca could be considered prepotent for a variety of traits such as, super fine fleece, high fleece weight, a particular colour coat or blue eyes. Linebreeding, by reducing the variety of genes, increases an alpaca's prepotency to produce consistent quality offspring. Alpacas that are prepotent for, selected, desired traits should be of more value than the average.

Marketing and value of bloodlines

I believe that in the near future, quality, linebred alpacas will be more highly valued than an alpaca of similar quality with no common ancestor due to their increased likelihood of passing on visible traits. That is; "What you see is what you get". A serious breeder should value an alpaca whose phenotype and genotype closely match and therefore provide a higher level of reliability in passing on desired traits. The days of purchasing a particular alpaca with an unknown pedigree, based simply on its phenotype (physical appearance) are numbered. Breeders will become reluctant to invest heavily in what may be a Pandora's Box with the genetic diversity to produce virtually anything.

Developing a breeding plan that suits you

Every Alpaca breeder should have a well established breeding plan or clear direction. Every breeder should be able to justify their choice of sires and the combination of ancestors appearing in the pedigree of a particular alpaca they breed. Dr Jay Lush states, "The more superior a breeder's herd or flock is to the average merit of its breed, the more reason he has to practice linebreeding to his very best animals or the very best of the recent ancestors" [5]. I predict that in the next ten years various alpaca studs will emerge, producing alpacas that may be identified as a strain within the breed. For example one stud will be known for consistently producing alpacas with extremely long staple length fleeces while another may be identified by the shape of their alpaca's heads. Some will consistently produce animals that are highly desired and sought after due to market influences at the time. Others will go relatively unnoticed until the current fad matches the phenotype of their herd. However this will depend on selection decisions made now based on the best and most accurate information available at the time. Maintaining consistency with selection is difficult, but can be rewarded with uniformity and consistency among progeny.

Linebreeding should not be looked at as the answer to producing the perfect alpaca. Equally, it would be shortsighted to dismiss it as being not viable or not useful. Dr Pierre Baychelier states, "There are advantages and disadvantages in the use of inbreeding and outbreeding in domestic animal reproduction. Both approaches complement each other and when used rationally can help breeders progress in their genetic gain" [6]. Linebreeding will most likely be used by many breeders in the alpaca industry as a tool to complement other breeding systems. Linebreeding is a long term process requiring careful planning and selection, and patience for success.

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