How to Accurately Select for Alpacas with High Breeding Value: Pedigree, Phenotypic Performance, or Progeny Test

By Mike Safley

Accurately Selecting Alpacas with High Breeding Value

> "*The Fetish of the Pedigree: Until disillusionment dawned, the belief in the value of pedigrees was a fetish with many animal breeders. Most of them have now learned that pride of names in a pedigree carries no assurance of equal pride in performance of the progeny.*"
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> Frederick B. Hutt and Benjamin A. Rasmusen
> Animal Genetics, 1984

At first blush, animal breeding seems relatively simple. If you believe ***'like begets like'*** all you need to do is mate similar animals. If you want a further edge-up - study pedigree. If that is not good enough, you can measure phenotype making sure only the best are included in your breeding plan.

The problem is that none of these strategies is particularly effective, and many of the beliefs that breeders rely on are black magic. Myth makes the animal improvement equation more complex than it need be. Before we can get on to steady measurable improvement, we need to sweep a few more of these myths out of the closet.

One of the more pervasive myths in the alpaca industry is, ***'The best way to select elite breeding stock is by analyzing their phenotype.'*** It is closely followed in importance, by the myth that ***'pedigree equals breeding value.'*** I think is it is fair to say that breeders' faith in pedigree often takes on mythic proportions, but their faith is not born out of the science of genetics. In this article, I hope to persuade you that the true path to breed improvement is through the progeny test. But, before I get to that we need to critically analyze the role that phenotype and pedigree play in breed improvement programs.

Phenotype is at least 50% environment, nurture and husbandry. Add that fact to Mendel's laws of inheritance, which states that dominate genes express themselves and recessive genes hide from view and you can see why phenotype is a poor guide to breeding value. If we are to breed for ideal alpacas, we must have a dependable method of determining which animals will pass on superior traits in predictable fashion. Simply analyzing an alpaca's phenotype as a guide to the animals breeding value is an entirely ineffective improvement strategy. In fact assessing an alpaca's phenotype to determine whether it will have high breeding value is one of the least reliable methods of selection.

Pedigrees document ancestors beautifully but are only of marginal assistance when being used to identify alpacas that will breed true. The great-grandsire of any given alpaca contributes 1/8th of his genes to the total genetic makeup of the grandson or daughter, when bred, the grandson or daughter, will pass on 1/16 of the great grandfather's genes. A grandsire contributes only 1/4 of his genes. The sire contributes 1/2 of his genes to the cria and 1/2 are acquired from the sire's dam.

The fact is that selection based on a pedigree as the sole selection criteria, assuming a 30% heritability factor, is from 38 to 55% accurate. This means if you use the pedigree to make breeding decisions you will be right about 40 to 50% of the time. When you add the measurements of an individuals phenotypic traits—records for fleece density, micron count, staple length and so on-- to

your analysis the accuracy of selection increases to about 61 to 67 percent. However, if you add sufficient production records of the ancestor's progeny to your analysis the ability to predict selection improvement increases to near 100%.

SELECTION BY PEDIGREE

Many alpaca breeders in the United States use pedigree as a primary selection tool. A pedigree is a record of an animal's ancestors that contains more than 30 pieces of specific information about an alpaca's heritage. It is an important record for people who breed "pure bred" stock. But, as we have discussed above, and will discuss below, the value of pedigree as a selection tool to determine superior stock, is vastly overrated by most alpaca breeders. There is simply too much that a pedigree does not tell you about an alpaca.

Before we analyze the strengths and weaknesses of a pedigree we need to understand how different breed registries record pedigrees: 1) by ancestor exclusively and completely; 2) by selected ancestor; and 3) by ancestor together with production records. Each method can paint a different picture of the breeding value[1] of a particular animal.

PEDIGREE BY ANCESTOR

The American Kennel Club (AKC) registers dogs based on the owner's unverified representation of parentage. This practice encourages mistakes and makes the pedigree less reliable as a predictor of the quality of a dog's offspring. The International Alpaca Register of Australia (IAR), on the other hand, blood types the male but not the female. This means the male parent identified in a pedigree is always accurately described.

The Alpaca Registry Incorporated (ARI) is the registry of record for American alpaca breeders. The ARI registers any and every offspring presented by the owner as a progeny of registered parents, irrespective of quality. In an ARI pedigree, both of the alpaca's parents are scientifically verified by DNA testing and therefore, 100% accurate.

The ARI pedigree is a particularly valuable piece to the alpaca-breeding puzzle for several reasons. First, a pedigree is a necessary tool when using two of the five classic livestock mating systems: inbreeding/linebreeding or outcrossing by pedigree (See, Alpacas: Synthesis of a Miracle). Second, an alpaca cannot be registered unless it is the proven progeny of a previously registered parent. Third, unless most or all of the animals of a breed are registered it is difficult to progeny test on an across herd basis, and progeny testing is the most effective way to select elite alpaca. Fourth, the value of a registered alpaca is far greater than an unregistered alpaca. Finally, an owner cannot show an alpaca without a pedigree.

[1] Breeding value: 1) the value of an individual as a (genetic) parent; and 2) the part of an individual's genotypic value that is due to independent and therefore transmittable gene effects.

PEDIGREE BY SELECTED ANCESTOR

Some registries, primarily those in Europe, register animals based on an independent judgment of the animal's merit. Many registries that register in this fashion must also have their member's proposed matings approved by a "special master" who uses their special knowledge to anoint specific matings. This method of selective registration is undoubtedly the least reliable way, for breeding purposes, to record pedigree. It is also archaic. When only the superior examples of a breed are recorded, the breeder's ability to progeny test and predict the breeding value of a given animal is ambiguous at best.

PEDIGREE PLUS PERFORMANCE RECORDS

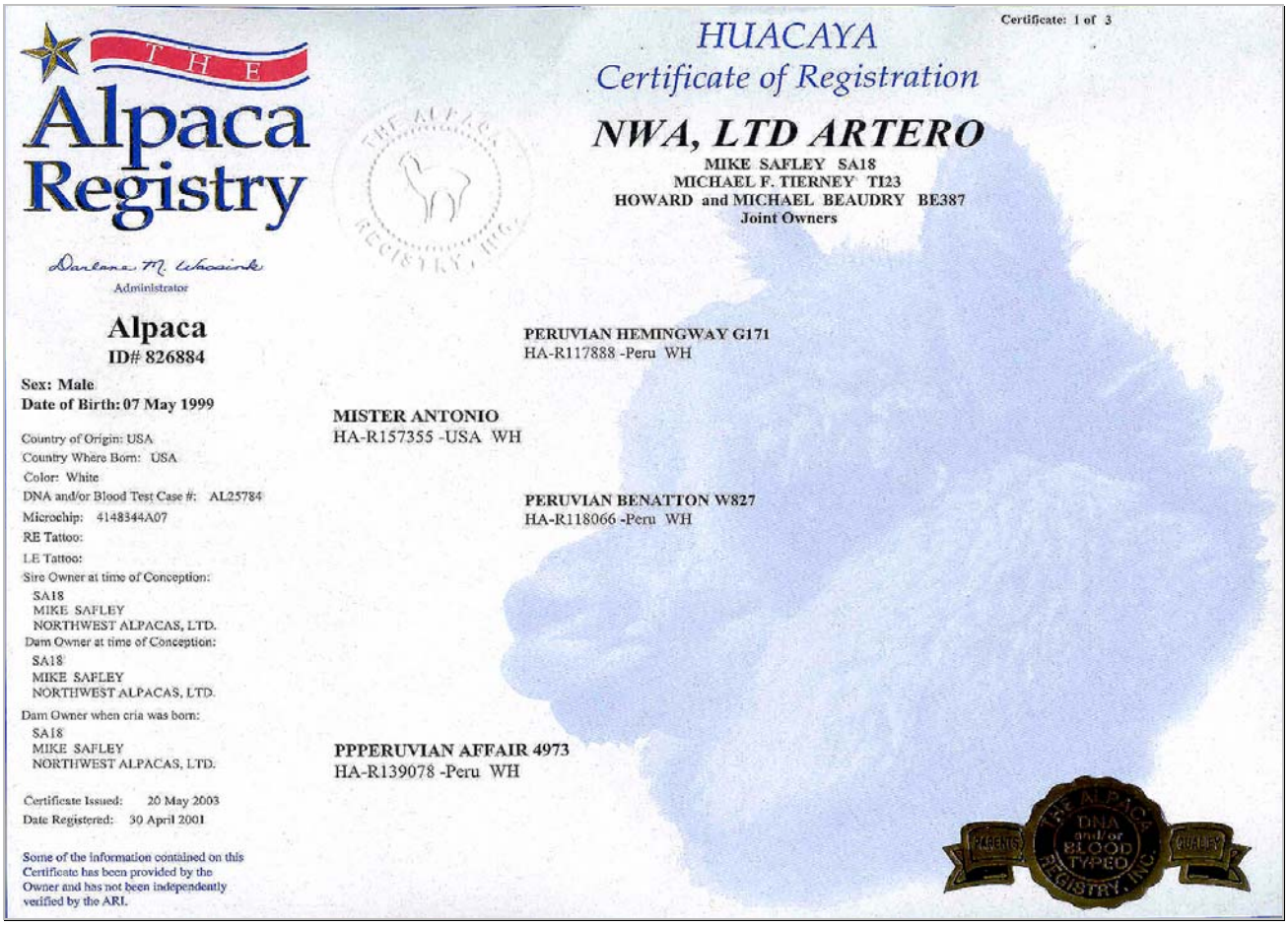
The third type of pedigree includes performance records. Production or performance records, for purposes of this discussion, would include information about an animal's fleece weight, fineness, color, staple length, character, and uniformity. This is by far the most valuable pedigree of all.

The best example of this system exists in the dairy industry where the records for milk production are reported with the individual pedigree. But, as you will see, even a pedigree, which includes the animal's production records, is only about one half as effective as the most accurate methods of predicting breeding value.

THE ARI PEDIGREE

There is a lot to be learned from reading an alpaca's ARI pedigree. Beginning at the top, we will walk through Northwest Alpacas, Ltd. Artero's pedigree (FIGURE 1), and see what it tells us.

FIGURE 1



THE Alpaca Registry

Darlene M. Whosink
Administrator

Certificate: 1 of 3

HUACAYA
Certificate of Registration

NWA, LTD ARTERO
MIKE SAFLEY SA18
MICHAEL F. TIERNEY TI23
HOWARD and MICHAEL BEAUDRY BE387
Joint Owners

Alpaca
ID# 826884

Sex: Male
Date of Birth: 07 May 1999

Country of Origin: USA
Country Where Born: USA
Color: White
DNA and/or Blood Test Case #: AL25784
Microchip: 4148344A07
RE Tattoo:
LE Tattoo:
Sire Owner at time of Conception:
SA18
MIKE SAFLEY
NORTHWEST ALPACAS, LTD.
Dam Owner at time of Conception:
SA18
MIKE SAFLEY
NORTHWEST ALPACAS, LTD.
Dam Owner when cria was born:
SA18
MIKE SAFLEY
NORTHWEST ALPACAS, LTD.

Certificate Issued: 20 May 2003
Date Registered: 30 April 2001

Some of the information contained on this Certificate has been provided by the Owner and has not been independently verified by the ARI.

PERUVIAN HEMINGWAY G171
HA-R117888 -Peru WH

MISTER ANTONIO
HA-R157355 -USA WH

PERUVIAN BENATTON W827
HA-R118066 -Peru WH

PPPERUVIAN AFFAIR 4973
HA-R139078 -Peru WH

THE ALPACA REGISTRY, INC. PARENTS DNA and/or BLOOD TYPED QUALITY

1. Heading: At the very top, we learn whether the alpaca is a huacaya or a suri. We find the name of the animal, the owner of record, the owner's ranch name, address, and owner code. Preceding the name, you might also find the herd identifier code of the person who owned the dam when she was bred.

2. Center of the certificate: Here we find the registered alpaca's ancestors (if known). If the ancestors or the alpaca in question were imported, you will find the country they were imported from, which might be different from where they were born. The center of the certificate also shows what breed the ancestors were, either huacaya (HA) or suri (SA), their registration number, and color. The designation of an ancestor's breed will be important for people who are crossbreeding suris. The information on the color of ancestors will be of interest to breeders concentrating on breeding colored alpacas. If the alpaca was imported, there will be an import number after its name, which was also its ear tag number.

3. The left hand column on the pedigree will tell you the following about the animal in question:

a. Sex
b. Date of birth
c. Country of origin
d. Country where born
e. Color
f. DNA or blood type case number
g. Microchip number, if any
h. Ear tattoo, if any
i. Sire owner at conception
j. Dam owner at conception
k. Dam owner when cria born
l. Date certificate issued
m. Date registered
n. Disclaimer

All of the above information is important but even when taken in its entirety; it is not reliable as a predictor of an alpaca's breeding value. The pedigree should only be regarded as a first step in the selection of superior breeding stock.

THE MYTH OF SELECTING BY PEDIGREE

The critical flaw in using pedigree to select and breed alpacas is that the information most useful to the breeder, from a genetic improvement perspective, is not on the pedigree. ARI pedigrees 1) do not record an alpaca's phenotypic performance statistics; 2) do not identify siblings or progeny; and 3) do not identify prepotency or breeding value. This is why the idea of relying on a pedigree as an effective way to select superior breeding stock is based more on myth than fact.

Craig Wheaton-Smith made the following observation about the use of pedigree in his book Breeding Better Cows (1957).

> "MAKING USE OF PEDIGREE: As things stand the vast majority of our dairy stock are sired by unproven bulls, and quite a few are by bulls proved to be bad (if the proof were fully available) the deficiency of merit being well compensated for by sales technique and management."
>
> "Bulls, then, sold on their pedigrees and widely used before their merits are known, place considerable obstacles in the way of breeding from only the better half of the population."

Wheaton-Smith is not the only one to point out the problems associated with using pedigree as a selection tool. The renowned geneticist Dr. A. L. Hagedoorn had this to say about the value of pedigree in the fourth edition of his famous text, Animal Breeding:

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> "The faith in a beautiful pedigree is often astonishing. I remember how the Dutch agricultural press wrote about the 'breeding value' of a bull sold to a Japanese delegation, in terms that made one think this must have been a bull proven by long lists of exceptionally good daughters. It was said to be a pity that such bulls were sold to foreigners. When the article went on to state that the bull was ten months old, one wondered about the faith Orientals still seem to have in ancestry.
>
> "As long as customers of livestock set great value upon pedigree, it will pay to sell calves and foals and piglets with official papers: but I do believe it is high time that the intelligent breeders themselves should know that the value of such papers is greatly overrated."

Pedigrees can be helpful in locating relatives of families known to have high breeding values for certain traits, and the higher the heritability factor for the trait being selected for, the more one can rely on the ancestor's presence in the pedigree. But, the truth of the matter is that the only accurate way to determine the breeding value or dominance of a particular parent is to research their progeny.

LOOK FORWARD, NOT BACKWARDS

The book The Merino Past, Present and Probable, written in 1943 by H. B. Austin, is chock full of practical, scientifically sound animal breeding advice and the prose never lacks for color. The following paragraph from that book puts into context the perspective necessary when you are looking to improve your alpacas:

> "There is no middle path...between the philosophy of the old 'studmaster' and that of the 'progeny-tester.' The former looks backward. His Breed Associations are built up on the theory of 'pure blood.' The best ram, according to the Merino studbreeder, is the one that has the best pedigree and most show ribbons. More attention is, only too often, paid to ancestors than to descendants. The genetically minded Merino breeder faces forward. He judges breeding stock by the average of the unselected offspring—and mark the word "'unselected."

Keep this in mind when thinking about a pedigree. A pedigree is a record of the past—it never changes. The progeny of our alpaca are the records of the future. They document an alpaca's genotype. The records of a parent's progeny are constantly changing, giving us more information on which to base our selections. Without this information, breed improvement is a low percentage guessing game.

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PERFORMANCE RECORDS

Before we proceed to a discussion of progeny testing a word about performance records. The primary reason that an animal breeder keeps performance records is to track the breeding value of a given dam or sire.

In the alpaca business, these records are most often used to promote a specific animal's quality. You may have noticed the extensive use of a herdsire's histogram to hype the claim that he is potent and wonderful, simply based on his micron count.

An astute observer might also notice that in successive ads, published over a period of time, the micron count never changes. This is physiologically impossible and, aside from being a misuse of the performance record, it should serve to make the point that one can't always believe the hype of a herdsire's potency offered by an owner.

The idea of a "proven" stud is often misunderstood in the alpaca business. Many people take the term to mean that the stud has simply sired a number of defect-free offspring. When a geneticist or a knowledgeable animal breeder uses the term, they mean that the sire has "proven" that he can consistently pass his positive production traits onto his progeny. In other words, he has a high breeding value.

PEDIGREE VERSUS PROGENY TESTING

To make accurate selection decisions about your herd, you must be able to assess the breeding value of a given alpaca – whether or not it will pass its genotype and its phenotypic superiority on to its offspring. To assess a sire's breeding value, you must know how many cria it has and how consistently they express the parent's phenotype. In other words, you must progeny test.

TABLE 1

Differing Progeny Tests (in White Leghorns) of Three Full Brothers, All Mated Successively to the Same Females; Daughters Tested to 500 Days of Age

ITEM	FIRST BROTHER U 2	SECOND BROTHER U 14	THIRD BROTHER U 26
Daughters tested, number	51	40	34
Eggs per daughter, number	226	173	168
Eggs per bird, flock average	200	206	188
Mortality, percent	17.6	25.0	23.5
Died of neoplasms, percent	3.9	0.0	14.7

Source: Data of Hutt and Cole, Cornell University

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We have seen that pedigree alone is a poor predictor of performance. A geneticist will tell an animal breeder that they must assess the progeny of a given ancestor before deciding if the ancestor is the appropriate sire or dam for a large number of their cria. This is known as a progeny test, a test involving multiple matings of an individual animal and a measured evaluation of its offspring that helps predict that individual's breeding value.

Frederick B. Hutt, Professor Emeritus at Cornell University, and Benjamin A. Rasmusen, of the Department of Animal Science at the University of Illinois whose quote, about the "fetish of pedigree," I used at the beginning of this article, proved the value of progeny testing. They measured the breeding value of three white leghorn roosters, each with an identical pedigree, by successfully mating them to the same hens. They then recorded the production of each rooster's progeny. The results of their experiment (Table 1) clearly identify the strength of progeny testing and the weakness of pedigree as a selection method.

Remember, in this experiment the roosters were identical by pedigree, and they were each mated with exactly the same hens. U 2's daughters were obviously superior egg producers and therefore U2 was obviously the superior cock (male chicken). The other two roosters' offspring were sub-par egg producers by a significant margin.

Alpaca breeders need to realize that even full brothers of identical pedigree will have varying breeding values. This is why we spend so much time and effort at *www.alpacas.com* and *www.IdealAlpaca.com* on making information on a parent's progeny available.

TABLE 2

PHENOTYPIC EVALUATION RECORDING FORM

Animal #	Animal Name	Breed	Sex	DOB	Sire Reg. #	Dam Reg. #	Herd #	Fleece Wt.	Fiber Dia-meter	Co/V	SD	Staple or Lock Length	Medul-lation	Curva-ture	Spinn-ing Fine-ness	Bite	Height	Weight	Confor-mation
1																			
2																			
3																			
4																			
5																			

This data could be compiled in paper records but ideally it would be stored in an electronic spreadsheet and filed by year for every animal in the herd. A second report could be compiled from these records as an individuals record by year. If stored in a database program the records could also be queried by dam, sire, sibling or characteristic trait.

Progeny testing for alpacas involves using a phenotypic evaluation form to evaluate the phenotype of a stud's offspring for such important traits as, fleece weight and fineness. Other

heritable traits such as size and bite can also be scored. See the sample Phenotypic Evaluation Recording Form, Table 2. (For a full discussion of selection, see *Alpacas: Synthesis of a Miracle*, Chapter 4.) The records that are gathered on phenotype evaluation forms or from the breeder's production, records become the basis for establishing Expected Progeny Differences (EPDs). Evaluating only the outstanding cria is not sufficient. EPDs allow the comparison of breeding values between multiple herdsires.

In addition, to be accurate, progeny testing must be done in an environmentally neutral manner. This means that all the sires whose cria are examined must have been raised in similar circumstances with similar feed and care, or there must be multiple records from animals raised in diverse environments for each of the sires being compared.

GET-OF-SIRE

Alpaca shows have a class, called Get-of-Sire, where three offspring of a herdsire are shown together as a single entry. This is an example of a form of progeny testing that can be misleading. The problem with this method of assessing the male's breeding value is that you have a very restricted view of the male's cria. In this instance a males lesser quality cria are left out of the test and the result lacks credibility.

As a breeder, looking to purchase a replacement herdsire, would you rather base your buying decision on the three selected offspring that an exhibitor brought to a show or a complete survey of the cria from the stud's production? The bottom line is that for progeny testing to be effective the majority of a stud's production must be measured and the records analyzed.

SUCCESSFUL PROGENY TESTING

Many livestock industries have successfully adopted progeny tests. Prospective bulls breed dairy cows, their daughters are milked to determine volume, and fat content before the bull is put into general service. Boar pigs are bred to a limited number of sows to determine their influence on litter size, survivability, and weaning weight before they are widely used. The same system is employed in poultry breeding operations.

Progeny testing is not just a strategy for large breeders. Small breeders can use the concept to choose service sires for outside breeding. Purchasers can use it to select foundation-breeding stock. If employed industry wide or across multiple herds, the rate of genetic gain would accelerate dramatically.

PROGENY TESTING AND HERD IMPROVEMENT

Once breeders have established their herds, how can they use progeny testing to improve their cria?

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The most important decision any breeder makes is when they select the male that will breed their females. The next most important decision is when they select a replacement male.

To make these selections successfully you must breed a prospective male alpaca to between 10 to 20 females. Then you must assess the progeny of the prospective herdsire before using the male across a large number of females. If you decide to use a male owned by someone else, you should inspect its progeny. To succeed, progeny testing must be rigorously applied. It is of little value if a breeder measures only the best cria or only cria from his best dams.

Once this testing method is used to evaluate several males, breeders can select superior animals as studs and avoid using the males with low breeding values across their herd. The males they finally choose, and which they most frequently use, will have higher breeding values as will their offspring over time. In this manner, the herd's quality will rapidly compound.

EVALUATING THE ACCURACY OF BREEDING VALUE PREDICTION BASED ON PEDIGREE, PHENOTYPIC PERFORMANCE, AND PROGENY RECORDS

We have discussed the relative value of pedigree as a selection tool, adding performance or production records to an individual's pedigree information, and finally the importance of analyzing the performance records of an individual's progeny before selecting breeding stock. Making good decisions about improving their livestock is what everyone wants. We must avoid the poor producers as sires.

To make my point with the utmost of clarity, I am going to rely on the following excerpt from *Understanding Animal Breeding* by Richard M. Bourdon, Prentice Hall, 1997 (pgs. 228-230). Study this material carefully. It is the key to selecting and breeding the ideal Alpaca.

> "As you might guess, the weighting factors needed for a selection index[2] involving multiple sources of information, vary depending on the amount and relevance of data from each source. For example, if an animal has extensive pedigree data and a performance record of its own, but little progeny data, we expect that in calculating that animal's EBV [*estimated breeding value*], most of the emphasis will be placed on the pedigree and the animal's own performance information. On the other hand, if the same animal acquires vast amounts of progeny data, we expect the emphasis to shift to that source of information. Progeny data, after all, provide the ultimate test of an individual's breeding value. When simultaneous equations are used to solve for selection index weights, each weight automatically reflects the appropriate amount of emphasis that should be placed on its corresponding source of information.

[2] Selection Index: A linear combination of phenotypic information and weighting factors that is used for genetic prediction when performance data comes from generally similar contemporary groups.

TABLE 3

Proportional Emphasis Placed on Different Sources of Records Used for Predicting Breeding Value When Numbers of Records Vary[a]

Number of Records				**Proportional Emphasis**				
IND	PHS	MHS	PROG	IND	PHS	MHS	PROG	ACC
Pedigree data only:								
0	10	2	0	.00	.76	.24	.00	.38
0	200	2	0	.00	.87	.13	.00	.52
0	400	4	0	.00	.80	.20	.00	.55
Pedigree and own performance data:								
1	10	2	0	.71	.22	.07	.00	.61
1	200	2	0	.54	.40	.06	.00	.67
Pedigree, own performance, and progeny data:								
1	10	2	10	.30	.09	.03	.58	.77
1	200	2	10	.27	.20	.03	.50	.79
1	10	2	200	.03	.01	.00	.96	.97
1	200	2	200	.03	.02	.00	.95	.97

[a] IND = individual; PHS = paternal half sibs; MHS = maternal half sibs; PROG = progeny; ACC = accuracy of prediction; h^2 = .3

You can think of this as the "magic" of simultaneous solution of equations. Table 3 has been constructed to illustrate some aspects of this mathematical magic.

Listed, in Table 3, are decimal proportions representing the relative emphasis being placed on particular sources of information for breeding value prediction. Each row represents a different scenario, with each scenario involving different amounts of data on individual performance (IND), average performance of paternal half sibs (PHS), average performance of maternal half sibs (MHS), and average performance of progeny (PROG). The measured trait is assumed to be non-repeated (animals may have only one record apiece) with a heritability of .3.

The rows (scenarios) in Table 3 are grouped in three sections. The first three rows represent situations in which only pedigree information is available on an individual. Perhaps the individual is not yet born, or is too young, to have a performance record of its own. The next two rows reflect combinations of pedigree and own performance information. The last four rows combine pedigree, own performance, and progeny information—data that would be available

only on an older animal. Note that accuracy of breeding value prediction (right-hand column) increases with additional information.

The scenario depicted in the very first row represents a modest amount of pedigree information. The dam of the *individual of interest*—the individual whose breeding value we are predicting—has two previous offspring, and the sire is probably young, having only 10 other progeny. More emphasis is placed on paternal than maternal sib records because there are more paternal sib records, but altogether there is little information to go on, and accuracy is low (.38). In the second row, the sire of the individual of interest, having 200 progeny records, is well evaluated. The emphasis on paternal sib information increases accordingly, and accuracy is higher.

In row three of the table, numbers of records have been doubled. The number of paternal sib records increases from 200 to 400, and the number of maternal sib records increases from two to four. Despite the much larger increase in the number of paternal sibs, the relative emphasis on paternal sib *decreases*. This is because the paternal side of the pedigree is already well established. With 200 progeny, the breeding value of the sire of the individual of interest is predicted with high accuracy, and adding 200 more progeny will not help a great deal. The dam's side of the pedigree, on the other hand, is the "mystery" side. With only two offspring, we know little about her breeding value. Adding two more offspring may not seem like much of an improvement, but those two records provide information on a part of the pedigree where there was little before. Scarce information carries more weight per record than abundant information.

Accuracy of breeding value prediction based solely on pedigree information is not very high. In the examples in Table 3, accuracy peaks at .55 in row three. As explained in the discussion of single-source predictions, pedigree data cannot account for Mendelian sampling. A pedigree estimate [a genetic prediction based solely on pedigree data] is useful as a best first guess, but we cannot expect it to be reliable.

"Rows four and five of the table combine pedigree information with the individual's own performance record. Because the trait is moderately heritable (h^2 = .3), the individual's own record carries considerable weight—71% when there is little pedigree data and 54% when there is an abundance of paternal sib data. The individual's record is just one record, but it is a record on the individual's closest relative (itself), and it reflects the Mendelian sampling of genes; it tells us something about the value of the genes that the individual actually received from its parents.

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> "The last four rows of Table 3 incorporate all three kinds of information: pedigree, own performance, and progeny data. Note the relative importance of progeny data, even when progeny numbers are small. With large numbers of progeny (last two rows), other sources of information become practically inconsequential, even when they are represented by many records. And with enough progeny data, accuracy of prediction is very high--.97+ in this example."

If you will study the material above from Bourdon's book, you cannot escape the following conclusions:

1. Pedigree alone is the least reliable way to select for breeding stock with high breeding value.
2. Incorporating an animal's own phenotypic performance records with the animal's pedigree information adds accuracy to decisions about which animals should be parents.
3. Adding the phenotypic performance records of an ancestor's progeny to the available information is crucial to making highly accurate selection decisions.

Breeders who incorporate the information gleaned from progeny testing into their mating decisions will experience a steep improvement curve within their herd. The myth that ***'pedigree equals breeding value,'*** or that, ***'the best way to select breeding stock is by analyzing their phenotype'*** will no longer be a roadblock to breed improvement. The increased quality herd wide will quickly compound and be reflected in fleece weights, fiber fineness and other quantifiable economic and conformation traits. The gains made over three to four generations will be dramatic.

There are several factors which inhibit the ability of breeders successful deployment of the factors described above. They include average herd size, a poor central record-keeping facility, lack of shared records, and lack of access to progeny tested males. In another article I will explain how breeders can overcome these obstacles.