

Homozygous Suris: What are the Odds? A Suri Breeders' Guide to Probability

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"In animal breeding there is just now starting the same revolution in methods that was in full activity about 1910 in plant breeding. We are fighting conservatism and ignorance, especially among the men who have been looked up to as authorities in these matters. We have to help the breeders to discard some of the same wasteful and stupid methods that the old school of plant breeding used."

Dr. A. L. Hagedoorn, "Animal Breeding", 1939

It was in 1997 when Dr. Raul W. Ponzoni of the South Australian Research and Development Institute released his paper titled "Phenotypes Resulting From Huacaya by Huacaya, Suri by Huacaya and Suri by Suri Alpaca Crossings", stunning the alpaca industry.

He wrote it together with D.J. Hubbard, R.V. Kenyon, C.D. Tuckwell, B.A. McGregor, and G.J. Judson, and made the amazing claim that "The results indicated control by a single gene (or by an haplotype), and dominance of the allele responsible for the suri type (*AIFs*) over that responsible for the huacaya type (*AIFh*)."

In other words, suri fleece type was dominant in alpacas. Up until that time, it was the widely held belief that the huacaya fleece type was dominant over the suri fleece type. How else to explain the fact that there were about ten to twenty times as many huacaya alpacas in the world than suris? (In his paper, Dr. Ponzoni believed suris to comprise 10% of the alpaca population; others believe it to be only 5%.) If the suri allele is dominant, why weren't there more suris? Could Dr. Ponzoni really be serious?

We know now that with their exposed backlines, suris are more at risk to weather conditions in the high Andes. Their fiber is also more difficult to process, thus making them less desirable to native breeders. We also know that unlike dog breeds, when suris and huacayas are mated together, their fleece types remain distinct. In *"Animal Breeding and Production of American Camelids"*, Rigoberto Calle Escobar wrote that "Notwithstanding the fact that the Suri and Huacaya varieties have been bred in complete promiscuity for several centuries, it is true that each has kept its ethnic features perfectly defined and differentiated.

"Barreda rightly says 'that it is a real miracle' that the ethnic features are still presented for both varieties, when from remote epochs, and even to date, both have been bred mixed and together. This type of breeding can still be seen today in alpaca raising in farms that are relatively advanced in Puno, Peru."

Before he died, Don Julio Barreda realized that it was not a miracle, but simply a matter of genetics. In the Introduction to *"The Alpaca Colour Key"*, Elizabeth Paul described how she used a fluorescent phase microscope at the Dept. of Biotechnology and Environmental Biology at RMIT

University for pigment studies, and concluded that "Suri and huacaya alpacas are two fleece forms of the same animal; there is no difference as far as colour genetics is concerned".

Reinforcing Dr. Ponzoni's conclusion of a single gene governing alpaca fleece TYPE is a passage by Prof. Jay L. Lush, from *"The Genetics of Population"*: "Natural selection will surely have favored the simpler and less vulnerable pathways. ... These considerations make it not surprising that many of the characters which show a clear-cut monofactorial Mendelism are minor external details of color or conformation ..."

To illustrate how the alleles work in practice, the best way is to use a Punnett Square. If we assume that there is an allele for suri fleece that is dominant, it would be shown as "S". The recessive huacaya gene would normally be shown as "s", but to help clarify how the alleles interact, I will label it as "h". In *"Basic Genetics For Camelid Breeders"*, Dr. George Saperstein wrote that "A dominant trait will be expressed when the offspring inherits one or two dominant genes in a pair. A recessive trait will only be expressed when the offspring inherits both recessive genes." The following Punnett Square shows all the possible ways the 4 alleles could combine if a homozygous suri male were mated to a huacaya:

		Huacaya female (hh)	
		h	h
Suri male (SS)	S	Suri cria (Sh)	Suri cria (Sh)
	S	Suri cria (Sh)	Suri cria (Sh)

A heterozygous suri male mated to a huacaya produces a different set of probabilities:

		Huacaya female (hh)	
		h	h
Suri male (Sh)	S	Suri cria (Sh)	Suri cria (Sh)
	h	Hua. cria (hh)	Hua. cria (hh)

We need to define some terms; Dr. Wayne C. Jarvis presented a simple explanation of the basic concept we are dealing with in *"Genetics 101"*: "when the alleles are the same, this condition is called **homozygous**. When the alleles are different, it is called **heterozygous**."

In *"Understanding Animal Breeding"*, Richard M. Bourdon writes that historically the term "F₁" referred to the first cross of two purebred populations. More recently, it has taken on a broader meaning, signifying the first cross of two unrelated populations whether they are purebred or not."

So with regard to suris, a progeny from a suri and a huacaya is an F₁. It is now generally accepted that an F₁ mated to another F₁ will produce an F₂ offspring, even if they are not brother and sister. In the first example above, all possible outcomes result in a phenotypical suri cria, and all would be considered to be F₁s, while the second example shows that the odds are 50% of producing an F₁ suri, and 50% of producing a huacaya.

Dr. Andy Merriwether wrote on an alpaca forum about F₁ suris: "Suris out of suri-huacaya crosses are very variable and you cannot make any assumptions at all about what kinds of fleece they will have. Some have taken championships. They are no different whatsoever genetically from any other heterozygote suri, of which a large percentage of the US herd already is." We know that many of the suris exported to both Australia and North America, especially the colored suris, were a result of just such a mating. So what happens when these alpacas arrive in their new homes, and are mated to other heterozygous suris? This explains the possibilities:

		Suri female (Sh)	
		S	h
Suri male (Sh)	S	Suri cria (SS)	Suri cria (Sh)
	h	Suri cria (Sh)	Hua. cria (hh)

It shows that there is a 25% chance of producing a homozygous suri cria, a 50% chance of producing another heterozygous suri cria, and a 25% chance of producing a huacaya.

"Backcrossing" is defined by Prof. Bourdon as "The mating of a hybrid to a purebred of a parent breed or line". To increase the number of homozygous suris, alpaca breeders should plan to mate their heterozygous suri females to a known homozygous suri male. The progeny would be a BC₁. This Punnett Square illustrates the possible outcomes:

		Suri female (Sh)	
		S	h
Suri male (SS)	S	Suri cria (SS)	Suri cria (Sh)
	S	Suri cria (SS)	Suri cria (Sh)

It shows that the progeny would be a phenotypical suri, but the odds are 50% that it would be homozygous, and 50% that it would be heterozygous. The last two examples, taken together, show that anytime you mate two suris together

and produce a huacaya cria, both the male and female are heterozygous. Only the recessive huacaya allele from each could combine to create a huacaya fleece.

Conversely, two huacayas mated together can only produce a huacaya. The very few examples of suris out of two huacayas reported in the Australian and North American registers have been proven to be recording errors.

Obviously, you need a homozygous suri male as a stud sire in order to backcross and reliably produce more homozygous suris (remembering that homozygosity for fleece TYPE has absolutely nothing to do with fleece QUALITY). At present, Alpaca Genomics Australia Pty Ltd has given a grant to the University of Melbourne to develop a homozygous suri genetic test. But until that project is finished, how does one go about discovering whether a particular suri male is homozygous or not?

The easiest and quickest way is to test mate him to huacaya females, and see if he produces any huacaya progeny. If he does, you know immediately that he is heterozygous, and not homozygous. But how many is enough to give you a feeling of confidence?

Returning to Prof. Bourdon's book, he gives us an equation which provides us with an answer:

"Let

n = the number of "successful" matings -- successful in the sense that an offspring results.

$P[D_n]$ = probability of *detection* of n matings -- i.e., the probability that at least one homozygous recessive offspring will be born given n matings. This is our level of confidence in the test.

P_{BB} = probability that a mate is homozygous dominant at the locus of interest.

P_{Bb} = probability that a mate is heterozygous at the locus of interest.

P_{bb} = probability that a mate is homozygous recessive at the locus of interest.

"Then

$$P[D_n] = 1 - (P_{BB} + \frac{1}{2}P_{Bb} + \frac{1}{4}P_{bb})^n$$

Applying the formula to alpacas, P_{BB} would be the probability that the females were homozygous, P_{Bb} the probability that the females were heterozygous, and P_{bb} the probability that they were huacayas. Substituting "S" for "B" and "h" for "b" might make the equation easier to understand. (In the examples that I show, the probabilities will be from 0 to 1, with numbers in between expressed as decimals.)

(Note: from this point on, a scientific calculator is needed. I downloaded one from Microsoft "Power Toys", but a Google search for "free scientific calculator" will turn up many others.)

Some people say that mating your male to 7 huacayas will give you sufficient confidence in his homozygosity. Here is how they came up with that belief:

$$P = 1 - (0 + \frac{3}{4}(0) + \frac{1}{2}(1))^7$$

$$P = 1 - (0.5)^7$$

$$P = 1 - 0.00781 = 99.2\%$$

Notice that the probability the females are homozygous suris (P_{BB}) is 0, the probability they are heterozygous suris (P_{Bb}) is also 0, but the probability that they are huacayas (P_{bb}) is 1.

If all 7 crias were all suris, 99.2% would make me feel confident that the male is homozygous, but what if we instead mated him to 9 huacaya females?

$$P = 1 - (0 + \frac{3}{4}(0) + \frac{1}{2}(1))^9$$

$$P = 1 - (0.5)^9$$

$$P = 1 - 0.00195 = 99.8\%$$

That increases the probability / confidence to nearly 100%. It is important to remember that from a statistical point of view, a suri can be PROVEN heterozygous, whereas it can NEVER be proven homozygous (without a yet to be developed genetic test). If a suri (male or female) has just ONE huacaya progeny, it has been proven to be heterozygous. Which is why it is said that some North American suri owners have buried their huacaya progeny, rather than register them.

By doing enough test matings, the probability can APPROACH 100% that a male is homozygous (e.g. 12 matings to huacayas that produce all suris is a 99.976% probability), but it can't be proven.

Instead of huacayas, what if the suri male were mated to suri females, but we didn't know if they were homozygous or heterozygous? If we were to assume that the odds were that 30% of the suris were homozygous, and the other 70% were heterozygous, this is what the equation would look like if we randomly selected 15 suri females:

$$P = 1 - (0.3 + \frac{3}{4}(0.7) + \frac{1}{2}(0))^15$$

$$P = 1 - (0.3 + 0.525)^15$$

$$P = 1 - 0.0558 = 94.4\% \text{ probability / confidence}$$

However, if we change the assumptions around, and say that 70% of the suris were homozygous, and the other 30% were heterozygous, the result becomes:

$$P = 1 - (0.7 + \frac{3}{4}(0.3) + \frac{1}{2}(0))^15$$

$$P = 1 - (0.7 + 0.225)^15$$

$$P = 1 - 0.3105 = 69\% \text{ probability / confidence}$$

This illustrates that as suris as a group become more homozygous, more females are required to improve the confidence level that a particular suri male is homozygous.

If the population is totally homozygous, then no amount of matings would prove that the male is homozygous:

$$P = 1 - (1 + \frac{3}{4}(0) + \frac{1}{2}(0))^n = 0.$$

A corollary to this is as the percentage of homozygous suris (SS) increase, it is more difficult to totally remove heterozygous suris (Sh) from the population. Prof. Bourdon tells us why in his book by giving us an example. (When reading this, substitute "suri" for "black coat color", and "huacaya" for "red coat color")

"In contrast, if you select *against* a completely recessive allele, progress is fast until the recessive allele becomes relatively rare. At that point, most recessives "hide" in heterozygotes. They remain there undetected, resistant to selection.

"Black/red coat color provides a classic example of how difficult it is to select against a completely recessive gene. For many years, Angus breeders in the United States considered red coat color to be a genetic defect and culled red animals from their herds. Still, they were never successful in eliminating the red gene, and it remains at low frequencies in the Black Angus population to this day. Figures 6.7 and 6.8 explain why. They also explain why so many recessive genes for those true genetic defects, despite strong natural and artificial selection against them, still persist in animal populations."

To summarize, the quickest way to test a suri male for homozygosity would be to mate him to a group of huacaya females. The next best way would be to mate him to known heterozygous females. The least effective way would be to mate him to randomly selected suri females.

If we wanted to test our suri male against a mixed group of suris and huacaya females, the equation becomes a little more complex, in that the results for each group are multiplied together. An example I was asked about had one group of 7 known heterozygous suri females (F_1 females produced by previous suri/huacaya matings), and a second group of 6 huacaya females. This is the equation:

$$P = 1 - ((0 + \frac{3}{4}(1) + \frac{1}{2}(0))^7 \times (0 + \frac{3}{4}(0) + \frac{1}{2}(1))^6)$$

$$P = 1 - ((0.75)^7 \times (0.5)^6)$$

$$P = 1 - (0.1335 \times 0.0156) = 1 - 0.00208 = 99.8\% \text{ probability / confidence}$$

Let's take this one step further; what if we decided on the confidence level that we wanted? How many matings would it take to a randomly selected group of suri females to achieve that level in the male? Prof. Bourdon gives us the same original equation for one uniform group of mates, but solved for a different variable:

$$n = \log(1 - P) / \log(P_{BB} + \frac{3}{4}P_{Bb} + \frac{1}{2}P_{bb})$$

or, in suri terms,

$$n = \log(1 - P) / \log(P_{SS} + \frac{3}{4}P_{Sh} + \frac{1}{2}P_{hh})$$

Let's assume again that 30% of the suris were homozygous, and the other 70% were heterozygous, and

we wanted to achieve a 99% confidence level for our male. (99% gives you a 1 in 100 chance that he is not heterozygous -- 95% gives you a 1 in 20 chance.) How many randomly selected females would he have to be mated to in order to achieve that level? Solving this equation tells us:

$$n = \log(1 - 0.99) / \log(0.3 + \frac{3}{4}(0.7) + \frac{1}{2}(0))$$
$$n = \log(0.01) / \log(0.3 + 0.525) = -2 / -0.0835 = 23.95$$

Since alpacas don't come in fractions, we would need to mate the male to 24 suri females and produce 24 suri crias. However, if we again change the assumption to 70% of the suris were homozygous, and the other 30% were heterozygous, the result becomes:

$$n = \log(1 - 0.99) / \log(0.7 + \frac{3}{4}(0.3) + \frac{1}{2}(0))$$
$$n = \log(0.01) / \log(0.7 + 0.225) = -2 / -0.0339 = 59$$

By changing the assumption, we would need nearly 2½ times as many matings to achieve the same level of confidence.

After all these computations, I believe that the most important point to remember is that fleece QUALITIES, such as fineness, uniformity, density and luster, are influenced by genes unrelated to the one which governs fleece TYPE.