Lethality of the gray gene in alpacas.

by Elizabeth Paul

Introduction:

Having fallen in love with the first gray alpaca I ever saw, I was told by the owner, when I enquired about breeding more of them, that grays did not breed true. That sparked my interest to find out why, and I have been studying the situation with grays ever since. I hope these notes will be of interest and assistance to other gray breeders. I have included a few explanatory notes on the structure of the Australian database.

Gray in Alpacas:

In alpacas, the gene which produces grey appears to be a single dominant gene, but it is not a colour gene. It is a pattern and diluting gene. It overlays the base colour to produce the typical white face, neck and legs of a gray, but it needs a dark colour base to clearly express the diluting effect. The pigment granules are shifted over to one side of the fibre in little clumps, connected by swirls of other granules. This allows more light to pass through the fibre and creates the diluted effect, which is very similar to that of merle in dogs. It should be noted that the gray saddle fibre is a mix of diluted and dark fibres, not dark and white fibres. Guard hair on a gray eg down the back of the neck, is fully dark.

The most typical expression has a full white face, which ends around the ear line. The ears and topknot stay darker, giving the effect of a coloured "bonnet" which frames the face. The white usually continues under the chin down the front of the neck to the brisket, or it may be restricted to just the face, giving a baldy faced look. Occasionally the white may extend over the ears, around the back of the neck as far down as the withers, making a very pale gray. There is usually still a little patch of the base colour, between the ears, as the bonnet. Eye colour can also be affected, producing a blue flash, half blue or full blue eyes in one or both eyes in gray alpacas. Some gray alpacas may also have dark eye rings, giving a very striking effect in the white face.

The base colours are black, which produces silvergray, and dark brown or mahogany bay, which produces rosegray. Some lighter fawns with white faces, especially if they have the "bonnet" effect, can also be rosegray, but the diluting effect on the lighter base colour is lost. Most typical grays should therefore be considered as part of the dark colour herd. Many grays have some spots of the base colour, but there is great variation in the number, size and location of any spots.

It must be clearly understood that gray progeny can only be produced, when at least one of the parents is carrying the gray gene. If two apparently non-gray parents produce a gray pattern cria, then at least one of them must be carrying for the gene, however unlikely that may seem.

Lethal Genes:
A lethal gene is a dominant gene which is lethal in the homozygous condition, meaning that an embryo with the homozygous condition will either not be born, or will die at birth. An example of this is roan in horses, where the roan pattern is controlled by a dominant allele R. Roan horses have the genotype Rr, and in a mating between two roans, the expected normal Mendelian ratio of 3 roans to one non-roan does not occur. The ratio is two roans to one non-roan, ie only 66% roan instead of the expected 75%. In studying breeding results, the 66% ratio is taken as an indicator that the gene in question could be a homozygous lethal.

Colour Chart:
In the Australian colour registry, only the colour of the blanket or saddle fleece is considered when determining a gray. No mention is made of including white faces or legs in classification. The colour classifications are Light Gray, Medium Gray and Dark Gray, to encompass all shades of silver gray; and Rosegray/Roan, which obviously includes any shade of roan as well. Presence of coloured spots might be taken into consideration in the showring, but not for registration purposes.

AAA Database:
There are about 75,000 progeny results recorded in the database, which includes both the Australian and New Zealand national herds. These results are recorded in Herd Books, which begin on the first of January and end on the 31st of December for each year. The current Herd Book is No. 15, ending 31st Dec, 2007.

All alpacas registered in the database for that year, appear in the Herd Book, which is not necessarily all the alpacas born during that year. There is always a certain amount of "catch-up" in the following herd book, for various reasons. A cria can only be registered in the database, if both of its parents are also registered, and if the sire is also DNA certified. DNA certification is not required for dams, unless there happens to be a dispute over a crias' parentage, or nowadays for ET records. There is no compulsion to register crias by any particular time, or at all, except a late fee if the cria is past its first birthday at the time of registration. However, most breeders would register their female crias, making the sex ratio about 2/3 female to 1/3 male cria registrations.

Males used for breeding within this system are given certification examinations and listed as certified sires.

Gray in alpacas is the rarest colour, with only about 6% gray progeny being recorded for the database. Only about 11% of all matings recorded involve at least one gray parent, which produce about 30% gray progeny overall. Gray x gray matings represent only about 2.5% of all matings recorded. They produce about 65% gray progeny, with about 15% each of black and dark brown (bay) as the non-gray components. Being essentially dark alpacas, grays produce only very few lighter fawns and whites, and this is consistent with the results of dark x dark matings in the non-gray herd.

'Hidden' Grays:
I am fairly confident that most alpacas listed as gray, actually do conform to the most typical appearance of gray. Australia appears to have very few blackheaded roans, which is a distinctly different pattern to the more usual whitefaced gray. The ones that I know of, (less than 10) were born and registered as black, and turned gray over more than 12 months. The colour registration may be changed by the owner if they wish, but few people probably bother to do this. There are also a number of grays, which do not have the white face, but which have gray fibre running through the fleece, at birth. These would probably be mistaken for blacks, or named as roans, if so they would be listed as RG/Roan.

There would be a few whitefaced fawns, which are possible rosegrays. These would only be confirmed, if they were mated to solid dark colours and threw eg a silvergray. Up to now, most Australian breeders would have registered a whitefaced fawn as Fawn or W/Fawn, or Fancy, because of the emphasis placed on solid colours. No doubt there were also a few dark grays with white faces, registered as Black/white at birth when they were wet.

The sire of my current silvergray sire, is a streaky fawn, most probably a fawn rosegray. The dam of my sire is a solid dark mahogany bay, and she could not have passed on the gray pattern. I have a record of a high profile suri male, also a streaky fawn, which has produced some 30% typical grays from nongray females, over about 140 matings.. This is only possible if he is himself a "hidden" gray. A photo taken when shorn showed that he does in fact have a white face. His dam is mahogany with a white face and feet. His half brother from the same dam, has a white face, white socks, dark mahogany fleece and two full blue eyes. This half brother also has produced two perfect silvergray crias from black dams. Both of

these males, and probably their mother as well, are "hidden" rosegrays.

Generally however, production of gray crias from the non-gray herd, is extremely low, less than 5% of progeny. The main exception is for matings between White, and Black or dark brown, which give up to 7% gray progeny. The whites in these matings are almost certainly blue-eyed whites, which are the other 'hidden' gray source.

Blue eyed whites:
It is impossible to talk about grays, without also discussing blue-eyed white, or bew. Bew is the most extreme, viable form of gray, but it is not homozygous for gray. There is no single gene that produces bew. It appears from the breeding results to be a combination of at least gray and tuxedo patterns, and possibly a third gene from whites. There is little doubt that bew's are almost certain to be completely deaf, as a result of the extreme changes caused to the pigmentation system by this combination. Mating a bew to solid dark mate should break up the combination, and restore the pigmentation. It will mostly produce coloured and gray crias, all of which can hear. While a mating between a gray and eg a tuxedo black, can produce a bew, most bews in fact come white or very light parents. Matings between grays and whites also have a much higher risk of producing a bew.

The most prominent bew sire in our database was a foundation (ie original import) male, who had 34 grey progeny, from dark coloured females, or about 22% grays from 158 mating results overall. His last owner confirmed that he was in fact a bew, whether he was deaf is not known. He was by that time very old and died not long after.

Gray Mating Results:
Table I shows the results of all gray x gray matings listed in the database. I have combined all LG, MG and DG as silver grays SG, and all RG/roans as rosegray RG. Most silvergray alpacas in Australia/NZ would be classified as MG.

Table 1: Progeny Results of All G X G Matings = 1825

Gray	Brown	Black	Fawn	White
1169	272	286	55	43
64%	15%	15.6%	3%	2.3%

Grays produce very few fawn cria, because they are essentially dark. From the herd book results, dark alpacas are very unlikely to produce lighter fawns or whites. There are a few records of white progeny from the older Herd Books, but I have no positive evidence that two typical grays have produced a bew cria.

However, some of the lighter or fawn rosegrays, could produce solid fawn because their colour base is fawn rather than dark. To reduce this event, I have also included the mating results for only silver grays.

Table 2: Progeny Results of SG x SG Matings only = 527

Grey	Brown	Black	Fawn	White
342	43	127	7	9
64.8%	8%	24%	1.3%	1.7%

If both grays are true silver gray, ie black based, then we would not expect brown (bay) crias. Some of these silver greys could be very pale lavender rosegrays, and some are no doubt gray on black bay, giving a silver grey with dark brown underbelly, rather than a silver gray based on blue black. These could account for some of the brown progeny.

For all non-gray x non-gray matings, the sex bias is 35% males registered to 65% females. However for gray x gray matings, the bias is 47% males registered to 53% females. Breeders are more likely to register black or gray male crias, than lighter coloured males.

The following table 3 shows the grouped progeny numbers and colours from G X G matings for 202 gray sires in AAA Herd Book's 4-12.

Table 3. Progeny Numbers and Colours from 202 Gray Sires in G X G Matings

Progeny No's.	Grey Only	Grey +/or NG	%
1-10	62	110	86%
1-20	2	18	10%
21-30	0	5	2.5%
31-40	0	4	2%
41-100	0	1	0.5%
Totals	**64**	**138**	**202**

86% of these gray males have less than 10 progeny registered for G X G matings; and only 36% of these have had only gray cria from G X G matings.

Many of this group had less than 5 progeny registered altogether. 14% of gray males have had more than 11 crias registered, and less than 5% have progeny numbers higher than 20.

All can be shown to be heterozygous for gray, if their G X NG matings are also taken into account.

The following table 4 compares the gray progeny listed for both the gray and nongray matings of ten prominent gray sires. I have also included the colours of each sire?s sire and dam for interest. The last column represents the overall percentage of gray crias from all matings for that sire.

Table 4. Sire Comparison by No's of Gray Crias from both Gray and Nongrey Matings.

Sire	Col	S'S	S'D	GxG	GC	%GC	GxN	GC	%GC	Total	%GC
A	RG	SG	RG	67	44	66%	58	29	50%	125	58%
B	SG	DG	RG	44	31	70%	22	9	41%	66	61%
C	RG	W	SG	41	22	54%	119	33	28%	160	34%
D	SG	W	W	55	35	63%	36	13	36%	91	53%
E	RG	W	W	43	27	63%	45	11	24%	88	44%
F	SG	W	W	35	25	71%	28	6	21%	63	49%
G	RG	SG	RG	31	25	80%	32	18	56%	63	68%
H	SG	W	W	53	29	55%	74	18	24%	127	37%
J	SG	W	W	43	27	63%	8	1	12%	51	55%
K	SG	BK	SG	14	10	71%	20	9	45%	34	56%
Totals				426	275	65%	442	147	33%	868	49%

Note that although several males, with progeny numbers under about 80 have higher gray cria figures, over 80 the figure falls back to around 65%. Note also, the average production of gray crias from all types of matings is around 48%. Note also sires C and H have both produced less than 60% gray crias from gray matings, and less than 40% gray crias overall. Therefore, these two sires would be at the bottom of the list for anyone looking to maximise their chance of a gray cria. Sire K is my previous silvergray sire.

All of these males can be shown to be heterozygous for gray, if their G X NG matings are also taken into account. However, it is not really heterozygosity of gray that is the issue, but whether the homozygous form of gray

is a lethal. Apart from comments by other breeders, I have some breeding results to show that this might be the case.

I had bought a mating to male H above as he was an imported sire, and I would not get the chance again. (This was before I had calculated his strike rate for this table). My first gray female, from two gray parents, mated to male H above, became pregnant three times in succession. Each pregnancy was confirmed by ultrasound, but she lost each one around 3 - 3-1/2 mths. She was then mated to another gray male and carried that pregnancy, producing a gray cria. A second gray female, not related to the first, was then sent to male H. Her mother was gray and her sire was black. She also became pregnant and lost it again at about 3-1/2 months. She also got pregnant to a different gray male immediately afterwards, also producing a gray cria. Neither of these females was a maiden, and both had had previous successful pregnancies. (Just to complete this story, I sent a third female to this male, a brown one, to cut out a possible gray lethal effect -- incredibly, she died of snake bite when about 2 months pregnant, so we gave up!)

I also have a record of a dark gray female which, mated to four different gray males, had failed to carry any pregnancy to full term. Two pregnancies failed early, a third was aborted at a later stage, and one cria was born premature and died. While this is not the usual pattern, she was mated to a black sire this season, and now has a live and healthy gray female cria. The owners will always use a black sire for her from now on.

The following matings for gray are not recommended:
Gray x BEW -- This mating should not be attempted, as this is the most likely combination to create another bew. Bew should be mated to solid dark, preferably black, to eliminate the chance of getting another bew.

Gray x white or very light fawn (cream) -- the most likely result will be a fawn, however there is also a strong possibility of getting a bew.

Gray x light or medium fawn -- most likely darker fawns or light browns, or some whitefaced fawns. Not a great colour match.

Breeders do these matings presumably to improve the fleece quality on a gray cria. Of course, there is nothing wrong with that object, but the chance of getting a typical gray from these matings is very small. The colour base is too light to show gray, the very light mates are less likely to be carrying the very dark genes, and there is increased possibility of bew crias.

Gray x tuxedo -- if breeders are concerned about a possible bew, then I would recommend they not do this mating. However, I have done this mating type quite a few times, usually as gray sire x black tuxedo dam, and have not managed to produce a bew. The usual results are half grays, and half dark crias, which have less white on them, than their mothers. I have also mated gray to white appaloosa, as an experiment, and got two almost white appaloosas, with dark eyes, but again this is not a great match from a colour point of view.

What are the issues?
It could be argued that if gray is a lethal gene, then mating gray x gray is not a great idea. That would be a fair argument, if these matings produced, say, a percentage of deformed crias which could not lead a healthy life and either died in distress or had to be put down. However, a lethal gene which kills the developing homozygous fetus at an early stage of pregnancy, is not a problem in this way. It merely reduces the overall number of progeny.

As far as I know, G x G matings do not produce any particular malformation defect. The problem is then one of monitoring a gray x gray mating more closely to see if the female loses it on a more regular basis. Excessive re-mating might be considered an issue, or breeders might prefer to mate gray females only to black. However, female alpacas of all colours can lose their pregnancies for all sorts of reasons, and have to be re-mated, so I don't really see this as being a big issue.

Conclusions:
The combined breeding results and anecdotes tend to indicate that gray in alpacas is a homozygous lethal. However, mating gray to gray is the best mating to maximise the chance of getting a gray cria -- which is, after all, the point of the exercise. Gray females pregnant to gray sires should be more closely monitored, to check if they have lost the pregnancy. Most gray sires can be relied on to produce 2/3 gray crias when mated to grey females. It could be worth breeders checking the gray strike rate of a gray sire if they can, but usually the numbers are too small or not easily obtainable.

The above are my opinions, based on my own herd and database research. I am happy to discuss them at any time.

Elizabeth Paul
Erehwon Alpacas Aus
Dec 15th 2007