Who's Your Daddy? – Selective Breeding in Goats

This is part of an overview on goat genetics covered during the Goat Genetics and Reproduction Field Day at Cornell University – Sept 20, 2003

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Part 1

Some characteristics that are passed on genetically (inherited) from parents to offspring can be identified as distinct types. For example, you can wonder what color eyes or texture of hair a baby is going to inherit from its parents. When the baby is born you can describe these characteristics as blue eyes, brown eyes, kinky hair, curly hair etc. However, many of the most important characteristics or traits that affect how well we perform in life can't be named by type. Instead, they are a matter of degree. Some examples in humans might be differences among us in height, weight, running ability or reading ability. Some important examples in goats might be the amount of milk a doe produces, the birth weight and weaning weight of a goat kid, the amount of fiber or fleece on an angora goat.

If you measure the size of two people's hands, it is very unlikely that they will be exactly the same and it is very likely that you can find someone else whose hand size falls between them. These traits that vary by degree rather than type are called quantitative traits. They are usually determined by many genes that each have a small effect rather than by just a few genes that have a large effect. They are usually influenced strongly by environment as well as genetics. Many important performance traits in livestock are quantitative traits.

We can often determine what genes for eye color, hair type, floppy ears, etc a pair of parents has by examining a few of their offspring. This is not true of quantitative traits. Instead we usually need information or data from lots of offspring before we can make a good guess at the parent's genotype. Traits like milk yield, mature weight, fleece weight usually have a "normal distribution" in a population. Some goats will milk very little, some goats will milk quite a lot and most goats will be somewhere in the middle. If you plot out the amount of milk given by the number of goats that give that much you will end up with a "bell shaped" plot or distribution.

The first step in evaluating a goat genetically is to try to find out what the "population mean" is. To do this you need to calculate what the average measurement is for the trait in a particular population of goats. For example, the average 305 d milk yield for an Alpine doe on official DHI milk test in 1999 was 2096 lb. We often express the estimated genotype of a goat as a comparison to a population average for a specific year. An Alpine doe with +120 has a genetic value for milk of +120 over the Alpine population for that "base" year. She will pass half her genes to her offspring so her "breeding value" will be +60 lb, half her genetic value. Some of her offspring will inherit her best genes for milk, some will inherit her worse but on average they will gain about 60 lbs of milk from her genotype alone for a 305 d lactation.

Not only is the population mean important but the population distribution is too. For example, let's pretend that when breeding season came around a meat goat breeder bred two bucks, Hercules and Zeus, to his does. The kids from Zeus weighed on average 53 lbs at weaning while the kids from Hercules only averaged 48 lbs. Thus, kids from Zeus averaged 5 lbs more at weaning than the kids from Hercules. The goat producer might conclude that Zeus is a better buck than Hercules. However, some of this depends on how wide a range or distribution there is for weaning weight in his herd and also in the general population. If the distribution is very narrow then 5 lbs of difference will probably mean more than if the distribution is very wide. The distribution or plot of a trait tells us how much animals tend to vary for this trait.

Normally we do not plot out the entire distribution for a trait to get an idea of how much it can vary. Instead we take a measurement called the "variance". Look at Chart 1. If I try to sum up the differences of each kid's weight from the average or mean weight for all the kids in the herd, what happens? The differences sum up to zero, which is no help at all in trying to determine how much weaning weight can vary compared to birth weight. Instead, to get the variance for birth weight you need to subtract the birth weight of each kid from the average birth weight for the entire kid crop and then **square** that difference. You subtract the weaning weight of each kid from the average weaning weight to get the variance for weaning weight. The variance of weaning weight in this herd is 876 lb and the variance of birth weight is 21.5 lb. If Hercules and Zeus's kids differed 5 lbs from each other in birth weight that would be a very big difference between these bucks. It would be very likely that much of this difference is due to genetics. Because the variance for weaning weight is so much more, it is hard to tell if Zeus really is genetically superior to Hercules for this trait. We also do not know if other things besides the genetic make-up of their sire are influencing the size of these kids.

Chart 1. Comparing kids from Zeus and Hercules for birth and weaning weights.

Sire	Kid #	Litter Size/Sex	**Birth Weight**	Mean	Deviation from mean	Dev^2	**Weaning Weight**	Mean	Dev	Dev^2
Zeus	R1	S/M	**8**	7.5	.5	.25	**50**	50	0	0
Zeus	R2	S/M	**7**	7.5	-.5	.25	**46**	50	-4	16
Herc	R3	Tw/F	**8**	7.5	.5	.25	**64**	50	14	196
Herc	R4	Tw/F	**8**	7.5	.5	2.25	**59**	50	9	81
Zeus	R5	S/M	**9**	7.5	1.5	.25	**52**	50	2	4
Zeus	R6	S/M	**8**	7.5	.5	.25	**49**	50	-1	1
Herc	R7	Tw/F	**8**	7.5	.5	.25	**45**	50	-5	25
Herc	R8	Tw/F	**7**	7.5	-.5	.25	**44**	50	-6	36
Zeus	R9	S/M	**10**	7.5	2.5	6.25	**67**	50	17	303
Herc	R10	Trip/F	**6**	7.5	-1.5	2.25	**42**	50	-8	64
Herc	R11	Trip/F	**5**	7.5	-2.5	6.25	**39**	50	-11	121
Herc	R12	Trip/F	**6**	7.5	-1.5	2.25	**43**	50	-7	49
Calculating **overall means** for all 12 kids (total weight) / (# of kids)			90/12= **7.5 lb**				600/12= **50 lb**			
Average weights for Hercules kids			**6.9 lb**				**48 lb**			
Average weights for Zeus kids			**8.4 lb**				**53lb**			
Getting the variances for birth weight and weaning weight					Sums to 0 **NO HELP!**	Sums to **21.5**	Getting the variance for weaning weight	Sums to 0 **NO HELP!**		Sums to **876**

Let's say it turns out that that Hercules' offspring are all doe kids from triplet and twin litters. Zeus's kids are all single buck kids. Are doe kids usually bigger than buck kids at weaning? No, most doe kids tend to be smaller than buck kids at weaning time. Are kids from a triplet litter usually bigger than a kid who is born as a single? No, the larger the litter is the slower the kids tend to grow. The main reason for this is that more kids are sharing the milk from their dam. Look at Chart 1 again. Does this extra information change your opinion of Zeus and Hercules? Suddenly, there appear to be lots of environmental reasons why the kids sired by Hercules are smaller at birth and at weaning than the kids sired by Zeus. Hercules could actually be genetically superior for birth weight and weaning weight.

Traits that have a lot of variance generally have more promise for genetic improvement than traits with little variance. Most Nubian dairy goats only have a little cashmere wool even in the wintertime and their variance for cashmere is very low. The variance of Spanish goats for cashmere is much higher. If you were to try to develop a line of goats with lots of cashmere from one of these populations, the Spanish goat would probably be more promising. However, this genetic potential is also dependent on how much of the differences we observe are due to genetics and how much of the differences are due to environment.

When we compared Hercules and Zeus's kids we could not see their real genotype for weaning weight. Instead of looking directly at their genes, we were judging them by what we could see on a weight scale, i.e., by their phenotype. Let's look at the size of our hands. When we look at our hands we are seeing our "phenotype". But hidden in that hand is a whole history of why that hand ended up the size it is. When we were born we inherited genes from our parents that would help determine what size our hands would be. This is our genotype for hand size. However, what other things can influence the size of our hands? Do females usually have bigger hands than males? Do 5 year olds usually have bigger hands than 10 year olds? Would you expect a person who uses their hands a lot like a violin player or a blacksmith to have a smaller hand than the same person might if they did not exercise with their hands very much? Would you expect a person who was fed poorly as a child to be as tall and have as large hands as they would have with better nutrition?

These are all effects that we need to take into consideration when deciding what sort of genes we actually have for hand size. Some of these, for example, the effect of nutrition, exercise and age on hand size, are considered environmental effects. We might be able to say that good nutrition and manual exercise are positively correlated with hand size. Or that people's hands tend to reach $2/3^{rd}$ of their mature size by 14 years of age. If we can study enough hands we might be able to factor out very accurately these environmental effects. Some of these influences are genetic rather than environmental. If boys tend to have larger hands than girls then we might say that sex and hand size have a positive genetic correlation. We might be able to come up with adjustment factors to factor out the effect of sex. For example, if women have hands that average ¾ the size of men's, we can multiply men's hands by .75 to account for the genetic effect of sex. If people with genes for being tall tend to have larger hands than people with genes for being small, then we would say that the genes for height are positively correlated with the genes for hand size.

Heritability is a word for the proportion of variance or difference you observe in a trait that is due to genetics. Some traits are influenced a lot by genetics. Some traits are influenced a lot by environment as well. You can usually make faster genetic progress with traits with higher heritabilities.

Whenever we evaluate a goat for a trait it is important to try to factor out some of the environmental variance that also affects this trait. Animal breeders usually develop adjustment factors to account for the most obvious environmental effects and genetic correlations when they conduct a formal genetic evaluation. We as goat producers also need to take these environmental influences and genetic correlations into account when informally evaluating our herd sires and breeding does.

Part 2

A herd sire contributes 50% of the genes in a kid crop. His influence is immense. The first step in selecting a buck is to evaluate your herd. What inherited traits are most important to profitability and where is the most improvement needed? What traits do you find yourself having to cull does out of your herd for. Having to cull a doe because of a health, soundness or behavior problem that is so severe that she will not be able to survive in your herd is called involuntary culling. If you have a specific problem that causes a lot of involuntary culling in your herd you want to either improve your management or include it in your genetic improvement plan (unless there is no genetic basis for the problem). Decide which heritable traits to focus on. Remember that genetic improvement usually slows down as you include more traits.

There are many ways to genetically improve a herd. Tandem selection is when you focus on one trait until it's where you want it and then switch to another trait. For example, you might focus on getting meatier conformation on does and later switch to getting more milk. The disadvantage with tandem selection is that progress is inconsistent because it can't consider the relationships between traits. For example, if meatier does also tend to be poorer milkers, then you may actually be selecting your does for opposite traits each time you make a switch.

Another common practice is nonassortative mating. This is when you breed a goat that is weak in some traits to a goat that is strong in the same traits and vice versa. You might breed a goat that is genetically poor in protein percentage but high in milk yield to a goat that is high in protein but low in milk. The disadvantage again is that the relationship between traits isn't considered. Biologically, the easiest way for a doe to give more milk is to dilute the milk resulting in lower protein percentage. Therefore, we say that the genetic traits for milk yield and protein percentage are negatively correlated. Using nonassortative mating doesn't allow you to identify genetically unique goats that produce lots of protein-rich milk.

Two other methods allow you to make faster genetic progress. One way is selecting on "independent culling levels". This is when you only consider sires that meet certain standards for each trait. You might use only bucks who were from twin or larger litters, in the top 5% of their herd for yearling weight, and in the top 10% for overall conformation. The only disadvantage with this method of selection, is that you ignore bucks that may be so superior in one trait that it makes up for all their other deficiencies.

Another way to select bucks is to use a selection index where you weigh each trait by its relative value and then calculate each buck's overall score. One example is the Oklahoma Meat Buck Performance Test. Bucks are scored 30% on feed efficiency, 30% on average daily gain, 20% on rib-eye area, and 20% on rear leg circumference. Selection indices usually result in the fastest progress.

Bucks can be evaluated on their own performance and/or on their offsprings' performance. There are benefits and weaknesses to each of these methods of evaluation bucks.

Performance testing is when bucks are taken to special testing facilities and treated equally and fed individually. It is valuable for traits that are highly heritable, for example, market weight. This is especially true if the goats are tested under the same conditions that they would be tested at home. For example, if you raise your kids out on pasture or browse with only a little grain, a performance test where the goats are penned up and fed a complete ration free choice may not be a rock solid indicator of which buck will grow best back home on your farm. A performance test evaluates an animal's phenotype rather than his genotype. Rather than adjusting for environmental influences, it tries to give all the bucks the same environment for the duration of the test.

Progeny testing is when you evaluate a buck based on his offspring. The buck's offspring need herdmates born in the same kidcrop but from different sires to compare against and you usually need genetic links across more than one herd. It requires good record keeping but is the best way to 1) evaluate traits like litter size and milking ability that are strongly influenced by environment as well as genetics, and 2) predict how well an animal's genetics will perform in a wide variety of herds and environments.

The Pennsylvania Department of Agriculture, in Cooperation with Penn State's Department of Dairy and Animal Science, sponsors a Meat Goat Buck Performance Testing Program. You can contact Glenn Eberly or Greg Hubbard at 814/238-2527 for more information. Other exciting news is that the American Boer Goat Association is initiating a preliminary case study on on-farm genetic testing of Boer goats.