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Cats Like Wool Too!

Maternal Heterosis in Sheep

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Before we talk about maternal heterosis a word about heterosis as such is in order. By definition, heterosis is a term used (usually for animals, for plants the term used is hybrid vigor) to refer to the deviation observed between the performance of crosses from that of their parental breeds. To avoid bias caused by the maternal effects of the breeds, the average of the two reciprocal crosses is compared to the average of the two parental breeds. The value of heterosis can be negative, positive or zero, if the average of the two crosses is lower, higher or equal to that of the parental breeds respectively.

There are three types of heterosis, individual, paternal and maternal. The individual heterosis is associated with the individual himself; it is by how much a crossbred individual differs from the average of his two purebred parents. It is expressed in traits such as growth rate, feed efficiency, fertility, prolificacy, carcass quality and wool production, etc. Paternal heterosis is expressed in traits such as libido, sperm production and quality when a crossbred ram outperforms a purebred ram. Finally, maternal heterosis is the extra advantage a lamb receives from his crossbred dam in the form of higher milking and mothering ability as compared to a purebred dam.

What brings about heterosis? Many theories tried to explain this phenomenon and its opposite phenomenon the "inbreeding depression." None of these theories explain fully the two phenomena. It seems that increasing heterozygosity results in heterosis and increasing homozygosity results in inbreeding depression. Heterosis depends in its magnitude on the degree of diversity between the breeds involved in the crossing, the further apart the breeds the higher the heterosis to be expected.

How can we take advantage of heterosis? The first step, of course, is to cross. In most cases, one breed is superior than the other. If the performance of the cross is not superior than the better of the two parents then there is no point of crossing because no advantage can be obtained. On the other hand, if the breeders raise the inferior parental breed, then crossing is beneficial since the cross will be certainly better than the inferior breed.

Maternal heterosis can be calculated from two sources of crossbreeding programs.

1. When crossbred and purebred parental breeds are available at the same time and mated to:

A. Rams of a third breed (C).

B. Rams of a genotype with 50% of genes from each of the parental breeds (F_1 or F_2).

C. Each female group is mated half with rams of breed A and half with rams of breed B.

The reason for the restriction on the sire to use is to avoid confounding the individual with the maternal heterosis. The calculating equation for maternal heterosis is:

$$hm = \frac{(C \times AB) + (C \times BA)}{2} - \frac{(C \times A) + (C \times B)}{2}$$

2. Maternal heterosis can also be obtained from crossbreeding involving F_1 and F_2 generations. Estimates from such sources are often less accurate because of selection and/or inbreeding when generating F_2 animals; this, in addition that the comparison estimates only half the heterosis and the figure has to be multiplied by 2 to get the actual value.

In the following table maternal heterosis from both sources are presented for some of the economically important traits and compared with individual heterosis estimates.

Table 1. Maternal and Individual heterosis from crossbreeding experiments.

	Maternal Heterosis				Individual	
	Cross vs. Pure		F_1 vs. F_2		Heterosis	
	No. of exp.	Estim. %	No. of exp.	Estim. %	No. of exp.	Estim. %
Birth weight of lambs	12	5.1	1	2.1	42	3.2
Weaning weight of lambs	27	6.3	1	8.8	56	5.0
Ewe body weight	22	5.0	4	11.0		
Fleece weight	14	13.4	3	20.7		
Fertility	30	8.7	3	12.1	20	2.6
Ovulation rate	4	2.0	3	2.2		
Prolificacy	31	3.2	3	17.8	24	2.8
Survival rate	25	2.7	3	14.5	29	9.8
Lamb born/ewe exposed	25	11.5	4	35.5	20	5.3
Lamb reared/ewe exposed	25	14.7			20	15.2
Total weight of lamb reared per ewe exposed	23	18.0	1	51.3	24	17.8

Growth

Maternal heterosis for birth weight and weaning weight (about 5 and 6-7% respectively) was found to be slightly higher than individual heterosis. The physiological basis of this lies in the uterine and postnatal conditions, which are apparently more favorable in crossbred than in purebred ewes.

Reproduction

As in the case of early lamb growth, the physiological basis of maternal heterosis for reproductive performance is different from that of individual heterosis. A reproductive increase observed in two-way crosses is mainly based on a superiority of crossbred lambs in prenatal and postnatal vitality. On the other hand, superior reproductive performance of crossbred ewes is expected to be due to an increase in oestrous and gonadal activity and improved uterine as well as perinatal and postnatal conditions for embryonic and lamb survival. These differences in the physiological basis for maternal and individual heterosis are expressed in the average values of heterosis for the various reproductive traits. Whereas a reproductive increase through individual heterosis was primarily due to improved lamb survival (h^1 = 10%), the main component of maternal heterosis in reproduction is the superior fertility, i.e., reduced barrenness, of crossbred ewes (h^m = 9%). The highest heterosis estimates in fertility have been found in young ewes. It seems, therefore, that the maternal heterosis for fertility includes some gain from heterosis in sexual maturity.

Compared with the mean maternal heterosis for fertility, that for lamb survival and prolificacy is rather low (2.7 and 3.2% respectively). The relatively low heterosis in prolificacy agrees with the results of the few experiments involving ovulation rate, which is the main component of litter size in sheep. Ovulation rate in sheep seems to be inherited additively. The published results indicate that heterosis for ovulation rate in sheep is about zero, and slightly negative rather than positive ($h^m = -2\%$).

As for the estimates of individual heterosis, the variation of maternal heterosis is higher for reproductive traits than for lamb growth. Again, the estimates for fertility show the greatest variation. For fleece weight, the variation is similarly high, and the average heterosis is higher than one would expect for such a trait.

Compound traits

The cumulative effect of maternal heterosis is considerable for compound traits such as the total weight of lambs weaned per ewe exposed, maternal heterosis equals individual heterosis (approximately 18% each).

The same trend of values obtained by crossbred vs. purebred method was confirmed by the F_2 vs. F_1 method. This latter method is preferred in such cases when crossbreeding is planned with widely different breeds as often happen with sheep. One of the parental populations could be unsuited to the environment in which the animals are tested. But for animals having only 50% of genes from these extreme populations the testing environment may be sufficient to allow full expression of their potential.

The next step is how to benefit from maternal and other types of heterosis. Crossbreeding systems which involve the use of crossbred ewes will surely benefit from maternal heterosis. The optimum system is to use crossbred dams and sires from a third breed, thus taking advantage of maternal heterosis of the ewe and individual heterosis of the lamb. This system, however, requires keeping purebred populations to replace the crossbred ewes. This problem can be avoided by using a rotational 2, 3 or 4 breed crossing system. Although the heterosis in this system will be somewhat less, the need for keeping the purebred population is eliminated.

It can be concluded that heterosis is a free gift which every breeder should use for his benefit.

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