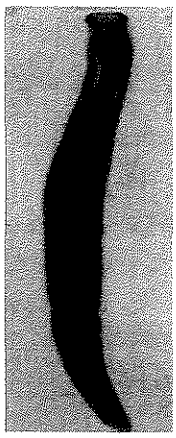
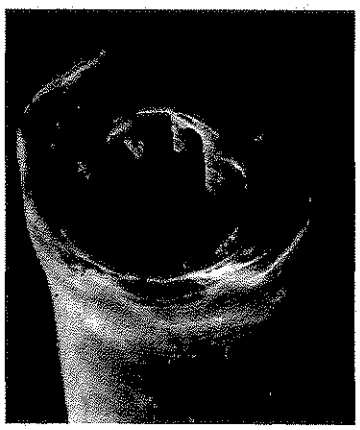


STRATEGIES FOR GENETIC IMPROVEMENT OF PARASITE RESISTANCE IN SHEEP

David R. Notter

Department of Animal & Poultry Sciences

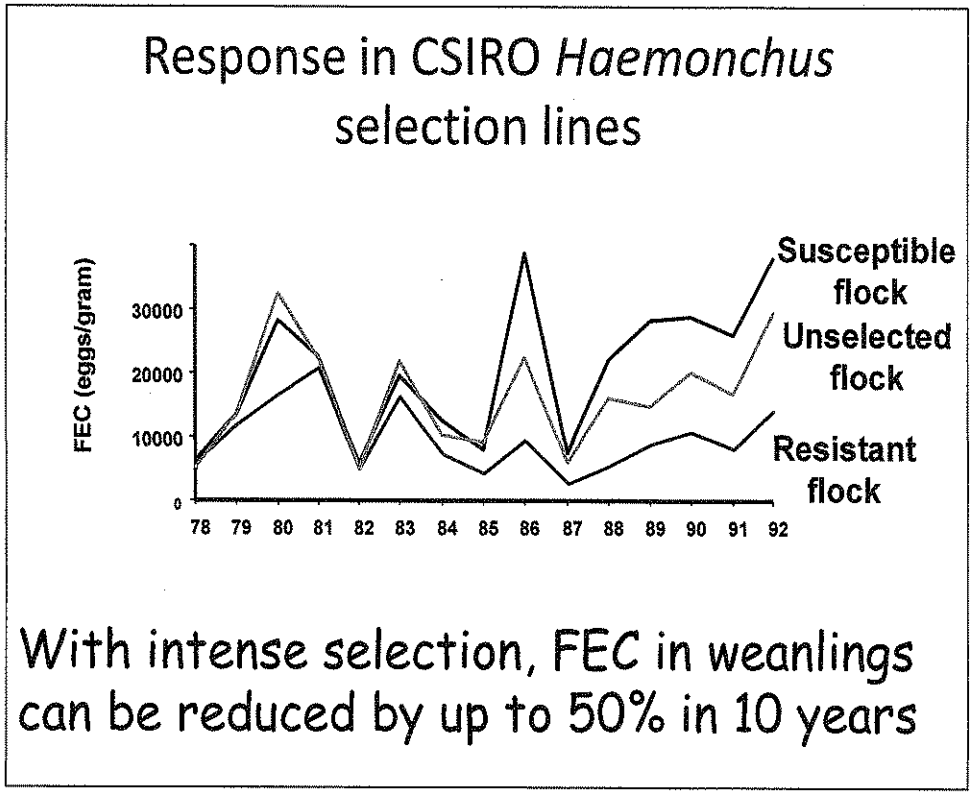
Virginia Tech



MANAGEMENT OF INTERNAL PARASITES IN SHEEP & GOATS
• Parasites are rapidly becoming resistant to ALL available dewormers • Direct marketing of "natural" or organic products is becoming more important, and more profitable • "Easy-care" philosophy is beginning to take hold in small ruminant production • Commodity lamb is becoming rare in the East

STRATEGIES FOR MANAGEMENT OF INTERNAL PARASITES INCLUDE:
• Pasture rotation/use of clean pastures • Strategic deworming, on demand, to reduce development of resistance to dewormers, often involving the FAMACHA system • Alternative dewormers such as copper oxide or tannin-rich forages • Adequate protein during early lactation to allow ewes to better cope with the periparturient rise during lambing and early gestation • Use of genetically resistance sheep types

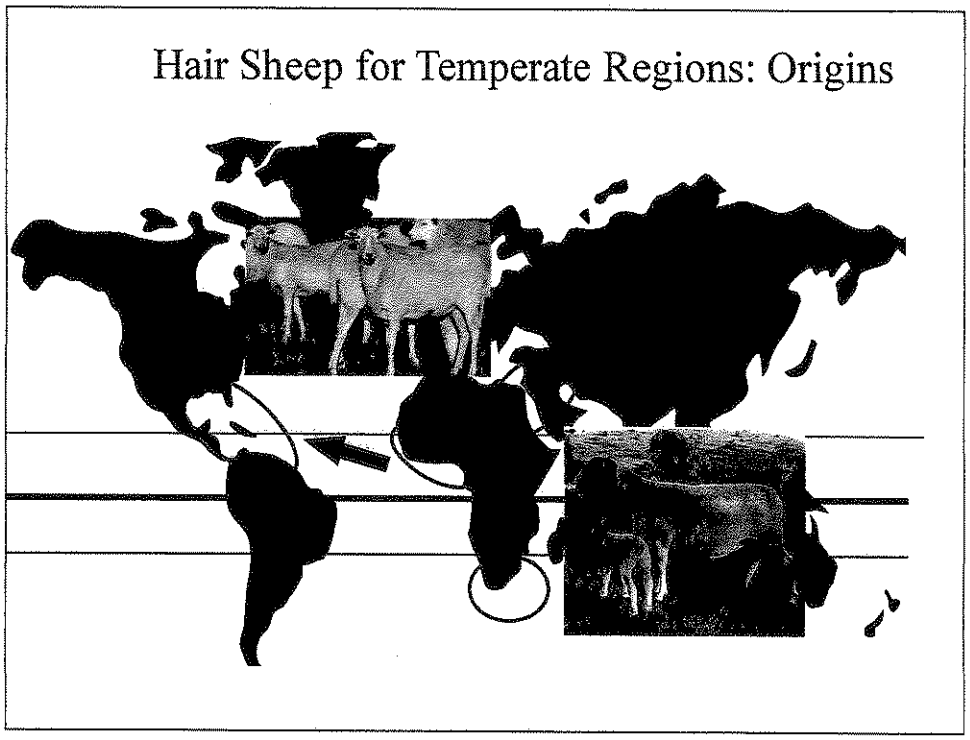
Opportunities to Enhance Parasite Resistance
• Parasite resistance is commonly associated with hair sheep • But that is clearly not the whole story. • Parasite resistance is a quantitative performance trait—no different from weaning weight or loin eye area—and will respond to selection in any breed. • However, innate levels of parasite resistance are highest in Caribbean hair breeds such as the St. Croix and Barbados Blackbelly and in naturally selected wool breeds such as the Gulf Coast and Florida Natives • The Katahdin breed shares some of that genetically mediated resistance • Also, with regard to parasite resistance, all hair sheep are NOT created equal • Breeds of Caribbean origin have generally high levels of resistance • Dorper is much less resistant, as expected from its origins as an arid-lands breed.



This slide shows results of 14 years of intensive, single-trait selection for reduced worm egg counts in Australian Merino sheep. All animals received a large artificially administered challenge dose of infective larvae of *Haemonchus contortus*, the barber-pole worm, which accounts for the very high observed worm egg counts. Animals selected for breeding were those with the lowest resulting worm egg counts, corresponding to the animals with the greatest resistance to infection.

Animals were tested at approximately 14 months of age, which is appropriate for the Australian Merino, who are bred to lamb for the first time at 2 years of age. However, similar results to those shown above would be anticipated from testing and selection of lambs at 4 to 6 months of age in U.S. flocks.

The Australian Merino is typically highly susceptible to internal parasites. This graph shows that there was little measurable response to selection in the first 5 years of the project (to 1982). Some divergence began to be observed by 1983-85, but a clear differentiation among the lines was not observed until after 1987; i.e., until after 9 years of selection. This is probably close to the anticipated result for selection for worm resistance in a highly susceptible breed.



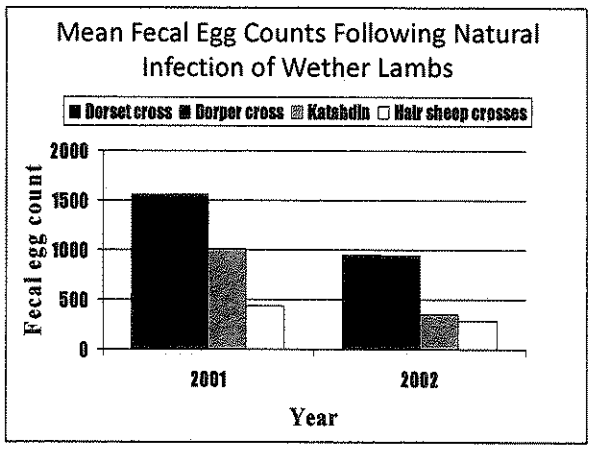
- The ancestors of the Caribbean breeds, such as the St. Croix, came from the bulge of West Africa, a region with a hot, humid climate that is ideal for growth and development of internal parasites. The development of resistance to these parasites was mandatory for survival of sheep in these regions.
- The West African hair sheep were then transported to the Caribbean, often in association with the slave trade. In the subtropical climate of the Caribbean, they again benefited from the parasite resistance they had developed in their home climate and maintained that resistance when eventually imported to the U.S.
- In contrast, the hair sheep ancestor of the Dorper is the Blackheaded Persian, which originated in the Middle East, an environment characterized by an arid climate that was not particularly well suited for development of internal parasites.
- The Blackheaded Persian later migrated down the west coast of Africa, through Ethiopia, Somalia, and Kenya and eventually into South Africa. All these are generally arid regions, where high levels of parasite resistance were again not required.
- Development of the Dorper involved crossing of the Blackheaded Persian with Dorsets in South Africa and their continued use and further development in mostly arid regions of that country.
- Thus the Dorper does not share the same history of intense natural selection for parasite resistance experienced by the Caribbean hair sheep breeds, and is correspondingly considerably less parasite resistant.

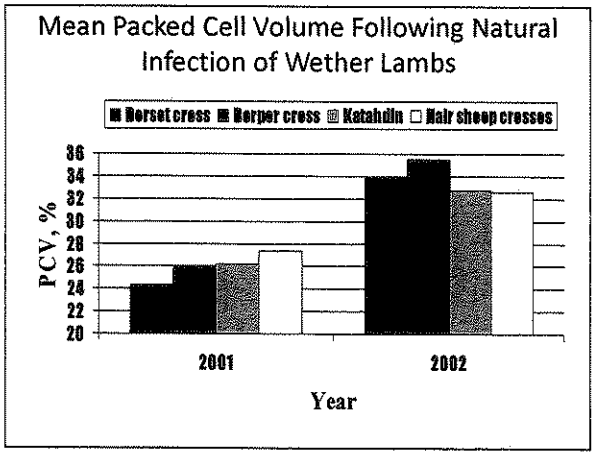
These two charts show the results of a comparison of Dorper crosses, Dorset crosses, Katahdin, and Hair Sheep lambs at the Southwest Virginia Agricultural Research and Extension Center at Glade Spring, VA. Dorset and Dorper crosses were sired by Dorset or Dorper rams and out of crossbred, Polypay-type wool sheep ewes, Katahdin lambs were purebred Katahdins, and the hair sheep crosses were mainly of St. Croix breeding, but with some infusion (perhaps up to one eighth) of Barbados Blackbelly ancestry.

Fecal egg counts did not differ between the Dorset and Dorper crosses, but were significantly lower for the Katahdin lambs, and much lower for the hair sheep crosses. Thus these data show that the Dorper crosses were not more parasite resistant than Dorset crossbreds, and that Katahdin lambs were approximately intermediate to their wool and hair sheep ancestors in worm egg counts.

However, the picture is somewhat different for packed cell volume, out best measure of anemia in the lambs. In 2001 (with high worm burdens), the breeds ranked the same for both PCV and FEC, but PCV for Dorper crosses was considerably higher than for Dorset crosses, even thought the two types had nearly identical FEC. And in 2002, when worm challenge was relatively low, the Dorpers had the highest mean PCV (i.e., were least anemic), even though they had the highest FEC. The Dorper crosses thus appear to have innately higher levels for PCV and to be better able to maintain hemoglobin levels despite parasite infection. This result would explain why Dorpers continue to do well with regard to parasites in regions of mild to moderate parasite challenge, but do not perform well when parasite levels are high.

These charts likewise demonstrate the difference between parasite ***resistance*** and parasite ***resilience***. Caribbean hair sheep are parasite ***resistant***; they are capable of limiting infection and keeping worm numbers (and therefore FEC) low, even in areas of high parasite challenge. In contrast, Dorpers appear to not be parasite resistant (as evidenced by their high mean FEC) but are ***resilient***, in that they can maintain reasonably high hemoglobin levels (and presumably performance levels) despite the presence of worms in the gut. But there is a limit to the protection provided by resilience, in that it can be overcome by high parasite challenge. Also, resistant types shed fewer eggs and have the ability to limit pasture contamination whereas nonresistant, but resilient, types such as the Dorper continue to contaminate their pastures. Pasture contamination can be a particular problem if the ewes are producing crossbred lambs that are both parasite susceptible and lack some of the resilience of their purebred dams.





STRATEGIES FOR MEASUREMENT AND GENETIC EVALUATION OF PARASITE RESISTANCE

Possible indicators of parasite susceptibility include both direct measurements of parasitism such as:

- Fecal egg counts
- Packed cell volume (hematocrit)
- FAMACHA scores

As well as indirect measurements such as:

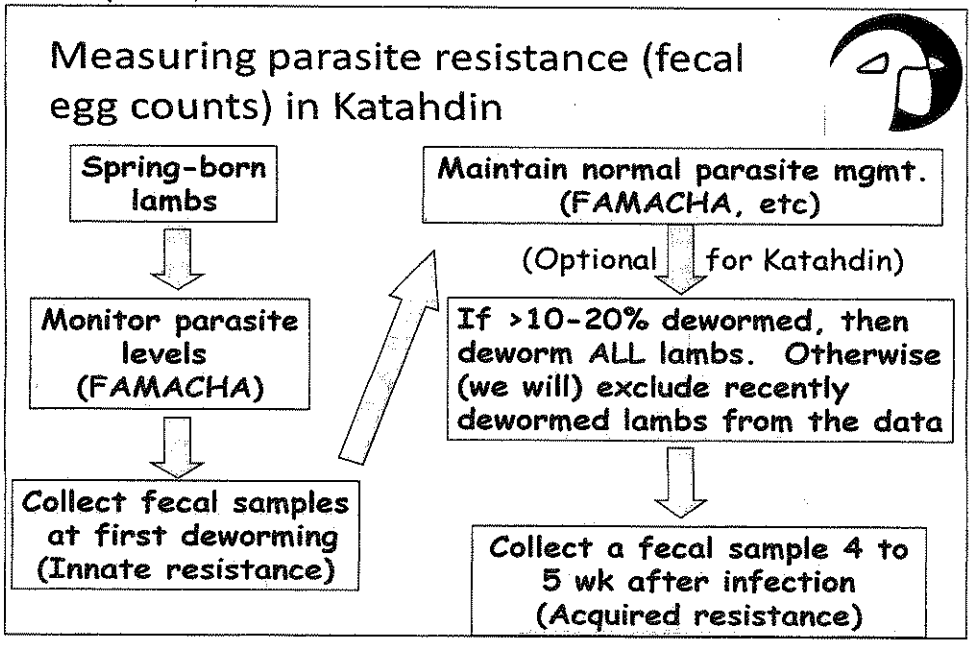
- Summer growth
- Body weight and condition

There have also been several efforts to find DNA markers for parasite resistance. While there has been some success in this search, no clearly useful markers have yet been discovered and adequate validation of potential markers has not yet occurred.

Based on response to selection in Australian Merino and New Zealand Romney sheep, quantitative approaches involving selection for low FEC appears to be the most promising current strategy. The U.S. National Sheep Improvement Program currently provides EPDs for fecal egg counts in Katahdin sheep, providing an opportunity for further improvement in parasite resistance in this breed.

The recommended sampling strategy for measuring FEC in Katahdin sheep is shown below.

- Must measure resistance when worms are present—cannot just set a calendar date
- Must coordinate measurements with the deworming schedule and protocol
- Fecal egg counts appear to be the best measure of parasite resistance
    - Indicative of actual worm burden
    - Obtain by rectal fecal grab samples from each lamb
- How many samples are required and when should they be taken?
    - One or two samples on different days
    - Samples from previously infected lambs at 4-6 mo of age (acquired immunity) seem most reliable and consistent
    - But early measurements (innate or early acquired immunity) also have a genetic component, at least in Katahdins



Three sets of analyses have been conducted to assess genetic control of parasite resistance in Katahdin sheep.

I. Katahdin 2003-05 Fecal Egg Count EPD Pilot Study:

- Six participating flocks, each with at least 2 sires and a minimum of 10-12 lambs per sire
- Total of ~ 850 lambs by 26 sires over 3 years
- Average ages at sampling of ~8 and ~22 weeks
- Heritabilities for FEC
  - 0.48 at 8 wks
  - 0.54 at 22 weeks
  - genetic correlation of 0.50 between measurements at the two ages.

II. Ohio SARE On-Farm Research Project:

- A farmer-led project involving 10 flocks
- Measure FEC at approximately 8 wk (n = 244), 13 wk (n = 289), and 17 wk (n = 139)
- Heritabilities were again very high:
  - 0.41 at 8 weeks
  - 0.52 at 13 weeks
  - 0.54 at 17 weeks

III. Katahdin 2006-07 Fecal Egg Count EPD Analysis:

- Three different measurement ages:
  - Early-season FEC (innate resistance) at 35 to 92 days.
  - Mid-season FEC shortly after weaning at 65 to 127 days.
  - Late-season FEC at 92 to 184 days. All records, regardless of level of FEC
- Two different sets of lambs:
  - All lambs, regardless of level of FEC
  - Only groups with Mean FEC > 500 epg
  - Included or excluded ***entire group***, not individual lambs
  - Still had individual lambs with zero FECs, but only within groups with mean FEC > 500.
- Results are shown on the following page.

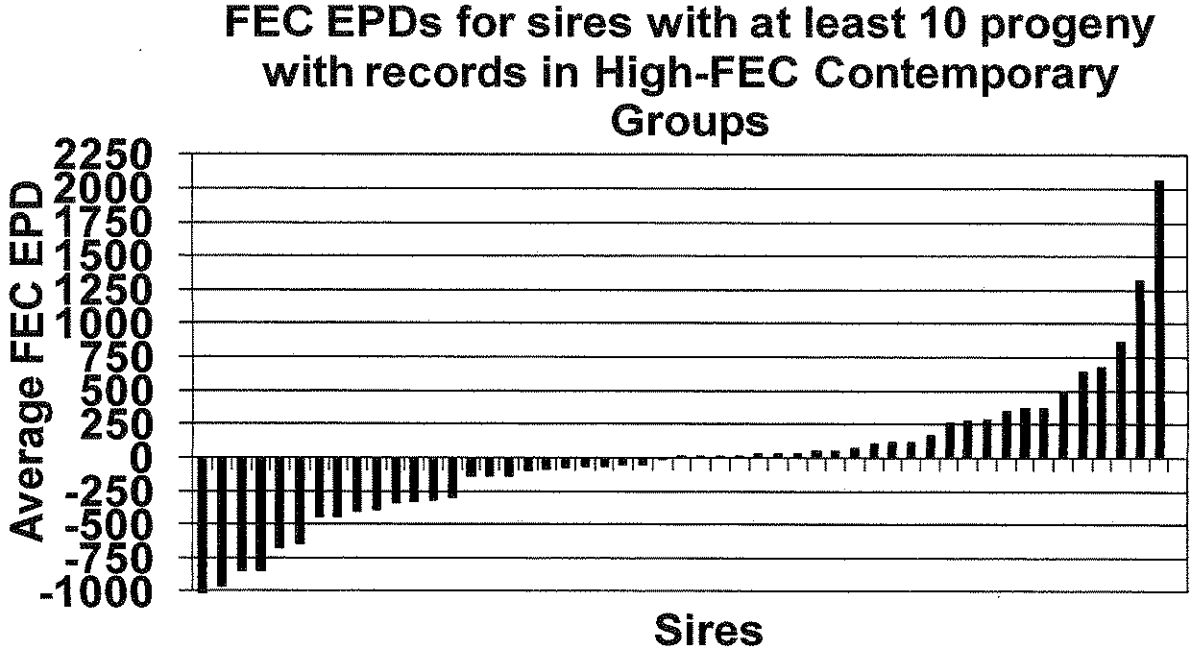
Heritabilities derived from all the data were somewhat lower than those obtained in previous studies and were more typical of those reported in the international scientific literature. However, heritabilities derived from only the high-FEC groups were again quite high, suggesting considerable potential for genetic improvement of parasite resistance in Katahdin sheep.

There was also a strong additional resemblance among littermates beyond that anticipated from their genetic relationship alone. The cause of this additional resemblance is not clear, but may involve antibodies provided by the ewe, effects of milk production on ability to cope with parasite infection, or common grazing sites (and therefore common levels of parasite exposure) for the littermate lambs.

	All Data			High FEC Data		
	Early	Mid-	Late	Early	Mid-	Late
Heritability	0.42	0.33	0.28	0.27	0.65	0.51
Litter (Maternal)	0.18	0.25	0.33	0.34	0.11	0.29

Genetic correlations among measurements taken at different ages were substantial, especially when data were restricted to high-FEC groups. Two particular results stand out: 1) the mid- and late-season measurements, taken at average ages of approximately 90 and 120 days, were almost perfectly correlated, suggesting that the Katahdin immune system is mature by around 90 days; 2) while the correlations involving the early-season FEC were somewhat lower than those involving later measurements, they were still very high (genetic correlations above 0.76, suggesting that selection based on FEC measurements taken at young ages (6 to 10 weeks) would be effective in improving overall parasite resistance.

Correlations	All data			High FEC Data		
	Early-Mid	Early-Late	Mid-Late	Early-Mid	Early-Late	Mid-Late
Genetic	0.79	0.30	0.76	0.85	0.76	0.99
Phenotypic	0.20	0.34	0.28	0.55	0.38	0.95



This chart shows fecal egg count EPDs for 51 Katahdin sires with at least 10 progeny in high-FEC groups. EPDs are indicators of genetic merit and predict differences among sires in the mean future performance levels (in this case, FEC) of their progeny. These FEC EPDs are adjusted to a flock mean for FEC of 2,000 eggs/gram of feces and show remarkably large differences among the sires in predicted progeny FEC, ranging from -1,000 to over +2,000 eggs/gram.

- Rapid genetic improvement generally requires:
  - Accurate animal evaluation = high heritability and/or progeny testing
  - Intense and timely selection: keep only the best and do not delay in choosing replacements
  - Variation within the population: the more variation that is present, the easier it is to identify the best
- However, all these characteristics rarely occur together:
  - Highly heritable traits generally are less variable that lowly heritable traits
  - Progeny testing increases accuracy but takes lots of time
  - Rapid turn-over of the flock limits the accuracy that can be achieved for an individual animal
- But all are present for FEC, suggesting that very rapid rates of genetic improvement may be possible:
  - Heritabilities are relatively high at 25% and appear to be very high (near 50%) in Katahdin
  - Very high levels of variation for FEC
  - Animals can be successfully evaluated early in life
  - In pedigree flocks with EPDs, progeny testing can occur along with the individual evaluations