Breeding Program Protocols for Improving Parasite Resistance and Resilience in Small Ruminants

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Introduction

Breeding small ruminants for nematode resistance relies on the presence of genetic variation in resistance or tolerance to parasitic infections and the ability to identify and selectively breed resistant animals. Most within-breed studies use fecal egg count (FEC) as an indicator of resistance, demonstrating significant heritability in sheep (0.2–0.4) and slightly lower values in goats (0.1–0.35). Genetic correlations suggest resistance to different nematodes is highly interrelated, and resistance to one species can increase resistance to others. Quantitative trait loci (QTL) studies reveal resistance-associated genes are scattered throughout the genome, with notable regions near interferon gamma and the MHC locus.

Selective Breeding

Experimental evidence shows that selective breeding based on reduced FEC is both feasible and effective. For instance, after 15 years of selection for lower FEC in Merino sheep, FEC and worm burdens were reduced by approximately 80%. Such selection has demonstrated short-term success in goats, though its efficacy in tropical systems remains underexplored. Nonetheless, natural selection has led to the development of breeds in tropical regions with innate resistance or tolerance to nematodes.

The benefits of breeding for nematode resistance extend beyond the genetically-resistant animals. Reduced FEC results in lower pasture contamination, decreasing nematode burdens for all grazing animals and enhancing overall herd performance. Studies highlight this epidemiological advantage, showing decreased larval challenge and improved productivity. Additionally, breeding for resistance offers sustainability, as the improvements are permanent and require minimal ongoing intervention.

While FEC is a primary indicator trait, other measures of resistance include worm burden, worm size, fecundity, and immune responses such as eosinophilia

Figure 1: FAMACHA Card Scoring to Assess the Level of Anemia.

and antibody levels (IgA, IgG, IgM). Traits like anemia (measured by packed cell volume or FAMACHA scores), pepsinogen levels, growth rate, and treatment frequency provide insights into the impact of infection and resilience. Anemia and growth rate are heritable and negatively correlated with FEC, making them valuable targets for selection.

Breeding animals like meat goats and sheep so they are better at fighting off parasites is important for sustainable herd and flock management. It also helps keep the animals healthy without having to rely on anthelminthics, hence preventing anthelminthics resistance.

This guide provides clear steps for setting up breeding programs that focus on making small ruminants more resistant to parasites. It indicates choosing which animals to breed, keeping track of their family history, and making sure there is enough genetic variety in the herd. These steps help make sure the breeding program works well, and the animals stay healthy.

Mating Selection Strategies

Identifying resistant individuals (goats/sheep): Select breeding stock with demonstrated resistance to

gastrointestinal parasites. This can be assessed through fecal egg count tests, FAMACHA scoring, body condition scoring, pasture-based observations, and historical data on parasite load (Consistently low fecal egg count, greater 2.5 BSC and FAMACHA score of 1 or 2 will yield selection for resistance). These measurable phenotypic characteristics will help to assess the animal's ability to suppress internal parasite infections. Resistant animals exhibit immune responses that either prevent the establishment of larvae, hinder the development of mature egg-laying adults, or suppress the fecundity of the parasites. Consequently, resistant animals shed significantly fewer eggs in their feces compared to non-resistant counterparts under similar exposure conditions.

Consideration of pedigree

Consideration of pedigree involves examining the ancestry or family history of potential breeding stock to understand their genetic background and inheritance of traits related to parasite resistance. This process helps identify individuals that come from a line of ancestors known for their ability to resist parasites.

The steps in pedigree selection with respect to parasite resistance include:

- **Evaluate pedigree:** This entails looking at the lineage or family tree of each potential breeding animal. Pedigree-based selection leverages the relationship between animals and their ancestors to predict breeding values, focusing on traits such as fecal egg count (FEC), growth rate, and resilience to parasitic infections. It's like looking at a family album but for animals instead of people. By studying the pedigree, breeders can trace the genetic history of the animal back several generations.
- **Assess genetic background:** Breeders analyze the genetic makeup of the animal's ancestors to determine if they possess traits associated with parasite resistance. This includes examining records of past performance, health, and any known genetic markers linked to resistance (Fig. 1).

Inheritance of parasite resistance traits: Breeders consider how traits related to parasite resistance are inherited from one generation to the next. They look for patterns of inheritance within the pedigree, such as dominant or recessive traits, to understand the likelihood of offspring inheriting resistance.

- **Prioritize resistant lineages:** Based on the evaluation of the pedigree, breeders prioritize individuals with a history of resistance within their lineage. That is to say that if we see that many of the animal's relatives, like parents, grandparents, or siblings, were good at resisting parasites, that's a good sign. It means there's a good chance the animal we're looking at might also be good at it. Animals with multiple generations of resistance are favored as they are more likely to pass on desirable traits to their offspring.
- **Selection criteria:** Breeders establish specific criteria for selecting breeding stock based on their pedigree analysis. This may include prioritizing animals from pedigrees with documented resistance, avoiding individuals with a history of susceptibility, and considering the overall genetic diversity of the population (picking the animals with a strong family history of resisting parasites. These are the ones we want to use for breeding because they're more likely to pass on their good parasite-fighting traits to their babies).
- **Mating pair selection:** Pair resistant individuals with complementary traits to maintain genetic diversity while enhancing resistance. Avoid inbreeding by selecting mating pairs with low genetic relatedness.
- **Crossbreeding considerations:** Introduce genetic diversity through crossbreeding with breeds known for parasite resistance. Monitor the performance of crossbred offspring to identify desirable traits for future breeding.
- **Pedigree tracking:** Pedigree tracking or tracing refers to systematic identification of the ancestry or the family history of the sheep and goats for breeding of resistant stock to parasite for sustainable farming. The various methods of tracking include.
- **Record Keeping:** Maintain detailed records of breeding stock, including pedigree information, performance data, and parasite resistance traits. Use electronic databases or paper-based systems to organize and track pedigree information effectively (Table 1).
- **Lineage analysis:** Conduct regular analyses of pedigrees to identify individuals with desirable traits and track their contributions to future generations. Monitor changes in trait expression over time to assess the effectiveness of breeding programs. This process helps breeders identify patterns of inheritance and make informed decisions regarding breeding strategies. Through lineage analysis, breeders can trace the genetic history of animals back several generations, assess the prevalence of

Table 1: Small ruminant's record

Tag	Breed	Sex	Pedigree Information						
			Date	Date	Date	Date	Date	Date	Date
Birth Weight									
Average Daily Weight Gain									
Body Condition Score									
FEC Score									
FAMACHA Score									
Genetic Testing Results									
Estrous Cycle Length									
Age at First Estrus									
Number of Parturitions									
Number of Livebirths									
Twining									

desirable traits within specific lineages, and select breeding stock with the highest potential for passing on desired traits to future generations.

- **Genetic evaluation:** Utilize pedigree data to estimate genetic parameters related to parasite resistance traits. Implement selection indices and breeding values to identify superior breeding stock and guide mating decisions. The evaluation parameters include.

  Heritability, which refers to the extent to which a particular trait is influenced by genetics. By understanding the heritability of traits related to parasite resistance such as fecal egg counts, FAMACHA score etc, breeders can predict how likely it is for those traits to be passed down from parents to offspring. FEC has been widely used as an indicator for host resistance to GIN in sheep showing to be a heritable trait, with a moderate heritability of 0.27. The heritability of FAMACHA© score was determined to be 0.11 ± 0.08.

- **Breeding values:** Breeding values estimate the genetic merit of individual animals for specific traits based on their own performance and the performance of their relatives. Animals with higher breeding values for parasite resistance are more desirable for breeding purposes as they are likely to produce offspring with improved resistance.

- **Genetic markers:** Genetic markers, such as single nucleotide polymorphisms (SNPs) and quantitative trait loci (QTL), provide valuable tools for selecting sheep and goats with resistance to internal parasites. These markers are specific DNA sequences associated with traits of interest and enable more precise breeding decisions. By identifying genetic markers linked to parasite resistance, breeders can select animals with favorable marker profiles to enhance resistance in the population. Studies identify specific markers or QTLs linked to resistance traits. For instance, loci on chromosomes 3 and 20 (near interferon-gamma and MHC regions, respectively) have been consistently associated with parasites.

Genetic Diversity Management

Genetic diversity management involves strategies and methods employed to maintain and enhance genetic variability within a population of small ruminants, such as sheep and goats. This is important for ensuring the resilience, resistance, and adaptability of the population to changing environmental conditions and disease challenges. Genetic diversity management therefore involves the following processes.

Evaluate genetic diversity assessment: Evaluating the genetic diversity of a small ruminant population using tools like genetic markers and pedigree analysis is critical for understanding the genetic health of the herd. Identifying issues such as inbreeding or loss of genetic variability helps mitigate risks of reduced fitness, increased susceptibility to diseases, and lower reproductive success. Incorporating genetic diversity assessments into an operation ensures a robust gene

pool, which enhances resilience to environmental challenges and long-term adaptability.

Population Structure Analysis and Its Benefits

Population structure analysis: Analyzing population structure allows producers to identify genetic subgroups with unique traits, such as resistance to internal parasites or superior adaptability to local conditions. By integrating individuals from genetically diverse backgrounds, operations can enhance overall resistance, adaptability, and productivity. This approach reduces the risk of genetic bottlenecks while ensuring that valuable resistance traits are distributed across the population, leading to more consistent and sustainable performance.

Breeding Program Design and Its Benefits

Breeding program design: Well-designed breeding programs that prioritize parasite resistance while maintaining genetic diversity provide a sustainable way to improve herd health and productivity. Strategies like rotational mating, outcrossing, and selecting for rare alleles minimize inbreeding and preserve genetic variability, which are crucial for avoiding the negative effects of genetic uniformity. Such programs optimize both short-term gains in resistance and long-term herd viability, ensuring economic and environmental sustainability for the operation.

Monitoring and Adjustment and Its Benefits

Monitoring and adjustment: Continuous monitoring of genetic diversity and population structure ensures that breeding strategies remain effective over time. Periodic assessments allow producers to detect emerging issues, such as declining genetic variability or unintended selection pressures, and adjust accordingly. This proactive approach supports adaptive management, ensuring that operations can respond to new challenges, maintain genetic health, and sustain improvements in parasite resistance and overall herd performance.

Conclusion

Carrying out selective breeding initiatives to enhance parasite resistance in small ruminants demands meticulous planning, thorough documentation, and continuous surveillance of genetic factors. Adhering to the guidelines provided in this guidebook enables breeders to efficiently administer breeding programs aimed at boosting parasite resistance, all the while upholding genetic variety in their flocks. These endeavors are instrumental in fostering the enduring viability and efficiency of small ruminant enterprises.

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