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# Breeding for worm resistance—whole farm benefits

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**Abstract**

Resistance of sheep worms against the available anthelmintic drenches is increasing. Breeding sheep for resistance against gastrointestinal parasites is the only long-term solution. Research has shown that breeding for worm resistance is a highly feasible option and that genetic gains of more than 2% per year can be achieved without loss of production. Replicated field trials in which resistant animals were managed separately from unselected control sheep showed that there was a 10-fold difference in worm egg counts between resistant and control ewes. Resistant ewes were 18% heavier than the controls at the time of peak worm-challenge in a Mediterranean environment. At weaning, there was a five-fold difference in worm egg counts between resistant and control lambs, which resulted in an improvement of weaning weight of up to 22%. It is therefore better to include selection for worm resistance in breeding programs than to omit it for fear of diminishing future genetic gains in other traits.

## Introduction

Gastrointestinal parasites are a major constraint to livestock production. It is well established that parasites reduce animal performance and increase costs of production. Besier et al. (1996) showed that a drench that is 65% effective can depress wool growth and body weight by about 10% in Merino wethers and Coop et al. (1985) showed that lamb growth rate can be decreased by about 30% in parasitised lambs.

To breed for worm resistance, it is important that the trait used is measurable, heritable and that there is variation between animals in the trait. In addition, to design appropriate breeding programs for a complex breeding objective that includes worm resistance, knowledge of the genetic and phenotypic relationships between worm resistance and production traits is required. This emphasis of this article is on genetic relationships that may impact on breeding programs for improving worm resistance. Preliminary results demonstrating the benefits of breeding for worm resistance in lambs are presented.

## Inheritance of worm resistance

It has been shown over many years that faecal worm egg count (WEC) is a good indicator trait of worm resistance in sheep. Woolaston and Piper (1996), Greeff and Karlsson (1995) and Pollock and Greeff (2004a, b) showed that WEC is a heritable trait. Most published heritability estimates lie between 0.2 and 0.3, indicating that it is possible to breed for worm resistance. Karlsson and Greeff (1995), Woolaston and Piper (1996) and Morris et al. (2000) showed that it is possible to breed sheep that are more resistant to internal parasites using WEC. In each case, these authors found that after a number of years of selection, the selection line had a reduced WEC compared to the unselected control flocks. Greeff et al. (1999) reported a decline in WEC of 2.7% per year, which is faster than what would be expected from a trait with relatively low heritability under natural conditions. As genetic gain is due to variation as well as heritability, the very high variation (normally more than

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100%) results in good genetic gains despite low heritability.

Pollott and Greeff (2004b) also reported that genotype × environment interaction does not appear to be important for breeding for worm resistance (chiefly against *Ostertagia* and *Trichostrongylus* species), as it contributes less than 5% of the phenotypic variation. However, as this was a relatively small dataset, future studies may show this to be more important if the environments and worm species are better characterized. They also showed that heritability of WEC was higher in low and high WEC environments other than normal, and suggest that in a low WEC environment, some rams have the genetic predisposition to have higher worm egg counts (more susceptible), while in a high WEC environment, some rams have the ability to resist the parasite more than others. The change in breeding values across WEC environments supports this. The increase in heritability with higher WEC environments supports previous work by Greeff et al. (1995) and Karlsson and Greeff (2004), which showed that the heritability of WEC was higher during winter than during summer in a winter rainfall environment, in which there is usually a higher worm challenge during winter than during summer. This indicated that the best time to measure WEC to obtain a reliable estimate of an animal's breeding value for worm resistance in a winter rainfall environment is approximately eight weeks after the start of the winter rainfall season, when the worm challenge has increased sufficiently to allow animals to express their genetic superiority. However, more work needs to be done to determine whether the best time to measure WEC differs between the various rainfall regions of Australia.

## Genetic relationships between faecal worm egg counts and production traits

Very few phenotypic and genetic correlations exist between WEC and production traits in Merino sheep. Eady et al. (1998) carried out a study of a number of Australian experimental flocks and Greeff and Karlsson (1998) published genetic and phenotypic relationships between WEC and production traits for the Rylington Merino experimental flock. That selection has been shown to be an effective tool for reducing WEC has encouraged a number of Merino breeders to include selection for worm resistance in their breeding program. During the past decade, these breeders have contributed to a large body of data on WEC and production. The Australian Sheep CRC initiated a genetic analysis of this data set to determine whether genetic parameters estimated from commercial flocks were similar to those estimated from experimental flocks. Results derived from a sire model and an animal model are shown in Table 1 (Pollott and Greeff, 2004a). The number of records for the traits varied from about 8000 records for eye muscle depth and staple strength to nearly 85,000 records for fibre diameter.

The estimates in Table 1 compare very well with previous estimates of parameters made by Eady et al. (1998) and by Greeff and Karlsson (1998). Although these authors did not report eye muscle and fat depths, Greeff and Karlsson (1998) observed a favourable genetic relationship between WEC and staple strength. It appears that only fat depth, staple strength and eye muscle depth will respond significantly to selection for low WEC or, alternatively, that selection for an increase in these traits would result in a favourable correlated response in WEC. This implies that measurements of staple strength, eye muscle depth and fat depth will add considerable value to WEC measurements, which will result in faster genetic gains in worm resistance.

## Benefits of breeding for worm resistance

To demonstrate the benefits of worm resistant sheep, it is important that resistant and susceptible animals be managed as separate groups to prevent cross-contamination. In the past, most breeding programs managed resistant sheep and control animals as one group. This resulted in worm resistant animals having to deal with a higher worm challenge because of the higher worm egg numbers shed by the susceptible sheep, while the susceptible sheep had a lower worm challenge because of reduced pasture contamination resulting from the lower worm egg output by worm resistant sheep. To make an unbiased assessment of the benefits of worm resistant sheep, it is essential that they are managed separately from susceptible animals.

**Table 1.** Phenotypic and genetic correlations (± s.e.) between faecal worm egg count (WEC) and production traits estimated in commercial Merino flocks.

| Trait | Sire model | | Animal model | |
|---|---|---|---|---|
| | $r_p$ | $r_g$ | $r_p$ | $r_g$ |
| Body weight | –0.03 | –0.09 ± 0.059 | –0.03 | –0.05 ± 0.048 |
| Clean fleece weight | 0.02 | –0.03 ± 0.050 | 0.00 | 0.13 ± 0.061 |
| Fibre diameter | –0.02 | –0.04 ± 0.045 | –0.02 | –0.06 ± 0.049 |
| Staple strength | –0.05 | –0.16 ± 0.099 | –0.03 | –0.05 ± 0.094 |
| Coefficient of variation of fibre diameter | –0.06 | 0.06 ± 0.046 | 0.02 | 0.11 ± 0.055 |
| Eye muscle depth | –0.04 | –0.17 ± 0.099 | –0.04 | –0.23 ± 0.100 |
| Fat depth | –0.06 | –0.26 ± 0.095 | –0.07 | –0.41 ± 0.096 |

Bishop and Stear (1999) simulated epidemiological relationships between production and resistance in young lambs and showed that selection for worm resistance resulted in large correlated increases in liveweight gain, more than twice that predicted by quantitative genetic theory. The underlying reason for this increase is the reduced worm egg count output from resistant animals, which reduces the larval challenge in young lambs.

A trial to demonstrate the economic benefits of breeding for worm resistance was initiated in 2003 and is currently being carried out at the Mt Barker research station in Western Australia. It consists of 300 Merino ewes of which 150 were from the Rylington Merino selection line and 150 were from an unselected control line.

The 150 ewes of each line were allocated to three paddocks of approximately 5 ha each, with 50 ewes per paddock to ensure a stocking rate of about 12 dry sheep equivalents, which is the norm in this region. A fixed stock management system in which the groups stayed permanently in the same paddocks, was used because it is a common system in this region and prevents cross-contamination between treatment groups. Six rams from the Rylington Merino resistant line and six rams from the control line were used. Two resistant rams were mated with each replicate of the resistant group and two control rams were mated with each replicate of the control group.

### *Preliminary results*

Table 2 shows the differences in body weight, condition score, dag score and WEC at various times of the year between mature ewes from the selection and control lines that lambed in July 2004. No significant differences were observed between the resistant and control lines for dag score, but highly significant differences were detected between lines for condition score, body weight and WEC at all times of the year. The resistant line was heavier and had higher condition score and lower WEC. The only exception was on 30 November 2004, when replicate three of the control had a lower WEC than the resistant line. This was mainly because this replicate was drenched as a result of a very high WEC when they were monitored. This clearly indicates the benefits of resistant animals.

**Table 2.** Least square means (± s.e.) of dag score, condition score, body weight and WEC of ewes at various times of the year between the replicates of the resistant and control groups that were managed separately.

| | Resistant | Control | Significance |
|---|---|---|---|
| Dag score on 18 March 2004 | | | |
| Replicate 1 | 0.009 ± 0.019 | 0.016 ± 0.018 | P = 0.16 |
| Replicate 2 | 0.017 ± 0.018 | 0.035 ± 0.019 | |
| Replicate 3 | 0.000 ± 0.020 | 0.043 ± 0.019 | |
| Condition score 18 March 2004 | | | |
| Replicate 1 | 3.20 ± 0.059 | 2.93 ± 0.056 | P < 0.001 |
| Replicate 2 | 3.14 ± 0.058 | 3.10 ± 0.058 | |
| Replicate 3 | 2.35 ± 0.062 | 2.03 ± 0.057 | |
| Condition score on 30 November 2004 | | | |
| Replicate 1 | 4.19 ± 0.096 | 3.84 ± 0.008 | P < 0.001 |
| Replicate 2 | 3.21 ± 0.091 | 2.48 ± 0.096 | |
| Replicate 3 | 3.16 ± 0.098 | 3.38 ± 0.092 | |
| Body weight on 18 March 2004 (kg) | | | |
| Replicate 1 | 51.1 ± 0.81 | 46.4 ± 0.76 | P < 0.001 |
| Replicate 2 | 50.7 ± 0.79 | 51.5 ± 0.80 | |
| Replicate 3 | 41.5 ± 0.84 | 35.5 ± 0.78 | |
| Body weight on 30 November 2004 (kg) | | | |
| Replicate 1 | 59.7 ± 1.00 | 52.7 ± 0.92 | P < 0.001 |
| Replicate 2 | 55.2 ± 0.95 | 45.7 ± 1.00 | |
| Replicate 3 | 52.4 ± 1.02 | 49.1 ± 0.96 | |
| WEC on 22 September 2004 (eggs/gram) | | | |
| Replicate 1 | 71 ± 105 | 117 ± 101 | P < 0.01 |
| Replicate 2 | 11 ± 104 | 713 ± 101 | |
| Replicate 3 | 37 ± 101 | 293 ± 101 | |
| WEC on 30 November 2004 (eggs/gram) | | | |
| Replicate 1 | 15 ± 35 | 114 ± 32 | P < 0.01 |
| Replicate 2 | 45 ± 33 | 207 ± 34 | |
| Replicate 3 | 102 ± 37 | 51 ± 33[a] | |

[a] All the animals in replicate 3 of the control line were drenched on 9 November 2004

Table 3 shows the differences between the selection and control lines for birth weight, weaning weight, faecal worm egg count, faecal consistency and dag score of weaners at weaning time over three years when the resistant and control lines were managed separately. Highly significant differences were found between the lines for WEC, and it appears that the difference became greater each year.

No significant differences were found between lines for birth weight. However, a highly significant difference was recorded for weaning weight, which was mostly due to the large difference in 2004. No significant differences were ever recorded for weaning weight between the Rylington Merino selection and control lines when the two lines were managed as one group. This indicates that the reduced challenged from the lower worm egg output from the dams and the higher level of resistance of the lambs may have resulted in the increase in weaning weight of the resistant line.

The control line had a significantly lower faecal consistency score than the resistant line at weaning but had a significantly higher dag score than the resistant line. This may indicate that the higher worm burden in the control line resulted in gut damage in the lambs, but further investigation is required to confirm this.

**Table 3.** Least square means (± s.e.) for birth weight, weaning weight, faecal worm egg count, faecal consistency score and dag score of the resistant and control line lambs over three years when the lines were managed separately.

| Trait | Resistant | Control | Significance |
|---|---|---|---|
| Birth weight (kg) | 3.90 ± 0.12 | 3.89 ± 0.12 | n.s. |
| Weaning weight (kg) | | | |
| 2002 | 22.9 ± 0.88 | 21.8 ± 0.87 | P < 0.001 |
| 2003 | 20.2 ± 0.86 | 20.0 ± 0.86 | |
| 2004 | 22.9 ± 0.88 | 18.7 ± 0.88 | |
| Faecal worm egg count (eggs/g) | | | |
| 2002 | 1292 ± 198 | 1403 ± 196 | P < 0.001 |
| 2003 | 911 ± 201 | 1346 ± 194 | |
| 2004 | 533 ± 198 | 1308 ± 196 | |
| Faecal consistency score | | | |
| 2002 | 2.46 ± 0.20 | 1.91 ± 0.19 | P < 0.01 |
| 2003 | 2.76 ± 0.20 | 2.82 ± 0.19 | |
| 2004 | 2.83 ± 0.20 | 2.59 ± 0.19 | |
| Dag score | | | |
| 2002 | 0.63 ± 0.16 | 1.02 ± 0.16 | P < 0.01 |
| 2003 | 0.81 ± 0.16 | 1.04 ± 0.16 | |
| 2004 | 0.35 ± 0.17 | 0.35 ± 0.16 | |

## Conclusions

The results confirmed that WEC is a heritable trait and that no antagonistic genetic correlations exist between WEC and any production traits. Breeding for worm resistance is therefore feasible while improving production. In this study, in which resistant animals were managed separately from unselected control animals, the preliminary results show that resistant ewes were 18% heavier and in better body condition than unselected control ewes during times of high worm challenge. This was probably due to the 10-fold difference in worm egg counts between resistant and control ewes at the time of peak worm challenge in a Mediterranean environment. The five-fold difference in worm egg counts between resistant and control lambs at weaning resulted in an improvement in weaning weight of up to 22%. Bisset et al. (1997) also reported a substantial reduction in worm egg counts and improved growth rates of lambs for resistant compared to susceptible Romney sheep that were managed separately.

Resistant animals have a significantly lower faecal worm egg output and this will reduce pasture contamination. The results indicate that lambs from resistant ewes are generally heavier at weaning because of the reduced faecal worm egg output of their dams and their own high level of resistance. In a winter rainfall environment, it is critically important that weaner lambs reach their maximum liveweight before the dry summer season commences. It is therefore better to include selection for worm resistance in breeding programs than to omit it for fear of compromising future genetic gains in other traits.

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