Evaluation of lambs subjected to a targeted selective treatment anthelmintic regime

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Abstract

Targeted selective anthelmintic treatments (TSTs) can identify individuals less reliant on anthelmintic, information from which could be utilised to select lambs based on anthelmintic requirement. However, it is important to first determine if selection based on anthelmintic requirement compromises genetic potential for productive traits. Sheep Improvement Limited (SIL) estimated breeding values (eBVs) for production traits and associated indexes for 214 female lambs and 158 male Coopworth lambs were compared with their requirement for anthelmintic following exposure to a liveweight gain-based TST regime. Mean liveweight gain for both sexes was reduced with increasing anthelmintic requirement ($P < 0.001$). Favourable increases in eBVs with decreasing anthelmintic requirement were observed for fecundity in both sexes ($P = 0.003$) and for survival in females only ($P = 0.03$). No effect was observed for eBVs for maternal survival, weaning weight, maternal weaning weight, live weight at eight months of age, and live weight and fleece weight at 12-months of age ($P > 0.05$ for all). Dual purpose index values for resilience increased with decreasing anthelmintic requirement ($P < 0.001$) while meat yield index and overall productivity were not affected ($P > 0.05$ for both). It is concluded that selection of lambs for low anthelmintic requirement can be made with no apparent compromise in the genetic potential for production traits.

Keywords: targeted selective treatments; resilience; genetic selection; sheep; nematodes

Introduction

Targeted selective treatment (TST) anthelmintic regimes are promoted as delivering effective and sustainable nematode control while helping ensure the responsible use of chemicals in food producing animals (Kenyon et al. 2009). This is primarily achieved through directing anthelmintic treatment only to those likely to benefit, the net result of which is a change in the mind-set of farm management from a whole flock/herd basis to one centred on needs of the individual animal. While the benefits of TST regimes have been predominantly attributed to preservation of anthelmintic efficacy through the provision of refugia (Kenyon et al. 2009; Leathwick et al. 2012), one aspect that has been frequently overlooked is the ability of these approaches to collect information on the anthelmintic requirement of individual animals. This information may assist with genetic selection programs, thus decreasing the reliance on anthelmintics in livestock systems (Bisset et al. 1994; Greer & Sykes, 2012). However, before selection of animals based on anthelmintic requirement can be promoted, consideration must first be given to the effects of such selection on the productive potential of the individuals in question to ensure that future production is not compromised.

The aim of this study was to evaluate the genetic potential of lambs for production traits relative to their anthelmintic requirement, when exposed to a TST anthelmintic regime.

Materials and methods

Animals and treatments

Requirement for anthelmintic through the 2011-12 grazing season was assessed using a TST approach in 214 female and 158 male Coopworth lambs from a Sheep Improvement Limited New Zealand (SIL) recorded flock at the Lincoln University Ashley Dene Pastoral Systems Research Farm, Canterbury, New Zealand. At weaning in November, at approximately three months-of-age, all lambs were weighed, treated with anthelmintic previously known to be effective on this property at the manufacturers recommended dose rate (65g/L levamisole and 30 g/L oxfendazole, SCANDA, Coopers Animal Health, Upper Hutt, New Zealand) and tagged with lightweight sheep electronic radio-frequency ear tags (RFID; Allflex, Palmerston North, New Zealand). Thereafter, all lambs were maintained as two mobs separated on sex under normal farm management and grazed pastures naturally infected with gastro-intestinal nematodes.

Experimental design

From weaning, individuals were assessed on their requirement for anthelmintic at approximately monthly intervals for five months, based on their ability to achieve acceptable levels of liveweight gain. Liveweight gain targets were determined with the use of 'sentinel' lambs according to an adjusted SIL protocol for the identification of resilient lambs. Briefly, a representative sentinel group of an additional 25 lambs of each sex, randomly selected from the same flock, were treated with anthelmintic at each of the monthly assessment times. The same lambs were used as sentinels throughout the study. Mean live

Table 1 Distribution of anthelmintic treatments administered to 214 female and 158 male lambs that received a targeted selective anthelmintic treatment (TST) and their mean liveweight gain ± standard error of the mean, during the entire trial period from December to April. Within each row, means with different superscripts are significantly different (P <0.05).

Sex	Measurement	Sentinel group	Number of anthelmintic treatments administered				
			1	2	3	4	5
Female	Number of lambs	23	9	94	98	12	1
	% of TST		4	44	46	6	-
	Liveweight gain (g/d)	141 ± 4.7[a]	133 ± 5.5[ab]	116 ± 2.0[b]	102 ± 2.1[c]	68 ± 7.0[d]	96
Male	Number of lambs	18	11	90	51	6	-
	% of TST		7	57	32	4	-
	Liveweight gain (g/d)	153 ± 7.0[a]	150 ± 3.9[a]	137 ± 206[a]	123 ± 3.5[b]	82 ± 12.5[c]	-

Table 2 Mean ± standard error of the mean of liveweight gain (g/d) in the preceding period of Sentinel and lambs that received a targeted selective anthelmintic treatment (TST) that were either treated or remained untreated, and the percentage of TST lambs that were treated (% TST treated) and the percentage of treated TST lambs that had also been treated in the previous sampling period (% treated time previous) that were weighed monthly between December and April. Within each column and within each sex, liveweight gains with different superscripts are significantly different (P <0.05).

Sex	Measurement	Weigh date				
		December	January	February	March	April
Female	LWG sentinel (g/d)	179 ± 18[b]	73 ± 12[a]	72 ± 12[b]	126 ± 9[b]	259 ± 9[a]
	LWG TST treated (g/d)	118 ± 5[c]	-8 ± 4[b]	-9 ± 5[c]	53 ± 4[c]	78 ± 7[b]
	LWG TST untreated (g/d)	207 ± 3[a]	95 ± 6[a]	126 ± 4[a]	164 ± 4[a]	278 ± 4[a]
	% TST treated	26	73	48	43	64
	% treated time previous	100	15	71	25	12
Male	LWG sentinel (g/d)	176 ± 14[b]	129 ± 16[a]	128 ± 26[b]	149 ± 15[b]	188 ± 13[a]
	LWG TST treated (g/d)	116 ± 6[c]	11 ± 5[b]	38 ± 7[c]	56 ± 7[c]	32 ± 9[b]
	LWG TST untreated (g/d)	225 ± 4[a]	152 ± 10[a]	202 ± 7[a]	208 ± 7[a]	216 ± 9[a]
	% TST treated	19	77	39	32	66
	% treated time previous	100	7	71	14	7

weight at weaning ± the standard error of mean were 22.6 ± 0.30 and 22.7 ± 0.89 kg for females, and 24.8 ± 0.37 and 24.2 ± 1.3 kg for males for the TST and sentinel groups, respectively. At each sampling time, sentinel lambs were drafted from the mob and their live weight recorded. Liveweight gain targets for TST lambs for each sex and for each measurement period were set at 80% of the mean liveweight gain achieved during the preceding month by sentinel lambs. TST lambs were then weighed using an automated weighing and drafting platform (Pratley Industries Ltd., Temuka, New Zealand) with those individuals not achieving these liveweight gain targets being separated and treated with anthelmintic, as described above, before re-joining their mob and returned to grazing. At every measurement time lamb live weight and requirement for anthelmintic, their draft direction, was recorded.

Data analysis

Timing of and total number of anthelmintic treatments administered to each TST individual throughout the entire grazing season, comprising five measurement times, was compared with their estimated breeding value (eBV) for ten production traits. These were: number of lambs born (NLB), lamb survival (SUR), maternal survival (SURM), lamb weaning weight (WWT), maternal weaning weight (WWTM), lamb live weight at 8 months-of-age (LW8), yearling live weight at 12 months-of-age (LW12), yearling fleece weight at 12 months-of-age (FW12), lamb age at first drench (DRAGE), resilience liveweight gain (RGAIN) and three productivity indexes, being: dual purpose production (DPP), dual purpose meat yield (DPM) and dual purpose resilience (DPZ) calculated from SIL as available on 31 October 2012.

Data were analysed using Minitab® statistical software (Version 16, 2010, Minitab Inc, State College, Pennsylvania, USA). As a result of culling decisions made by the farm manager a complete data set of the sentinel lambs was not available, consequently only the data from 23 female and 18 male sentinel lambs present at all sampling times were analysed. All TST lambs received at least one treatment. Due to only one TST lamb receiving five

Table 3 Mean ± standard error of the mean of estimated breeding values for number of lambs born (NLB), survival (SUR), maternal survival (SURM), weaning weight (WWT), weaning weight maternal (WWTM), live weight at 8 months-of-age (LW8), live weight at 12 months-of-age (LW12), fleece weight at 12 months-of-age (FW12), age of first drench (DRAGE), resilience liveweight gain (RGAIN), index values for dual purpose production (DPP), dual purpose meat (DPM) and dual purpose resilience (DPZ) for female and male lambs that received 1, 2, 3 or 4 anthelmintic treatments when exposed to a targeted selective treatment regime. For number of treatments, within each sex, values within each column with different superscripts are significantly different (P <0.05). Bold text indicates significance at P <0.05. Italic text indicates significance between P = 0.05 and P = 0.10.

Sex	Number of treatments administered	Trait					
		NLB	SUR	SURM	WWT	WWTM	LW8
Female	Sentinel	0.12 ± 0.02	0.004 ± 0.003	0.001 ± 0.001	2.3 ± 0.3	0.5 ± 0.1	5.7 ± 0.8
	1	0.16 ± 0.02[a]	0.015 ± 0.002[a]	0.002 ± 0.001	2.1 ± 0.2	1.2 ± 0.2	3.8 ± 0.5
	2	0.11 ± 0.01[a]	0.010 ± 0.001[ab]	0.003 ± 0.001	1.4 ± 0.1	0.9 ± 0.1	3.0 ± 0.2
	3	0.10 ± 0.01[a]	0.009 ± 0.001[ab]	0.002 ± 0.001	1.5 ± 0.1	1.0 ± 0.1	2.9 ± 0.3
	4	0.04 ± 0.03[b]	0.001 ± 0.004[b]	0.002 ± 0.002	1.6 ± 0.6	0.7 ± 0.2	3.4 ± 1.3
	P value	**0.003**	**0.03**	0.95	0.45	0.48	0.73
Male	Sentinel	0.10 ± 0.02	0.009 ± 0.002	0.003 ± 0.002	1.3 ± 0.3	0.9 ± 0.1	3.3 ± 0.7
	1	0.20 ± 0.14[a]	0.013 ± 0.004	0.001 ± 0.002	2.4 ± 0.2	1.5 ± 0.2	4.6 ± 0.4
	2	0.14 ± 0.01[b]	0.009 ± 0.001	0.001 ± 0.001	1.9 ± 0.1	1.0 ± 0.1	4.3 ± 0.2
	3	0.14 ± 0.01[b]	0.008 ± 0.002	0.002 ± 0.001	2.2 ± 0.1	1.2 ± 0.1	3.7 ± 0.2
	4	0.12 ± 0.02[ab]	0.008 ± 0.006	-0.001 ± 0.004	1.9 ± 0.4	1.3 ± 0.3	3.2 ± 0.8
	P value	**0.02**	0.59	0.69	0.10	*0.08*	0.15

Sex	Number of treatments administered	Trait						
		LW12	FW12	DRAGE	RGAIN	DPP	DPM	DPZ
Female	Sentinel	5.8 ± 0.7	0.39 ± 0.24	12 ± 3	0.15 ± 0.11	871 ± 91	146 ± 42	49 ± 12
	1	4.3 ± 0.5	0.36 ± 0.06	70 ± 2[a]	0.17 ± 0.09	1089 ± 67	14 ± 40	274 ± 7 7[a]
	2	3.0 ± 0.3	0.21 ± 0.03	14 ± 2[b]	0.12 ± 0.05	885 ± 68	89 ± 17	57 ± 8[b]
	3	2.9 ± 0.3	0.24 ± 0.03	11 ± 2[b]	0.09 ± 0.05	859 ± 39	49 ± 19	45 ± 7[bc]
	4	3.1 ± 1.4	0.36 ± 0.11	1 ± 4[b]	-0.15 ± 0.10	738 ± 150	145 ± 75	2 ± 16[c]
	P value	0.61	0.15	**<0.001**	0.27	0.20	0.13	**<0.001**
Male	Sentinel	3.6 ± 0.7	0.24 ± 0.04	7 ± 4	-0.03 ± 0.11	764 ± 95	35 ± 43	21 ± 15
	1	4.5 ± 0.6	0.28 ± 0.07	55± 9[a]	0.38 ± 0.11	1266 ± 72	35 ± 45	220 ± 33[a]
	2	4.0 ± 0.2	0.26 ± 0.02	19 ± 2[b]	0.33 ± 0.04	1008 ± 36	93 ± 21	78 ± 7[b]
	3	4.6 ± 0.2	0.30 ± 0.03	20 ± 2.[b]	0.19 ± 0.07	1030 ± 44	81 ± 31	82 ± 8[b]
	4	2.7 ± 0.6	0.17 ± 0.08	6 ± 5[b]	-0.12 ± 0.18	1120 ± 107	134 ± 98	22 ± 22[b]
	P value	0.12	0.63	**<0.001**	**0.03**	*0.09*	0.76	**<0.001**

treatments, data from this lamb for statistical comparisons was pooled with the data from lambs that received four treatments. Data for males and females were analysed separately using a general linear model with the number of treatments (1, 2, 3 and 4) as a factor and with post-hoc pairwise comparisons made using a Tukey's test and a significance level of 5%.

Results

Anthelmintic requirement and lamb performance

The distribution of the number of anthelmintic treatments administered to TST lambs is given in Table 1. Mean number of anthelmintic treatments administered was greater for female lambs than male lambs, being 2.54 ± 0.05 and 2.33 ± 0.05, respectively (P = 0.003) with 103 (48%) of females and 101 (64%) of males requiring one or two treatments. Mean liveweight gain during the entire period was greater for sentinel lambs compared with TST lambs, being 141 ± 4.7 and 108 ± 1.6 g/d for sentinel and TST females (P = 0.001) and 153 ± 7.0 and 131 ± 2.2 g/d for sentinel and TST males (P = 0.001), respectively. When compared with the number of treatments administered, liveweight gain was consistently greater in sentinel lambs and decreased for TST lambs with increasing number of anthelmintic treatments (Table 1).

Performance of both TST lambs and sentinel lambs, and the percentage of TST lambs treated at each sampling time, are given in Table 2. Mean liveweight gain of all groups and the proportion of TST lambs that were treated varied across sampling times. The percentage of repeat treatments, that is lambs that were treated which had also received a treatment the previous sampling time, was 100% of lambs in December, due to all lambs being treated at weaning, but generally remained low at other times except for February at which time 71% of both females and males that required treatment had also been treated in January.

Genetic merit relative to number of treatments

Mean estimates for individual breeding values (eBVs) and production indexes values for each level of anthelmintic treatment are given in Table 3. For the traits assessed, eBVs for NLB, SUR and DRAGE were greater in females and NLB, DRAGE and RGAIN were greater in males for animals that required fewer anthelmintic treatments ($P < 0.05$ for all traits). The number of anthelmintic treatments received was not reflected in significant differences in DPP or DPM indexes ($P > 0.05$ for all traits) although the number of treatments was inversely proportional with DPZ ($P < 0.001$ for both sexes).

Discussion

The primary purpose of targeted selective anthelmintic treatments (TSTs) is to optimise anthelmintic use and promote the responsible use of chemicals in food-producing animals while providing sustainable control of the impacts of nematode infection on grazing livestock. Recently, investigations with TSTs have focussed on their use as a means to provide a refuge nematode population and thus slow development of anthelmintic resistance (Kenyon et al. 2009). However, these approaches were initially developed to identify animals less reliant on anthelmintic, and therefore resilient to nematode infections (Bisset et al. 1994). In the current study, the TST regime used can be expected to have fulfilled both of these roles of providing refugia and identifying lambs less reliant on anthelmintic. Compared with a monthly neo-suppressive anthelmintic regime, anthelmintic use was reduced by approximately half in TST lambs. Previous investigations have shown that leaving as few as 10% of lambs untreated at any one time can have beneficial effects on preserving anthelmintic efficacy (Leathwick et al. 2012). Although parasitological data was not collected in the current study due to the inability of faecal egg counts to provide a reliable assessment of nematode burden or pasture contamination in this environment (Greer & Sykes, 2012), the fact that a maximum of 77% of lambs at any one time received an anthelmintic treatment and 48% of female and 64% of male lambs received just one or two treatments, allows the suggestion that benefits in terms of slowing the development of anthelmintic resistance can be expected.

The use of a fully recorded SIL flock provides an opportunity to evaluate the impact on potential productivity of identifying lambs with a low requirement for anthelmintic. Clearly the size and scope of this data set and limited timeframe of this study restrict the ability to allow any firm conclusions on the potential impact of such selection. However, these data suggest that there is no apparent disadvantage on the potential productivity through selecting for low anthelmintic requirement. Overall, for the traits evaluated there were few significant associations, but where there were associations, these followed expectations. The only significant effect on production traits were favourable associations between number of treatments with eBVs for NLB (both sexes) and SUR (females only) which presumably, at least in part, reflects a greater lamb growth in those that required fewer treatments. These observations are in agreement with previous authors who have reported negative genetic correlations between total number of drenches and both liveweight gain and autumn live weight (Bisset et al. 1994, 1996). In the current study this difference in growth relative to treatment frequency did not appear to have any effect on eBVs for LW8 or LW12. Favourable relationships between the resilience indices (DPZ) and requirement for treatment were anticipated, as was the reduction in DRAGE with increasing treatment frequency as the time until first drench can be considered a reliable indicator of resilience (Bisset et al. 1994). However, it is worth noting that from the current data set that of the 20 animals which received one treatment in total, three of these received this treatment within the first two assessment times and that of the 184 individuals which received two treatments in total, 23 of these received a treatment at the first assessment time and thus would be considered to have low resilience.

Including number of treatments administered in selection criteria may lead to improvements in total anthelmintic requirement in commercial settings. From the current study, selecting females that received either fewer than three or fewer than four treatments would be expected to result in respective reductions in the average number of treatments administered of 0.63 and 0.10. Heritability estimates for selection of lambs based on the number of anthelmintic treatments are generally low, ranging from 0.03 to 0.13 (Bisset et al. 1994, 1996). Despite variations in the methodology of determining the need for treatments in those studies compared with the present one, similar estimates of heritability for number of treatments can be expected as many of the non-genetic factors that influence resilience are still likely to exist. The methods used in previous studies to determine the need for treatment varied from relatively subjective assessment of body condition and dag score throughout the grazing season (Bisset et al. 1994) to liveweight gain targets that were determined by weighing a sub-sample of lambs and identifying the poor growing lambs on the first two treatment occasions post-weaning (Bisset et al. 1996). Assuming heritability for number of treatments of 0.08, being the mid-point of the estimates reported by Bisset et al. (1994, 1996), selecting females that received either fewer than three or fewer than four treatments can be anticipated to result in respective reductions in the mean number of anthelmintic treatments administered after one generation of 0.05 and 0.01. Further, it can be expected such selection would not detrimentally affect production potential as the average DPP index values for all females was 872, compared with 903 and 881 for female lambs that received fewer than three or fewer than four treatments, respectively. In part, the decision by Bisset et al. (1996) to use only the first two treatment times and not total anthelmintic requirement during the entire grazing season, was based on the practicality associated with increased labour requirement to assess the individual liveweight gain. With this in mind, the practicality of obtaining individual liveweight gain records has been greatly improved with the availability of RFID technology and automated weighing and drafting systems. As such it is possible, that at least for the traits assessed here, that commercial farmers could adopt liveweight gain-based TST regimes and achieve modest improvements in the requirement for anthelmintic use with little or no apparent negative impact on potential productivity. However, with many of the eBVs reported here being for traits that are expressed in life stages beyond the study period, the existence of any relationships between the number of treatments and actual productivity throughout the animal's life history remains to be determined.

The ability of a TST regime to identify lambs less reliant on anthelmintic is dependent on the suitability of the selection criteria. To this end, animal performance may be considered a suitable indicator for the need for anthelmintic as it accounts for the actual impact of infection on the host, regardless of their immunological state and/or nematode population dynamics (Greer & Sykes, 2012). Liveweight gain is affected by a number of non-parasitological influences, many of which can be expected to be accounted for with the use of sentinel lambs, which were used in the current study to mimic the SIL protocol for identifying resilient animals. Nevertheless, it is possible greater liveweight gain due to frequent treatment in sentinel lambs may lead to unrealistic targets being set for TST lambs. As such, it is unclear from the present study if the decrease in growth rates in TST lambs with increased number of treatments reflects a true requirement for anthelmintic or simply poorer genetic capacity for growth in those lambs. Mean liveweight gain of TST lambs was lower than sentinel lambs by 33 g/d and 22 g/d for females and males, respectively, indicating the level of larval challenge was sufficient to decrease performance in lambs treated less frequently. This is in contrast to previous investigations of a performance-based TST regime in which no difference in liveweight gain was reported with fortnightly assessment with a similar 50% reduction in anthelmintic use to that observed here (Greer et al. 2009). Presumably, this reflects both the longer period between sampling times in the current study which would allow a greater opportunity for the impact of infection to manifest a reduction in performance, and also the relatively low target liveweight gain used in the current trial protocol, which was developed to deliberately provide a nematode challenge and identify resilient lambs. Nevertheless, given the performance of the untreated TST lambs at each of the sampling times was at least comparable to, or greater than, the sentinel lambs, this suggests that the use of the sentinel lambs did not result in unrealistic growth targets being set.

In conclusion, targeted selective treatment can be used to obtain information on the requirement of anthelmintic treatments for individual animals. Further, at least for the traits assessed here, this information can be used to select lambs with a low anthelmintic requirement with no apparent compromise in the genetic potential for productive traits.

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References

Bissett SA, Morris CA, Squire DR, Hickey SM, Wheeler M 1994. Genetics of resilience to nematode parasites in Romney sheep. New Zealand Journal of Agricultural Research 37: 12–20.

Bisset SA, Morris CA, Squire DR, Hickey SM 1996. Genetics of resilience to nematode parasites in young Romney sheep – use of weight gain under challenge to assess individual anthelmintic treatment requirements. New Zealand Journal of Agricultural Research 39: 314–323.

Greer AW, Sykes AR 2012. Are faecal egg counts approaching their "sell-by" date? Proceedings of the New Zealand Society of Animal Production 72: 199–204.

Greer AW, Kenyon F, Bartley DJ, Jackson EB, Gordon Y, Donnan AA, McBean DW, Jackson F 2009. Development and field evaluation of a decision support model for anthelmintic treatments as part of a targeted selective treatment (TST) regime in lambs. Veterinary Parasitology 164: 12–20.

Kenyon F, Greer AW, Coles GC, Cringoli G, Papadopoulos E, Cabaret J, Berrag B, Varady M, van Wyk JA, Thomoas E, Vercruysse J, Jackson F 2009. The role of targeted selective treatments in the development of refugia-based approaches to the control of gastrointestinal nematodes of small ruminants. Veterinary Parasitology 164: 3–11.

Leathwick DM, Waghorn TS, Miller CM, Candy PM, Oliver MB 2012. Managing anthelmintic resistance – Use of a combination anthelmintic and leaving some lambs untreated to slow the development of resistance to ivermectin. Veterinary Parasitology 187: 285–294.