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Research paper

Perceptions and actions of Dutch sheep farmers concerning worm infections

H.W. Ploeger[a,*], A.F.G. Antonis[b], J.C. Verkaik[c], P. Vellema[d], M.H. Bokma-Bakker[c]

[a] Department of Infectious Diseases and Immunology, Faculty of Veterinary Medicine, Utrecht University, P.O. Box 80165, 3508 TD, Utrecht, The Netherlands
[b] Central Veterinary Institute of Wageningen UR, P.O. Box 65, 8200 AB, Lelystad, The Netherlands
[c] Wageningen UR Livestock Research, P.O. Box 338, 6700 AH, Wageningen, The Netherlands
[d] Department of Small Ruminant Health, GD Animal Health, P.O. Box 9, 7400 AA, Deventer, The Netherlands

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ABSTRACT

Gastrointestinal (GI) nematode infections are considered among one of the toughest challenges sheep farmers face worldwide. Control still is largely based on the use of anthelmintics, but anthelmintic resistance is becoming rampant. To facilitate implementation of alternative nematode control strategies and to reduce anthelmintic usage, the purpose of this study was twofold: (i) to gain insight in common practices, knowledge gaps and perceptions of farmers regarding nematode control, and (ii) to provide foci of attention for improving parasite control practices and transfer of knowledge within the sheep husbandry. An internet-based questionnaire was made available to all sheep farmers pertaining to the year 2013, resulting in 450 entered questionnaires for analysis.

The two most important nematodes mentioned, were *Haemonchus contortus* and, to a lesser extent, *Nematodirus battus*. Of all respondents, 25.6% said they did not have any worm problems. Of these, almost a third did notice clinical signs that can be related to worm infections and about three quarters did use anthelmintics. Overall, clinical symptoms mentioned by farmers matched the worm species they identified as the cause of problems.

Ewes and lambs were treated up to 6 times in 2013. On average, ewes were treated 1.53 and lambs 2.05 times. Farmers who treated their ewes more often, also treated their lambs more often ($P < 0.001$). Both ewes and lambs were frequently treated based on fixed moments such as around lambing, at weaning and before mating, rather than based on faecal egg counts. Treatments based on faecal egg counts were practiced, but on a minority of the farms (32.7%). The majority of the farms (75.6%) did not leave 2–5% of the sheep within a flock untreated. About 74% of farmers keep newly purchased animals quarantined for at least 10 days, but some (13.4%) leave quarantined animals untreated nor check faecal egg counts. Of farmers who do treat their quarantined animals, just 12.6% check the efficacy of the treatment.

Slightly over 40% of the respondents said they did not experience bottlenecks in parasite control. Yet, over half of these said having problems with worm infections, over half did see clinical signs related to worm infections and over three quarters used anthelmintics. Within the group of farmers experiencing difficulties in parasite control, the most often mentioned bottleneck concerned pasture management (75.8%). When asking farmers for solutions, 90% of all respondents indicated they are willing to adjust their pasture management. Farmers are also interested in other methods to reduce the risk of worm infections, such as possibilities to enhance the immune system of sheep in general (71%), to increase specific genetic resistance to worms and to apply anti-parasite forages, both about 40%.

Results of this study gave the following potential foci of attention: (1) making complex scientific knowledge more accessible to farmers through simple tools and applicable in the daily farming process; (2) changing the mindset of farmers about their current worm control practices, i.e. breaking long-standing habits such as treating ewes and lambs at fixed moments rather than based on actual worm infection monitoring data; (3) demonstrating effective pasture rotation schemes on specific farms and using these in extension work; (4) making farmers more aware that checking anthelmintic efficacy is important; (5) improving quarantine procedures; (6) creating a wider array of applicable alternative control

* Corresponding author.
E-mail address: h.w.ploeger@uu.nl (H.W. Ploeger).

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measures from which individual farmers can choose what fits them most; and finally, (7) improving mutual understanding among farmers, veterinary practitioners and parasitologists alike.

1. Introduction

Gastrointestinal (GI) nematode infections are considered one of the toughest challenges sheep farmers face worldwide, causing diarrhoea, reduced growth rate, anaemia, and mortality with severe economic losses to individual farmers and the sheep industry as a whole (Hoste and Torres-Acosta, 2011; Mavrot et al., 2015). GI nematode infections used to be controlled with highly effective anthelmintics for several decades, as time and again new products became available while in the meantime anthelmintic resistance (AR) developed to some older products. However, over the last decade, prevalence of AR has risen sharply in the Netherlands with reports on AR to ivermectin, moxidectin and monepantel (Borgsteede et al., 2010; Van den Brom et al., 2013, 2015; Ploeger, unpublished results). A recent review concluded that AR and multi-drug resistance have become widespread in Europe (Rose et al., 2015). These developments have triggered major concerns within the Dutch sheep industry whether current GI nematode control practices are sustainable.

GI nematode control still is based mainly on the use of anthelmintic drugs (Kenyon and Jackson, 2012; Charlier et al., 2014), but it is increasingly recognized that dependency on anthelmintic drugs should be minimized to keep at least some of the drugs effective and, for instance, available for emergency situations. This requires more sustainable control strategies based on grazing management, biological control, host immunity enhancing strategies including vaccination and genetic selection of less susceptible hosts, selective treatment measures and nutritional measures including the use of plants with natural anthelmintic activity (Hoste and Torres-Acosta, 2011). Although increasing knowledge is available on several of these alternative control strategies, acceptance and implementation may not always be an easy process. They have to overcome both farmer's and veterinary practitioner's traditional management and perceptions, should be tailor-made aiming at an integrated approach that fits into overall daily management on farm level, and have to be profitable in a relatively short period of time (Van Wyk et al., 2006; Woodgate and Love, 2012). Not every alternative, therefore, may be equally applicable on every sheep farm. Furthermore, specific knowledge gaps on nematode life-cycles and interpretation of, for instance, faecal egg counting results, as well as on utility and applicability of alternative management strategies may hamper implementation by farmers. Finally, implementation of innovative approaches is most likely to occur and sustain when embedded into solid and cooperative social structures (Geels, 2002). In this respect it is of relevance that (1) Dutch sheep farms are partly still under-serviced by veterinary practitioners, (2) the sheep industry is a sector consisting of a variety of sheep farm types with different production goals and not strongly organised as a whole, and (3) that interactive knowledge exchange between parasitology experts, veterinarians and sheep farmers is limited.

To facilitate implementation of alternative nematode control strategies, the purpose of this study was twofold: (i) to gain insight in common practices, knowledge gaps and perceptions of farmers regarding nematode control (bottlenecks, promising solutions and desired supportive tools for management support), and (ii) to provide foci of attention for improving parasite control practices and transfer of knowledge within sheep husbandry. Although the focus was on GI nematodes, farmers also pointed at liver fluke and tapeworm infections. Since occurrence of both tapeworm and liver fluke infections may have consequences for GI nematode control, it was decided to include these as well in this study.

2. Materials and methods

2.1. Sheep farms in The Netherlands

The sheep industry in the Netherlands is relatively small with less than one million breeding ewes kept on 28,762 farms of which 20,226 are small-scaled farms keeping on average less than 32 animals, and the remaining 8536 are larger farms (Identification &Registration-database of the ministry of Economic Affairs, 2013). Most of these sheep are kept for slaughter lamb production.

2.2. Questionnaire

An internet-based questionnaire was developed using the SurveyMonkey® platform. The questionnaire contained questions about general farm characteristics (number of animals, size of premises, type of farm, lambing period(s), breed, type of pastures or plots used) and worm control strategies (which GI nematode or other helminth species, observed symptoms, routine deworming practices, use of faecal egg counts (FEC), measures to slowing down development of drug resistance, quarantine practices). In addition, questions were asked about perceived bottlenecks in worm control, desired (alternative) control measures and supportive tools. Questions for internal checks about the general reliability and consistency of given answers were included.

The questionnaire was made available between October 2013 and February 2014. All sheep farmers in the Netherlands were alerted to the questionnaire through (e-)mails from sheep organisations and the Dutch GD Animal Health, as well as through personal contact groups of farmers and farming press. Alerts were sent out up to three times over a period of two months. Farmers could enter the questionnaire anonymously, but were asked to enter the four digits of their postal code, which contains four digits followed by two letters, to allow a general assessment of the geographical distribution of entered questionnaires.

2.3. Analysis

After completion of a questionnaire, it was automatically entered into a spreadsheet. After closing the website where the questionnaire was made available, the spreadsheet was electronically retrieved and imported into Excel (Microsoft Windows 2007/2010). This database contained 574 questionnaires. Subsequently, the database was manually checked. Questionnaires in which only the general questions on sheep farm characteristics were answered, were removed. Because SurveyMonkey® records IP-addresses, the database was checked for entered questionnaires from the same address. If so, questionnaire answers were compared and the most recent or complete questionnaire was retained unless answers differed while the four digit postal code on both questionnaires was the same. In some instances the postal code differed, which indicated that either the sheep farmer owned more than one farm or that two farmers entered the questionnaire together on the

Table 1
Overall general farm characteristics as well as per type of sheep farm.

Sheep farm type	N[a]	%	n[b]	nr. ewes[c]			ha. total		lambs born in 2013		mean nr. lambs per ewe[d]
				mean	median	range	mean	median	mean	median	
All respondents	450			73.8	31.0	2–1250	60.3	14.5	123.7	52.5	1.79
Slaughter lamb production	209	46.4	85	88.0	65.0	10–375	71.1	27.0	159.7	120.0	1.76
Lamb grazing	91	20.2	22	62.0	45.0	10–250	57.2	19.0	97.4	75.5	1.74
Breeding	127	28.2	26	49.4	38.0	14–160	50.8	21.0	104.2	72.0	2.05
Nature or land conservation	34	7.6	8	187.8	87.5	16–553	269.5	134.5	193.1	125	1.31
Dairy sheep	7	1.6	3	120.7	100.0	12–250	143.0	118.0	138.3	200	1.50
Hobby	194	43.1	132	13.1	11.0	2–37	13.4	4.0	21.6	17.0	1.72
Other	13	2.9	5	12.4	5.0	4–33	16.3	20.0	16.2	9.0	1.72

[a] Number and percentage indicate all farmers who entered they kept sheep for this purpose, irrespective whether they kept sheep for other purposes as well.
[b] Columns on the right (except for the top row) only include data for farmers who entered they only kept sheep for the respective purpose, or at least as their primary purpose. For instance, 209 farmers kept sheep for slaughter lamb production, but only 85 entered this was their primary purpose.
[c] Number of breeding ewes in 2013.
[d] No median given, because median did not differ significantly from the mean.

same computer. In fourteen cases, two or three questionnaires were entered from the same IP-address. In 11 of these cases, one of the entered questionnaires was removed. Questionnaires from participants who answered not to own ewes in 2013, were also removed. This concerned 15 respondents. Finally, for all respondents the ratio was calculated for the number of ewes in 2013 compared to the number in 2012. Questionnaires from respondents with more or less extreme ratios (<0.7 or >1.5) were all checked. In one case, the extreme ratio could not readily be explained, leaving some doubt about the actual number of ewes present. In all other instances, extreme ratios did not point at a potentially untrustworthy questionnaire. In fact, almost all extreme ratios were from farmers that kept just a few sheep as a hobby. Then, selling or purchasing even one or two sheep easily results in extreme ratios. In the end, 450 questionnaires, although not all fully completed, were retained for analysis.

For each variable, a descriptive analysis was carried out, producing frequencies for categorical variables and means and medians with standard deviations for continuous variables. Subsequently, differences between types of farmers were analysed using simple χ^2-analyses. Similarly, answers to questions about worm problems, treatments and observations on clinical signs were compared by general χ^2-analyses. As there was no specific outcome variable, no multivariate analyses were performed.

3. Results

3.1. General sheep farm characteristics

Respondents came from all over the Netherlands. Table 1 presents general farm size characteristics, overall as well as per type of sheep farm. Of the 450 sheep farmers, 227 (50.4%) kept Texel sheep and 155 (34.4%) Swifter sheep, a breed originally based on a Texel and Flamish crossing. On 66 of these 227 and 155 farms, both sheep breeds were present or sheep were crosses between these two breeds, meaning that 316 (70.2%) farmers kept either one, both or a cross of these breeds. In addition, another 17 farmers indicated they kept various crosses of Texel and/or Swifter with each other and/or other breeds. Other breeds were Zwartbles (n = 42), Dutch Spotted Sheep (n = 28), Bleu du Maine (n = 20), Suffolk (n = 19) and various other (cross)breeds. Of the 450 farmers, 355 (78.9%) purchased animals in 2013, 67 (14.9%) did not purchase any animals and 28 (6.2%) did not answer this question. On the vast majority of sheep farms, the lambing season is in spring centred around the months of February to April.

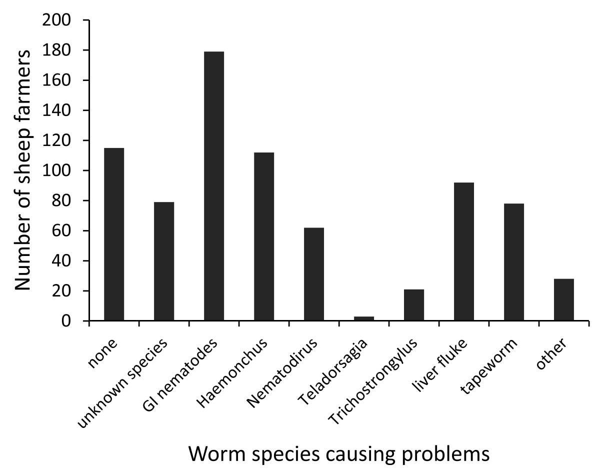

Fig. 1. Frequency distribution of answers to the question which worm species causes problems. Although the questionnaire was focused on GI nematodes, liver fluke was included as an option. Other included *Eimeria* species and ectoparasites.

Table 2
How many farmers entered having problems with GI nematodes in general versus problems with *Haemonchus contortus* specifically? Between brackets row percentage.

GI nematodes	*Haemonchus contortus*		
	no	yes	
no	201 (74.2%)	70 (25.8%)	271
yes	137 (76.5%)	42 (23.5%)	179
	338	112	450

χ^2 = 0.32, NS.

3.2. Perceived problems with worm infections

Many farmers indicated they have problems with GI nematodes in general (39.8%) and *Haemonchus contortus* in particular (24.9%) (Fig. 1). However, these two categories did not overlap significantly (Table 2). Apparently, some farmers recognize infections with *H. contortus* separately from the general term GI nematode infection. The same applied for *Nematodirus battus*, the main *Nematodirus* species in the Netherlands (Table 3).

Noteworthy is that 17.3% of all farmers indicated tapeworms were a problem. Particularly farmers grazing sheep for nature or land conservation, either as a primary activity or as one of several activities, pointed at tapeworms as a problem (26.5% vs. 16.6% of all other sheep farm types). This difference became larger if only farm-

Table 3
How many farmers entered having problems with GI nematodes in general versus problems with *Nematodirus* spp. specifically? Between brackets row percentage.

GI nematodes	*Nematodirus* spp.		
	no	yes	
no	229 (84.5%)	42 (15.5%)	271
yes	159 (88.8%)	20 (11.2%)	179
	388	62	450

$\chi^2 = 1.35$, NS.

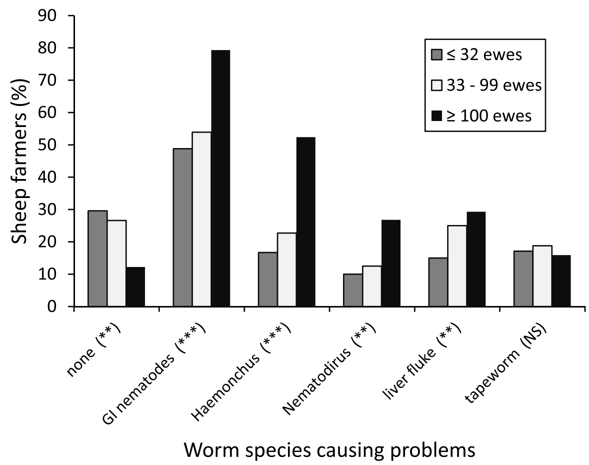

Fig. 2. Worm species causing problems according to the sheep farmer in relation to farm size. Between brackets on the horizontal axis, the level of statistical significance for the difference between farm sizes. NS = not significant; ** = P < 0.01; *** = P < 0.001.

ers were considered who kept sheep for nature or land conservation as their sole activity, in which case 37.5% indicated tapeworms as a problem vs. 17.0% of all other farmers. Due to the relatively low numbers of nature or land conservation farmers (see Table 1), these differences were not statistically significant. Next to tapeworm infections, 20.4% mentioned liver fluke as a problem and 6.2% pointed at other parasites (*Eimeria* spp. and ectoparasites).

Fig. 2 shows that larger sheep farms experienced more problems with GI nematodes and also with liver fluke. Perceiving problems with tapeworms was not associated with farm size.

3.3. Worm infections and clinical signs

Table 4 shows the associations between observed clinical signs and perceived problems with the different worm species. A total of 120 farmers (26.7%) did not see clinical signs related to worm infections, whereas 25.6% answered they had no worm problems. Of those who had no worm problems, 30.4% answered they observed clinical signs that could be related to worm infection. Of the farmers who did say they had worm problems, 88.1% also noticed clinical signs ($\chi^2 = 142.4$, $P < 0.001$).

In general, significant associations or lack of associations shown in Table 4 are more or less expected. Having problems with GI nematodes in general is strongly associated with observing weight loss and diarrhoea. Having problems with *H. contortus* is strongly associated with observing weight loss, mortality, pale mucous membranes, oedema and a high EPG, but not with diarrhoea. Problems with *N. battus* strongly associated with diarrhoea and mortality, while problems with liver fluke associated with weight loss and oedema. No association was found between having problems with *H. contortus* or *F. hepatica.* This implies that the associations of both with oedema were observed independently of

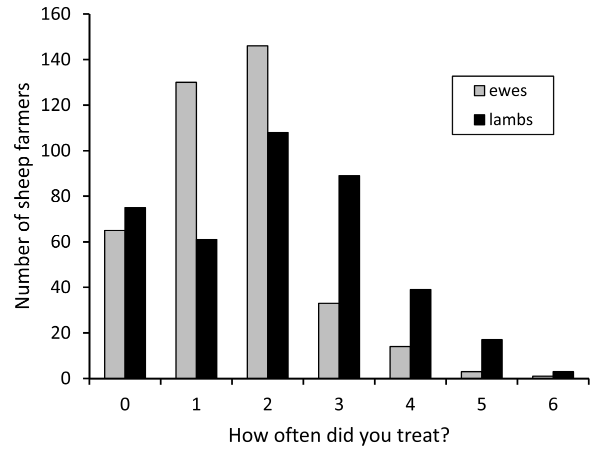

Fig. 3. Frequency of anthelmintic treatment of ewes and lambs 2013.

each other, which is not surprising considering the difference in seasonal occurrence of both parasites.

On the other hand, a few associations were not expected, in particular those between *N. battus* being associated with dry faeces, pale mucous membranes and oedema. However, the vast majority of these farmers also mentioned having problems with *H. contortus* in contrast with farmers who did not have problems with *N. battus* (64.5% vs. 18.6%, $\chi^2 = 60.0$, $P < 0.001$).

Having problems with tapeworms strongly associated with diarrhoea and also associated significantly with a high strongyle EPG (Table 4). Of farmers having problems with tapeworms, 56.4% also mentioned problems with GI nematodes, whereas of farmers without tapeworm problems 36.3% said they have problems with GI nematodes ($\chi^2 = 10.17$, $P < 0.01$).

3.4. Treatment practices

Of 450 farmers, 41 did not answer the question whether they had used anthelmintics in 2013. Of the remaining 409 farmers, 64 (15.6%) answered they had not used anthelmintics in 2013. In contrast, following another question whether anthelmintics were prescribed each time they had been used, just 7 (1.7%) answered they did not use anthelmintics. A similar response was obtained with the question from which source anthelmintics were purchased, with only 4 farmers (1.0%) saying they did not use anthelmintics. Fig. 3 shows how often ewes and lambs were treated. As expected, lambs were treated more often ≥3 times a year than ewes. Surprisingly, ewes were treated at least twice a year on 197 farms (48.2%). On average, lambs were treated 2.05 (SD 1.44) and ewes 1.53 (SD 1.05) times, both with a maximum of six times.

Of farmers who said they did not have worm problems, 75.2% (76/101) used anthelmintics for either the ewes, lambs or both. Of 308 farmers having worm problems, 87.3% (269/308) used anthelmintics, which is significantly more ($\chi^2 = 8.42$, $P < 0.005$). Of farmers expressing they had no worm problems, but had used anthelmintics, 35 had treated their ewes once (50.0%), 28 twice (40.0%), 6 three (8.6%) and 1 four times (1.4%). Regarding the treatment of lambs on those farms, 19 farmers had treated once (28.8%), 31 twice (47.0%), 10 three times (15.2%) and 6 four times (9.1%). An almost similar result was seen if having observed clinical signs was compared to having used anthelmintics or not. Of farmers not having observed clinical signs, 71.4% (75/105) still treated their ewes and/or lambs from once up to 4 or 5 times in 2013 vs. 88.8% (270/304) of farmers that did observe clinical signs ($\chi^2 = 17.88$, $P < 0.001$). Farms with ≤32 ewes treated less often (79.4%, 173/218) than larger farms ($\chi^2 = 8.87$, $P < 0.05$). Of farms with 33–99 or ≥100 ewes, 89.6% (103/115) and 90.8% (69/76),

Table 4
Associations between observed clinical signs and perceived problems with worm species (n = 450). Values in the table are presented as percentage of the number of sheep farms with or without problems with the given worm species or group.

Problem with		Clinical sign							
		weight loss n = 192 (42.7%)	diarrhoea n = 218 (48.4%)	mortality n = 102 (22.7%)	dry faeces n = 8 (1.8%)	pale mucous membranes n = 98 (21.8%)	oedema n = 46 (10.2%)	high FEC n = 61 (13.6%)	animal color deviates n = 38 (8.4%)
worms in general	no	12.2	21.7	8.7	1.7	5.2	1.7	2.6	0.0
	yes	53.1	57.6	27.5	1.8	27.5	13.1	17.3	11.3
	χ^2	57.1***	42.7***	16.2***	0.0 NS	23.6***	10.9***	14.6***	12.8***
GI	no	33.6	38.0	22.5	1.1	19.9	7.7	10.0	6.3
	yes	56.4	64.2	22.9	2.8	24.6	14.0	19.0	11.7
	χ^2	22.1***	28.7***	0.0 NS	0.9 NS	1.1 NS	3.9*	6.8**	3.5^{+}
Hc	no	39.1	46.7	16.0	0.3	10.4	6.2	9.2	3.0
	yes	53.6	53.6	42.9	6.2	56.2	22.3	26.8	25.0
	χ^2	6.7**	1.3 NS	33.2***	13.8***	101.3***	22.1***	20.8***	50.1***
Nb	no	40.7	44.1	20.4	1.0	19.3	9.0	11.6	5.9
	yes	54.8	75.8	37.1	6.5	37.1	17.7	25.8	24.2
	χ^2	3.8^{+}	20.3***	7.6**	6.2*	8.9**	3.5^{+}	8.0**	20.8***
Fh	no	38.8	47.2	20.7	1.7	20.1	6.1	11.7	8.1
	yes	57.6	53.3	30.4	2.2	28.3	26.1	20.7	9.8
	χ^2	9.8**	0.9 NS	3.4^{+}	0.0 NS	2.4 NS	29.6***	4.2*	0.1 NS
tapeworm	no	40.9	43.8	22.0	1.6	20.7	9.1	11.6	6.2
	yes	51.3	70.5	25.6	2.6	26.9	15.4	23.1	19.2
	χ^2	2.5 NS	17.4***	0.3 NS	0.0 NS	1.1 NS	2.1 NS	6.4*	12.6***

GI = gastronintestinal nematodes; Hc = *Haemonchus contortus*; Nb = *Nematodirus battus*; Fh = *Fasciola hepatica* (liver fluke). FEC = number of strongyle worm eggs per gram faeces. No analysis done for *Teladorsagia circumcincta* and *Trichostrongylus* spp. as there were too few cases for these. NS = not significant; $^{+}$ = P < 0.10; * = P < 0.05; ** = P < 0.01; *** = P < 0.001.

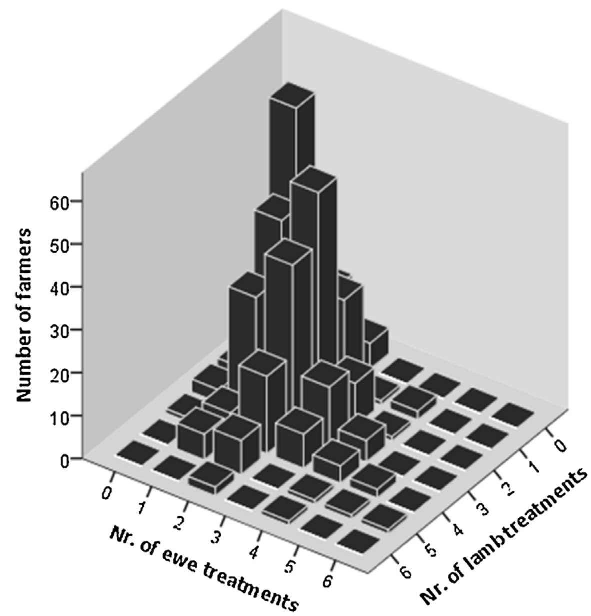

Fig. 4. Relationship between number of anthelmintic treatments in ewes and lambs.

respectively, used anthelmintics. Fig. 4 shows that farmers who treated their ewes more often, generally also treated their lambs more often (χ^2 = 293.0, P < 0.001).

Anthelmintics were used by farmers for various reasons, of which the most important were presence of diarrhoea (44.0%), positive FEC (32.7%) and reduced growth rate (27.6%). Observing pale mucous membranes caused 14.0% of the farmers to treat, while 16.4% used anthelmintics following advice from their veterinary practitioner. Interestingly, there was no significant association between treating based on FEC and advice by veterinary practitioners, even though most of the FEC were done by the veterinary practitioner (61.1%) instead of by the farmer him- or herself (34.0%). Also, there were no significant associations between treating based on reduced growth rate, presence of diarrhoea or pale mucous membranes and treating based on FEC. Anthelmintic treatments on larger farms were significantly more often preceded by a FEC (51.2%, 43.0% or 20.8% of farms with ≥100 ewes, 33–99 ewes or ≤32 ewes, respectively; χ^2 = 34.3, P < 0.001). This association was confirmed through another question asking who performed FEC, where significantly more of the smaller farms indicated no FEC was done. In general, nature or land conservation farms and breeding farms relied more on FEC, either done themselves or by their veterinary practitioner, than other farm types, with hobby farmers relying least on FEC.

Next to treating as indicated by specific observations, many treatments were carried out routinely at specific moments. Such moments for ewes were at or shortly after lambing (77.1% of the farms), at weaning (9.8%) and before mating (34.9%), and for lambs at weaning (35.8%), when moved to another pasture (12.9%) and in spring, usually intended to prevent nematodirosis (4.9%). There were no differences between smaller and larger farms in this respect, except that a slightly smaller percentage of the larger farms (≥100 ewes) routinely treated their sheep at fixed moments (75.6% vs. 84.4% of farms with 33–99 ewes, and 87.1% of farms with ≤32 ewes; χ^2 = 6.1, P < 0.05).

Regarding treating the whole flock or part of the flock, 73.5% of the farmers indicated they always treat the whole flock, 8.3% only treat the worst animals and 24.4% leaves 2–5% of the animals untreated. The larger farms tend to treat the whole flock less often (differences NS) and more often leave 2–5% of the animals untreated (34.2% of farms with ≥100 ewes vs.28.7% of farms with 33–99 ewes, and 18.8% of farms with ≤32 ewes; $\chi^2 = 8.8$, $P < 0.05$).

Of 409 farmers, 80.9% purchased anthelmintics from their own veterinary practitioner, while 33.7% mentioned they (also) did so from other sources, like another veterinary practitioner and sources unrelated to veterinary practices. Most associations with farm size or type of farm were not significant. However, breeding farms purchased anthelmintics less often from their own veterinary practitioner than other farm types (74.6% vs. 83.5%; $\chi^2 = 4.3$, $P < 0.05$). Farms participating in nature or land conservation purchased anthelmintics more often from veterinary practitioners specialized in sheep (28.1% vs. 6.9%, $\chi^2 = 17.0$, $P < 0.001$). After having purchased anthelmintics, most farmers (69.7%) kept unused product for later use. Just 7.6% of the farmers returned unused product to their veterinary practitioner, while 17.6% kept unused product for later use in consultation with their practitioner. Of 409 farmers, 21 (5.1%) mentioned they apply unused anthelmintic product acquired for sheep also on/to other animal species than sheep.

3.5. Measures to slow down development of anthelmintic resistance

This question was answered by 443 farmers, of which 68.8% (305) said they took measures to slow down anthelmintic resistance. Of the latter, 32.1% (98/305) mentioned they only treat based on FEC, 8.2% (25/305) follows the advice of an internet-based decision tool for sheep worm control (www.wormenwijzer.nl), 31.8% (97/305) put newly purchased animals in quarantine, 72.8% (222/305) uses pasture management measures, 3.0% (9/305) did not treat all animals in a flock, 8.9% (27/305) changed between anthelmintic products on a regular basis, and 5.2% (16/305) tried to minimize the number of treatments as much as possible. The most often mentioned pasture management measures were grazing on aftermath (76/219), moving to safe pasture (41/219) and rotating pastures every 2–3 weeks (91/219). However, it could not be identified how strict these measures were applied during part or the entire grazing season.

Of the farmers who use anthelmintic treatment based on FEC, 59.9% (88/147) also answered to do this as a measure to slow down AR development.

Overall, quarantine as a specific measure to slow down AR development was mentioned by 97 farmers, although 9 of them also answered they did not take measures to slow down AR development. However, following the question whether quarantine as such was applied for purchased animals, a total of 273 farmers (62.3%) said they did so, implying that 64.5% of them apparently did not associate quarantine with slowing down AR development. If quarantine was used, 74.0% of farmers (202/273) kept animals at least 10 days in quarantine of which 65.3% (132/202) treated the animals with a single product and 21.3% (43/202) with at least two anthelmintic products. This leaves 27 farmers (13.4%) who did not treat animals kept in quarantine for at least 10 days. Of farmers treating sheep during a quarantine period of at least 10 days, just 12.6% (22/175) checks the efficacy of a treatment before the end of the quarantine period.

3.6. Perceived bottlenecks in parasite control

More than half of 434 respondents (59.0%) who answered this question, indicated having problems to control worm infections. Interestingly, of the 41.0% farmers not experiencing this problem, 61.2% (109 of 178) still said having problems with worm infections in their sheep. Similarly, 58.4% (104 of 178) still said having seen clinical signs related to worm infections. For the group of farmers perceiving bottlenecks in parasite control, these percentages were 85.2% in both cases, which is as might be expected significantly more ($\chi^2 = 32.3$ and 39.2, respectively, $P < 0.001$). Likewise, 89.7% of farmers perceiving bottlenecks used anthelmintics, which is more often than farmers not perceiving a bottleneck (76.5%; $\chi^2 = 13.0$, $P < 0.001$). Particularly farms with ≥100 ewes indicated bottlenecks in parasite control (74.1%) compared to farms with 33–99 ewes (57.3%) or ≤32 ewes (54.6%) ($\chi^2 = 9.6$, $P < 0.01$).

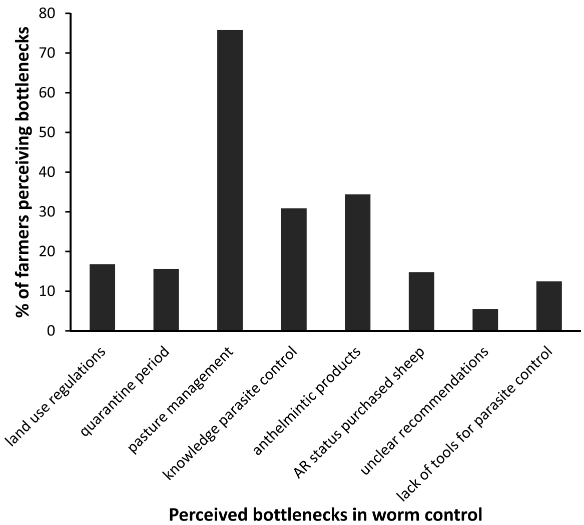

Fig. 5. Perceived bottlenecks in parasite control by Dutch sheep farmers.

Fig. 5 shows the major bottlenecks farmers perceive, of which pasture management is most often mentioned (75.8%), which mainly relates to perceived difficulties to apply proper rotation schemes to keep worm infections low because of limited availability of grass and size of pastures. Next, 30.9% of the farmers mention they lack knowledge how to implement parasite control measures, and 34.4% point at various limitations in using anthelmintics (eg. withdrawal periods, AR, prescription regulation). Farmers who graze sheep on dykes or on land subject to nature preservation regulations are obliged to follow rules on how and when they are allowed to graze their sheep, which may not match recommended grazing schemes to control worm infections. Finally, 14.8% of farmers pointed at a lack of knowledge about the actual AR status of purchased sheep.

Farmers who perceived difficulties with applying appropriate pasture management schemes, significantly more often mentioned having problems with *H. contortus* (39.9% vs. 15.5%, $\chi^2 = 32.8$, $P < 0.001$) or *N. battus* (27.9% vs. 4.0%, $\chi^2 = 50.0$, $P < 0.001$), but not with GI nematodes in general (44.3% vs. 38.2%) or with liver fluke (23.0% vs. 18.7%). Although larger farms (≥100 ewes) more often mentioned that applying appropriate pasture management posed difficulties, there were overall no significant differences between farm size or types concerning perceived bottlenecks in parasite control.

3.7. Solutions and desired tools to aid parasite control

Farmers were asked what kind of measures they are willing to take to improve their control of GI nematode infections (Fig. 6). The great majority (384/428, 89.7%) is willing to adjust their pasture management, while 70.9% (299/422) would like to use measures to raise general resistance or resilience of their sheep to worm infections (unrelated to breeding for host resistance). The latter category includes general nutritional measures (protein, concentrates, supplements, colostrum) as well as vaccines against GI nematodes. Overall, 24.2% of all farmers (102/422) answered they would like to vaccinate against GI nematodes. Next, 64.5% of farmers (272/422)

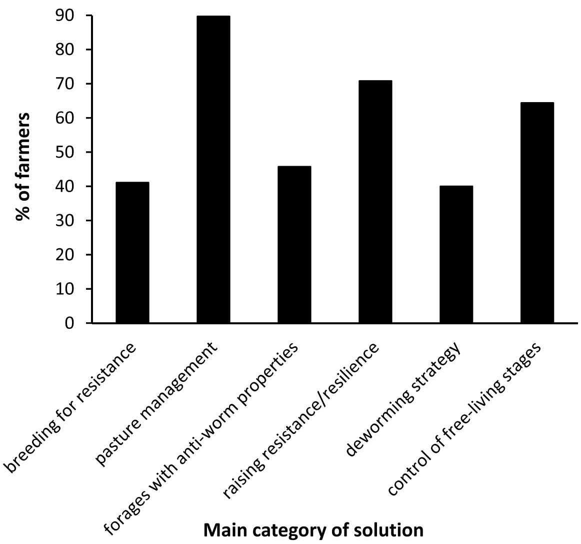

Fig. 6. Category of solutions farmers want to work with to control GI nematode infections.

is willing to apply measures to decrease the number of free-living stages in the environment by means of biological control (65/272), mowing (132/272), not grazing pastures for 3 months (86/272) and/or alternate grazing with other animal species (101/272). Around 40 to 45% of the farmers answered they are willing to breed for genetic resistance against worms, use forages with anthelmintic properties and/or make changes in their deworming strategy.

With respect to breeding for genetic resistance against worm infections, 51.7% (91/176) of the farmers contemplating this option think about using more resistant rams, while 33.5% (59/176) mentions selection based on FEC, 16.5% (29/176) selection based on excluding animals for breeding that show symptoms (resilience), and 15.3% (27/176) selection based on DNA markers.

Overall, there were few significant differences between types of farms or between larger and smaller farms in their answers about the question on preferred solution categories. The major differences were that both sheep breeders and farms participating in nature or land conservation more often would like to breed for genetic resistance than other farm types. For breeding farms this was 55.8% (67/120) vs. 35.4% (109/308) ($\chi^2 = 14.9$, $P < 0.001$), and for nature or land conservation farms this was 61.8% (21/34) vs. 39.3% (155/394) ($\chi^2 = 6.5$, $P < 0.05$). Also, larger farms are more inclined to apply selection for genetic resistance. Of farms with ≥100 ewes, 54.3% (44/81) is interested in genetic resistance, compared to 46.7% (57/122) of farms with 33–99 ewes, and 33.3% (75/225) of farms with ≤32 ewes ($\chi^2 = 13.0$, $P < 0.005$). Further, farms with ≥100 ewes were more inclined to change their deworming strategy (45/80, 56.2%) than farms with 33–99 ewes (50/119, 42.0%) or with ≤32 ewes (74/223, 33.2%) ($\chi^2 = 13.3$, $P < 0.005$). Similar results were obtained with respect to willingness to change pasture management, but differences were overall smaller as the vast majority, irrespective of farm type (89.7%), is already prepared to make changes in pasture management.

Finally, farmers were asked about desired tools to improve their GI nematode control and the kind of support they would like to see. Of 421 respondents, 134 (31.8%) answered they did not need (new) tools or support to aid them in controlling worm infections. These farmers did less often report having problems with worms in general (58.2% vs. 83.6%, $\chi^2 = 31.9$, $P < 0.001$), *H. contortus* ($\chi^2 = 18.9$, $P < 0.001$), *N. battus* ($\chi^2 = 11.5$, $P < 0.005$), and tapeworms ($\chi^2 = 8.8$, $P < 0.005$). They also tended to use anthelmintics less often (78.2% vs. 87.3%, NS), and in particular treated their lambs less often (on average 1.71 vs. 2.21 times, $P < 0.001$).

Of the farmers who indicated a need for tools or aid, 58.9% would like to be able to do their own FEC (169/287), 32.1% would welcome a warning system and/or decision tool for control measures (92/287), 30.7% wants to participate in study groups with other farmers (88/287), 29.3% favours the availability of the Famacha® chart (84/287), 20.2% would welcome a chart with norm bodyweights per sheep breed (58/287), 18.8% mentioned a farm analysis tool to identify and solve specific bottlenecks in worm control (54/287), and 16.7% would like to see a greater involvement of their own veterinary practitioner (48/287). With respect to type of farm or farm size, the most conspicuous result was that farms producing lambs for slaughter and breeding farms more often mentioned participating in study clubs, 16.2% (32/197) vs. 9.8% (22/224) ($\chi^2 = 3.9$, $P < 0.05$) and 35.6% (42/118) vs. 15.2% (46/303) ($\chi^2 = 21.4$, $P < 0.001$), respectively. Larger farms also more often mentioned the desire to participate in study clubs (28.4% of farms with ≥100 ewes, 27.1% of farms with 33–99 ewes, 13.9% of farms with ≤32 ewes; $\chi^2 = 14.6$, $P < 0.005$). Further, larger farms more often mentioned a farm analysis tool to identify bottlenecks in worm control (22.5% of farms with ≥100 ewes, 16.1% of farms with 33–99 ewes, 7.6% of farms with ≤32 ewes, ($\chi^2 = 13.2$, $P < 0.005$)). For all other mentioned tools, no (large) differences were observed between farm types or between larger and smaller farms.

4. Discussion

Over the last decades, efforts have been made to change farmer's and veterinarian's worm control practices in view of the steadily increasing anthelmintic resistance problems. Main efforts focused on reducing the number of anthelmintic treatments in ewes and lambs, and on pasture management measures such as appropriate rotation schemes to prevent haemonchosis (Eysker et al., 2005). Efforts included posting a web-based treatment advisory tool (www.wormenwijzer.nl) in 2007, making leaflets listing the main worm species and how to control these, and numerous papers in trade journals. Nonetheless, anthelmintic resistance has increased enormously over the last decade, including ivermectin and moxidectin resistance in *H. contortus* (Borgsteede et al., 2010; Van den Brom et al., 2013, 2015; Ploeger, unpublished results). Moreover, GI nematode infections were recently identified as one of the most challenging and urgent problems by the sheep industry, which has led to funding the present study. Apparently, efforts to educate both farmers and veterinarians are not as effective as one would hope, which conforms to experiences elsewhere (Van Wyk and Reynecke, 2011; Morgan et al., 2012; Woodgate and Love, 2012; McMahon et al., 2013). In order to get handholds for facilitating implementation of alternative strategies, the present survey was conducted to identify sheep farmer's perceptions concerning worm infections, their anthelmintic treatment practices, their actions to slow down AR development, and their perception of bottlenecks and possible solutions in worm control.

In general, results conform well to the results from a recent questionnaire on helminth control practices in the UK (Morgan et al., 2012). In the Netherlands, *Haemonchus contortus* and to a lesser extent, *Nematodirus battus* are considered the most important GI nematodes. These two species were often recognized separately from the more general term GI nematodes. The species *Teladorsagia circumcincta* and *Trichostrongylus* spp. were hardly mentioned by sheep farmers. Of all respondents, 25.6% said they did not have any worm problems. Of these, almost a third did notice clinical signs that can be related to worm infections and about three quarters did use anthelmintic treatments. Overall, clinical symptoms mentioned by farmers matched the worm species farmers identified as the cause of problems. One exception concerned tapeworm infections, which were mentioned as a problem by 17.3% of the farmers. Morgan et al. (2012) found that 32% of UK sheep farmers considered tapeworms a problem and suggested more research is needed on the requirement to treat against tapeworms. However, already in 1986 Elliott (Elliott, 1986) concluded that there was no evidence at all to support treating against tapeworms. Recently, Dever et al. (2015) concluded that removing tapeworms does not increase growth rates of lambs. Interestingly, farmers involved in nature and land conservation more often mentioned experiencing problems with tapeworms. This group of farmers is in close contact to each other. Unfortunately, we do not know the background of this opinion. Unnecessary treatments against tapeworms may impose additional selection pressure on AR development, although this currently may be a minor problem in the Netherlands as oxfendazole is the only registered product available for the treatment of tapeworms to which much AR is present, particularly in *H. contortus*. On the other hand, oxfendazole is recommended and also widely used against nematodirosis just because *H. contortus* is resistant against this product on almost every farm.

A surprisingly large proportion of farmers (15.6%) said they had not used anthelmintics in 2013. However, some conflicting answers were obtained as answers to other questions suggested that only a few per cent of all farmers had not used anthelmintics. This is difficult to explain. Nonetheless, some interesting aspects emerged from all questions related to treatment practices. Ewes and lambs were treated up to 6 times in 2013. On average, ewes were treated 1.53 and lambs 2.05 times. This is lower than observed in the UK (Morgan et al., 2012), where ewes were treated 2.35 and lambs 3.55 times. This difference may be the result of some differences in husbandry practices. Noticeably, the great majority of farms in the UK study treated lambs in January, whereas this is rarely done in the Netherlands. In both countries, it appears that both ewes and lambs are frequently treated based on fixed moments such as around lambing, at weaning and before mating. Another interesting observation is that farmers who treat their ewes more often, also tend to treat their lambs more often. One might expect lambs would require fewer treatments if ewes are more often treated. Apparently, farmers do not oversee treatment consequences in one group of animals for another group of animals. Treatments based on faecal egg counts is practiced, but on a minority of the farms (32.7%). The majority of the farmers also do not leave 2–5% of the animals within a flock untreated, even though this has been a recommendation (www.wormenwijzer.nl) for many years. Part of the reason may be that flocks are considered too small to leave animals untreated, which is supported by the fact that larger farms more often left a few animals untreated. However, this doesn't fully explain the overall low compliance to this recommendation. It is plausible that farmers in general do not trust or understand the reasoning behind leaving a few animals untreated. Also, leaving a few animals untreated implies that these animals keep contaminating pastures with worm eggs, a fact some farmers may find difficult to cope with. In general, results show that there still is a large, unnecessary and ill-justified use of anthelmintics, despite many efforts to reduce their use. It may be concluded from the results of this study that all efforts so far to get the message across regarding a more rational and minimal use of anthelmintics, were not as effective as one might have wanted which conforms to experiences elsewhere (Van Wyk et al., 2006; Morgan and Coles, 2010; Woodgate and Love, 2012; McMahon et al., 2013). The same applies for quarantine practices. About 74% of farmers keep newly purchased animals quarantined for at least 10 days, but some of these farmers (13.4%) leave quarantined animals untreated nor check faecal egg counts, thereby rendering the quarantine period ineffective with respect to worm infections. Of farmers who do treat their quarantined animals, just 12.6% check the efficacy of the treatment. This leaves much room for improvement in quarantine procedures and regularly checking the efficacy of used products, which again conforms to what was reported elsewhere (Lawrence et al., 2007; Morgan and Coles, 2010; Morgan et al., 2012; McMahon et al., 2013).

Slightly over forty per cent of the respondents said they did not experience bottlenecks in parasite control. Yet, over half of these said they were having problems with worm infections, over half did see clinical signs which could be related to worm infections and over three quarters used anthelmintics. Apparently, not experiencing bottlenecks in parasite control does not equate to being able to prevent a negative impact of worm infections on many of these farms. Within the group of farms experiencing difficulties in parasite control, the most often mentioned bottleneck pertains to pasture management, even though pasture rotation has been shown to be effective in reducing levels of worm challenges (Healey et al., 2004; Eysker et al., 2005). Farmers find it difficult to apply the proper pasture rotation schemes due to limited and variable grass availability and size of pastures (eg. difficult to create smaller paddocks), and probably in association with a lack of understanding the temporal dynamics of worm infections. Related to this bottleneck is that some farmers rent areas from (semi-) governmental organisations who put restrictions on how and when such areas can be grazed. Such restrictions often hinder application of proper pasture rotation in view of worm control.

Just a small percentage of farmers indicates that quarantine periods present difficulties. Yet, as noted above, many farmers do not follow proper quarantine procedures to prevent introduction of a resistant worm population. About 18% of the respondents mentioning bottlenecks indicates they lack sufficient knowledge on how to control worm infections. And about a quarter of the respondents mentioning bottlenecks indicated a lack of knowledge on which anthelmintics to use, and to what products AR is present, either on their farm or on farms from which they purchase sheep. Overall, answers to the question on perceived bottlenecks suggest that the major obstacle experienced concerns the use of pastures in relation to worm infections. And while about 75% of all respondents indicated having problems with worm infections, a minority mentioned bottlenecks that could be associated with lacking knowledge on aspects of parasite control. Apparently, most farmers feel they have sufficient knowledge as such but do not know how to effectively use this knowledge.

When asking farmers for solutions, 90% of all respondents indicates they are willing to adjust their pasture management. This is a large percentage as 41% of all respondents indicated not perceiving any bottlenecks in parasite control. Apparently, this 41% is still seeking improvement in worm control, supported by the fact that most of these do notice clinical signs related to worm infections and require anthelmintics. The fact that 90% do look for improving pasture management, implies that many farmers indeed appear to be somehow unable to improve pasture use without expert help. Worldwide, adapting pasture management has been mentioned as one of several possibilities to control worm infections (Eysker et al., 2005; Hoste and Torres-Acosta, 2011; Van Wyk and Reynecke, 2011). Yet, by far most efforts are focused on targeted selective treatments (Kenyon and Jackson, 2012; Charlier et al., 2014), which implies that most still regard anthelmintic usage as the basis of parasite control. However, proper pasture rotation is highly effective in minimizing exposure to worm infections making extensive use of anthelmintics redundant.

Farmers are also interested in other methods to reduce the risk of worm infections, such as possibilities to enhance the immune system of sheep in general, to increase specific genetic resistance to worms, and to apply anti-parasite products other than the currently available anthelmintics. About 40% of the farmers are interested in breeding sheep more resistant to worms. However, most of them do not expect to be using DNA markers in breeding for genetic resistance. Most want to use a more resistant ram for breeding or want to use FEC as a means to improve resistance to worm infections. In this questionnaire survey, the use of saliva IgA levels (Shaw et al., 2012) was not mentioned as a possibility. However, since 2014 we have been examining the use of this variable and it appears that some farmers are as interested in this parameter as they are in FEC (Ploeger et al., unpublished data). Overall, there is an overwhelming and wide interest in all possibilities to improve worm control.

Concluding, the results of the present study can be used to support improvements in parasite control practices and transfer of knowledge on why certain actions may be wise and others not. Woodgate and Love (2012) gave a solid account of factors involved in effectively communicating changes in management and approaches in worm control. These factors include the motivation to change, seeing immediate benefits of change, and complexity of solutions and messages. Learmount et al. (2015) demonstrated that working closely with farmers over a longer period produced significant reductions in anthelmintic usage without health and production penalties. Translating this to the current results for Dutch sheep farmers, foci of attention may be: (1) making complex scientific knowledge more accessible to farmers through simple tools and applicable in the daily farming process; (2) changing the mindset of farmers about their current worm control practices, i.e. breaking long-standing habits in management such as treating ewes and lambs at fixed moments rather than based on actual worm infection monitoring data; (3) demonstrating effective pasture rotation schemes on specific farms and using these in extension work; (4) making farmers more aware that checking anthelmintic treatments for efficacy is important; (5) effective quarantine procedures in case of purchased animals to prevent introduction of AR; and (6) creating a wider array of applicable alternative control measures from which individual farmers can choose what fits them most. Finally, probably the most essential aspect might be the need for a fundamental change in mindset and improved mutual understanding among farmers, veterinary practitioners and parasitologists alike. Most efforts are focused on optimising the number of anthelmintic treatments within initiatives such as targeted flock and individual treatment approaches and targeted selective treatments (Kenyon and Jackson, 2012; Charlier et al., 2014) to delay anthelmintic resistance. However, all such efforts are still built on the premise that anthelmintic treatments form the basis of parasite control, as if this is an inescapable fact of life. It might be more fruitful to focus on production systems and control measures that do not require the use of anthelmintic treatments unless absolutely necessary, which would be more in line with the notion of responsible use of medicines. Interestingly, there are a number of Dutch sheep farmers who apparently do not need to use anthelmintic drugs. The same is, for example, true for Great Britain (Morgan et al., 2012). In the Netherlands, at least some of those farms are not different from the average commercial sheep farm, and yet apparently manage well without anthelmintic drugs. It might be worthwhile to focus more on such farms, and if possible, making those farms exemplary for other sheep farmers.

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