Indian Journal of Animal Sciences **80** (7): 593–600, July 2010

Worm-control practices, anthelmintic use and its implication on anthelmintic resistance in gastrointestinal nematodes of sheep in Rajasthan

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Received: 23 May 2009; Accepted: 3 January 2010

ABSTRACT

The base line information on management of sheep flocks with greater emphasis on worm control practices was collected from sheep farmers of Rajasthan. The status of anthelmintic resistance in gastrointestinal nematodes against commonly available anthelmintics (benzimidazole, tetramisole and closantel) was determined through faecal egg count reduction test, and results were correlated with flock-management practices. Information obtained from this study indicates lack of knowledge about worm-control strategies, anthelmintic use and the problem of anthelmintic resistance among the majority of sheep farms. There is high prevalence of benzimidazole resistance (86.4%) and moderate prevalence of tetramisole resistance (55.7%) with distinct regional variation. The existing drench frequency is not justifiable and there is a high opportunity to harvest the benefits of agro-climatic conditions, grazing resources and practices to save money by avoiding unnecessary en-mass treatments in sheep flocks of Rajasthan. The predominance of *Haemonchus contortus* (Rudolphe, 1803) and use of all types of anthelmintics revealed that there is a need to educate farmers and extension workers on appropriate anthelmintics to be used in their locality. Animals shared the same pasture sources particularly in monsoon and post-monsoon season, thus to prevent borrowing and probability of emergence of multiple resistance. There is a need to coordinate farmers in all management systems at a community or village level with respect to use of anthelmintic type for a particular year with greater involvement of researchers, pharmaceuticals, field veterinarian and extension workers.

Key words: Anthelmintic resistance, Flock rearing practices, Gastrointestinal nematodes, Sheep, Worm management

Routine, frequent and indiscriminate uses of anthelmintics have resulted in the emergence of resistant strains of parasites all over the world. The question today is whether farmers are administering the right product at the right time to right category of animals (Keyyu *et al*. 2003). Worm-control practices for small ruminants and/or cattle are well documented in England (Gettinby *et al.* 1987), New Zealand (Scherrer *et al.* 1989), Denmark (Maingi *et al*. 1996a, b), Kenya (Maingi *et al.* 1997), USA (Reinemeyer *et al*. 1992), Tanzania (Keyyu *et al.* 2003). The association between anthelmintic resistance and risk factors in management which potentially contribute to its development was also investigated on sheep farms in New Zealand (Kettle *et al.* 1981, 1982), Australia (Edwards *et al*. 1986) and Denmark (Maingi *et al*. 1996 a).

Surveys to examine control practices for helminth parasites in livestock in various countries were undertaken to improve helminth-control programmes (Scherrer *et al.*1989). The rising undocumented reports of anthelmintic failure and detection of strains of sheep nematodes resistant to anthelmintics (Singh and Swarnkar 2008), indicated the need for a survey of sheep flocks to determine how widespread resistance is and anthelmintics and species involved. An information from such studies is essential to manage the rising incidence of anthelmintic resistance.

In India nothing is documented on worm-control practices and anthelmintic usages in any class of livestock, therefore it may be possible that worm-control practices in different agro-climatic regions might be erratic or a waste of anthelmintics. A questionnaire survey was undertaken to collect the information on the worm-control practices as adopted by sheep farmers of Rajasthan, and their influence on emergence on anthelmintic resistance was established to know whether there was obvious waste of anthelmintics and any shortcoming in the knowledge about worms and worm control among farmers in traditional sheep farming in different agroclimatic regions of Rajasthan.

MATERIALS AND METHODS

Study area: The study was conducted in 4 zones — semi-arid (zone I and IV) and arid (zone II and III) agro-climate

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of Rajasthan. The climatological characterization of different zones is presented in Table 1.

Questionnaire survey: Information on sheep management, worm-control measures, anthelmintic use pattern and other prophylactic health measures was collected by interviewing 550 sheep farmers from different zones of Rajasthan using a questionnaire. The questionnaire broadly contained 2 sections. One section dealt with worm-control practices being adopted by farmers and aimed at establishing the facts regarding frequency and timing of drenching, criteria used for selection of anthelmintics, types of anthelmintics used in past, preference for satisfactory anthelmintics in farmer's opinion and criteria used for dose determination. Another section of the questionnaire aimed at establishing the management practices adopted by sheep breeders, and information was gathered for flock dynamics, grazing resources and pattern, lambing pattern, type of grazing, disposal of animals and economics of the flock.

Detection of anthelmintic resistance: In-vivo faecal egg count reduction test (FECRT) was used to detect resistance in nematode parasites (Coles *et al*. 1992). The study was conducted on 141 flocks using benzimidazole (@ 5 mg/kg body weight), tetramisole (@ 15 mg/kg body weight) and closantel (@ 10 mg/kg body weight). According to size of flock, animals were grouped in 2–4 groups (differentiated by marking with different colours). In each flock 1 group of animals was kept as control (undrenched). Faecal egg count reduction (FECR)% was calculated on samples collected on 10–12 days post-treatment using RESO programme. Treatment-wise pooled faecal samples were cultured at 27ºC for 5–7 days to obtained generic composition of strongyle larvae on both the occasions. The efficacy of closantel was calculated only for *Haemonchus contortus* (Rudolphi, 1803) using coprocultural proportion through RESO programme.

Interaction between worm-management practices and status of anthelmintic resistance: The information gathered

Table 1. Climatological characterization of different zones of Rajasthan (Rudolphe, 1803)

Period	Zones			
	I	II	III	IV
Mar–May	T_{max} – 37.76°C T_{min} –24.13°C TRF – 9.01 mm RH – 35.50% Hot-Dry (High temp. Low humidity and Scanty rainfall)	T_{max} – 38.22°C T_{min} –20.94°C TRF – 11.33 mm RH – 45.61% Hot-Dry (High temp. Moderate humidity and Low rainfall)	T_{max} – 38.77°C T_{min} –23.31°C TRF – 2.75 mm RH – 45.97% Hot-Dry (High temp. Moderate humidity and Scanty rainfall)	T_{max} – 37.87°C T_{min} –21.66°C TRF – 7.63 mm RH – 38.92% Hot-Dry (High temp. Low humidity and Scanty rainfall)
Jun–Aug	T_{max} – 35.41°C T_{min} –26.70°C TRF – 140.94 mm RH – 69.83% Hot-Humid (High temp. High humidity and High rainfall)	T_{max} – 39.05°C T_{min} –27.73°C TRF – 70.14 mm RH – 66.64% Hot-Humid (High temp. High humidity and Moderate rainfall)	T_{max} – 37.15°C T_{min} –26.61°C TRF – 61.97 mm RH – 74.39% Hot-Humid (High temp. High humidity and Moderate rainfall)	T_{max} – 33.18°C T_{min} –25.02°C TRF – 137.84 mm RH – 76.00% Hot-Humid (High temp. High humidity and High rainfall)
Sep–Nov	T_{max} – 33.97°C T_{min} –21.16°C TRF – 12.71 mm RH – 52.69% Hot-Humid (High temp. Moderate humidity and Low rainfall)	T_{max} – 33.62°C T_{min} –18.20°C TRF – 5.46 mm RH – 61.97% Hot-Humid (High temp. High humidity and Scanty rainfall)	T_{max} – 35.72°C T_{min} –20.89°C TRF – 6.17 mm RH – 53.61% Hot-Humid (High temp. Moderate humidity and Scanty rainfall)	T_{max} – 33.22°C T_{min} –17.60°C TRF – 16.02 mmRH – 61.08% Hot-Humid (High temp. Low humidity and Low rainfall)
Dec–Feb	T_{max} – 25.80°C T_{min} –11.36°C TRF – 7.98 mm RH – 60.67% Cold-Humid (Low temp. Moderate humidity and Scanty rainfall)	T_{max} – 24.36°C T_{min} –7.39°C TRF – 7.49 mm RH – 77.67% Cold-Humid (Low temp. High humidity and Scanty rainfall)	T_{max} – 28.22°C T_{min} –11.53°C TRF – 2.75 mm RH – 54.19% Cold-Humid (Low temp. Moderate humidity and Scanty rainfall)	T_{max} – 27.28°C T_{min} –8.93°C TRF – 3.14 mm RH – 60.50% Cold-Humid (Low temp. Moderate humidity and Scanty rainfall)

on worm-management practices adopted by sheep breeders of Rajasthan were categorized according to flock size in 3 groups, viz. small (up to 50 sheep/flock), medium (50–100 sheep/flock) and large (> 100 sheep/flock). All these practices were correlated with prevalence of anthelmintic resistance through cross-tab and chi-square analysis using SPSS ver 15 programme.

The data of questionnaire survey were categorized by frequency distribution and cross tabulations were made between related responses. Differences between proportions were analyzed statistically using chi-square test.

RESULTS AND DISCUSSION

Sheep husbandry practices adopted by farmers

Flock size: The average flock size was 69.00 ± 2.24 sheep/flock. However, average flock strength per farmer varied significantly (P>0.001) in different parts of Rajasthan. In Eastern (zone I) and Southern (zone IV) parts of the state (semi-arid), it ranged from 69.56 ± 4.13 to 78.90 ± 4.09 and in Northern (zone II) and Western (zone III) parts (arid) it varied from 53.08 ± 2.87 to 55.46 ± 3.49 sheep per flock. The overall adult : lamb ratio in flock was 76.6: 23.4 and ranged from 72.9: 27.1 in zone II to 80.3: 19.7 in zone IV.

Type of rearing: Among the flocks surveyed, 86% were reared through stationary system while 14% were managed through semi-migratory system. The proportion of farmers rearing their flocks exclusively on stationary pattern ranged significantly (P>0.001) from 76.6% (zone I) to 99% (zone IV). The semi-migratory flocks usually undergo temporary migration towards Uttar Pradesh, Madhya Pradesh, Haryana and Punjab during spring and summer.

Sheep rearing experience: In Rajasthan 76.0% of the farmers interviewed, follow sheep rearing occupation as a family tradition and having more than 20 years of experience while 13.4% were having 5–20 years of experience in sheep rearing. Only 5.7% of farmers were new incumbent during the period of survey.

Grazing resources: Community grazing land, on-farm waste and top feed are commonly utilized by sheep farmers (82.2%) for their flocks.

Interspecies grazing: In Rajasthan 70.8% of the sheep flock owner grazed sheep and goat mixed together. The practice of interspecies grazing varied significantly (P> 0.001) between different zones. In semi-arid region around 40% of flocks were exclusively sheep, while in arid region only 10–12% of flocks possessed only sheep in their flocks.

Reproductive management: In field flocks open mating is the only method practiced by farmers. The mean annual lambing rate ranged from 72.65 ± 1.56 (zone IV) to 84.58 ± 2.14% (zone II) with an overall rate to the tune of 79.29 ± 0.74%. In Eastern and Northern Rajasthan annual lambing was more than 80% in majority of flocks whereas in Western and Southern Rajasthan it was between 50 and 80%. Though lambing in flocks occurred throughout the year, majority lambed during September to December in all the zones.

Health management: In Rajasthan the regular vaccination against sheep pox was carried out in 43.2% of flocks surveyed, while 19.3% found to vaccinate their flock occasionally after occurrence of disease. The adoption rate for sheep-pox vaccination showed significant (P > 0.001) zonal variation and ranged from 16.5% (zone IV) to 55.6% (zone I). A total of 54.4% farmers regularly vaccinated their flock against enterotoxaemia. The practice of enterotoxaemia vaccination was significantly (P> 0.001) influenced by zones and adoption rate varied from 24.3% (zone IV) to 73.9% (zone I). The use of acaricides in sheep flocks for the control of ecto-parasites was very limited and only 17.0% of flock owners used ectoparasiticidal drugs at regular interval. The acaricide application rate ranged from 9.2% (zone II) to 27.8% (zone III).

Anthelmintic management: In field flocks of Rajasthan, use of anthelmintics is the only measure adopted to control problem of gastrointestinal parasitism in sheep. The mean annual frequency of strategic anthelmintic drench varied significantly (P> 0.001) from 2.31 ± 0.07 (zone II) to 2.68 ± 0.06 (zone IV) with an average of 2.59 ± 0.03/sheep/year. In majority of flocks (51.9%) the animals received 3 drenches of anthelmintics in a year followed by 2 drenches/year (39.9% flocks). Only 5.0% of the farmers practiced > 3 drench/year. Majority of farmers (61.3%) in zone II usually drenched their sheep twice a year. Monthly distribution of drench frequency exhibited overall drenching period during April/June, September/November and February indicating that usual practice of anthelmintic intervention was coupled with shearing of sheep.

Around 70.0% farmers selected anthelmintics based on their own perception or sought advice of chemist, while only 27.6% of the farmers consulted local veterinarian for selection of anthelmintic. In semi-arid region around 20% farmers depended on veterinarian’s advice in contrast to around 40% in arid region for selection of anthelmintics. Usually no set criterion was used by farmers (38.2%) for determining the dose of anthelmintics for sheep. However, 43.7% of farmers formulated the dose according to information mentioned in bulletin/literature supplied with anthelmintic in consultation with chemist.

The common anthelmintics with which farmers were well familiar were benzimidazole (BZ) and tetramisole (TEM). Both of these anthelmintics were used by >50% of farmers regularly since their introduction in to the market. Only 13.0 and 12.4% farmers used single class of anthelmintic either BZ or TEM, while 19.2% of farmers used many other types of anthelmintics (rafoxanide, closantel, CUNIC mixture etc) in addition to BZ and TEM. The proportion of farmers using only BZ was significantly (P> 0.001) higher in the Northern Rajasthan. After use of anthelmintics since long, farmers had developed their own perception about effectiveness of anthelmintics. Survey revealed that 70% farmers showed preference for TEM as better anthelmintic and only 26.5% farmers for BZ group. Zone-wise analysis exhibited that perception for best anthelmintic varied significantly (P> 0.001) among farmers of different zones. In zone II, exceptionally 67.1% of farmers revealed that BZ group is still effective in controlling the worm infection in their flocks compared to 8.5 – 27.5% in other zones. Majority of farmers (83.4%) revealed that problem of gastrointestinal nematodiosis in flock was evident mainly during monsoon season.

Prevalence of anthelmintic resistance in GI nematodes of sheep

Benzimidazole (BZ)*:* Flocks (140) were tested for BZ-resistance by *in-vivo* FECRT using fenbendazole. In Rajasthan BZ-resistant strains of GI nematodes were found in 86.4% of the flocks (Table 2). The percentage of flocks harbouring BZ-resistant worm ranged from 71.0 (zone II) to 92.1 (zone IV). On the basis of post-treatment coproculture *H. contortus* was found predominant parasite, which had developed resistance to BZ. The efficacy of BZ in sheep naturally infected with GIN was >95% in 7.0% (zone I) to 25.8% (zone II) of the flocks. It was observed that in zone I, majority of flocks (39.5%) exhibited 50–80% (with an average of 65.1 ± 2.6%) efficacy with BZ (Table 3). In zone II, 35.5% of the flocks had 50–80% efficacy with an average of 70.2 ± 1.9%. In zone III, 39.3% of the flocks showed an average efficacy to the tune of 62.5 ± 2.4% while in zone IV, 34.2% of flocks exhibited an average of 87.2 ± 1.5% efficacy against natural GIN infection.

Tetramisole (TEM)*:* Out of 115 flocks tested on FECRT, TEM-resistant strain of GIN was observed in 55.7% of the flocks in Rajasthan (Table 2). Zone-wise analysis revealed that prevalence of TEM-resistance varied from 13.0 (zone II) to 83.9% (zone IV). Studies on efficacy of TEM against GIN in sheep revealed that in zone II, the maximum number of flocks (87.0%) showed > 95% efficacy with an average of 99.3 ± 0.5% efficacy, followed by zone I (42.1% of flocks with average efficacy to the tune of 98.4 ± 0.4%). On the other hand, in zone III and IV, majority of flocks (47.8 and 41.9% respectively) exhibited efficacy between 80 and 95% with an average of 89.5 ± 1.5 and 88.5 ± 1.2% respectively.

Closantel (CLS)*:* Closantel is an anthelmintic having persistent effect only against haematophagous parasites such as *H. contortus*. Therefore, the %FECR was calculated only for *H. contortus* in each flock. Out of 56 flocks in which the drug was tested none of the flocks showed CLS-resistant *H. contortus.*

Interaction between worm-management practices and status of anthelmintic resistance

Drench frequency: The use of anthelmintic was the only method applied to combat the problem of gastrointestinal nematodiosis in sheep. Flock size had nonsignificant influence on drench frequency. The average number of drench per year per sheep varied from 2.55 ± 0.06 in small flocks to

Table 2. Prevalence of anthelmintic resistance in GINs from sheep in Rajasthan

	Benzimidazole					Tetramisole				
	I	II	III	IV	Over all	I	II	III	IV	Over all
No. of flocks tested	43	31	28	38	140	38	23	23	31	115
Susceptible flock (%)	0.0	12.9	7.14	2.6	5.0	23.7	78.3	21.7	12.9	31.3
Likely resistant flock (%)	9.3	16.1	3.6	5.3	8.6	21.1	8.7	17.4	3.2	13.0
Resistant flock (%)	90.7	71.0	89.3	92.1	86.4	55.3	13.0	60.9	83.9	55.7

Table 3. Anthelmintic efficacy against natural infection of GIN in sheep flocks of Rajasthan

Zone	% FECR							
	> 95%		80–95%		50–80%		< 50%	
	% flock	Mean FECR	% flock	Mean FECR	% flock	Mean FECR	% flock	Mean FECR
Benzimidazole								
I	7.0	96.3 ± 0.3	32.6	86.6 ± 1.1	39.5	65.1 ± 2.6	20.9	15.9 ± 5.7
II	25.8	98.5 ± 0.3	19.3	91.7 ± 1.3	35.5	70.2 ± 1.9	19.4	32.5 ± 6.5
III	10.7	99.0 ± 1.0	25.0	87.1 ± 1.7	39.3	62.5 ± 2.4	25.0	36.4 ± 4.9
IV	7.9	97.0 ± 0.6	34.3	87.2 ± 1.5	28.9	60.5 ± 2.2	28.9	28.8 ± 5.1
Tetramisole								
I	42.1	98.4 ± 0.4	26.3	89.4 ± 1.4	23.7	74.8 ± 1.4	7.9	30.3 ± 15.4
II	87.0	99.3 ± 0.5	8.7	91.0 ± 4.0	4.3	71.0	–	–
III	30.4	98.6 ± 0.4	47.9	89.5 ± 1.5	17.4	65.8 ± 4.1	4.3	24.0 ± 0.3
IV	12.9	99.3 ± 0.5	41.9	88.5 ± 1.2	38.7	69.8 ± 2.1	6.5	25.5 ± 6.5

2.63 ± 0.13 in large flocks (Table 4). Similarly, flock size found to have nonsignificant effect on the prevalence of anthelmintic resistance (Table 5), however, a linear rise in prevalence rate of anthelmintic resistance was observed with increase in flock size. On FECRT, it was observed that emergence of BZ and TEM resistance in *H. contortus* was significantly ($P<0.05$) influenced by drench frequency and had positive correlation.

Table 4. Interaction between worm-management practices and size of field flocks in Rajasthan

Practices	Flock (%)			Overall
	Small	Medium	Large	
Drench frequency/year				
1	2.3	0.0	0.0	1.4
2	42.0	47.7	37.5	43.2
3	54.5	47.7	62.5	53.4
>3	1.1	4.6	0.0	2.1
Mean	2.55 ± 0.06	2.59 ± 0.09	2.63 ± 0.13	2.57 ± 0.05
Anthelmintic type used				
Only BZ	16.5	4.5	0.0	11.1
Only TEM	5.9	2.3	6.7	4.9
Both BZ and TEM	61.2	59.1	33.3	57.6
All	16.5	34.1	60.0	26.4
Anthelmintic selection criteria				
Own	5.7	9.1	12.5	7.5
Chemist	50.6	52.3	56.3	51.7
Vet	43.7	38.6	31.2	40.8
Perception for best anthelmintic				
BZ	30.6	38.1	42.9	34.4
TEM	66.7	61.9	42.9	62.5
Other	2.8	0.0	14.3	3.1

Table 5. Interaction between worm management practices and status of anthelmintic resistance in *H. contortus* from field flocks in Rajasthan

Practices	Proportion (%) of flock								
	Resistance			Likely to resistance			Susceptible		
	BZ	TEM	CLS	BZ	TEM	CLS	BZ	TEM	CLS
Flock size									
Small	87.5	50.9	0.0	6.3	15.8	16.7	6.3	33.3	83.3
Medium	90.0	63.4	0.0	10.0	14.6	14.3	0.0	22.0	85.7
Large	92.3	66.7	0.0	0.0	0.0	8.3	7.7	33.3	91.7
Drench frequency/year									
Up to	85.2	44.0	0.0	4.9	12.0	14.3	9.8	44.0	85.7
2> 2	91.5	67.8	0.0	8.5	15.3	13.8	0.0	29.4	86.2
Anthelmintic type used									
Only BZ	75.08	20.0	0.0	12.5	10.0	33.3	12.5	70.0	66.7
Only TEM	3.3	100.0	0.0	0.0	0.0	0.0	16.7	0.0	100.0
Both BZ and TEM	94.6	61.9	0.0	4.1	15.9	20.7	1.4	22.2	79.3
All	81.3	51.7	0.0	12.5	13.8	5.3	6.3	34.5	94.7
Anthelmintic selection criteria									
Own	91.4	54.5	0.0	9.1	9.1	16.7	9.1	36.4	85.3
Chemist	87.1	56.6	0.0	8.1	11.3	11.11	4.8	32.1	88.9
Vet	91.4	57.8	0.0	5.2	17.8	6.7	3.4	24.4	83.3
Perception for best anthelmintic									
BZ	81.6	33.3	0.0	7.9	9.1	10.0	10.5	57.6	90.0
TEM	88.9	73.8	0.0	8.3	14.8	13.3	2.8	11.5	86.7
Other	100.0	33.3	0.0	0.0	66.7	0.0	0.0	0.0	100.0

Type of anthelmintics used: Type of anthelmintic used by farmers to control GIN in sheep was affected significantly (P< 0.001) by size of flock. Among small farmers 61.2% used both BZ and TEM. In medium category, 59.1% utilized both BZ and TEM followed by 34.1% with all types of anthelmintics. On the contrary, majority of large farmers (60.0%) utilized all types of anthelmintic (Table 4) followed by both BZ and TEM (33.3%). Type of anthelmintic used by farmers had nonsignificant effect on the prevalence of BZ-resistance; however TEM-resistance was significantly (P<0.05) influenced by type of drug used (Table 5). As all the types of anthelmintic are in use in field flocks of same locality, the parasite in refugia as well as in host comprised both population susceptible and resistant to anthelmintic. Thus, there is possibility of borrowing of resistant worms, and it could be the reason behind such results that flocks in which BZ was never used exhibited 83.3% prevalence of BZ-resistance in parasite population. Similarly, in flock never drenched with TEM exhibited 20.0% prevalence of TEM-resistance.

Anthelmintic selection criteria: Almost similar level of criteria was used by farmers of all categories while selecting the anthelmintic. The majority of farmers (>50%) depend upon the advice of chemist for anthelmintic type, while 40.0% of farmers sought veterinarian's advice for selection of anthelmintic (Table 4). The criteria for selection of anthelmintic showed no significant effect on the prevalence of anthelmintic resistance (Table 5).

Perception of farmer for best anthelmintic: Flock size showed nonsignificant influence on farmer's perception for best anthelmintic. Majority of farmers (62.5%) had preference for TEM as best anthelmintic (Table 4). Following prolonged use of anthelmintic, sheep farmers had their own perception for best drug. The data related to their perception for best anthelmintic showed significant (P < 0.001) correlation with prevalence of TEM-resistance (Table 5).

Flock size and anthelmintic efficacy: Flock size had nonsignificant effect on efficacy of anthelmintics. Among anthelmintic-resistant group the % efficacies were 62.03 ± 2.33 and 74.86 ± 2.56 for BZ and TEM respectively (Table 6). In anthelmintic susceptible group the % efficacies were 99.83 ± 0.17, 99.69 ± 0.09 and 99.63 ± 0.13 for BZ, TEM and CLS respectively.

Epidemiological studies in Rajasthan indicated that worm burden in sheep was the lowest during dry season (February to May), increased gradually through the rainy season to reach peak at the end of rainy season (September). Thus there is a great potential for improvement of control programme through utilizing epidemiological knowledge, grazing resources available and practices adopted by farmers (Singh *et al.* 1997, Swarnkar *et al.* 2008) and better targeting of anthelmintic treatments as opposed to the observed situation where most treatments are based on the availability of money and governed mainly by the chemists.

Results from this survey indicated that such treatment frequency is not justifiable and there is a high opportunity to harvest the benefits of agro-climatic conditions, grazing resources and practices to cut the expenditure by avoiding unnecessary en-mass treatments. Further, reduced use of anthelmintic will aid to growth of nation in terms of preserving and extending the life of the existing anthelmintics. The high frequency of treatment might be related to advice from extension personals, suggesting deworming at regular intervals (4 times a year) regardless of the epidemiology and management system (Keyyu *et al.* 2003). The predominance of *H. contortus* and of amphistomes, particularly in semi-arid Rajasthan, and use of all types of anthelmintics revealed that there is a great need to educate farmers and extension workers on appropriate anthelmintics to be used in their locality. Since, animals shared the same pasture sources, particularly in monsoon and post-monsoon season, to prevent borrowing and probability of emergence of multiple resistance, there is a need to link or coordinate farmers in all management systems at a community or village level with respect to use of anthelmintic type for a particular year.

It has been observed that anthelmintic use in field flocks of all regions depended on the availability of fund and not based on epidemiological need to drench against gastrointestinal parasites. Farmers were generally relied on the advice of commercial interests when formulating their drench schedule. The use of anthelmintic for control of GIN was common for both lambs and adult sheep. The most commonly used occasion for drenching sheep was at the time of sale of wool after shearing. The anthelmintic treatment during climatic extreme (June and December/February)

Table 6. Interaction between anthelmintic efficacy and size of field flock in Rajasthan

Flock size	Mean Efficacy (%)								
	Resistance			Likely to resistance			Susceptible		
	BZ	TEM	CLS	BZ	TEM	CLS	BZ	TEM	CLS
Small	60.94 ± 3.40	73.14± 3.74	–	96.80± 0.37	97.00± 0.62	96.00± 1.15	98.80± 0.20	99.58± 0.14	99.57± 0.20
Medium	64.58± 3.17	73.54± 4.42	–	96.00± 0.41	96.67± 0.80	97.50± 0.64	–	99.78± 0.14	99.71± 0.18
Large	60.67± 6.61	85.37± 2.96	–	–	–	98.00	100.0	100.0	99.55± 0.13
Overall	62.03± 2.33	74.86± 2.56	–	96.44± 0.29	96.47± 0.51	97.00± 0.57	99.83± 0.17	99.69± 0.09	99.63± 0.13

enhances the development of resistance (Coles and Roush 1992). Further rotation of flocks after drenching on harvested field or grazing only on top feed resulted in build up of resistant larvae on pasture in next favourable season with subsequent increase in the speed of emergence of anthelmintic resistance. Mixed grazing with other species which is likely to reduce pasture infectivity due to host specificity of the predominant parasites, was practised by very few farmers thus effect of reducing the worm population was likely to be low (Maingi *et al*. 1996 a).

The mean number of anthelmintic treatments/year (2.57) recorded in present survey was almost similar to that reported in Australia (2.8) by Edwards *et al.* (1986), USA (3.3–4.0) by Reinemeyer *et al.* (1992), UK (2.44) by Gettinby *et al.* (1987), and in Denmark (2.3) by Maingi *et al.* (1996 a). Anthelmintics should be used at the minimum number of time necessary to achieve acceptable productivity (Waller 1987, Coles and Roush 1992). In majority of flocks, animals were under-dosed due to reliance on age and body conformation through visual perception rather than weighing, use of faulty and non-calibrated drenching device, use of sub-standard drugs and mixing of 2 drench types in some cases. All these factors are in operation and mainly attributed to illiteracy and false belief among farmers, dependence of farmers directly on chemists and lack of pre-drench consultancy with veterinarians. Anthelmintic resistance was significantly higher on farms where sheep were treated according to perceived average weight of sheep in a flock than on farms where sheep were treated according to the weight of the heaviest sheep (Edwards *et al*. 1986). Coles and Roush (1992) recommended that a single drug class be used for an entire farming year, followed by alteration to a different class. Farmers frequently complained about the cost of drenching but such complaints were usually associated with an excessive use of drench. The production gains attributable to the judicious use of drench showed a very favourable cost : benefit balance. Increased drench frequency, visual perception of body weight, failure to rotate anthelmintic class and adoption of drench and move practice were found to enhance selection for resistance in Denmark (Mainigi *et al.* 1996 a). Due to trade liberalization, there is a great need for quality assurance of anthelmintics especially in rural areas as well as need to increase liaisons and communication between veterinarians and sheep breeders.

Our observations indicated the lack of knowledge about worm-control strategies, anthelmintic use and the problem of anthelmintic resistance among the majority of sheep farms in Rajasthan. To improve farmer's awareness about the improvement of worm-control practices for sheep, a concerted effort between the researchers, pharmaceuticals, field veterinarian and extension workers is needed.

ACKNOWLEDGEMENTS

The study was supported by the ICAR, New Delhi, under All India Network Programme on Gastrointestinal Parasitism. The facilities provided by Director, CSWRI, Avikanagar, are thankfully acknowledged. Much appreciation is extended to officers and staff of Department of Animal Husbandry, Rajasthan and to many sheep breeders that made this study possible.

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