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THE EPIZOOTIOLOGY OF NEMATODE PARASITES OF SHEEP IN THE KAROO

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The Karoo is a vast, semi-arid region extending westwards from the Drakensberg and covering most of the escarpment as far inland as the northern borders of the Cape Province. The mean annual rainfall varies from 25 mm in the west to 440 mm in the east, most of the rain being recorded in the form of infrequent thunderstorms during February and March.

The vegetation consists mainly of Karoo bushes (*inter alia Pentzia* spp., *Eriocephalus spinescens*) with few perennial grasses, geophytes, annuals, and in isolated areas shrubs and trees. In most areas only Karoo bushes are encountered and grass has long since disappeared (Acocks, 1953). This vegetation is only suited to sheep ranching, and carries approximately 12,000,000 sheep.

In spite of these arid conditions internal parasites are a major cause of economic loss to the wool industry. Consequently an experiment on the seasonal incidence of nematodes was carried out at the Grootfontein Agricultural College (31°29′S, 25°02′E, altitude 1263m), situated in the eastern part of the Karoo in the Middelburg district.

Materials and Methods

A camp of 100 morgen (210 acres) was used. The vegetation consisted of 90 per cent Karoo bushes (*Pentzia* spp.) and 10 per cent grass (*Aristida* spp.). To infest the pasture, eighty heavily infested Merinos approximately 12 to 18 months old were introduced on 19 August, 1962 for a period of seven weeks and from 29 November, 1962 for a further six weeks.

The experimental flock consisted of 100 wethers, purchased on 25 October, 1962, from three farms within a 30 mile radius, and placed in the camp. Fortnightly faecal examinations from 6 December indicated a gradual increase in worm burdens; by March the flock was heavily infested.

Some sheep died of helminthiasis at the end of May. Consequently the flock (except 12 animals, selected for slaughter over the following three months) was treated with 20 gm micro-fine phenothiazine on 3 June, 1963.

From 1 June, 1963 the sheep had free access to a salt-bonemeal-sulphur lick. In addition from 1 June to 15 September, 1963 lucerne hay was supplied *ad lib.*

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Two sheep were selected at random from the flock at intervals usually varying from 13 to 16 days; in three instances the intervals were 20, 23 and 42 days respectively. After starvation for three to four days, faecal samples were collected for differential egg counts and the sheep slaughtered. Examination *post mortem* was done as described by Reinecke (1961). Simultaneously faecal egg counts were carried out on 20 sheep in the flock.

The experimental period extended from 27 March, 1963 to 12 March, 1964. Climatic data were recorded from the day of introduction of the infested sheep i.e. 19 August, 1962 until the survey ceased.

Results

Preliminary observations

These are given in Table 1. Regular worm egg counts on faeces showed that

TABLE 1.—*Results of faecal egg counts prior to slaughter*

Month	*Nematodirus* spp.			Other nematodes		
	Average *e.p.g.	Range e.p.g.	Percentage positive	Average e.p.g.	Range e.p.g.	Percentage positive
1962 December, 6.....	27	0–233	41	65	0–533	64
December, 21.....	22	0–166	52	112	0–700	72
1963 January, 10.....	19	0–100	31	233	0–666	74
January, 22.....	6	0–100	11	666	0–5,866	94
February, 11.....	1	0–33	4	3,099	333–12,400	100
February, 21.....	3	0–33	7	7,520	2,033–24,233	100
March, 12.....	3	0–33	5	5,693	1,033–27,666	100

* e.p.g. = eggs per gm of faeces

more than half the sheep were infested with *Nematodirus* spp. in December, 1962 but this fell to 5 per cent in March, 1963. Sixty-four lambs were positive for other nematodes at the first examination on 6 December, 1962. Early in February, 1963 all were positive and by March the average number of eggs per gm of faeces had almost doubled.

Species recovered post mortem

These are summarized in Table 2.

Haemonchus contortus: The most striking observation was the dominance of fourth stage larvae throughout the winter, spring and early summer. This reached a peak in June and July when 36,774 larvae were recovered from sheep 360 killed on 4 July. Third stage larvae were present in May and June. Adults were frequently present in winter but the numbers rose to a minor peak in October, fell again and rose to a peak continuing from January until March. During this latter period adults exceeded larvae.

Ostertagia spp.: *Ostertagia circumcincta* was the dominant parasite, *O. trifurcata* being recovered in six necropsies only. These worms were present in moderate numbers and in most instances there were more fourth stage larvae than adults. In sheep 360 and 365 more than 2,000 worms were recovered, mainly fourth stage larvae. Adults exceeded 100 worms per sheep from February to May and again in July, while the number of fourth stage larvae rose steadily, reaching a peak in July and August.

Trichostrongylus spp.: *Trichostrongylus falculatus* exceeded the other species. *T. rugatus* was usually present while *T. colubriformis* and *T. axei* were recovered in five and three necropsies respectively. *T. axei* was only recovered from the abomasum, but *T. falculatus* and *T. rugatus* were consistently recovered from the abomasum and small intestine.

A marked feature was the fact that adults always exceeded fourth stage larvae in contradistinction to the previous two genera. All stages of development reached their peak in June, July and August, although *T. falculatus* adults were recovered in very large numbers from individual sheep until January.

In February relatively few worms were recovered. Fourth stage larvae were absent, but in March larvae were present in two of the four sheep slaughtered.

Nematodirus spathiger: Both fourth stage larvae and adults reached their peak in July and August and fell to low levels for the rest of the survey period, although another peak in the occurrence of fourth stage larvae was recorded in January. Sheep 370, killed on 30 January, 1964, had 263 adults, but in the others fourth stage larvae exceeded adults from November onwards. From February adults were absent. No third stage larvae were recovered.

Oesophagostomum columbianum: In nearly 80 per cent of the necropsies fourth stage larvae were present in larger numbers than adults. With six exceptions more fourth stage larvae were recovered from the intestinal wall than from the lumen. In most instances more larvae were present in the wall of the caecum and colon than of the small intestine, contrary to the findings of Reinecke, Horak & Snijders (1963).

In 13 of the 14 sheep slaughtered from May to August more than 500 fourth stage larvae were recovered, the highest burdens being recorded in July and August. During this period more than 500 adults were recovered from two sheep only. The highest adult worm burdens were recorded from June to August and again in October.

Cestodes and Trematodes: Moniezia spp. were present until the end of April. No Trematodes were recovered.

A comparison between differential egg counts and worm burdens

The results are illustrated graphically in Figure 1.

TABLE 2.—*Worms recovered* post mortem

Date	Sheep No.	*HAEMONCHUS*			*OSTERTAGIA*				*TRICHOSTRONGYLUS*						*NEMATODIRUS*		*OESOPHAGOSTOMUM*		
		*3rd	*4th	*contortus*	3rd	4th	*circumcincta*	*trifurcata*	3rd	4th	*falculatus*	*rugatus*	*colubriformis*	*axei*	4th	*spathiger*	3rd	4th	*columbianum*
27 Mar.... 1963	358	0	24	702	0	12	94	6	0	0	1,152	0	0	0	10	70	0	116	85
	353	0	162	898	0	22	175	13	0	23	1,859	0	0	0	27	3	0	81	104
10 Apr....	289	0	3,296	3	0	263	70	0	0	171	3,578	156	0	0	0	13	0	208	175
	351	0	6,479	1,123	0	0	220	0	0	77	1,589	99	0	11	33	253	0	112	178
25 Apr....	323	0	9,827	180	0	0	137	0	0	129	6,088	0	0	0	0	0	0	453	126
	283	0	10,333	590	0	0	203	0	1	29	7,261	0	0	0	47	357	0	316	177
9 May....	325	0	18,809	217	35	35	110	0	1	80	212	0	0	0	77	0	0	792	220
	293	0	20,505	350	0	32	147	0	154	123	12,276	1,117	0	0	3	313	0	617	25
24 May....	349	1,337	24,290	60	0	0	43	0	67	87	5,809	433	0	0	0	200	0	539	17
	330	25	4,300	10	0	0	10	0	17	60	2,551	305	0	0	30	0	0	886	165
6 June....	322	0	5,612	0	0	447	0	0	70	197	2,428	258	0	0	33	0	0	506	26
	375	0	14,488	10	0	492	84	0	10	191	5,497	287	0	0	0	67	0	779	171
20 June....	312	1,103	23,029	0	0	0	16	0	380	263	12,147	1,242	266	127	287	37	0	420	69
	339	383	22,502	7	0	672	46	0	493	439	4,731	694	0	0	23	43	0	558	518
4 July....	314	0	16,785	368	0	865	128	0	140	150	11,852	733	0	0	17	527	0	569	49
	360	0	36,774	13	0	1,826	255	15	57	153	17,184	1,434	0	0	60	473	0	949	417
18 July....	365	0	19,642	40	0	2,135	156	12	35	80	12,103	760	0	0	3	240	0	1,250	628
	310	0	8,894	0	0	144	16	0	45	40	4,557	289	0	0	13	80	0	770	5
1 Aug....	376	0	22,984	0	0	970	23	0	67	77	5,039	1,041	0	0	50	767	0	807	176
	290	0	20,238	0	0	698	63	0	7	110	16,112	1,372	0	0	17	370	0	502	426
12 Sep.....	279	0	22,679	1,117	0	95	53	0	7	0	1,316	39	13	0	0	0	0	215	62
	350	0	2,555	267	0	215	7	0	3	0	2,096	62	0	0	7	0	0	476	137
26 Sep.....	337	0	4,030	260	0	40	13	0	10	213	9,576	350	0	0	0	0	0	210	17
	354	0	12,564	390	0	273	70	0	3	217	21,305	865	0	0	30	0	0	5	389
11 Oct.....	338	0	3,047	1,503	0	346	47	0	7	40	7,310	0	0	0	53	70	0	198	439
	378	0	3,944	1,593	0	88	53	0	0	10	8,660	351	0	0	7	293	0	231	170
24 Oct.....	326	0	3,444	2,177	0	48	43	0	40	0	13,302	159	0	0	0	27	0	20	441
	306	0	4,173	987	0	79	37	0	0	0	3,815	241	0	0	33	0	0	19	231

TABLE 2.—*Worms recovered* post mortem (*contd.*)

Date	Sheep No.	*HAEMONCHUS*			*OSTERTAGIA*				*TRICHOSTRONGYLUS*						*NEMATODIRUS*		*OESOPHAGOSTOMUM*		
		*3rd	*4th	*contortus*	3rd	4th	*circumcincta*	*trifurcata*	3rd	4th	*falculatus*	*rugatus*	*colubriformis*	*axei*	4th	*spathiger*	3rd	4th	*columbianum*
6 Nov....	366	0	2,178	327	0	113	47	0	0	10	12,179	382	0	0	40	7	44	39	163
	362	0	685	420	0	19	23	0	0	23	3,754	3	0	0	37	3	22	34	108
22 Nov....	282	0	330	303	0	15	3	0	0	143	3,025	38	0	0	27	13	0	166	10
	296	0	117	929	0	38	47	0	0	17	1,278	0	9	0	20	0	0	199	96
5 Dec.....	323	0	7,041	483	0	385	22	0	0	157	9,868	0	0	0	107	0	0	28	53
	292	0	1,580	138	0	108	77	0	0	30	13,953	0	0	0	87	47	0	190	339
20 Dec.....	291	0	272	536	0	217	7	0	0	0	3,972	110	0	0	47	0	0	175	84
	336	0	1,197	3	0	85	13	0	0	140	9,832	303	0	0	47	0	0	333	94
10 Jan.....	333	0	33	1,453	0	0	0	0	0	40	433	0	0	0	7	3	0	283	13
1964	352	0	113	1,137	0	10	33	0	0	0	90	0	0	0	10	0	0	119	4
30 Jan.....	315	0	384	2,553	0	6	83	0	0	2	14,468	144	0	0	247	0	0	330	382
	370	0	68	2,023	0	3	43	0	0	0	1,722	34	0	0	100	263	0	400	78
13 Feb.....	295	0	2,417	900	0	163	262	11	0	0	7	0	80	0	17	0	0	320	8
	313	0	243	2,220	0	134	923	0	0	0	2,063	145	241	24	0	0	0	613	34
27 Feb.....	309	0	3	160	0	5	163	0	0	0	20	0	0	0	37	0	0	155	27
	355	0	23	313	0	0	7	0	0	0	1,649	66	0	0	157	0	0	289	9
12 Mar....	317	0	5	153	0	0	104	9	0	0	454	32	0	0	0	0	0	728	76
	307	0	8	897	0	0	77	0	0	17	7,516	16	0	0	7	0	0	305	20

*3rd = Third stage. *4th = Fourth stage.

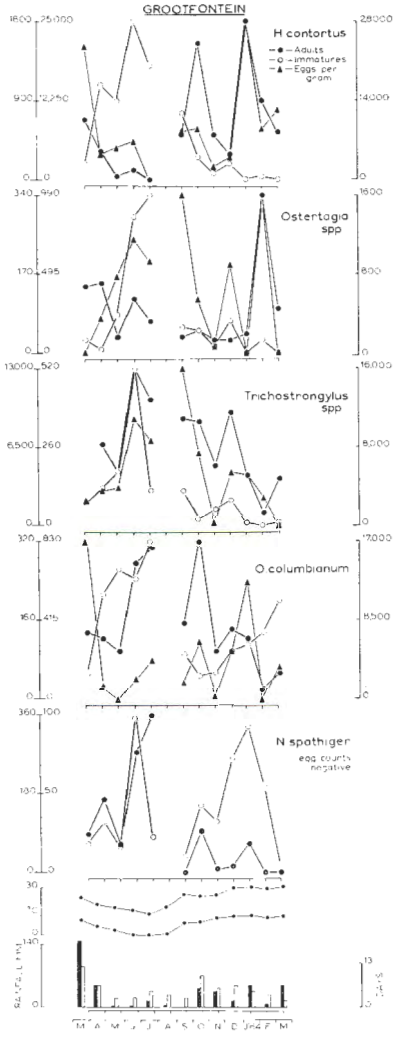

FIG. 1.—Comparison of average worm burdens *post mortem* and faecal egg counts *ante mortem*. Abscissae = periods of four weeks. Ordinates: left outer = adults; left inner = immature worms; right = eggs per gram.

·—· = Mean monthly maximum and minimum temperatures.
▮ = Monthly rainfall.
▯ = Number of days rain fell.

From Table 2 it is apparent that the number of worms of each species, recovered from the individual experimental animals, is subject to marked fluctuation. The results of four necropsies as well as differential egg counts prior to slaughter, were therefore grouped together to indicate the general trend.

(*a*) *Haemonchus contortus:* There was a reasonably close correlation between egg counts and adult worm burdens.

(*b*) *Ostertagia* spp.*:* No correlation could be demonstrated between egg counts and worm burdens.

(*c*) *Trichostrongylus* spp.*:* Although a close correlation was noted at the beginning of the experiment, this was not marked as the sheep grew older.

(*d*) *Oesophagostomum columbianum:* Egg counts appear to give a slightly better indication of worm burdens than with *Oestertagia* spp. and *Trichostrongylus* spp.

(*e*) *Nematodirus spathiger:* Egg counts were positive in only three sheep, thus no comparison is possible.

Climatic data

These are summarized in Table 3.

TABLE 3.—*Monthly rainfall at Grootfontein Agricultural College*

Month	From August, 1962 to March, 1963		Average over last 20 years	
	mm	No. of days rain fell	mm	No. of days rain fell
August, 1962	8·2	4	8·1	3
September	1·8	1	18·3	3
October	0·8	2	23·3	4
TOTAL	10·8	7	49·7	10
November	55·4	9	37·4	5
December	7·1	7	37·5	5
January, 1963	178·3	19	43·4	6
February	2·9	5	56·7	7
*March	143·1	13	63·4	8
TOTAL	386·8	53	238·4	31
April	50·4	7	28·9	5
May	2·4	3	17·8	4
June	3·1	3	7·5	2
July	12·8	5	10·3	3
August	3·1	4	8·1	3
September	1·3	3	18·3	3
October	45·0	10	23·3	4
November	37·7	6	37·4	5
December	15·7	7	37·5	5
January, 1964	50·3	5	43·4	6
February	8·4	4	56·7	7
March	51·0	2	63·4	8
TOTAL	281·2	59	352·6	55

* March, 1963: Slaughter commenced

From the time the experimental sheep were placed on the pasture (25 October, 1962) until slaughter commenced (27 March, 1963), exceptionally heavy rains were recorded, particularly in January and March. Whereas the average rainfall over the past 20 years is 238·4 mm, a total of 386·8 mm was recorded in the five month period preceding the commencement of the survey (Table 3).

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Discussion

This experiment began with the introduction of the infested stock in August, 1962. The subsequent introduction of the lambs in October meant that they grazed in an infested paddock. They slowly became infested, some of them still having negative faecal egg counts in January. Under the influence of heavy rains (178·3 mm), distributed over 19 days in January, ideal conditions were created for the free-living larvae. By the middle of February all the sheep were infested and average egg counts increased markedly (Table 1). Some of the lambs had diarrhoea but showed no other symptoms.

When the first sheep were slaughtered at the end of March, the worm burdens were moderate. Two weeks later, however, there was a marked increase in larval stages of *H. contortus*, *O. columbianum* and adult *Trichostrongylus* spp., followed by a further increase. This was probably due to the effect of the heavy rains in March and April (Table 3). The rainfall from May to September was below average. The increase in the worm burdens until August therefore, was not due to this influence.

According to Gordon (1948) a mean temperature of 17·7°C is essential for the development of *H. contortus* larvae. Dinnik & Dinnik (1954–1955), however, showed that *H. contortus* will develop where the temperature varies from a mean minimum of 11·1°C to a mean maximum of 23·4°C. At Grootfontein temperatures varied from 10·9°C to 23·2°C in March and 11·5°C to 26·4°C in November. In the intervening months the temperatures were below these levels. Thus, if the criteria of Gordon and of Dinnik & Dinnik applied, *H. contortus* could not develop to the infective stage in the veld.

In this experiment third stage larvae were recovered only until June. Fourth stage larvae increased throughout the winter, fell from August to March to reach a low level in November. Their presence throughout winter and spring is not easily explained. It seems reasonable to assume that these worms were delayed in their development in a similar fashion to that of *Haemonchus placei* and few developed to adults (Roberts, 1957).

Large numbers of fourth stage *O. columbianum* larvae in the intestinal wall was probably due to the prolonged histiotrophic phase (Veglia, 1928). There were more larvae in July and August; their numbers fell throughout the summer months but increased again in March. The infective larvae probably prefer cooler conditions and hence the increase of fourth stage larvae from autumn to spring. In less than half the necropsies adults exceeded larvae. This agrees with the experimental observations of Sarles (1944) who showed that there was an inverse ratio between the number of infective larvae dosed and the number of adults recovered.

Large numbers of fourth stage *Ostertagia* spp. were recovered and less adults, particularly during winter. This confirms Sommerville's (1954) observations that *O. circumcincta* has a prolonged histiotrophic phase.

Moderate numbers of adult *N. spathiger* were recovered in lambs. As the sheep became older, the worms were delayed in the fourth stage and few adults were recovered. This is probably due to an immune reaction.

Trichostrongylus spp. differed markedly from the other genera. Third stage larvae were consistently recovered from May to September. In October they were present in half the necropsies and disappeared entirely from November to March. Fourth stage larvae were consistently present from April to August but from September onwards they were frequently absent. This suggests that the free-living stages found the cool conditions from April to September more suitable for their development. The heavy worm burdens of the sheep killed in September in spite of phenothiazine treatment in June, provided further evidence of the suitability of the winter months for the free-living stages.

There is a correlation between the egg counts in slaughtered sheep and adult worm burdens of *H. contortus*, and to a lesser extent *O. columbianum* and *Trichostrongylus* spp.

All the animals were starved three to four days prior to slaughter. Decreased faecal output resulted in higher egg counts than would have been the case in grazing sheep. As starvation periods were similar this is probably a constant error.

These observations suggest that strategic or preventive drenching (Gordon, 1948) should be as follows:—

(1) April—against all species.
(2) September—against *O. columbianum.*
(3) December—against *H. contortus.*

On account of the presence of immature stages of *H. contortus*, *Ostertagia* spp. and *O. columbianum* in April, the drug of choice would be thiabendazole.

Although adult *O. columbianum* could be effectively controlled by other anthelmintics, the presence of larvae in September necessitates the use of either thiabendazole or methyridine. The rise of *H. contortus* during January can be controlled by any anthelmintic effective against this parasite.

Tactical drenching may be necessary four to six weeks after heavy rains.

Summary

Total and differential worm counts were carried out *post mortem* on sheep slaughtered at regular intervals at the Grootfontein College of Agriculture, Middelburg, Cape Province.

Fourth stage larvae were recovered at every autopsy. Usually the larvae exceeded the number of adult worms in *H. contortus* and *O. columbianum.*

There was a positive correlation between faecal egg counts and adult worm burdens of *H. contortus* and to a lesser extent *O. columbianum* and *Trichostrongylus* spp.

Strategic dosing is recommended in April, September and December.

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