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FURTHER STUDIES ON THE EPIZOOTIOLOGY OF NEMATODE PARASITES OF SHEEP IN THE KAROO

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ABSTRACT

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The dominant parasites in the Karoo are *Nematodirus spathiger* (Railliet, 1896) and *Trichostrongylus falculatus* Ransom, 1911. In the moister eastern regions *Haemonchus contortus* (Rudolphi, 1803) and *Oesophagostomum columbianum* (Curtice, 1890) occur but they decrease markedly as the region becomes more arid. *Ostertagia circumcincta* (Stadelmann, 1894) is of little or no significance.

The free-living stages of *N. spathiger* are highly resistant to heat and desiccation, but *T. falculatus* cannot survive if the mean monthly mean temperatures exceed 20°C and even if the monthly rainfall exceeds 50 mm, there is but a slight increase in worm burdens. Both species reach peak worm burdens in winter. The presence of *H. contortus* or possibly *O. columbianum* has a deleterious effect on *N. spathiger*.

Strategic drenching is recommended in March and July and tactical drenching when climatic conditions are favourable.

INTRODUCTION

Studies on the seasonal incidence of nematode parasites of sheep have been carried out in different areas of the Cape Province (Fig. 1) by Barrow (1964), Rossiter (1964), Viljoen (1964) and Muller (1968). The studies at Grootfontein (Viljoen, 1964) were extended to the central Karoo to include Nelspoort and Klerefontein (Fig. 1); the results of these experiments are described in this paper.

The vegetation in this area consists of a mixture of Karoo bushes, e.g. *Pentzia* spp., *Chrysocoma* sp., *Eriocephalus* sp., and *Mesembryanthemum* spp., and annual grasses (*Aristida* spp.), together with other stunted shrubs and thorn trees along river beds (Acocks, 1953).

The rainfall is seasonal, but very erratic, and varies from an annual average of 190 mm (7.6 in) at Klerefontein in the west, to 365 mm (14.6 in) at Grootfontein. Most of the rain is recorded during the late summer-autumn period in the form of infrequent thunderstorms. Spring rains are often absent; if any rain falls in spring it is usually less than the early summer rainfall. Temperatures fluctuate considerably and in both summer and winter differences of 13° to 17°C between the mean monthly minimum and mean monthly maximum are frequently recorded.

Ryksen (1939) pointed out that conditions in the semi-arid Karoo are unfavourable for the survival of the free-living larvae of the common parasitic nematodes: the rainfall is low and poorly distributed; the low density of stocking does not facilitate a high intake of larvae by the host and, finally, the pasture provides very little shelter and few facilities for migration by the larval forms. Nevertheless, worm infestations of sheep do occur in the Karoo.

Ryksen (1939) found that *Nematodirus* is the main parasite in arid regions. Mönnig (1942) stated that other genera introduced into this area by the large scale migration of sheep during the 1933 drought, could also persist here as *Nematodirus* lowered the resistance of the host to other infestations.

Viljoen (1964) showed that at Grootfontein, moderate to high burdens of *Nematodirus*, *Haemonchus* and *Trichostrongylus* can be found.

Of the two experiments described here one is a study of the seasonal incidence of the common nematode parasites of sheep, while the other concerns the availability to the grazing sheep of live infective larvae on the veld.

I. SEASONAL INCIDENCE IN LAMBS AND YEARLINGS

This was an extension of the trials carried out at Grootfontein to include the arid central Karoo. In order to determine the variations in worm burdens critical slaughter trials were carried out at regular intervals (Tetley, 1949; Morgan, Parnell & Rayski, 1951; Parnell, 1962; Barrow, 1964; Rossiter, 1964; Viljoen, 1964; Dunsmore, 1965).

Materials and Methods

Location: These trials were carried out at the Grootfontein Agricultural College (31°29′ S, 25°02′ E, altitude 1263 m), Middelburg district; at Nelspoort (32°10′ S, 23°03′ E, altitude 1012 m), Beaufort West district; and at Klerefontein (30°58′ S, 22°08′ E, altitude 1253 m), Carnarvon district (Fig. 1).

Climatic conditions: Throughout the experimental period, climatic conditions were recorded at each of the three stations (Appendix Tables 1, 2 and 3).

Grazing: The grazing at the three stations is natural Karoo veld and the sheep were kept under a continual grazing system without any rotation. At Grootfontein the camp was 84 hectares, at Nelspoort 414 and at Klerefontein 408 hectares.* Because of the prevailing drought conditions, lucerne hay was supplied during the second half of the survey at Grootfontein and Klerefontein; at Nelspoort it was frequently supplied throughout the experimental period. The experimental camps were all infested beforehand by sheep introduced from the immediate vicinity of each station.

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(*) 1 morgen = 10,000 yd² = 8 361. 3m², i.e. 0.83613 hectares

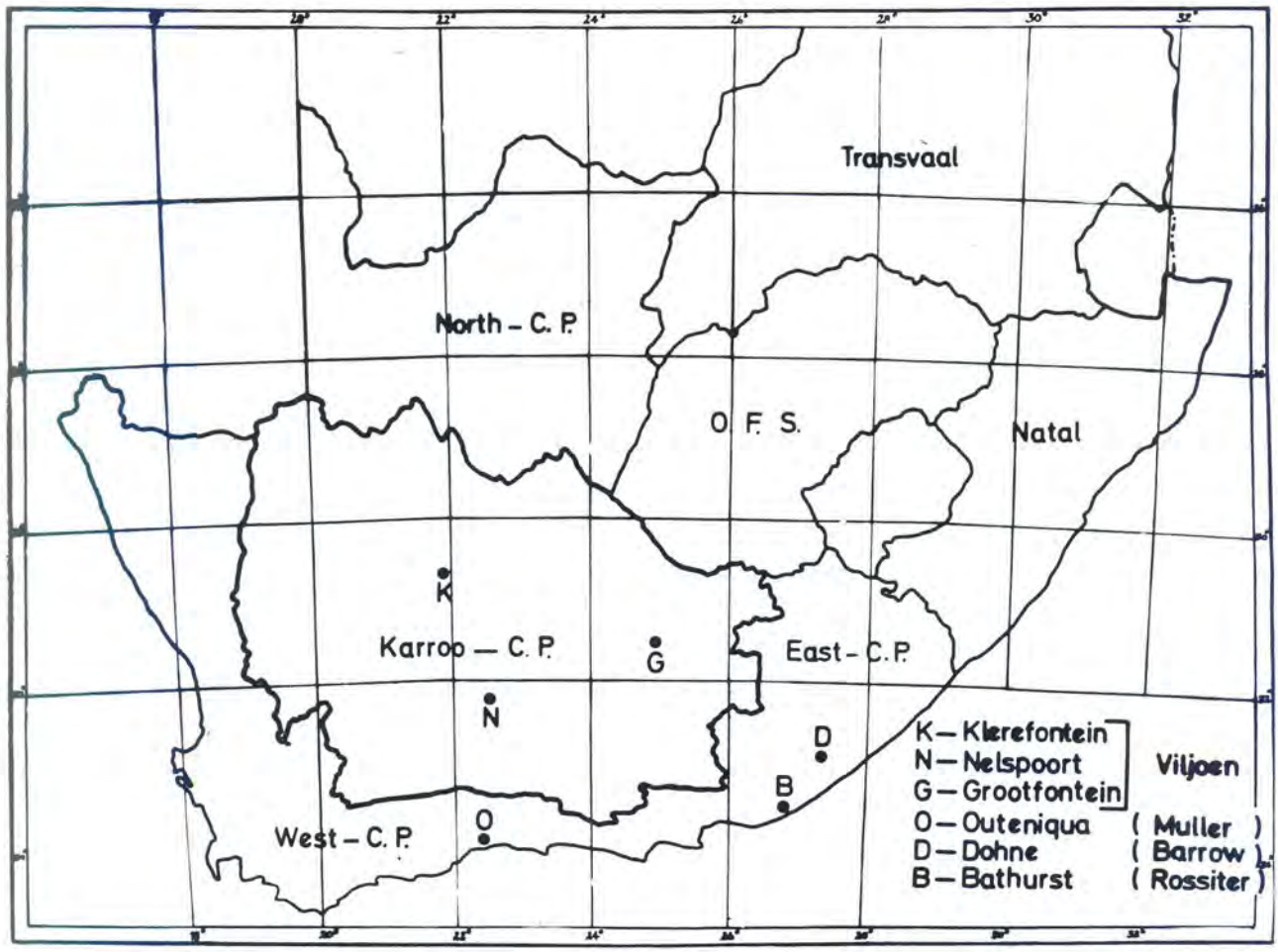

FIG. 1.—Stations where critical slaughter trials were performed

Sheep: Initially each experimental flock consisted of 150 Merino lambs, bought from farmers adjacent to Grootfontein, Nelspoort and Klerefontein respectively. At Nelspoort the lambs were born early in the winter while those at Grootfontein and Klerefontein were spring lambs. They were weaned and introduced into the experimental camps at an age of 3 to 4 months. All the animals were ear-tagged and inoculated against enterotoxaemia and bluetongue at an early age. Thereafter these inoculations were repeated annually.

All sheep were treated against cestodes. The flock at Nelspoort acquired a heavy infestation of *Nematodirus* while grazing on a green lucerne pasture for one week before introduction into the trial. Some of them died and the rest of the lambs were treated with thiabendazole to prevent further deaths. The other flocks were not treated against nematodes.

Slaughter and examination post mortem: Periodic slaughtering commenced when the lambs were 3 to 4 months old and continued for a period of 2 years, as follows:

(i) At Grootfontein from 4 February 1965 to 2 March 1967.

(ii) At Nelspoort from 8 October 1964 to 11 August 1956.

(iii) At Klerefontein from 10 February 1965 to 7 March 1967.

Whenever possible five randomly selected sheep from each flock were slaughtered every 28 days. On a few occasions, however, the intervals between slaughter varied from 24 to 32 days.

Sheep were slaughtered after a starvation period of 72 hours. The gastro-intestinal tract was removed and the worms were recovered according to the procedures described by Reinecke (1961). Identification of the larvae was done according to the descriptions of Veglia (1915, 1923), Mönnig (1927), Kates & Turner (1955) and Douvres (1956, 1957a, b).

If large numbers of worms of the same genus were present, at least 80 adult males were identified and the number belonging to each species estimated from this identification. Only the genus of the females was determined.

Stocking rate: As sheep were slaughtered they were replaced by an equal number of animals of the same age to maintain the stocking rate. This was three sheep per 1.7 hectares at Grootfontein and one per 2.5 hectares at Nelspoort and Klerefontein.

Statistical methods: As there was a variance in individual worm burdens in the sheep slaughtered during any particular month, the log (x + 1) trans-

TABLE 1. — *Climatic Data at Grootfontein*

Month	Rainfall		Temperatures					
			Mean maximum		Mean minimum		Mean monthly mean	
	mm	Average over last 20 years	°C	Average over last 20 years	°C	Average over last 20 years	°C	Average over last 20 years
February 1965	14.3	56.7	30.5	28.9	12.3	12.4	21.4	20.7
March	6.8	63.4	27.8	26.3	10.8	10.6	19.3	18.5
April	50.6	28.9	21.0	22.6	8.0	6.6	14.5	14.6
May	0.4	18.3	19.2	18.8	2.6	3.1	10.9	11.0
June	36.2	7.5	13.7	16.2	— 1.8	— 0.5	6.0	7.9
July	55.7	10.3	15.8	15.4	1.3	— 0.9	8.6	7.3
August	4.9	8.1	20.2	18.7	4.0	0.7	12.1	9.7
September	6.1	18.3	22.8	21.3	6.7	3.6	14.8	12.5
October	58.8	23.3	21.1	24.3	6.5	6.5	13.8	15.4
November	93.2	37.4	24.9	26.3	8.8	8.9	16.9	17.6
December	0.6	37.5	29.8	29.3	9.4	10.8	19.6	20.1
January 1966	32.3	43.4	32.0	29.7	14.6	12.1	23.3	20.9
February	38.7	56.7	27.7	28.9	12.0	12.4	19.9	20.7
March	13.2	63.4	29.0	26.3	11.8	10.6	20.4	18.5
April	22.0	28.9	22.0	22.6	5.0	6.6	13.5	14.6
May	0.4	16.3	19.8	18.8	3.3	3.1	11.6	11.0
June	12.7	7.5	17.3	16.2	1.0	— 0.8	9.2	7.9
July	0.0	10.3	16.7	15.4	0.9	— 0.9	8.8	7.3
August	0.6	8.1	19.9	18.7	2.6	0.7	11.3	9.7
September	18.1	18.3	21.2	21.3	4.1	3.6	12.7	12.5
October	16.6	23.3	25.6	24.3	7.8	6.5	16.7	15.4
November	15.5	37.4	27.9	26.3	10.0	8.9	19.0	17.6
December	18.4	37.5	31.8	29.3	13.7	10.8	22.8	20.1
January 1967	95.0	43.4	29.9	29.7	13.5	12.1	21.7	20.9
February	44.3	56.7	27.7	28.9	13.6	12.4	20.7	20.7

TABLE 2. — *Climatic Data at Nelspoort*

Month	Rainfall		Temperatures					
			Mean maximum		Mean minimum		Mean monthly mean	
	mm	Average over last 15 years	°C	Average over last 20 years	°C	Average over last 20 years	°C	Average over last 20 years
September 1964	37.0	18.0	20.4	22.7	6.0	7.8	13.2	15.3
October	28.6	20.0	23.8	25.8	9.9	10.4	26.9	18.1
November	30.0	38.0	26.7	28.2	11.1	12.6	18.9	20.4
December	23.2	28.0	29.8	30.4	13.5	14.4	21.7	22.4
January 1965	63.3	21.0	32.9	32.5	15.8	16.2	24.4	24.4
February	2.5	36.0	31.6	31.8	15.4	16.3	23.5	24.1
March	34.1	61.0	28.3	29.0	17.4	14.7	22.9	21.9
April	22.7	20.0	23.3	24.8	11.2	10.8	12.3	17.8
May	10.0	15.0	19.7	21.5	7.4	7.8	13.6	14.7
June	6.3	13.0	16.8	19.0	— 1.4	5.0	7.7	12.0
July	18.9	9.0	18.3	18.1	5.9	4.9	12.1	11.5
August	2.6	10.0	22.0	20.2	7.1	5.5	14.6	12.9
September	2.3	18.0	24.9	22.7	9.6	7.8	17.3	15.3
October	32.2	20.0	23.6	25.8	10.1	10.4	16.9	18.1
November	24.9	38.0	27.2	28.2	12.2	12.6	19.7	20.4
December	5.0	28.0	30.0	30.4	13.0	14.6	21.5	22.5
January 1966	25.5	21.0	34.0	32.5	17.1	16.2	25.6	24.4
February	9.5	36.0	29.0	31.8	12.4	16.3	20.7	24.1
March	6.5	61.0	30.3	29.0	11.9	14.7	21.2	21.9
April	10.0	20.0	20.3	24.8	8.3	10.8	14.3	7.8
May	1.1	15.0	22.0	21.5	4.5	7.8	13.3	14.7
June	6.3	13.0	19.2	19.0	0.4	5.0	9.8	12.0
July	0.0	9.0	18.1	18.1	0.3	4.9	9.2	11.5
August	3.2	10.0	20.3	20.2	1.3	5.5	10.8	12.9

TABLE 3. — *Climatic Data at Klerefontein*

Month	Rainfall		Temperatures					
			Mean maximum		Mean minimum		Mean monthly mean	
	mm	Average over last 30 years	°C	Average over last 20 years	°C	Average over last 20 years	°C	Average over last 20 years
February 1965	0.0	28.5	33.2	34.0	16.6	17.1	24.9	23.6
March	95.8	39.4	29.3	30.7	14.1	14.9	21.7	22.8
April	43.4	34.4	23.4	26.1	10.8	10.2	17.1	18.2
May	0.0	12.9	22.2	22.2	5.8	5.8	14.0	14.0
June	4.0	5.6	16.3	18.6	— 0.1	2.0	8.1	10.3
July	3.3	6.0	18.2	18.3	1.8	1.2	10.0	9.8
August	1.5	5.3	22.4	21.4	4.5	3.0	13.5	12.2
September	0.0	11.2	26.4	23.9	9.5	6.0	18.0	15.0
October	11.8	9.7	25.1	26.1	9.7	9.8	17.4	18.0
November	19.7	17.3	30.5	30.6	13.0	13.1	21.8	21.9
December	0.0	12.5	31.0	33.3	17.0	15.3	24.0	24.3
January 1966	94.9	16.5	35.4	24.6	19.2	17.6	27.3	26.1
February	3.8	28.5	29.0	34.0	12.5	17.1	20.8	25.6
March	4.9	39.4	28.4	30.7	12.7	14.9	20.6	22.8
April	0.0	24.4	20.4	26.1	7.2	10.2	13.8	18.2
May	0.0	12.9	19.9	22.2	2.8	5.8	11.4	14.0
June	12.1	5.6	17.5	18.8	1.7	2.0	9.6	10.4
July	0.0	6.0	15.4	18.3	0.3	1.2	7.9	9.8
August	0.0	5.3	18.9	21.4	2.4	3.0	10.7	12.2
September	0.8	11.2	21.5	23.9	4.2	6.0	12.9	15.0
October	9.6	9.7	26.6	28.1	9.1	9.8	17.9	19.0
November	9.5	17.3	28.5	30.6	10.9	13.1	19.7	21.9
December	6.4	12.5	32.1	33.3	11.5	15.3	21.8	24.3
January 1967	3.5	16.5	31.6	34.6	15.0	17.6	23.3	26.1
February	9.2	28.5	31.4	34.0	13.2	17.1	22.3	25.6

formation described by Snedecor & Cochran (1967) was used to normalize the data. This transformation converted individual burdens, as well as monthly averages, into homogenous and comparable figures. The transformed data were used to plot the graphs in Fig. 2.

Results

The variations in worm burdens recovered every 4 weeks are summarized in Appendix Tables 4, 5 and 6 and shown graphically in Fig. 2.

The following species of helminths were identified:
Haemonchus contortus (Rudolphi, 1803)
Ostertagia circumcincta (Stadelmann, 1894)
Trichostrongylus colubriformis (Giles, 1892)
Trichostrongylus falculatus Ransom, 1911
Trichostrongylus rugatus Mönnig, 1925
Nematodirus spathiger (Railliet, 1896)
Oesophagostomum columbianum Curtice, 1890

A few *Trichuris* sp. were found in several sheep during the survey at Grootfontein; these were ignored.

Trichostrongylus spp.

Out of a total of 409 experimental sheep slaughtered at the three stations only 4 per cent (18 sheep) were negative for *Trichostrongylus* spp.

T. falculatus predominated but a few *T. colubriformis* and *T. rugatus* were present in 12 sheep. *T. falculatus* usually contributed 90 per cent or more of the total adult males examined. Fourth stage larvae were present in low numbers in some of the animals during the autumn of 1965.

Grootfontein: Worm burdens rose steadily, with minor fluctuations, to a peak in December, then fell gradually to a low level in May of the following year. Thereafter, although the trends were similar to those of the previous year, fewer worms were recovered.

Nelspoort: After an initial rapid rise from October to January, worm burdens remained at a fairly constant level for the following year. Thereafter they fell until April, then rose again steadily until August.

Klerefontein: Worm burdens fluctuated, rose to a peak in August and then remained at a fairly constant level until September of the following year. Thereafter they varied markedly during the rest of the survey period.

Nematodirus spathiger

This species was usually present and only 30 per cent (42 sheep) at Grootfontein, 14 per cent (20) at Klerefontein and 9 per cent (12) at Nelspoort were negative.

On all the farms worm burdens fluctuated markedly, particularly in the relationship between the number of adults and of larvae recovered. More adults were recovered during the first 8 to 11 months of the experimental period in sheep less than 12 to 15 months of age. As the animals grew older the larval stages became more numerous and were usually recovered in greater numbers than the adults. The total burdens of both larval and adult worms varied as follows:-

Grootfontein: Worm burdens increased in August and September and then fell again from November to January throughout the survey period.

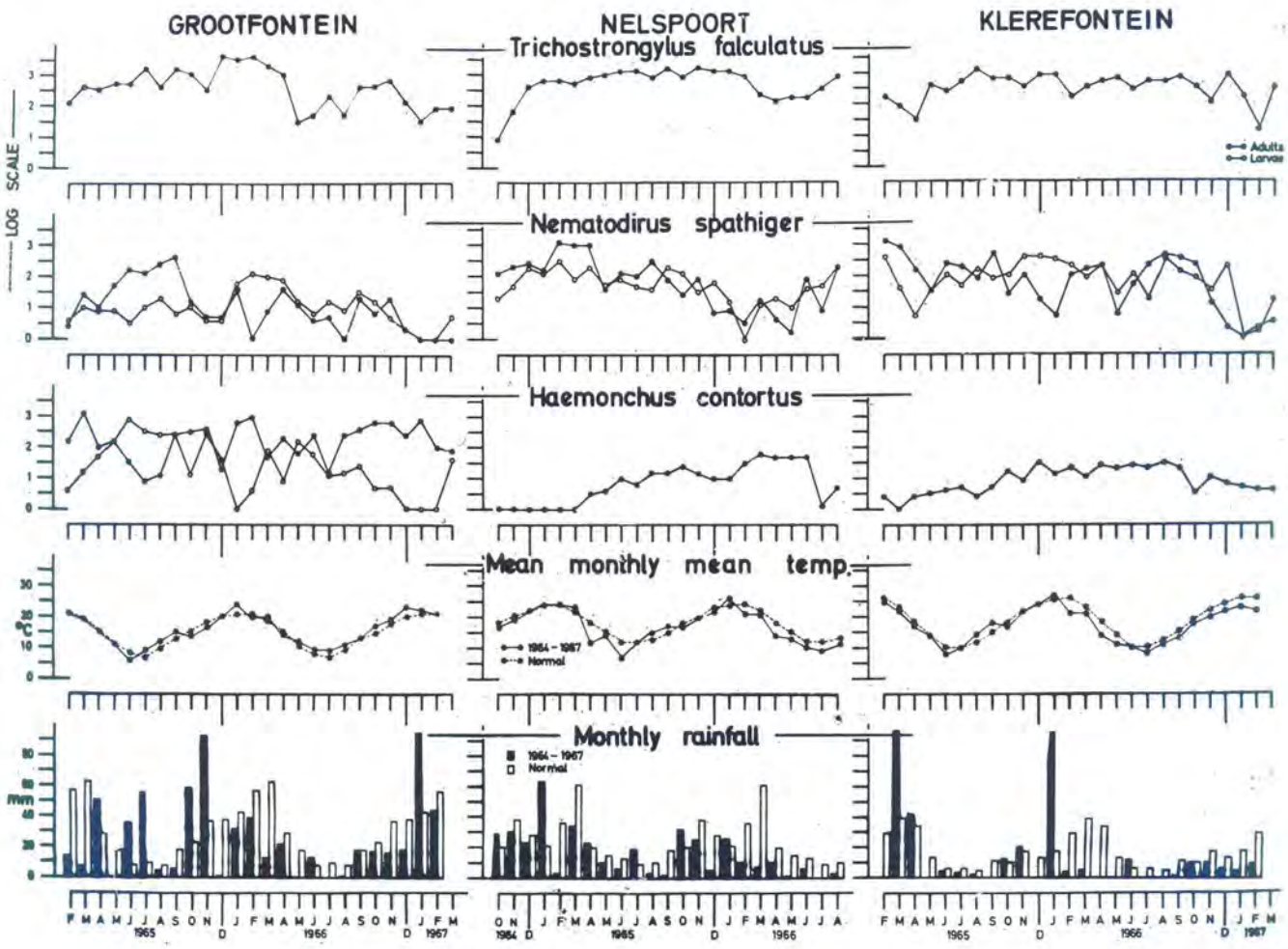

FIG. 2.—Seasonal incidence survey. Monthly variations in worm burdens

Nelspoort: Following good rains in January 1965 (63.3 mm), the worm burdens rose in February to a high level that was maintained until April, then fell slowly. Subsequently they showed a slight rise from February to the end of the survey in August 1966.

Klerefontein: The worm burdens differed from those at the other stations in that they were high initially in February, then fell rapidly until the end of April. Thereafter they rose again until June, fluctuated markedly for the following 12 to 14 months, rose to a peak in August 1966, and then fell again to low levels.

Haemonchus contortus

Apart from one animal, this species was consistently recovered at Grootfontein. At Nelspoort 40 per cent and at Klerefontein 28 per cent of the sheep were negative. Adult burdens were usually high at Grootfontein, but seldom exceeded 100 worms at Klerefontein or Nelspoort.

Grootfontein: From May to September fourth stage larvae were predominant, and increased to a very high level. Adult burdens showed a downward trend until the end of September, then rose again.

The decline of fourth stage larvae in October coincided with a high burden of adult worms. During November fourth stage larvae rose to a new peak, then fell again to very low levels from December 1965 to February 1966. After a slight depression in December, adults rose to a peak in January and February. From late summer until July adult worm burdens showed a downward trend, but more fourth stage larvae were recovered. From July onwards there was a rapid increase in adults, with peak burdens during October 1966 and January 1967, after which they again decreased. From May 1966 to November 1966 decreasing numbers of fourth stage larvae were recovered and they completely disappeared from December 1966 to February 1967. They reappeared in March 1967, when the survey was ended.

Nelspoort and Klerefontein: As already mentioned the incidence of this parasite was low and immature stages were seldom seen.

Ostertagia circumcincta

Small numbers of adult *O. circumcincta* were found from February 1965 to August 1965 at Grootfontein, Klerefontein and Nelspoort. Immature stages were found during the late summer, autumn and winter of 1965 at Grootfontein.

Oesophagostomum columbianum

Despite the fact that 91 per cent of the sheep at Grootfontein were infested with *O. columbianum*

TABLE 4.—*Grootfontein: Worms recovered* post mortem

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
153	1964—November	1965—4 February	19	94	0	0	0	63	0	0	0	0
155	November	4 February	7	72	0	0	0	89	0	3	2	0
151	November	4 February	0	353	0	0	0	93	0	0	0	0
152	November	4 February	3	493	2	0	0	382	13	20	4	0
154	November	4 February	0	47	0	0	0	196	13	0	0	0
160	1964—November	1965—4 March	0	2,353	13	0	3	211	20	28	2	42
157	November	4 March	210	343	0	13	0	504	10	10	42	26
156	November	4 March	72	1,150	0	0	0	469	6	73	0	12
158	November	4 March	73	2,309	0	6	0	244	3	13	8	24
159	November	4 March	0	1,462	30	13	0	513	13	20	0	19
164	1964—November	1965—2 April	76	453	0	0	0	453	0	23	0	3
165	November	2 April	0	250	0	0	0	408	36	0	0	19
163	November	2 April	16	626	0	6	0	506	13	56	0	6
162	November	2 April	0	275	0	0	0	506	0	53	0	5
161	November	2 April	90	1,273	0	0	3	258	16	10	0	13
281	1964—November	1965—29 April	16	150	0	23	0	542	13	20	0	20
224	November	29 April	1,220	113	0	10	0	586	10	0	0	40
230	November	29 April	460	0	0	3	0	89	50	0	0	10
246	November	29 April	1,313	0	0	0	0	349	10	3	0	1
178	November	29 April	143	553	0	13	0	129	0	123	0	10
216	1964—November	1965—26 May	260	203	0	6	3	684	6	0	0	13
182	November	26 May	433	1,336	0	0	0	544	23	63	0	358
288	November	26 May	193	1,513	0	6	0	583	16	126	0	16
217	November	26 May	558	63	0	0	0	394	0	163	2	300
238	November	26 May	6	3	0	0	0	543	5	130	0	9
202	1964—November	1965—21 June	1,243	70	0	0	0	278	0	235	0	60
274	November	21 June	780	40	0	0	0	620	3	63	0	10
186	November	21 June	746	0	0	0	0	814	0	243	0	70
222	November	21 June	550	40	0	0	0	992	10	276	2	30
231	November	21 June	870	160	0	20	0	248	3	73	0	10

TABLE 4.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
275	1964—November	1965—21 July	590	70	0	10	0	1,056	186	36	0	50
223	November	21 July	206	0	0	0	0	2,333	50	13	0	40
227	November	21 July	324	23	0	0	0	1,923	0	423	0	20
218	November	21 July	865	20	0	9	0	596	0	170	0	60
177	November	21 July	106	0	0	0	0	2,056	6	836	0	130
237	1964—November	1965—19 August	306	6	0	10	0	1,558	26	213	0	61
263	November	19 August	106	3	0	203	0	0	63	143	0	29
198	November	19 August	253	46	0	36	0	526	0	170	0	31
269	November	19 August	836	20	0	0	0	1,792	33	500	0	10
240	November	19 August	180	10	13	0	0	1,097	40	230	0	27
283	1964—November	1965—16 September	46	130	0	0	0	2,390	20	563	0	19
300	November	16 September	882	820	0	0	0	1,946	83	183	0	47
294	November	16 September	340	96	0	0	0	1,248	3	263	0	12
255	November	16 September	70	386	0	0	0	1,312	0	370	0	11
225	November	16 September	530	414	0	0	0	1,557	0	616	0	19
245	1964—November	1965—14 October	982	1,593	0	0	0	1,149	30	296	0	11
282	November	14 October	0	102	0	0	0	506	10	83	0	16
241	November	14 October	0	188	0	0	0	1,646	6	0	0	20
180	November	14 October	0	46	0	0	0	1,436	56	3	0	20
187	November	14 October	260	3,063	0	0	0	190	0	6	0	42
174	1964—November	1965—11 November	236	253	0	0	0	1,135	0	0	0	19
221	November	11 November	363	143	0	0	0	1,292	0	380	0	12
190	November	11 November	336	523	0	6	0	9	0	0	0	9
289	November	11 November	43	700	0	0	0	3,636	703	6	0	4
290	November	11 November	2,920	553	0	3	0	36	0	0	0	43
185	1964—November	1965—9 December	90	573	0	0	0	1,907	1,426	0	4	12
247	November	9 December	310	3,583	0	0	0	2,838	510	0	0	26
268	November	9 December	43	0	0	0	0	6,824	315	2,430	0	4
254	November	9 December	96	0	0	0	0	6,792	503	0	4	12
253	November	9 December	0	0	0	0	0	2,626	53	0	0	8

TABLE 4.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
169	1964—November	1966—6 January	0	2,343	0	0	0	7,810	3,486	1,123	0	49
205	November	6 January	0	2,790	0	0	0	5,141	2,476	150	0	93
285	November	6 January	0	313	0	0	0	3,393	153	636	0	44
295	November	6 January	0	76	0	3	0	2,193	0	0	0	31
194	November	6 January	0	360	0	0	0	863	0	0	0	30
229	1964—November	1966—3 February	0	4,210	0	0	0	17,936	7,300	0	0	68
278	November	3 February	0	376	0	0	0	13,616	2,896	0	0	57
192	November	3 February	0	987	0	0	0	383	0	0	0	34
209	November	3 February	40	753	0	0	0	7,036	46	0	0	8
264	November	3 February	13	730	0	0	0	2,160	23	0	0	116
212	1964—November	1966—3 March	908	0	0	0	0	7,023	146	0	0	6
250	November	3 March	319	601	0	0	0	2,112	180	0	0	0
277	November	3 March	360	0	0	0	0	8,712	1,883	290	0	0
299	November	3 March	1,636	1,370	0	0	0	3,126	0	0	0	2
235	November	3 March	83	16	0	0	0	20	0	0	0	0
208	1964—November	1966—31 March	0	140	0	0	0	19,213	2,356	5,676	0	94
266	November	31 March	16	20	0	0	0	272	96	0	0	72
242	November	31 March	173	120	0	0	0	18,154	953	0	0	24
259	November	31 March	66	163	0	0	0	126	30	0	0	0
168	November	31 March	6	643	0	0	0	15,149	663	316	0	34
204	1964—November	1966—28 April	100	153	0	0	0	6,679	246	0	0	22
280	November	28 April	0	410	0	0	0	5,453	133	53	0	78
239	November	28 April	210	776	0	0	0	4,282	243	1,246	0	3
267	November	28 April	0	460	0	0	0	360	330	1,390	0	135
272	November	28 April	0	13	0	0	0	10	0	0	0	2
256	1964—November	1966—26 May	390	0	0	0	0	183	830	562	4	56
203	November	26 May	20	66	0	0	0	0	0	0	0	4
276	November	26 May	740	390	0	0	0	76	6	0	0	30
181	November	26 May	40	23	0	0	0	36	0	6	0	30
201	November	26 May	670	1,926	0	0	0	43	123	53	0	47

TABLE 4.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
258	1964—November	1966—23 June	26	46	0	0	0	179	0	0	0	0
270	November	23 June	333	3,953	0	0	0	4,406	90	1,410	0	180
197	November	23 June	66	216	0	0	0	0	103	0	0	33
271	November	23 June	113	80	0	0	0	76	0	0	32	15
261	November	23 June	20	216	0	6	0	6	0	0	0	3
189	1964—November	1966—21 July	95	0	0	6	0	69	83	17	3	7
252	November	21 July	29	130	0	0	0	6,998	203	2,602	28	70
262	November	21 July	6	3	0	0	0	2,241	36	442	18	4
279	November	21 July	20	16	0	0	0	3	0	33	6	4
200	November	21 July	0	122	0	0	0	38	0	0	4	5
287	1964—November	1966—18 August	102	359	0	0	0	0	0	0	0	57
220	November	18 August	60	384	0	0	0	193	0	0	0	3
211	November	18 August	0	102	0	0	0	0	30	0	0	0
297	November	18 August	120	516	0	0	0	783	16	0	6	30
263	November	18 August	0	178	0	0	0	2,217	70	0	20	50
167	1964—November	1966—8 September	36	612	0	0	0	60	23	0	0	15
195	November	8 September	36	786	0	0	0	5,076	16	20	0	8
234	November	8 September	50	567	0	0	0	4,237	626	203	0	0
232	November	8 September	0	120	0	0	0	0	0	0	2	0
—	November	8 September	203	380	0	0	0	8,657	100	476	0	21
179	1964—November	1966—6 October	0	583	0	0	0	673	0	0	0	22
199	November	6 October	70	1,906	0	0	0	5,756	33	0	0	138
207	November	6 October	0	443	0	0	0	710	30	23	0	16
175	November	6 October	0	370	0	0	0	4,420	70	0	0	90
219	November	6 October	50	536		0	0	0	20	286	0	60
251	1964—November	1966—10 November	26	907	0	0	0	726	26	393	0	16
*184	November	10 November	0	640	0	0	0	5,180	0	0	0	17
183	November	10 November	0	212	0	0	0	106	0	10	0	14
213	November	10 November	96	1,466	0	0	0	36	0	0	0	8
173	November	10 November	0	487	0	0	0	4,806	113	710	0	15

TABLE 4.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
206	1964—November	1966—8 December	0	596	0	0	0	4,353	0	0	0	71
257	November	8 December	0	306	0	0	0	660	36	43	0	80
171	November	8 December	0	150	0	0	0	553	0	0	0	28
210	November	8 December	0	470	0	0	0	33	0	0	0	61
286	November	8 December	0	102	0	0	0	0	0	0	0	121
244	1964—November	1967—5 January	0	1,459	0	0	0	10	0	0	0	6
193	November	5 January	0	454	0	0	0	23	0	0	0	0
284	November	5 January	0	398	0	0	0	296	0	0	0	16
291	November	5 January	0	794	0	0	0	303	0	0	0	9
292	November	5 January	0	853	0	0	0	0	0	0	0	15
215	1964—November	1967—1 February	0	103	0	0	0	16	0	0	0	16
248	November	1 February	0	6	0	0	0	463	0	0	0	11
236	November	1 February	0	496	0	0	0	36	0	0	0	171
260	November	1 February	0	96	0	0	0	466	0	0	0	22
228	November	1 February	0	233	0	0	0	13	0	0	0	21
188	1964—November	1967—2 March	0	6	0	0	0	1,391	0	0	22	5
293	November	2 March	10	106	0	0	0	0	0	0	58	4
166	November	2 March	46	476	0	0	0	2,433	33	0	106	19
191	November	2 March	40	713	0	0	0	3,313	90	0	18	9
226	November	2 March	496	746	0	0	0	20	0	0	130	12
233	November	2 March	483	0	0	0	0	0	0	0	0	0

TABLE 5.— *Nelspoort: Worms recovered* post mortem

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
5	1964—July	1964—8 October	0	0	0	0	0	7	30	140
4	July	8 October	0	0	0	0	0	43	23	183
3	July	8 October	0	0	0	0	0	7	13	64
2	July	8 October	0	0	0	0	0	7	23	207
1	July	8 October	0	0	0	0	0	0	20	113
132	1964—July	1964—5 November	0	0	0	0	23	200	103	330
85	July	5 November	0	0	0	0	7	67	47	120
33	July	5 November	0	0	0	0	10	40	57	167
92	July	5 November	0	0	0	0	3	37	37	157
112	July	5 November	0	0	0	0	0	70	30	237
79	1964—July	1964—4 December	0	0	0	0	0	139	23	316
54	July	4 December	0	0	0	0	0	1,156	193	313
65	July	4 December	0	0	0	0	23	923	320	873
126	July	4 December	0	0	0	0	0	696	340	470
38	July	4 December	0	0	0	0	0	563	26	536
29	1964—July	1964—31 December	0	0	0	0	0	563	373	183
145	July	31 December	0	0	0	0	0	323	423	166
129	July	31 December	0	0	0	0	0	480	70	60
119	July	31 December	0	0	0	0	0	516	276	410
137	July	31 December	0	0	0	0	0	716	160	70
133	1964—July	1965—28 January	0	0	0	0	0	752	187	420
47	July	28 January	0	0	0	0	0	561	406	293
109	July	28 January	0	0	0	0	0	770	10	4
68	July	28 January	0	0	0	0	0	1,040	237	213
59	July	28 January	0	0	0	0	0	460	157	813

TABLE 5.— *Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
148	1964—July	1965—25 February	0	0	0	7	0	302	832	984
70	July	25 February	0	0	0	0	0	548	253	1,297
115	July	25 February	0	0	0	9	0	1,161	230	1,807
96	July	25 February	0	0	0	9	0	517	320	996
42	July	25 February	0	0	0	2	0	571	107	1,740
100	1964—July	1965—29 March	0	0	0	3	0	28	3	94
108	July	29 March	0	0	0	6	0	2,268	433	2,136
18	July	29 March	0	0	0	10	0	4,593	460	6,204
22	July	29 March	0	0	0	10	0	883	360	928
143	July	29 March	0	0	0	6	6	88	6	724
105	1964—July	1965—22 April	0	6	0	0	0	1,102	218	2,486
75	July	22 April	0	2	0	8	2	290	338	1,784
67	July	22 April	0	10	0	0	0	858	148	56
61	July	22 April	0	2	0	18	0	564	172	2,074
69	July	22 April	0	6	0	0	0	1,310	212	2,324
121	1964—July	1965—20 May	0	0	0	14	6	1,004	222	112
30	July	20 May	0	32	0	0	0	1,550	158	614
25	July	20 May	0	8	0	5	0	1,328	116	158
77	July	20 May	0	4	0	4	0	746	98	0
90	July	20 May	0	0	0	0	0	418	0	12
	1964—July	1965—17 June	0	0	0	0	0	1,428	162	1,410
103	July	17 June	0	0	0	0	0	572	52	136
125	July	17 June	0	32	0	0	0	980	116	342
35	July	17 June	0	18	0	0	0	3,032	10	4
135	July	17 June	0	240	0	0	0	1,014	466	102
89	1964—July	1965—15 July	0	4	0	0	0	1,282	576	3,358
146	July	15 July	0	28	0	2	0	1,078	306	1,270
39	July	15 July	0	2	0	0	0	826	0	4
76	July	15 July	0	2	0	0	0	2,054	60	100
149	July	15 July	0	4	0	0	134	1,280	16	4

TABLE 5.— *Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
120	1964—July	1965—12 August	0	10	0	0	0	3,380	266	446
142	July	12 August	0	44	0	0	0	2,560	48	16
23	July	12 August	0	4	0	0	0	48	62	328
150	July	12 August	0	24	0	0	0	528	186	476
99	July	12 August	0	24	0	0	0	1,342	0	1,524
*49	1964—July	1965—9 September	6	32	0	0	0	1,326	26	0
40	July	9 September	0	20	0	0	0	1,390	26	54
147	July	9 September	0	20	0	0	0	2,016	394	40
141	July	9 September	0	4	0	0	0	2,632	290	1,084
20	July	9 September	0	8	0	0	0	1,250	4,410	1,216
106	1964—July	1965—7 October	0	32	0	0	0	3,844	1,674	1,088
87	July	7 October	0	18	0	0	0	2,982	202	0
74	July	7 October	0	16	0	0	0	8	0	0
136	July	7 October	0	28	0	0	0	2,316	162	20
118	July	7 October	0	16	0	0	0	956	850	302
64	1964—July	1965— 4 November	0	14	0	0	0	504	2	2
17	July	4 November	0	10	0	0	0	1,812	0	22
44	July	4 November	0	14	0	0	0	2,428	1,784	1,658
78	July	4 November	0	26	0	0	0	488	394	462
45	July	4 November	0	24	0	0	0	1,966	20	58
43	1964—July	1965—2 December	0	4	0	0	0	2,406	190	8
52	July	2 December	0	18	0	0	0	1,512	0	6
28	July	2 December	0	26	0	0	0	403	830	0
21	July	2 December	0	0	0	0	0	1,270	710	100
19	July	2 December	0	52	0	0	0	1,858	4	0
73	1964—July	1966—3 January	0	24	0	0	0	3,168	384	6
57	July	3 January	0	18	0	0	0	2,324	0	4
80	July	3 January	0	54	0	0	0	3,714	0	96
32	July	3 January	0	26	0	0	0	1,578	0	5
66	July	3 January	0	38	0	0	0	840	88	0

TABLE 5.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
88	1964—July	1966—27 January	0	20	0	0	0	70	0	30
104	July	27 January	0	0	0	0	0	64	0	12
31	July	27 January	0	0	0	0	0	1,910	6,698	464
101	July	27 January	0	0	0	0	0	5,198	5,506	984
97	July	27 January	0	18	0	0	0	2,534	0	0
113	1964—July	1966—24 February	0	58	0	0	0	10	0	0
34	July	24 February	0	5	0	0	0	254	0	0
51	July	24 February	0	54	0	0	0	3,972	0	0
37	July	24 February	0	38	0	0	0	3,298	0	0
81	July	24 February	0	58	0	0	0	6,261	0	182
124	1964—July	1966—24 March	0	86	0	0	0	44	0	0
27	July	24 March	0	50	0	0	0	3,726	578	412
62	July	24 March	0	22	0	0	0	6	0	0
72	July	24 March	0	100	0	0	0	3,366	498	1,410
50	July	24 March	0	64	0	0	0	66	0	0
114	1964—July	1966—21 April	0	40	0	0	0	122	40	4
140	July	21 April	0	54	0	0	0	0	0	0
93	July	21 April	0	54	0	0	0	130	0	0
98	July	21 April	0	18	0	0	0	3,204	364	138
82	July	21 April	0	88	0	0	0	826	112	0
116	1964—July	1966—18 May	0	56	0	0	0	114	0	0
55	July	18 May	0	82	0	0	0	398	6	0
24	July	18 May	0	20	0	0	0	2,948	130	14
138	July	18 May	0	54	0	0	0	172	6	0
102	July	18 May	0	40	0	0	0	4	14	0
83	1964—July	1966—16 June	0	44	0	0	0	0	0	0
110	July	16 June	0	56	0	0	0	180	30	18
122	July	16 June	0	64	0	0	0	5,736	5,324	1,640
130	July	16 June	0	30	0	0	0	36	134	136
41	July	16 June	0	66	0	0	0	3,290	6	498

TABLE 5.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
95	1964—July	1966—14 July	0	0	0	20	0	104	12	16
84	July	14 July	0	0	0	36	0	36	14	4
111	July	14 July	0	4	0	36	0	2,814	138	0
53	July	14 July	0	0	0	28	0	936	36	0
463	July	14 July	0	0	0	6	0	236	396	336
86	1964—July	1966—11 August	0	0	0	52	0	260	14	4
46	July	11 August	0	0	0	128	0	1,552	632	22
36	July	11 August	0	54	0	0	0	4,412	506	272
71	July	11 August	0	6	0	20	0	219	304	6,502

TABLE 6.—*Klerefontein: Worms recovered* post mortem

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
303	1964—October	1965—10 February	0	3	0	10	0	1,113	360	704	0	0
305	October	10 February	0	13	0	13	0	791	333	526	0	0
304	October	10 February	0	0	0	3	0	37	113	592	0	0
302	October	10 February	0	0	0	0	0	31	303	2,227	0	0
301	October	10 February	0	0	0	3	0	83	1,565	3,423	0	0
309	1964—October	1965—10 March	0	0	0	0	0	4	30	384	0	0
307	October	10 March	0	0	0	0	3	76	63	2,463	0	0
306	October	10 March	0	0	0	0	0	316	363	1,326	0	0
308	October	10 March	0	0	0	0	0	35	13	506	0	0
310	October	10 March	0	0	0	0	0	780	13	743	0	0
403	1964—October	1965—7 April	0	0	0	0	0	512	0	552	0	0
432	October	7 April	0	0	0	0	0	10	0	420	0	0
141	October	7 April	0	0	0	23	0	16	10	410	0	0
337	October	7 April	0	2	0	3	0	480	63	3	0	0
379	October	7 April	0	23	0	10	0	0	3	363	0	0
403	1964—October	1965—6 May	0	6	0	0	46	1,000	0	0	0	0
314	October	6 May	0	0	0	33	0	115	260	337	0	0
327	October	6 May	0	0	0	3	0	1,353	26	0	0	0
365	October	6 May	0	6	0	0	0	236	46	2,396	0	0
357	October	6 May	0	3	0	23	0	442	100	32	0	0
377	1964—October	1965—3 June	0	0	0	0	0	356	143	1,276	0	0
402	October	3 June	0	13	0	0	0	226	90	1,020	0	0
354	October	3 June	0	6	0	0	0	390	126	1,290	0	0
425	October	3 June	0	6	0	0	0	264	100	1,140	0	0
318	October	3 June	0	0	0	0	0	113	90	820	0	0
426	1964—October	1965—1 July	3	3	0	0	0	588	46	432	0	10
419	October	1 July	0	13	0	0	0	616	33	703	0	0
418	October	1 July	0	6	0	0	0	263	0	0	0	0
366	October	1 July	0	16	0	0	0	406	33	296	0	0
347	October	1 July	3	10	0	0	0	634	46	3	0	0

TABLE 6.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
384	1964—October	1965—29 July	0	0	0	0	0	1,313	160	2,073	0	70
488	October	29 July	0	0	0	0	0	2,150	226	46	0	0
392	October	29 July	0	0	0	0	0	953	56	1,330	0	0
438	October	29 July	0	16	0	0	0	4,096	153	2,843	0	0
407	October	29 July	0	25	0	0	0	2,159	153	1,752	0	0
415	1964—October	1965—26 August	0	0	0	0	0	876	173	10	0	0
429	October	26 August	0	0	0	0	0	460	213	3	0	0
396	October	26 August	0	23	0	3	0	992	73	1,033	4	10
422	October	26 August	0	3	0	0	0	1,306	123	263	0	0
345	October	26 August	0	0	0	0	0	337	163	276	0	0
385	1964—October	1965—23 September	0	10	0	0	0	823	110	846	0	0
390	October	23 September	0	10	0	0	0	563	166	770	0	0
340	October	23 September	0	3	0	0	0	758	63	70	0	0
401	October	23 September	0	0	0	0	0	846	50	116	0	0
328	October	23 September	0	3	0	0	0	536	30	890	0	0
398	1964—October	1965—21 October	0	33	0	0	0	986	16	3	0	0
360	October	21 October	2	70	0	0	0	666	153	416	0	10
330	October	21 October	0	13	0	0	0	803	270	50	0	20
382	October	21 October	0	10	0	0	0	203	93	0	0	0
338	October	21 October	0	6	0	0	0	656	190	146	0	0
329	1964—October	1965—18 November	0	20	0	0	0	477	306	569	0	0
421	October	18 November	0	0	0	0	0	1,304	706	197	0	0
439	October	18 November	0	20	0	0	0	728	923	190	0	1
342	October	18 November	0	3	0	0	0	583	453	316	0	2
349	October	18 November	0	10	0	0	0	16	110	0	0	0
320	1964—October	1965—15 December	0	0	0	0	0	1,543	2,846	1,046	0	5
372	October	15 December	0	86	0	0	0	1,243	716	0	0	0
412	October	15 December	0	46	0	0	0	1,046	616	0	0	1
450	October	15 December	0	66	0	0	0	1,546	6,803	1,386	0	7
378	October	15 December	0	83	0	0	0	156	0	0	0	1

TABLE 6.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
397	1964—October	1966—13 January	0	63	0	0	0	2,130	6,170	0	0	3
395	October	13 January	0	0	0	0	0	880	1,440	100	0	0
434	October	13 January	0	10	0	0	0	750	430	0	0	0
311	October	13 January	0	10	0	0	0	180	0	0	0	2
374	October	13 January	0	23	0	0	0	1,617	1,000	30	0	0
429	1964—October	1966—10 February	0	10	0	0	0	440	756	783	0	0
339	October	10 February	0	33	0	0	0	0	0	0	0	0
322	October	10 February	0	13	0	0	0	563	770	280	0	0
352	October	10 February	0	20	0	0	0	866	2,080	336	0	0
373	October	10 February	0	30	0	0	0	360	366	220	0	0
427	1964—October	1966—10 March	0	43	0	0	0	50	0	0	0	0
403	October	10 March	0	60	0	0	0	363	123	1,473	0	2
368	October	10 March	0	0	0	0	0	523	310	2,766	0	2
446	October	10 March	0	0	0	0	0	336	556	1,696	0	0
435	October	10 March	0	23	0	0	0	580	186	16	0	0
381	1964—October	1966—7 April	0	16	0	0	0	130	280	173	0	0
364	October	7 April	0	10	0	0	0	743	663	326	0	4
351	October	7 April	0	46	0	0	0	1,063	0	0	0	2
313	October	7 April	0	30	0	0	0	1,000	700	1,463	0	0
371	October	7 April	0	26	0	0	0	360	1,593	2,726	0	5
436	1964—October	1966—5 May	0	13	0	0	0	493	6	16	0	3
334	October	5 May	0	36	0	0	0	1,043	0	0	0	8
348	October	5 May	0	10	0	0	0	573	543	260	0	0
339	October	5 May	0	16	0	0	0	686	160	0	0	0
346	October	5 May	0	17	0	0	0	333	16	0	0	0
415	1964—October	1966—2 June	0	0	0	0	0	126	23	313	0	0
355	October	2 June	0	20	0	0	0	76	33	700	0	0
315	October	2 June	0	33	0	0	0	0	0	423	0	7
369	October	2 June	0	30	0	0	0	850	170	50	0	0
314	October	2 June	0	33	0	0	0	470	416	10,323	0	0

TABLE 6.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
394	1964—October	1966—30 June	0	33	0	0	0	1,386	166	50	0	3
317	October	30 June	0	66	0	0	0	1,576	110	0	0	3
312	October	30 June	0	43	0	0	0	1,143	266	0	0	1
341	October	30 June	0	50	0	0	0	476	23	0	0	7
370	October	30 June	0	30	0	0	0	956	1,620	643	0	15
375	1964—October	1966—28 July	0	13	0	0	0	940	0	0	0	0
324	October	28 July	0	13	0	0	0	696	66	96	0	0
387	October	28 July	0	33	0	0	0	346	33	2,696	0	0
333	October	28 July	0	20	0	0	0	2,274	16	4,143	0	0
391	October	28 July	0	23	0	0	0	103	36	216	0	0
342	1964—October	1966—25 August	0	36	0	0	0	806	400	43	0	0
443	October	25 August	0	16	0	0	0	673	240	600	0	0
380	October	25 August	0	40	0	0	0	696	130	4,510	0	0
383	October	25 August	0	10	0	0	0	303	226	1,116	0	0
376	October	25 August	0	23	0	0	0	256	690	103	0	0
442	1964—October	1966—29 September	0	10	0	0	0	363	110	296	0	3
420	October	29 September	0	6	0	0	0	759	86	46	0	0
433	October	29 September	0	46	0	0	0	463	223	1,743	0	2
445	October	29 September	0	16	0	0	0	956	196	23	0	2
335	October	29 September	0	53	0	0	0	430	43	3,090	0	5
449	1964—October	1966—20 October	0	16	0	0	0	960	583	3,593	0	0
316	October	20 October	0	0	0	0	0	70	50	56	0	4
344	October	20 October	0	0	0	0	0	636	696	1,650	0	0
404	October	20 October	0	0	0	0	0	383	100	1,013	0	0
400	October	20 October	0	30	0	0	0	186	0	0	0	0
331	1964—October	1966—17 November	0	10	0	0	0	710	73	0	0	2
325	October	17 November	0	10	0	0	0	13	110	93	0	0
323	October	17 November	0	13	0	0	0	166	43	33	0	0
431	October	17 November	0	6	0	0	0	30	0	0	0	8
448	October	17 November	0	6	0	0	0	203	93	150	0	0

TABLE 6.—*Continued*

Sheep No.	Date of birth	Date killed	*H. contortus*		*O. circumcincta*		*T. falculatus*		*N. spathiger*		*O. columbianum*	
			Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults	Fourth stage larvae	Adults
353	1964—October	1966—13 December	0	0	0	0	0	1,750	160	0	0	0
361	October	13 December	0	36	0	0	0	1,603	116	0	0	0
356	October	13 December	0	13	0	0	0	1,576	460	0	0	0
343	October	13 December	0	16	0	0	0	466	100	0	0	0
389	October	13 December	0	0	0	0	0	140	216	20	0	6
399	1964—October	1967—12 January	0	0	0	0	0	516	0	0	0	0
367	October	12 January	0	10	0	0	0	484	0	0	0	14
343	October	12 January	0	0	0	0	0	103	0	0	0	2
359	October	12 January	0	6	0	0	0	8	0	0	0	19
332	October	12 January	0	26	0	0	0	343	0	0	0	0
409	1964—October	1967—7 February	0	0	0	0	0	0	0	0	0	0
423	October	7 February	0	13	0	0	0	83	0	0	0	1
417	October	7 February	0	0	0	0	0	0	0	0	0	0
410	October	7 February	0	3	0	0	0	440	0	6	0	0
350	October	7 February	0	10	0	0	0	13	36	0	0	1
368	1964—October	1967—7 March	0	17	0	0	0	343	0	13	0	0
441	October	7 March	0	3	0	0	0	67	0	0	0	2
440	October	7 March	0	0	0	0	0	295	57	374	0	0
432	October	7 March	0	0	0	0	0	370	0	6	0	0
447	October	7 March	0	13	0	0	0	456	0	33	0	7
358	October	7 March	0	6	0	0	0	280	33	10	0	0
413	October	7 March	0	3	0	0	0	750	0	240	0	6
363	October	7 March	0	3	0	0	0	203	0	3	0	0
437	October	7 March	0	10	0	0	0	1,113	40	0	0	0
416	October	7 March	0	0	0	0	0	113	0	100	0	0

the individual burdens were low; 20 per cent only had burdens of 50 or more adults. Larvae were recovered only from February to August 1965. Small numbers of adults were recovered from some sheep at Nelspoort and Klerefontein.

Trematodes and Cestodes

Despite the initial treatment for tapeworms, sheep were infested with *Moniezia* spp. after weaning.

Comments

Bioclimatographs

Details of the variations in rainfall and temperature are summarized in Appendix Tables 1, 2 and 3.

These data were used to construct bioclimatographs comparing temperature and rainfall.

Levine (1963) records the temperature limits for the development of *Trichostrongylus* spp. as 6° to 20°C and those for *H. contortus* as 15° to 37°C. According to Gordon (1948, 1953), Forsyth (1953) and Levine (1963), both these species require a minimum of 50 mm (2 in) rainfall; Roberts, O'Sullivan & Riek (1952) and Riek, Roberts & O' Sullivan (1953) consider 76.2 mm (3 in) to be the optimum.

In this survey the temperature requirements of *Trichostrongylus* spp., i.e. 6° to 20°C, were fulfilled at all the stations from April to October (autumn to early spring). The minimum temperature requirements of *H. contortus* (15°C) were exceeded from October to March (spring and summer). The minimum rainfall requirement (50 mm) was rarely fulfilled at any of the stations. There was sufficient at Grootfontein only in April, July, October and November 1965 and in January 1967; at Klerefontein in March 1965 and January 1966 and at Nelspoort only in January 1965.

It is clear, therefore, that although the temperature requirements of both *Trichostrongylus* and *Haemonchus* are satisfied in the Karoo, the rainfall is quite inadequate. Furthermore, as the rain usually falls in scattered thunderstorms, the moisture is available for a limited period only. It is probably more realistic to regard 25 mm (1 in) as the minimum requirement for *H. contortus*. This is usually recorded in February and March at Nelspoort and Klerefontein and from November to April at Grootfontein (Fig. 3).

H. contortus was consistently present in sheep at Grootfontein; worm burdens rarely fell below 100 and frequently exceeded 1,000 worms. At both Nelspoort and Klerefontein they were either absent or present in small numbers, rarely exceeding 100. In summer a monthly rainfall of 25 mm seems to be adequate for this worm to maintain itself in reasonable numbers.

According to Mönnig (1930), Rogers (1940) and Kates (1950) *O. columbianum* is very sensitive to desiccation. This undoubtedly accounts for the fact

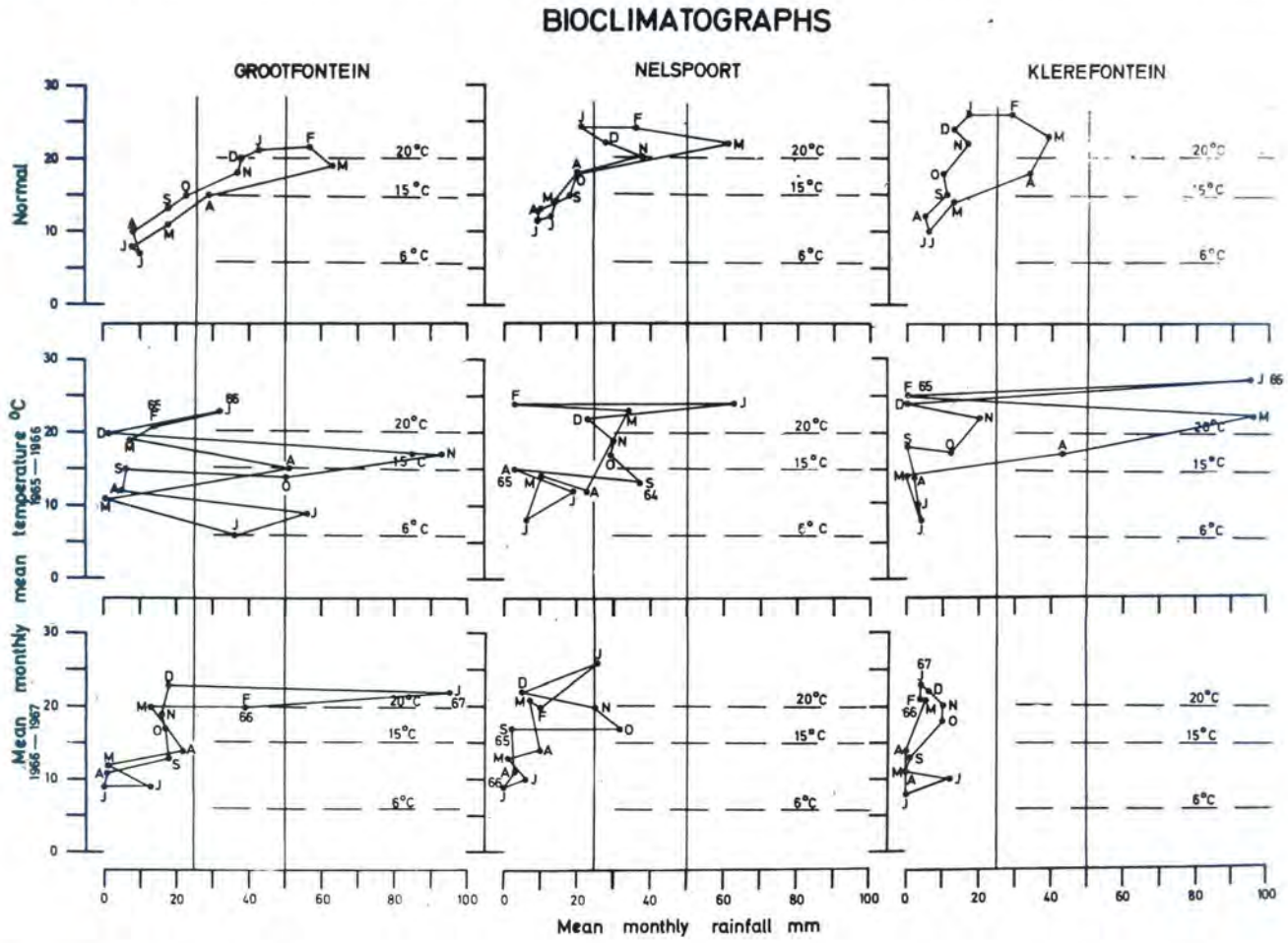

FIG. 3.—Seasonal incidence survey. Bioclimatographs, comparing normal year, with the years during which the survey was conducted

that it occurred in moderate numbers at Grootfontein only; it was rarely present at Klerefontein and all but absent at Nelspoort.

These surveys showed that *T. falculatus* and *N. spathiger* are well adapted to conditions prevailing in the Karoo. These trials were, however, unsatisfactory in that they did not indicate the availability to the grazing animal of live infective larvae at different times of the year.

II. Infestation on the pasture

Tetley (1959 a, b), Thomas & Stevens (1960) and Muller (1968) used worm-free lambs which grazed the pasture for a limited period to determine the availability of infective larvae at different times.

These lambs were slaughtered and total and differential worm counts carried out *post mortem*.

Muller (1968) considered this method preferable to either regular faecal worm egg counts or to pasture analysis, which were advocated by Taylor (1939), Crofton (1948, 1949, 1952, 1954, 1963), Baxter (1958, 1959), Spedding, Brown & Wilson (1958), Gibson (1959), Thomas (1959) and Brunsdon (1960, 1962 b; 1963 a).

It was therefore decided to introduce worm-free lambs onto the pasture for a specified period after which they were slaughtered. Their worm burdens were then compared with those of controls which had grazed the pasture from birth onwards. The disadvantage of this method is that it entails the collection and the identification of minute larval stages; these are difficult to detect even with a stereomicroscope as they are concealed by particles of the ingesta and of digested gut wall. This difficulty was overcome by concentrating the worms in a small volume with a modified Baermann apparatus placed in Shone's waterbath (Shone & Philip, 1967; Reinecke, 1967).

Materials and Methods

Location: These trials were carried out at Nelspoort in the camp used for the first experiment.

Climatic conditions: These were recorded throughout the survey period (Appendix Table 7).

Grazing: This consisted of a camp of natural Karooveld, 414 hectares in extent, that was grazed continually. Lucerne hay *ad lib.* was supplied as a supplementary feed for the first three months of the experimental period.

Sheep: The 180 Dorper (Dorset Horn × Black Head Persian) lambs used in this trial were born within a week of each other in the beginning of May, August and November 1967 and February 1968. At lambing the ewes and lambs were divided into two groups:

Group A—"Indicator" lambs: This group was kept worm-free from birth. They were housed indoors in pens with concrete floors, which were regularly cleaned. They were fed worm-free lucerne hay and feeding pellets. The ewes were treated for nematodes and cestodes to prevent contamination of the pens. These lambs and their dams were placed on the pasture as required.

Group B—"Control" lambs: These lambs, with their dams, were kept on the pasture until they were slaughtered; the ewes then remained on the pasture. The latter were treated against cestodes to prevent contamination of the pasture.

The animals were ear-tagged and inoculated against enterotoxaemia.

Stocking rate: A stocking rate of one sheep for every five hectares was maintained throughout the experimental period. The ewes remained on the pasture after their lambs had been slaughtered and other sheep were introduced to replace those slaughtered.

Exposure to infestation: Group A—"Indicator" lambs: Five lambs and their dams were placed on the pasture every 3 weeks. The lambs born in May and August 1967 presumably showed poor adaptation to grazing because they were suckling and consequently were very lightly infested at slaughter four weeks later.

Table 7. — *Climatic Data at Nelspoort*

Month	Weekly relative humidity per cent				Rainfall		Temperatures					
							Mean maximum		Mean minimum		Mean monthly mean	
	1	2	3	4	mm	Average over last 15 years	°C	Average over last 20 years	°C	Average over last 20 years	°C	Average over last 20 years
May 1967	—	—	—	—	72	15.0	20.3	21.5	9.5	7.7	15	14.7
June	67	66	49	57	9	13.0	16.8	19.0	6.1	5.0	12	12.0
July	58	59	60	41	9	9.0	16.4	18.1	3.9	4.9	10	11.5
August	43	45	48	38	1	10 0	20.8	20.2	6.5	5.5	14	12.9
September	46	49	36	49	0	18 0	20.6	22.7	7.1	7.8	14	15.3
October	39	38	46	45	6	20.0	25.9	25.8	10.0	10.4	18	18.1
November	39	40	45	40	4	38.0	29.4	28.2	9.7	12.6	20	20.4
December	35	35	44	49	19	28.0	33.2	30.4	12.3	14.6	23	22.5
January 1968	32	38	39	36	0	21.0	32.2	32.5	15.9	16.2	24	24.4
February	34	37	39	38	0	36.0	31.0	31.8	13.9	16.3	23	24.1
March	43	47	35	58	64	61.0	29.3	29.0	10.5	14.7	20	21.9
April	62	53	49	47	8	20.0	22.6	24.8	9.8	10.8	16	17.8
May	47	59	63	56	17	15.0	19.7	21.5	7.6	7.7	14	14.7
June	56	66	67	53	9	13.0	15.6	19.0	3.6	5.0	9	12.0

TABLE 8. — Group A: "*Indicator*" *lambs: worms recovered* post mortem

Sheep No	*Date of birth	Date on pasture	Date killed	*T. falculatus*		*N. spathiger*	
				**Fourth stage larvae	Adults	**Fourth stage larvae	Adults
522	1967— 1 May	1967—24 May	1967—21 June	0	20	13	6
542	1 May	24 May	21 June	0	18	16	39
554	1 May	24 May	21 June	0	6	6	5
534	1 May	24 May	21 June	5	28	11	25
520	1 May	24 May	21 June	0	23	16	3
562	1967— 1 May	1967—14 June	1967—12 July	8	15	19	23
524	1 May	14 June	12 July	0	33	35	56
546	1 May	14 June	12 July	0	12	4	58
536	1 May	14 June	12 July	0	0	6	0
544	1 May	14 June	12 July	0	23	34	0
514	1967— 1 May	1967— 5 July	1967— 2 Aug.	5	28	47	0
560	1 May	5 July	2 Aug.	0	15	3	10
530	1 May	5 July	2 Aug.	0	16	4	9
518	1 May	5 July	2 Aug.	2	12	31	18
540	1 May	5 July	2 Aug.	12	93	30	28
516	1967— 1 May	1967—26 July	1967—23 Aug.	10	64	28	104
532	1 May	26 July	23 Aug.	40	118	34	141
568	1 May	26 July	23 Aug.	3	4	0	6
526	1 May	26 July	23 Aug.	0	70	20	87
564	1 May	26 July	23 Aug.	16	96	21	32
538	1967— 1 May	1967—16 Aug.	1967—13 Sept.	0	12	10	16
558	1 May	16 Aug.	13 Sept.	0	50	13	3
548	1 May	16 Aug.	13 Sept.	0	0	0	0
512	1 May	16 Aug.	13 Sept.	0	13	0	0
552	1 May	16 Aug.	13 Sept.	0	14	5	10
578	1967— 8 Aug.	1967— 6 Sept.	1967— 4 Oct.	0	0	0	0
596	8 Aug.	6 Sept.	4 Oct.	0	0	0	0
584	8 Aug.	6 Sept.	4 Oct.	0	0	0	0
576	8 Aug.	6 Sept.	4 Oct.	0	0	0	0
590	8 Aug.	6 Sept.	4 Oct.	0	0	2	0
628	1967— 8 Aug.	1967—27 Sept.	1967—25 Oct.	0	0	13	0
612	8 Aug.	27 Sept.	25 Oct.	0	0	3	12
608	8 Aug.	27 Sept.	25 Oct.	7	3	79	35
594	8 Aug.	27 Sept.	25 Oct.	0	0	3	9
610	8 Aug.	27 Sept.	25 Oct.	0	0	0	3
588	1967— 8 Aug.	1967—18 Oct.	1967—15 Nov.	0	0	26	2
580	8 Aug.	18 Oct.	15 Nov.	0	0	15	3
586	8 Aug.	18 Oct.	15 Nov.	0	0	0	0
624	8 Aug.	18 Oct.	15 Nov.	0	0	38	3
622	8 Aug.	18 Oct.	15 Nov.	0	0	23	0
592	1967— 8 Aug.	1967— 8 Nov.	1967— 6 Dec.	0	0	2	0
626	8 Aug.	8 Nov.	6 Dec.	0	0	6	0
582	8 Aug.	8 Nov.	6 Dec.	0	0	0	0
620	8 Aug.	8 Nov.	6 Dec.	0	0	0	0
616	8 Aug.	8 Nov.	6 Dec.	0	4	36	22
632	1967— 8 Aug.	1967—29 Nov.	1968—10 Jan.	0	0	0	0
646	8 Aug.	29 Nov.	10 Jan.	0	0	3	0
502	8 Aug.	29 Nov.	10 Jan.	0	0	0	0
642	8 Aug.	29 Nov.	10 Jan.	0	0	0	0
644	8 Aug.	29 Nov.	10 Jan.	0	0	5	0
165	1967— 8 Aug.	1967—20 Dec.	1968—31 Jan.	0	0	2	2
636	8 Aug.	20 Dec.	31 Jan.	0	0	0	0
653	8 Aug.	20 Dec.	31 Jan.	0	0	0	0
629	8 Aug.	20 Dec.	31 Jan.	0	0	0	0
163	8 Aug.	20 Dec.	31 Jan.	0	6	10	0
506	1967— 8 Nov.	1968—10 Jan.	1968—21 Feb.	0	0	0	0
648	8 Nov.	10 Jan.	21 Feb.	0	0	6	3
634	8 Nov.	10 Jan.	21 Feb.	0	0	0	0
540	8 Nov.	10 Jan.	21 Feb.	0	0	0	0
640	8 Nov.	10 Jan.	21 Feb.	0	0	3	0

TABLE 8. — *Continued*

Sheep No.	*Date of birth	Date on pasture	Date killed	*T. falculatus*		*N. spathiger*	
				**Fourth stage larvae	Adults	**Fourth stage larvae	Adults
655	1967— 8 Nov.	1968—31 Jan.	1968—13 Mar.	0	0	13	3
657	8 Nov.	31 Jan.	13 Mar.	0	0	13	3
659	8 Nov.	31 Jan.	13 Mar.	0	0	0	0
510	8 Nov.	31 Jan.	13 Mar.	0	0	0	0
651	8 Nov.	31 Jan.	13 Mar.	0	0	9	0
671	1968— 1 Feb.	1968—21 Feb.	1968—31 Mar.	0	0	15	3
707	1 Feb.	21 Feb.	31 Mar.	0	3	0	3
697	1 Feb.	21 Feb.	31 Mar.	0	0	3	13
705	1 Feb.	21 Feb.	31 Mar.	0	0	26	13
719	1 Feb.	21 Feb.	31 Mar.	0	6	9	30
681	1968— 1 Feb.	1968—13 Mar.	1968—24 Apr.	0	32	96	56
661	1 Feb.	13 Mar.	24 Apr.	0	67	59	90
709	1 Feb.	13 Mar.	24 Apr.	0	73	359	60
683	1 Feb.	13 Mar.	24 Apr.	3	50	96	30
687	1 Feb.	13 Mar.	24 Apr.	0	270	119	136
691	1968— 1 Feb.	1968— 3 Apr.	1968—15 May	0	53	94	78
699	1 Feb.	3 Apr.	15 May	0	160	43	366
677	1 Feb.	3 Apr.	15 May	0	30	30	47
703	1 Feb.	3 Apr.	15 May	0	2	303	0
669	1 Feb.	3 Apr.	15 May	0	106	60	233
679	1968— 1 Feb.	1968—24 Apr.	1968— 5 June	18	52	132	15
667	1 Feb.	24 Apr.	5 June	26	60	146	20
695	1 Feb.	24 Apr.	5 June	2	18	95	44
713	1 Feb.	24 Apr.	5 June	6	16	76	50
701	1 Feb.	24 Apr.	5 June	9	56	43	32
665	1968— 1 Feb.	1968—15 May	1968—26 June	53	66	96	50
715	1 Feb.	15 May	26 June	0	98	56	152
717	1 Feb.	15 May	26 June	50	152	133	142
711	1 Feb.	15 May	26 June	0	94	100	86
693	1 Feb.	15 May	26 June	0	80	142	32

* Lambs were born within 7 days of the day indicated
** Third and fourth stage grouped together as fourth stage larvae

TABLE 9. — *Group B "Control" lambs: worms recovered* post mortem

Sheep	*Date of birth on pasture	Date killed	*T. falculatus*		*N. spathiger*	
			**Fourth stage larvae	Adults	**Fourth stage larvae	Adults
1	1967—1 May	1967—14 June	0	0	0	0
2	1 May	14 June	0	0	0	0
3	1 May	14 June	0	0	0	0
4	1 May	14 June	0	0	0	0
5	1 May	14 June	0	0	0	0
6	1967—1 May	1967— 5 July	8	40	18	6
7	1 May	5 July	19	34	36	20
8	1 May	5 July	18	24	53	33
9	1 May	5 July	8	32	14	16
10	1 May	5 July	0	33	16	12
11	1967—1 May	1967—26 July	0	27	5	0
12	1 May	26 July	0	25	2	6
13	1 May	26 July	0	89	9	34
14	1 May	26 July	0	6	3	3
15	1 May	26 July	0	47	17	13
16	1967—1 May	1967—16 Aug.	0	12	10	18
17	1 May	16 Aug.	0	93	30	99
18	1 May	16 Aug.	12	311	81	150
19	1 May	16 Aug.	0	44	39	28
20	1 May	16 Aug.	0	33	10	25
21	1967—1 May	1967— 6 Sept.	0	36	8	9
22	1 May	6 Sept.	0	112	25	30
23	1 May	6 Sept.	10	93	10	36
24	1 May	6 Sept.	4	100	50	66
25	1 May	6 Sept.	0	50	14	13
26	1967—8 Aug.	1967—27 Sept.	3	0	0	0
27	8 Aug.	27 Sept.	0	0	0	4
28	8 Aug.	27 Sept.	0	4	2	0
29	8 Aug.	27 Sept.	2	3	0	0
30	8 Aug.	27 Sept.	0	0	0	0
31	1967—8 Aug.	1967—18 Oct.	0	0	0	0
32	8 Aug.	18 Oct.	0	3	0	6
33	8 Aug.	18 Oct.	0	0	3	0
34	8 Aug.	18 Oct.	0	0	0	0
35	8 Aug.	18 Oct.	0	3	5	3
36	1967—8 Aug.	1967— 8 Nov.	0	6	0	0
37	8 Aug.	8 Nov.	0	0	3	3
38	8 Aug.	8 Nov.	0	0	0	3
39	8 Aug.	8 Nov.	0	23	3	20
40	8 Aug.	8 Nov.	0	0	3	0
41	1967—8 Aug.	1967—29 Nov.	0	0	19	16
42	8 Aug.	29 Nov.	0	10	26	16
43	8 Aug.	29 Nov.	0	0	13	16
44	8 Aug.	29 Nov.	0	3	28	40
45	8 Aug.	29 Nov.	0	0	66	3
46	1967—8 Nov.	1967—27 Dec.	0	0	0	0
47	8 Nov.	27 Dec.	2	0	0	0
48	8 Nov.	27 Dec.	0	0	0	0
49	8 Nov.	27 Dec.	0	0	0	0
50	8 Nov.	27 Dec.	0	0	3	0
51	1967—8 Nov.	1968—17 Jan.	0	0	0	0
52	8 Nov.	17 Jan.	0	0	0	0
53	8 Nov.	17 Jan.	0	0	0	0
54	8 Nov.	17 Jan.	0	0	0	0
55	8 Nov.	17 Jan.	0	0	0	0

TABLE 9. — *Group B Continued*

Sheep	*Date of birth on pasture	Date killed	*T. falculatus*		*N. spathiger*	
			**Fourth stage larvae	Adults	**Fourth stage larvae	Adults
56	1967—8 Nov.	1968— 7 Feb.	0	6	10	0
57	8 Nov.	7 Feb.	0	0	10	0
58	8 Nov.	7 Feb.	0	0	3	6
59	8 Nov.	7 Feb.	0	0	4	3
60	8 Nov.	7 Feb.	0	0	2	0
61	1967—8 Nov.	1968—28 Feb.	0	0	9	0
62	8 Nov.	28 Feb.	0	0	0	0
63	8 Nov.	28 Feb.	0	6	3	0
64	8 Nov.	28 Feb.	0	0	0	0
65	8 Nov.	28 Feb.	0	0	0	0
66	1968—1 Feb.	1968—20 Mar.	0	0	0	3
67	1 Feb.	20 Mar.	0	0	0	0
68	1 Feb.	20 Mar.	0	0	0	3
69	1 Feb.	20 Mar.	0	0	0	0
70	1 Feb.	20 Mar.	0	0	0	0
71	1968—1 Feb.	1968—10 Apr.	2	0	10	12
72	1 Feb.	10 Apr.	0	16	45	10
73	1 Feb.	10 Apr.	0	26	46	10
74	1 Feb.	10 Apr.	0	10	33	10
75	1 Feb.	10 Apr.	6	90	100	22
76	1968—1 Feb.	1968—30 Apr.	2	53	39	72
77	1 Feb.	30 Apr.	0	72	127	175
78	1 Feb.	30 Apr.	0	53	73	3
79	1 Feb.	30 Apr.	10	120	56	173
80	1 Feb.	30 Apr.	0	26	39	30
81	1968—1 Feb.	1968—22 May	3	26	36	54
82	1 Feb.	22 May	0	120	3	666
83	1 Feb.	22 May	0	76	55	222
84	1 Feb.	22 May	0	90	9	160
85	1 Feb.	22 May	2	63	20	233
86	1968—1 Feb.	1968—12 June	2	65	26	54
87	1 Feb.	12 June	0	203	16	206
88	1 Feb.	12 June	0	87	60	276
89	1 Feb.	12 June	0	141	46	222
90	1 Feb.	12 June	0	262	56	253

* Lambs were born within 7 days of the day indicated and remained on pasture until killed

** Third and fourth stage grouped together as fourth stage larvae

The lambs born in November 1967 and in February 1968 were therefore kept on the pasture for 42 days before being slaughtered. The lambs varied in age from about 2 to 4½ months at slaughter.

Group B—"Control" lambs: Five lambs were killed every 3 weeks. Their age at slaughter varied from about 6 weeks to 4 months.

Slaughter and Examination post mortem: Autopsies were carried out following the procedures described by Reinecke (1967) and a waterbath, as described by Shone & Philip (1967), was used for recovery of the worms.

The inner dimensions of this waterbath are as follows: length 2 m, width 2 m and depth 20 cm. The sides and bottom are made of 2.5 cm press board insulated on the outside with 2.5 cm Foamalite strips [Eastern Province Engineers, (Pty) Ltd., South Africa], and waterproofed with a double sheet of polythene [Gunplas, G. S. Gundel (Pty) Ltd., South Africa].

From January, 1968 onwards another waterbath was also used; this is constructed of fibre-glass and painted with a water-resistant paint [Peerless Fibre-glass and Plastics Co. (Pty) Ltd., South Africa]. Its inner dimensions are as follows: length 2 m, width 1.3 m and depth 30.5 cm.

The larval stages and the adults were identified as indicated earlier.

Graphs: The mean worm burdens were calculated by dividing the total number of worms recovered by the number of autopsies done during any particular month. These mean worm counts were used in the graphs to plot the monthly variations in worm burdens.

Results

The experimental period commenced on 1 May 1967, when the first lambs were born, and ended on 26 June 1968, when the last lambs were slaughtered.

The worm burdens are recorded in Appendix Tables 8 and 9 and illustrated graphically in Fig. 4.

The following species of helminths were identified:-

T. falculatus
N. spathiger
H. contortus
O. circumcincta

Group A—"Indicator" lambs

T. falculatus

The only *Trichostrongylus* sp. recovered was *T. falculatus*. Fourth stage larvae were found in most of the autopsies in August 1967 and in June 1968.

Adult worm burdens increased in August 1967 but they disappeared from October to March 1968. In April 1968 adult numbers again increased, then declined in May and June.

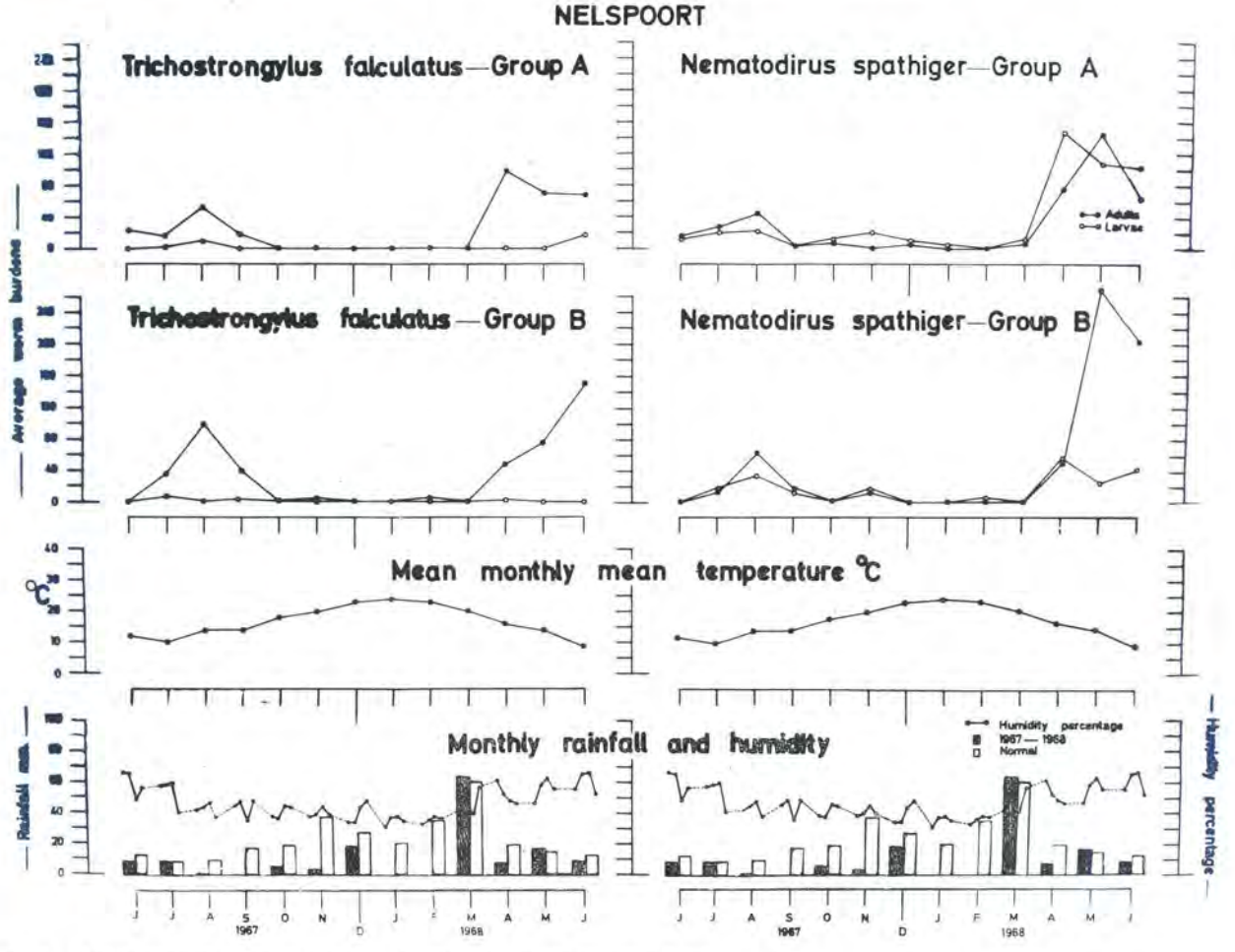

FIG. 4.—Availability of infective larvae. Monthly variations in worm burdens

N. spathiger

This was the only species of *Nematodirus* recovered. Fourth stage larvae showed minor peaks in August and November 1967 and a dramatic rise in April 1968. A downward trend was noticed in May and June 1968. Adult burdens rose to a minor peak in August, followed by a decline in September 1967; they remained low until March and rose again to a peak in May 1968. In June adult burdens showed a sharp decline.

H. contortus

H. contortus was found in insignificant numbers in three autopsies only during the beginning of the survey.

Ostertagia spp.

A few immature *Ostertagia* spp. were found in two autopsies in July and August 1967.

Group B—"Control" lambs

T. falculatus

Fourth stage larvae were found in small numbers in some of the autopsies in July, August and September 1967 and in April and May 1968. The adult worm burdens showed trends similar to those seen in the "Indicator" lambs. The increase in the number of adults in August, however, was more marked and the April rise was followed by a further increase in May and June 1968.

N. spathiger

Fourth stage and adult worm burdens showed the same trends as those seen in the "Indicator" lambs. The peak in adult burdens in May 1968 was more pronounced; this is probably due to the exceptionally high burden of 666 adults found in one of the lambs.

H. contortus

At the beginning of the experimental period, *H. contortus* was found in two sheep, but both had fewer than five worms.

Ostertagia spp

In September 1967, a few *Ostertagia* spp. were recovered in one autopsy.

Cestodes and Trematodes

No cestodes or trematodes were found.

Climatic data

Climatic data are summarized in Appendix Table 7 and presented graphically in Fig. 4.

It was a particularly dry period with little or no rain apart from the heavy rains (64 mm) recorded during the second half of March 1968.

The relative humidity was 60 per cent or higher during June and July 1967 and again from April to June 1968. The high humidity recorded at the beginning of the experimental period is attributed to high rainfall in May 1967 (72 mm) followed by cool, overcast conditions during June and July 1967.

Discussion

Ryksen (1939) showed that *Nematodirus* is a common parasite in the Karoo and Viljoen (1964) found that *T. falculatus* is also prevalent in this region. The results described above confirm that *N. spathiger* and *T. falculatus* are the dominant parasites of sheep in the Karoo. The burdens of these two species of worms followed a similar pattern in the winter and early spring of 1967. When the first batch of lambs was born in May 1967, 72 mm of rain was recorded, but only 9 mm fell in June and July and 1 mm in August. No rain was recorded in September. In the first two weeks of June the relative humidity was 67 and 66 per cent respectively, but thereafter it never exceeded 60 per cent and even fell as low as 36 per cent in the third week of September (Appendix Table 7). Throughout this period the mean monthly mean temperatures varied from 10 to 14 °C. The increase in the burdens of both species of worms in such dry conditions is probably largely due to the low temperatures which prevailed. This confirms the findings of Gordon (1948, 1958), Crofton (1954), Parnell, Rayski, Dunn & McIntosh (1954), Hobbs (1961), Barrow (1964), Reinecke (1964), Rossiter (1964) and Viljoen (1964) that the incidence of *Trichostrongylus* spp. increases during the cool months of the year.

During this period the mean monthly mean temperatures fell within the optimal limits recorded by Levine (1963), viz. 6 to 20 °C. The results do, however, show that *T. falculatus* can increase on the pasture when the monthly rainfall is much lower than the 50 mm which Levine considers optimal.

In 1968 the rainfall was higher: 64 mm fell in March and in the ensuing three months from 8 to 17 mm fell per month. During this period *Trichostrongylus* spp. increased even more markedly than in the preceding year (Appendix Table 7; Fig 4). A good fall of rain in autumn, followed by a cold winter, is favourable for the completion of the life-cycle of this parasite.

The hot dry conditions which prevail at Nelspoort from October to March are quite unsuitable for the survival of the free-living stages of *T. falculatus* on the pasture (Appendix Tables 8, 9; Fig. 4). The results of the previous experiment show that when the mean monthly mean temperature exceeds 20 °C rainfall, even if it exceeds 50 mm a month, only results in a very slight increase in the worm burdens.

These results confirm the observation by Kates (1950) that the infective larvae of *N. spathiger* are much more resistant to heat and desiccation than those of *Trichostrongylus* spp. Senger (1965), Senger & Forrester (1962) and Senger & Ruff (1962) have shown experimentally that larvae of *N. spathiger* may survive for at least a year in dry pellets and that both eggs and larvae can survive temperatures ranging from below freezing point to above 50 °C.

In the period from October to December 1967 the monthly rainfall varied from 4 to 19 mm, and no rain fell in January or February 1968. The mean monthly mean temperatures varied from 18 to 24 °C and the weekly relative humidity from 32 to 49 per cent. Despite this drought 39 of the 75 lambs slaughtered during this period were infested with *N. spathiger*, the individual worm burdens varying from 2 to 114. On the other hand *T. falculatus*, which is less resistant to desiccation, was only found in 10 of these lambs, in infestations ranging from 3 to 23 specimens per animal.

In this experiment it was noted that the larvae of *N. spathiger* were retarded in the fourth stage as the lambs grew older. When the lambs reached 12 to

15 months of age fewer worms became adult regardless of the season of the year. This is probably a manifestation of resistance similar to that found in this and other species of the genus by Kates & Turner (1953), Baxter (1957), Crofton (1957), Thomas (1959), Gibson (1959) and Brunsdon (1962a, 1963b).

Analysis of the data in the first experiment (Appendix Tables 4, 5 and 6; Fig. 2), shows that the further west one goes and the more arid the region is, the more suitable the conditions are for *N. spathiger*. Conversely *H. contortus*, which requires a higher humidity, found conditions most suitable for its survival at Grootfontein; its numbers dropped markedly at Nelspoort and it almost disappeared at Klerefontein, where the humidity is lower than it is at Grootfontein.

It seems probable that the lower burdens of *N. spathiger* at Grootfontein are not only the result of ecological differences affecting the free-living stages of the parasite; the presence of *H. contortus* in the host may have a deleterious effect on any *N. spathiger* present. This hypothesis is supported by the results of this experiment, in which 409 sheep were slaughtered, as well as those of the previous trials conducted at Grootfontein (Viljoen, 1964) and at Bathurst, in the coastal areas of the eastern Cape (Rossiter, 1964), where *H. contortus* was dominant and *N. spathiger* recovered in small numbers only. Moreover on the Highveld where *H. contortus* is rife *N. spathiger* was not recorded by Thomas (1968).

However, the above hypothesis is not supported by the findings of some other workers. Turner, Kates, Sinclair & Foster (1952) and Turner & Colglazier (1954) concluded that *H. contortus* either causes a breakdown in the hosts' resistance to *N. spathiger* or reverses the normal selflimiting course of the latter species. In an anthelmintic test, Anderson (1968) infested 11 sheep simultaneously with *Gaigeria pachyscelis* Railliet & Henry, 1901, *H. contortus* and *N. spathiger*. The resultant worm burdens in the five untreated controls were remarkably uniform. These conclusions, though, are based on experiments involving small numbers of animals, viz. Turner *et al.* (1952) used 12, Turner & Colglazier (1954) 8 and Anderson (1968) 5 animals.

Alternatively *O. columbianum* may have a detrimental effect on *N. spathiger*. *O. columbianum* is a common parasite at Grootfontein but is rare at Klerefontein and all but absent at Nelspoort.

Reinecke (1966) attempted to establish concurrent infestations of *G. pachyscelis*, *T. colubriformis*, *H. contortus*, *O. circumcincta*, *N. spathiger* and *O. columbianum* in 18 sheep. He recovered from 1 to 40 *N. spathiger* from 11 sheep and none from the remaining 7 animals. The other species, although not established in uniform numbers, were consistently present.

Reinecke does not comment on the possible interaction of these species, but it seems reasonable to assume that one or more of the other worms had a suppressive effect on *N. spathiger*.

Worm burdens in lambs, yearlings and older sheep may be kept at a low level by strategic or preventive dosing, as advocated by Gordon (1948). In the Karoo this should be applied as follows:

1. *March:* Early autumn drenching to reduce overwintering fourth stage larvae of *H. contortus* (eastern parts of the Karoo) as well as the increasing burdens of *N. spathiger* and *T. falculatus*.

2. *July:* Mid-winter drenching to prevent further increase of *N. spathiger* and *T. falculatus* burdens during late winter.

The drenching of pregnant ewes in lamb in March and July protects spring and autumn lambs against parasitic invasion.

Tactical drenching can be instituted in the summer after more than 25 mm rainfall and if sheep show visible clinical signs of parasitism. Drenching at this time of the year is especially important in the eastern parts of the Karoo to reduce high burdens of *H. contortus;* in the more arid regions it combats high burdens of *N. spathiger*.

Summary

1. The epizootiology of nematode parasites of sheep was investigated at three stations in the Karoo, viz. Grootfontein, Nelspoort and Klerefontein.
2. Slaughter trials were conducted on sheep on a continuous grazing system and on sheep grazing the pasture for limited periods of time.
3. The dominant parasites found in the Karoo were *T. falculatus* and *N. spathiger*. The importance of *H. contortus* and *O. columbianum* decreases as one passes from the moister regions of the east to the arid regions in the west. *O. circumcincta* was found in insignificant numbers in both experiments.
4. During spring and summer a monthly rainfall of 25 mm or more is adequate for *H. contortus* to maintain itself in reasonable numbers.
5. *T. falculatus* and *N. spathiger* increased during the cool months of the year with or without a monthly rainfall of 50 mm.
6. Dry warm conditions from October to March with mean monthly mean temperatures in excess of 20 °C are totally unsuitable for *T. falculatus* and even a rainfall of more than 50 mm resulted in a very slight increase in worm burdens.
7. Infective larvae of *N. spathiger* showed a higher resistance to heat and desiccation than those of *T. falculatus;* it is present in higher numbers and in more lambs slaughtered during the spring and summer period.
8. Experimental data confirm the author's hypothesis that either *H. contortus* or *O. columbianum* has a deleterious effect on *N. spathiger*.
9. Strategic drenching is recommended for March and July while tactical drenching during the summer period depends on favourable climatic conditions and the development of clinical signs of parasitism.

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