

The Influence of Nutritional Level on Verminosis in Merino Lambs.

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INTRODUCTION.

DESPITE the availability of a number of valuable curative remedies, verminosis in stock remains a problem of great economic importance. Up to now the question has been studied mainly with a view to combating the parasites, without due regard having been paid to the factors affecting the resistance and tolerance of the host animals.

While it is difficult to assess fully the role of such factors as climate and disease on the reaction of animals to worm infestation, the concensus of opinion appears to be that the nutritional status more than any other single factor determines the response to helminthiasis. In view of this fact the successful control of worm problems in stock necessitates as one of the primary measures a clear understanding of the relationship between diet and the effects of worm infestation. The work of Rhoads, Castle Payne and Sanson (1934), who demonstrated the beneficial effect of massive iron therapy on hookworm anaemia in man, is a classic example of this fact.

In experiments on the pathogenicity of hookworm (*Bunostomum trigonocephalum*) in lambs, Lucher and Neumayer (1946) found that even heavily infected lambs recovered from anaemia within three or four months. They conclude that this "may be due to the good housing, care and feeding received by the test animals".

Ackent (1939) showed that resistance to roundworms in poultry could be correlated with an adequate diet sufficient to ensure maximum growth.

Working with sheep, Andrews *et al* (1944) showed that the actual digestibility of feedstuffs is not decreased by the presence of severe gastro-intestinal worm infection, but that the energy requirements of the parasitised host are greatly increased. Sheep with verminosis therefore need a greater amount of feed in order to maintain normal growth and condition.

On the other hand Sarles (1944) concluded that on a relatively good diet the harmful effects of a nodular worm, (*Oesophagostomum columbianum*) infection in lambs became more marked with an increasing degree of artificial infection. Symptoms included loss in weight, decreased rate of gain in weight, slight elevation of rectal temperature, inactivity and unresponsiveness, diarrhoea, loss of appetite, weakness, emaciation, stunting and anaemia.

It is highly probable that the marked increase in verminosis in stock which has taken place in South Africa during the past 25 years is due mainly to a deterioration in the quantity and quality of the grazing available.

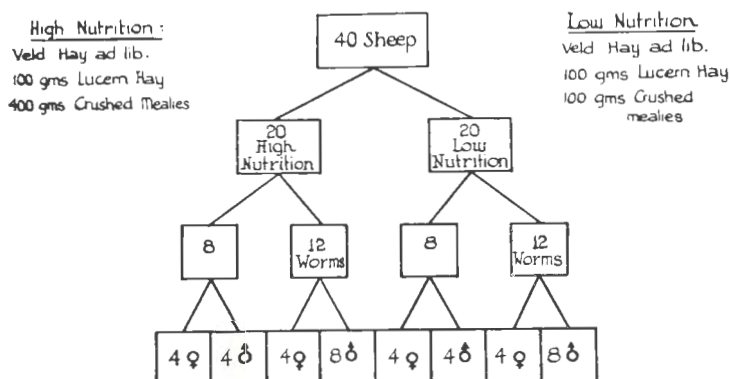
In view of these facts it was considered advisable to conduct an investigation into the effects of nutrition on verminosis in merino sheep under South African conditions.

INFLUENCE OF NUTRITIONAL LEVEL ON VERMINOSIS IN MERINO LAMBS.

A preliminary experiment was conducted on a batch of merino lambs (12 to 18 months old) which were brought in from an outstation heavily infected with wire worm (*Haemonchus contortus*) and nodular worm (*Oesophagostomum columbianum*). One group of these animals was fed lucerne hay and maize in generous amounts without any further therapy. The remainder were treated with anthelmintics but placed on the standard Onderstepoort ration, which is quite adequate for normal sheep. The first group rapidly lost their diarrhoea and started to improve in condition. The number of eggs voided in the faeces decreased but they continued to harbour a considerable number of parasites. The treated sheep on the other hand failed to improve in condition and the majority of them ultimately succumbed. This indicated that extra feed was more efficacious than anthelmintics.

The results of this preliminary trial were so definite that a fully controlled experiment was subsequently planned.

DIAG. I : Layout of Treatments *



EXPERIMENTAL PROCEDURE.

Forty merino lambs of from 4 to 5 months old were all treated for worms. They were then kept for a preliminary period of three months in a communal paddock on a concrete floor in order to accustom them to artificial feeding and living conditions.

The animals were then divided by random selection into two groups of 20 each. Both groups were fed veld hay *ad lib* plus 100 gm. of lucerne hay per day. In addition group 1 received 400 gm. of yellow maize per day while group 2 were given only 100 gm. of yellow maize. The details are given in Diagram I.

The rations were weighed out daily into feeding boxes in individual sheep pens and the residues weighed back every three days. At the commencement of the experiment it was found that the lambs did not consume their full ration and the maize allowance was accordingly reduced to 200 gm. and 50 gm. respectively. The full ration was later restored as will be indicated.

After a preliminary period of three weeks during which the animals consumed their ration satisfactorily, twelve lambs in each group were artificially infected, by dosing with worm larvae. The dates of infection and approximate numbers of larvae administered are shown in Table 1. By this time the lambs were 7-8 months old.

TABLE 1.—*The Approximate Numbers of Worm Larvae Administered per Sheep.*

Date.	<i>Haemonchus contortus</i> (Wire Worm).	<i>Oesophagostomum columbianum</i> (Nodular Worm).
18.11.46.....	1,960	40
20.11.46.....	5,000	1,200
22.11.46.....	1,200	400
TOTAL.....	8,160	1,640

All the lambs were weighed fortnightly and full details of the results will be found in Figure 1.

RESULTS.

All the infected lambs, regardless of the plane of nutrition, showed a depression in appetite approximately 10 days after having been infected. On the 13th day after the first dosing with worm larvae, all the infected lambs appeared depressed and were purging vigorously, the excretion being of a thin, black, tarry nature. The animals became sluggish and hollow-flanked.

On the 17th and 18th days after being infected 13 of the 24 animals died. Of these 9 were from the poorly fed group and 4 from the well fed group.

Post Mortem Findings.

The pathological changes in all the sheep which died of acute verminosis were found to be very constant. The main lesions were:—

- (1) Severe anaemia (2 to 4 gm. Hb per 100 c.c.).
- (2) Generalised oedema particularly of the lungs and the mesentery of the large intestines. The trachea invariably contained froth.
- (3) Sub-epicardial and subendocardial haemorrhages in a few cases.
- (4) Watery ingesta in the fore-stomachs.
- (5) Grey to black ingesta in the abomasum teeming with wire worm. Mucosa studded with numerous pin-point haemorrhages. The black pigment consisted of partly digested blood.
- (6) The small intestine showed the presence of numerous circumscribed purulent nodules which contained a creamy light green pus. Some of these nodules had ruptured through the peritoneal surface resulting in small areas of fibrino-purulent peritonitis.
- (7) In the large intestines and particularly in the caecum these nodules were extremely numerous and closely packed. The gut wall was thickened and oedematous. The mucosa was haemorrhagic, excoriated in patches and covered with adherent pus from freshly ruptured nodules. The lumen was filled with thick tarry black ingesta. No nodular worms could be detected macroscopically but 4th stage larvae were found in the nodules and in scrapings of the mucosa on microscopic examination. The mesenteric lymph glands were enlarged.

Cause of Death.

The immediate cause of death in all cases was acute pulmonary oedema. This was probably secondary to the severe anaemia and loss of blood colloids. Increased capillary permeability due to toxæmia from the massive bacterial infection of the large intestine may also have played a role.

THE EFFECT OF ANTHELMINTICS ON LAMBS WITH SEVERE ACUTE VERMINOSIS.

As it was evident that the remaining eleven infected lambs would also succumb, it was decided to treat them in order to ascertain the effects of anthelmintics on such a severe infection. They were accordingly divided into three groups and dosed the following remedies:—

- (a) Phenothiazine 15 gm. in watery suspensions (4 lambs).
- (b) "Tetram" (Tetrachlorethylenc emulsion) 15 c.c. (5 c.c. tetrachlorethylene) (3 lambs).
- (c) "Nodular Worm Remedy" (Copper tartrate and copper arsenate mixture) 1 gm. (4 lambs).

The above remedies were all administered immediately after the usual preliminary dose of copper sulphate solution to ensure closure of the oesophageal groove. All the lambs were purging severely and were very weak when dosed. One of the animals that had received "tetram" died within four hours after being dosed. In view of their very weak condition the remaining 10 lambs were slaughtered 48 hours after treatment in order to ascertain the effects of the anthelmintics on the worms. The main findings were as follows:—

(a) *Phenothiazine Treated.*

Anaemia, general including pulmonary oedema. Abomasum empty with complete disappearance of the greyish black ingesta seen in the untreated cases. No wire worms present. Abomasal mucosa appeared normal and without any petechiae. The small and large intestines had also become cleared of the black pigmented contents. No change could be detected in the number, size or nature of the purulent nodules. Nevertheless the symptom of persistent diarrhoea had definitely abated. Live 4th stage nodular worms were found in the nodules and on the mucosa.

(b) *"Tetram" (Tetrachlorethylene emulsion) Treated.*

Anaemia, general and pulmonary oedema. Stasis of the abomasum which was filled with tarry black ingesta. No wire worms or petechiae found. Pyloric sphincter closed. Black-stained ingesta in the intestines. No change in the intestinal wall. Young fourth stage living larvae in the nodules and on the mucosa.

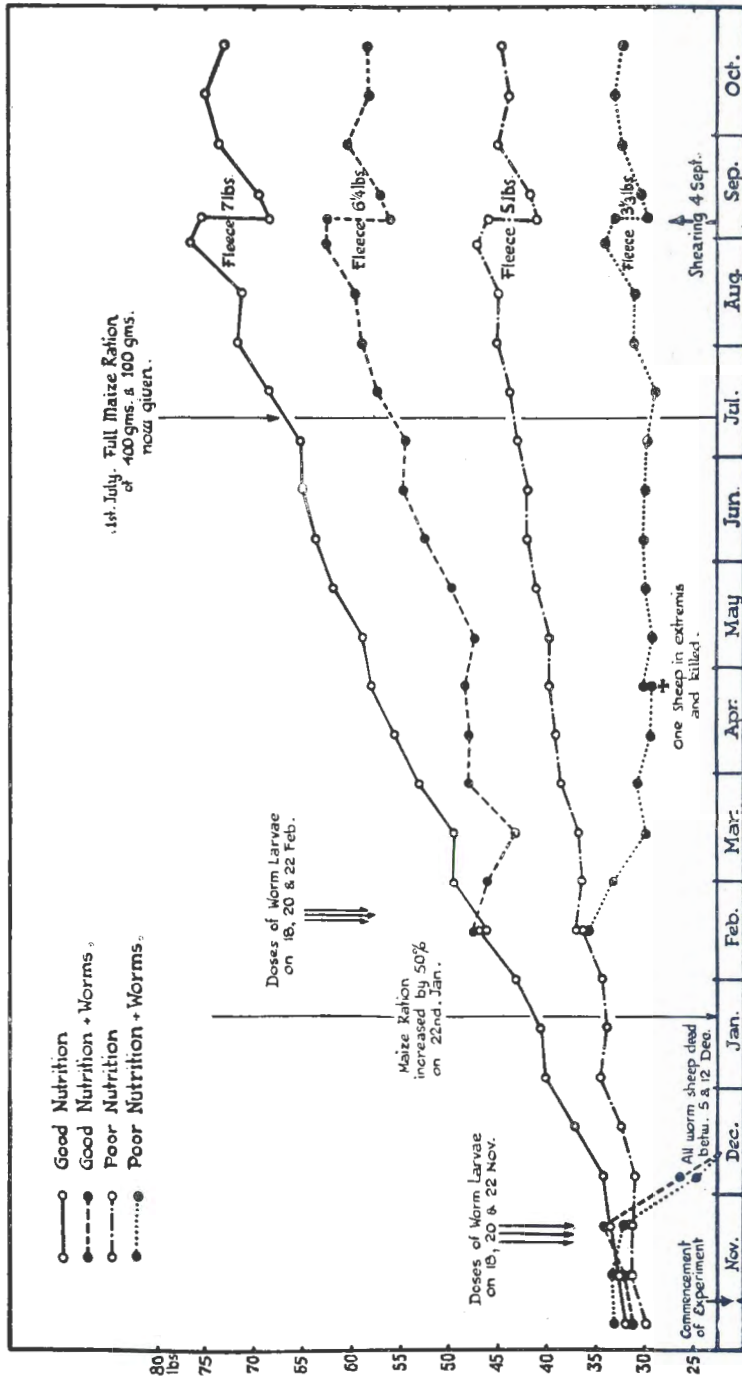
(c) *"Nodular Worm Remedy" (Copper tartrate and arsenate mixture) Treated.*

Exactly as for "Tetram" treated sheep except that in two cases numerous active wire worms were still present in the abomasum and the mucosa of this organ still showed numerous petechiae present. In the other two lambs the wire worms were either dead or very sluggishly motile.

DISCUSSION.

As has been shown, the number of worms administered to these lambs was so large that a peracute fatal infestation resulted in both groups. Under these conditions the comparative effects of nutrition on the resistance to worm infestation could not be demonstrated. However, valuable information was gained on the pathogenesis of acute verminosis and the effect of certain anthelmintics. In the latter connection the findings on the sheep treated with phenothiazine are of particular interest. Not only were all the wire worms removed but the drug appeared to have a purgative and cholagogue action as indicated by the disappearance of the black tarry contents from the abomasum and intestines and the reappearance of bile in the small intestine. The sheep treated with either "Tetram" or "Nodular Worm Remedy" on the other hand, showed a stasis of the abomasum and a persistence of black diarrhoea. None of the remedies used killed the 4th stage nodular worm larvae or had any effect on the nodules.

FIG. 1 : Average Body-Weight Curves of the Four Groups of Sheep.



The failure of the "Nodular Worm Remedy" to kill the wire worm in two out of the four lambs dosed may have been due to the presence of a large amount of free iron in the abomasum. This iron may have combined with the copper salts of the remedy rendering them inactive. On the other hand the failure of the remedy to kill the wire worm may have been due to failure in passing directly into the abomasum.

EXPERIMENT 2.

In view of the above findings it was decided to utilize the uninfected control lambs in a further experiment, but to maintain them on the two experimental planes of nutrition for another three months before infecting any of them. The test animals for the second experiment therefore comprised two groups of eight lambs each. The two groups each consisted of four wethers and four ewes. The experiments can be considered as having commenced at the beginning of November 1946 when the animals were approximately seven months old. The experimental rations of the two groups were then as already given viz:—

Groups 1—High Nutrition.

Veld hay *ad lib.*

Lucerne hay 100 gm. per day.

Yellow Maize 200 gm. per day.

Groups 2—Low Nutrition.

Veld hay *ad lib.*

Lucerne hay 100 gm. per day.

Yellow Maize 50 gm. per day.

The animals were maintained on these rations until the middle of the following January when the maize allowance was increased to 300 and 75 gm. respectively.

On the 18th, 20th and 22nd of February, when the animals were 10 to 11 months old, half of each group were infected with worm larvae. Two wethers and two ewes from each group were selected for infection and the approximate total number of larvae dosed per sheep were as follows:—

Haemonchus contortus 8,300.

Oesophagostomum columbianum 1,650.

On 12th July, 1949 the maize ration was again raised to 400 and 100 gm. respectively. The experiment was conducted on exactly the same lines as described for the first trial.

RESULTS.

1. *Body Weight.*

The average fortnightly weights for each group throughout the experiment are plotted in Figure 1.

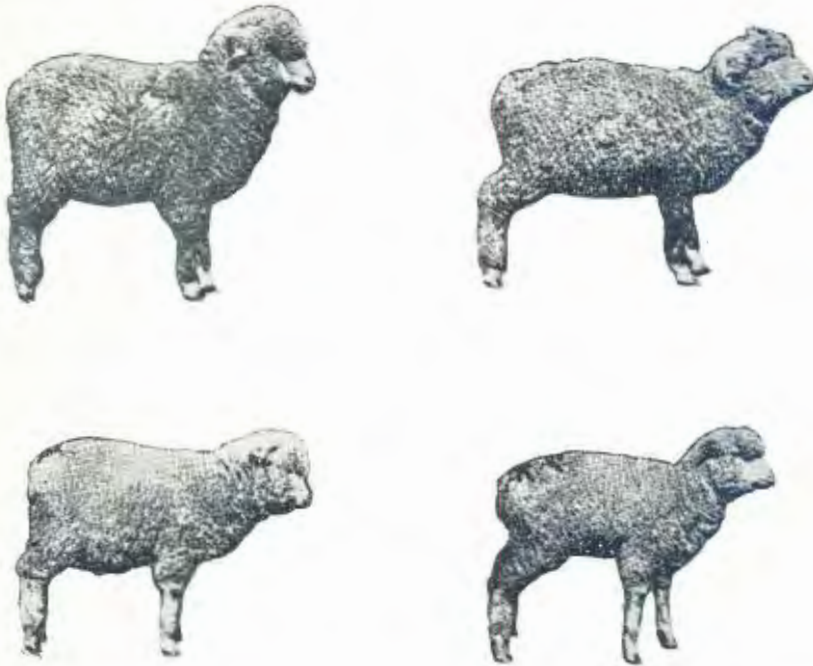
It will be noted from this graph that the "high nutrition" non-infected sheep maintained a steady increase in body weight.

The infected animals on the same ration showed a loss in weight for the four weeks following infection, but subsequently recovered and showed a steady though retarded gain.

The uninfected sheep on the poor diet maintained a very slow rate of gain, indicating that the ration supplied little above maintenance requirements.

Infection with worms among this group resulted in an immediate loss in weight which was never really made good.

The photographs depict typical members of each group 4 months after infection.



Representative members of each group (photographed 11th June, 1947, i.e. 4 months after infection).

Top left: Good nutrition, no worms.

Top right: Good nutrition, worms.

Bottom left: Poor nutrition, no worms.

Bottom right: Poor nutrition, worms.

2. *Worm Infestation.*

Samples of faeces were collected periodically throughout the experiment for the purpose of conducting worm egg counts.

The technique adopted for estimating the relative degree of infection was a simple one of concentration and flotation; in all cases 50 grams of fresh faeces were thoroughly broken up in water in a small fruit jar; the whole was then sieved through a nest of sieves with different size mesh, the finest and last sieve having a mesh of 2,500 to the square inch; in this way all the coarse material was eliminated leaving only the finest solids and eggs in suspension. After allowing the suspension to stand in a glass flask for about 20 minutes in order to allow all the solids to settle down the supernatant liquid was carefully poured off. All the sediment was then transferred into a 50 c.c. centrifuge tube, an equal volume of glycerine added, thoroughly shaken and then centrifuged at about 1,500 r.p.m. for 15 minutes. A 1 cm. diam. glass rod, with its end squarely cut off was now used to remove 5 samples from the surface of each tube; these samples were taken by just touching the surface five times with the rod, first in the centre and once each in the N., S., E., and W. corners of the surface. These five drops were placed in a row on a side and the total number of eggs in the drop was counted; where

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eggs were very numerous their number was estimated. From the number thus obtained from the various faeces samples an estimation of the degree of infection was made. This simple method, when similarly applied to all samples from a group, gives according to the writers' experience a very good indication of the comparative degree of infection and for all practical purposes is as reliable as the Stoll method where an actual count of the eggs present in a definite quantity of faeces is made; it is also far less time-consuming.

TABLE 2.

Plane of Nutrition.	Worm Infection.	WORM EGG COUNT.					Infection Noted at Post Mortem on 17.11.47.	
		Date.					Wire Worm.	Nodular Worm.
		14.3.47.	10.4.47.	11.6.47.	30.7.47.	16.9.47.		
High.....	Controls	— — —	— 1 — 1	— — 1	— — —	— — —	— — —	— — —
High.....	Infected 18.2.47	5 ¹ 5 5 ³ 5 ¹	5 ³ 5 5 ³ 5 ²	5 ¹ 2 4 5	5 1 4 2	5 1 4 1	1 — 0 1	— 1 2 0
Low.....	Controls	— — — —	1 1 1 —	— — — —	— — — —	— — — —	— — — —	— — — —
Low.....	Infected 18.2.47	5 ¹ 5 5 ³ 5 ²	5 ³ 5 ³ 5 ³ 5 ³	* 5 ³ 5 ³ 4	— 5 ² 5 ² 4	— 5 ² 5 2	— 3 2 —	— 3 2 1

* Sheep died.

Worm egg counts.

- 1 = 1-10 eggs
- 2 = 11-100 eggs
- 3 = 101-500 eggs
- 4 = 501-1,000 eggs
- 5 = 1,000-2,000 (estimated)
- 5¹ = 2,000-5,000 (estimated)
- 5² = 5,000-10,000 (estimated)
- 5³ = 10,000 and over.

Infection at Post Mortem.

- 1 = few
- 2 = medium
- 3 = heavy.

The results are shown in Table 2. As will be seen there was a very light natural worm infestation in some of the controls early in the experiment but the animals lost this infestation later on. All the infected sheep were passing large numbers of worm eggs one month after having been dosed with larvae. The sheep on the high plane of nutrition continued to harbour large numbers of parasites throughout the major part of the experiment so that the beneficial effects of the greater dietary intake cannot be ascribed to a lighter infestation of worms. Towards the end of the experiment, however, the better fed sheep tended to lose their infestation as clearly shown by the number of worms found at post mortem at the conclusion of the experiment. Only very slight reinfection can possibly have taken place during the course of the experiment as shown by the clean state of the control sheep. The fact that adult worms were still present nine months after larvae had been dosed therefore gives some indication of the life span of the two species of parasites in the animal body.

THE EFFECT OF VERMINOSIS ON HAY CONSUMPTION.

Figure 2 shows the average fortnightly consumption of hay by the sheep in each group throughout the experiment.

It will be noted that in the period before worm infestation took place, both groups consumed approximately the same amount of hay. The dosing of worm larvae was immediately followed by a marked drop in appetite in all the infested sheep. The intake of the infected animals remained lower than that of their non-infested counterparts but again the difference in maize intake did not affect the amount of hay consumed.

The marked adverse effect of verminosis on appetite for roughage as demonstrated in this graph, is a factor which has received scant if any attention thusfar. The retarded growth shown by the worm infested sheep is obviously due not only to the drain of nutriment by the parasites but also to their depressing effect on appetite.

As the appetite for maize was not affected by the verminosis it would appear that extra concentrates should be given to worm infested sheep in order to maintain growth and vigour. Where the animals are on natural grazing the loss in appetite may be expected to exert an even more drastic effect than was indicated in this experiment.

HAEMOGLOBIN.

At the termination of the experiment all the sheep were bled for haemoglobin determination. The average values for each group are given below.

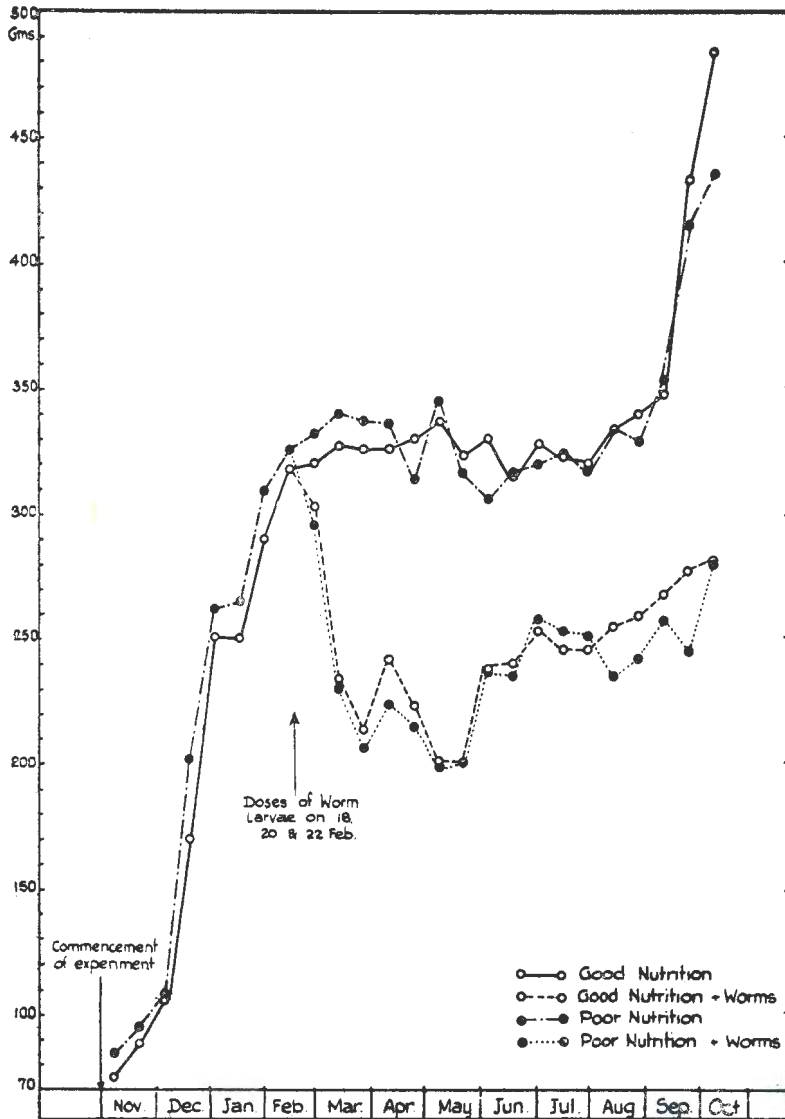
1. High Nutrition no worms	9.6
2. High Nutrition worm-infested	8.9
3. Poor Nutrition no worms	9.8
4. Poor Nutrition worm-infested	7.6

As it will be seen the lower ration was sufficient to maintain the haemoglobin level at a normal value in the absence of intestinal parasites.

The extra intake of maize by the better-fed sheep enabled them to maintain a haemoglobin level very little below that of the non-infested animals but the presence of worms in the poorly-fed sheep caused a definite decrease in haemoglobin.

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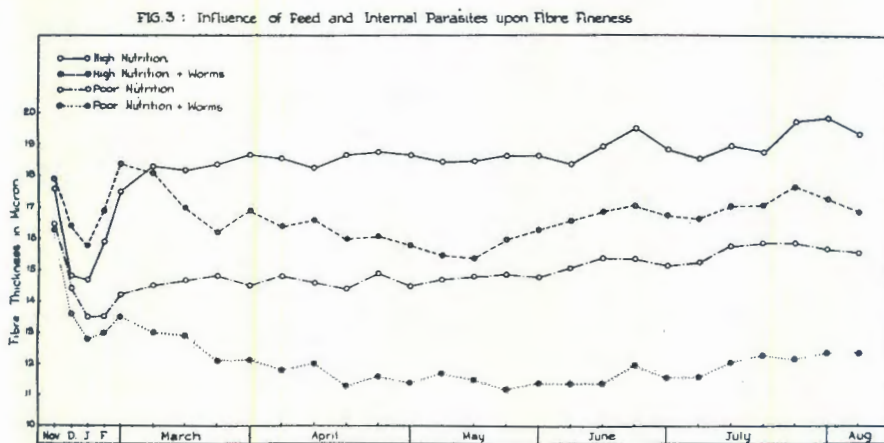
FIG 2 : Average Daily Veld Hay Consumption Curves of the Four Groups of Sheep



WOOL. GROWTH AND QUALITY.

Carter, Franklin and Gordon (1946) found a significant decline in the wool production of crossbred weaners infested experimentally with *Trichostrongylus colubriformis*, the wool production on tattooed skin patches dropping to 40 per cent. of that in the control animals.

In the present experiment the effect on wool production was studied by determining the fibre thickness on tattooed patches on the shoulder at weekly intervals, the week's growth being clipped closely from the skin with a pair of fine curved scissors. The fragments were well mixed in ether and mounted in Euparal, after which 250 fibres were measured. The group averages at weekly intervals are illustrated in Figure 3.



From the results it appears that changes in fibre thickness can be very readily demonstrated by means of this technique and it can therefore be recommended for the rapid detection of the effects of various treatments on the growth of the fibre.

At the end of the experimental period the sheep were shorn and the scoured fleece weights determined on an oven dry basis. Since the fleeces were partly grown during the pre-experimental period, the differences found underestimate the true effect of the treatment.

Average values for the groups are given in Table 3 on a relative basis, the mean fibre thickness being calculated over the experimental period.

TABLE 3.—Relative fibre thickness and scoured fleece weight.

Groups.	Gross Fleece Weight (lb.).	Relative Scoured Fleece Weight (dry).		Relative Mean Fibre Thickness.		Relative Square of Fibre Thickness.	
1(a) High Nutrition (Control).....	7.0	1	—	1	—	1	—
1(b) High Nutrition (infested).....	6.25	0.84	—	0.87	—	0.77	—
2(a) Low Nutrition (Control).....	5.0	0.68	1	0.77	1	0.60	1
2(b) Low Nutrition (Infested).....	3.3	0.47	0.69	0.62	0.80	0.38	0.63

As shown by figure 3, a marked reduction in wool fibre thickness occurred as a result of infestation, the separation of the curves being similar to that of body weight. The contribution of fibre thickness to scoured fleece weight which is proportional to the square of the fibre thickness, was reduced by approximately

one third, as shown in Table 2. To this reduction must be added a probable reduction in rate of fibre growth and in the number of fibres. The loss is confirmed by the scoured fleece weight, which include pre-treatment growth and nevertheless show a marked reduction. The loss in fleece weight may conservatively be estimated at one-half, and in all probability is much greater.

Apart from sheep losses, and the various implications of reduced health and condition, the profound effect of worm infestation in reducing fleece weights by at least one half reflects the enormous loss in income to the wool grower unless strict control is exercised, especially under adverse feeding conditions.

SUMMARY AND CONCLUSIONS.

1. A mass mixed infestation of *Haemonchus contortus* and *Oesophagostomum columbianum* larvae dosed to 7-8 month old merino lambs kept on two different planes of nutrition caused a peracute fatal verminosis in all the infested animals.

2. A similar infestation when dosed to 10-11 month old lambs under identical conditions caused a chronic verminosis. In this case the effect of nutrition on the response of the animals to verminosis was clearly demonstrated.

3. This finding demonstrates the greater susceptibility of young lambs to worm infestation, regardless of their diet, and emphasises the necessity of preventing mass infestation in young lambs under all conditions.

4. In the second experiment it was shown that an increase of the maize ration by 300 gm. a day caused a marked superiority in worm infested sheep as regards all of the following factors:—

Body weight, appetite for roughage, haemoglobin level, fleece weight and wool fibre thickness.

5. In all the above respects the worm infested sheep receiving 400 gm. of maize per day were superior to the non-infested sheep receiving only 100 gm. of maize per day.

6. The pathological findings in cases of acute verminosis are described and the immediate cause of death was found to be acute pulmonary oedema.

7. Phenothiazine was found to be superior to either tetrachlorethylene emulsion or copper tartrate and copper arsenate mixture as a vermifuge in that it appeared not only to kill all wire worm present but also to cause removal of the black-stained ingesta from the alimentary tract. It also appeared to promote normal bileflow.

8. The experiment clearly demonstrates the beneficial effects of a higher maize intake on the response of sheep to verminosis.

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