Effects of gastro-intestinal and lungworm nematode infections on ewe productivity in farm flocks under variable rainfall conditions in Syria

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Abstract

Ten farm flocks in north-west Syria were monitored over four years to determine the effect of gastro-intestinal and lungworm nematode infections on Awassi ewe productivity. A group of ewes in each flock served as the control, while the other was treated with fenbendazole in the autumn and in spring. The flocks were visited each month to start with and every three months later in the trial to collect faecal samples, and recordings were made of ewe and lamb live weight, ewe body condition score, changes in flock inventory and supplementary feeding practices. Treatment with the anthelmintic had no beneficial effect on ewe fertility, mortality and survival. But in spring treated ewes were heavier and generally had better body condition than untreated ewes, and this was associated with heavier lambs at birth and at weaning. Stepwise regression analysis suggested that better management, such as more rigorous culling, resulted in higher ewe fertility and survival. The overall effect of treatment on annual ewe productivity was small, equivalent to 0.5–1.0 kg additional lamb weaned per ewe exposed to rams. This covered the cost of the treatment. The trial demonstrated that useful studies on nematode parasites can be conducted in farm flocks and this gives the results added value for predicting the impact of treatment on other flocks in north-west Syria.

Keywords: Sheep production systems; Semi-arid areas; Nematode infections; Ewe productivity

1. Introduction

A characteristic feature of semi-arid areas receiving 200–500 mm annual rainfall is the large between- and within-season variations in rainfall. However, no published studies are known in West Asia which have examined the effect of variation in rainfall over several years on the prevalence of nematode parasites in farm flocks, and the consequences for small-ruminant productivity which may take some time to appear. Indeed, evidence that nematode parasites reduce the productivity of small ruminants in farm flocks in semi-arid areas is limited.
(Pandey et al., 1984), and usually extrapolated from slaughterhouse studies (Horchner, 1964; El-Moukdad, 1977). Some studies have been made on the seasonal variations in the larval counts of lungworms in north-west Syria (Thomson and Orita, 1988) and on gastro-intestinal nematodes in Iraq (Khadim, 1972; Altaif and Issa, 1983).

A four-year trial was conducted to assess the effect of nematode parasites on the productivity of ewes and parasite dynamics in a sample of sheep flocks in semi-arid north-west Syria where the farming system includes crops, small ruminants and fruit trees (Tully, 1984). The specific aims of the trial were to (1) estimate the effects of the nematode parasites on the productivity of the ewes by comparing untreated and treated groups in each flock, and (2) assess the seasonal variability in the severity of nematode infections during four consecutive years.

2. Materials and methods

2.1. The flocks

The trial started in February 1987 and continued for four years. It was conducted in a semi-arid area of north-west Syria where 250–350 mm rainfall is received between October and May, with little or no rain falling during the rest of the year (Fig. 1). Mean summer temperatures in the area are 36–38°C and mean winter temperatures are 1–4°C. Eight sheep-owning farmers were identified in February 1987 at Al-Bab and Gammari villages in Aleppo Province and at Al-Tah village in Idlib Province. One year later two additional flocks were added at Al-Taybeh village in Hama Province. The mean size of the eight flocks at the start of the trial was 103 (±48.3 standard deviation, SD) sheep and 8 (±5.8) goats. The two flocks added a year later initially contained 467 and 209 sheep. The flocks in the trial grazed the same sparse native pastures as the other flocks of the village from December to May, and cereal stubbles and crop residues from June to November. They received supplements of barley grain, cereal straw and agro–industrial by-products between November and March. At night throughout the year the individual flocks were kept inside a yard next to their owners’ house and were usually housed in a closed building during winter. The cleanliness and ventilation in these buildings varied between flocks. Each flock included sufficient rams to ensure good fertility.

2.2. Flock monitoring

Monthly records were kept of losses from the flocks, including ewes that died, that were sold as culls or to raise cash, or were slaughtered for home consumption because of poor productivity, illness and festivals. On 1st June each year losses of ewes in each flock were restored using yearlings so that the numbers being monitored remained about the same each year. Ewe live weights and body condition scores were recorded during visits when faecal samples were collected, the latter using a range from 1 (thin) to 3.5 (fat) (MLC, 1988). The total number of sheep being monitored was 227 in 1987/88, 406 in 1988/89, 386 in 1989/90 and 486 in 1990/91.

Eartagged lambs were weighed within two weeks of birth and then at two week intervals until they reached 85 days of age. Their birth weight and live weight gain to 56 and 85 days was estimated from the linear regression between live weight and time. The amount of supplementary feed offered according to category, such as barley grain, barley, wheat and lentil straw, cottonseed cake and cottonseed hulls, was recorded at monthly interviews.

2.3. Experimental treatments

With the exception of one flock in which between 12 and 18 ewes were used, 30 to 60 Awassi ewes were assigned to pairs with a similar live weight and age. Members of pairs were then allocated at random to untreated (control) and treated groups and eartagged. Untreated ewes were drenched with a placebo of tap water. Ewes in the treated group were drenched on two occasions separated by 14 days in both September and in March using fenbendazole (Panacur) at 625 mg per ewe weighing 40 to 60 kg. This is two-and-a-half times the recommended dose to ensure effective control of lungworms (Dakkak et al., 1979). The treatment schedule was selected according to the seasonal pattern of lungworm larval excretion (Thomson and Orita, 1988), which is similar to that of gastro-intestinal nematodes. The
interval of two weeks between treatments controlled possible hypobiotic larvae which Altaif and Issa (1982) reported in Iraq and Giangaspero et al. (1992) confirmed in Syria. Untreated and treated ewes were mixed with the remainder of each farm’s sheep and goats which were drenched at similar times. This served as an incentive to farmers to cooperate and would have reduced the risk of re-infection of treated ewes.

2.4. Parasitological measures

Rectal samples of faeces were taken from the same 10 untreated and 10 treated ewes monthly from February 1987 to November 1988 and from March 1989 to June 1990, and then every three months until March 1991. Eggs of gastro-intestinal nematodes were counted using the standard McMaster technique after flotation using sodium chloride solution. Eggs of Marshallagia and Nematodirus spp. were counted separately. The larvae of Dictyocaulus filaria and protostrongylid lungworms were extracted and counted as described by Thomson and Orita (1988) using 3 g samples of faeces kept for 16 h overnight in a Baermann apparatus at room temperature.

2.5. Meteorological data

Rainfall was recorded at Tel Hadya, ICARDA’s station 2 km from Gammari village, at one location in both Al-Bab and Al-Tah villages, and at Souran village which is 3 km from Al-Taybeh village.

2.6. Data preparation

The level of supplementary feeding in winter was derived from the amount averaged between October and March and for the summer period from the amount averaged between April and September. To enable comparisons across flocks, the daily amounts of the different types of supplements were converted into metabolizable energy (in MJ/sheep). Ewe productivity was estimated from the number of lambs alive at 85 days of age multiplied by their live weight, from 100 ewes exposed to rams. Live weights and body condition scores (BCS) were averaged between July and August to cover the mating period (summer live weight and summer BCS), and from February to April to cover the lactation period (spring live weight and spring BCS). Changes in live weight during the dry summer period were estimated from the difference between the mean live weight averaged between September and October with the live weight in June (summer live weight gain).

2.7. Statistical procedures

Data were processed using SPSS/PC+ (SPSS, Chicago, IL, USA) and statistically analyzed with SAS/STAT (Statistical Analysis System, SAS Institute). Deaths, sales, slaughters, survival and fertility in untreated and treated groups of ewes were compared using the GLM procedure after making the Arc sin (% ) transformation.

Faecal egg counts of trichostrongylids and larval counts of lungworms were log-transformed [log_{10}(x + 1)] to correct for heterogeneity in the variances and to achieve approximately normal distributions. For the parasites with a low level of infection, prevalence was used and percentages were adjusted using the Arc sin (°/2) transformation. Ewe live weights and BCS, lamb birth and weaning live weights and ewe productivity from the two groups were compared using the GLM procedure of SAS, including year and treatment effects with flocks as replicates. Stepwise regression analysis was applied to the data from each of the year-by-flock-by-treatment combinations (n = 76), separately for untreated and treated ewes. The type of night housing was added as an independent variable in the regression analysis using a scale from 1 (humid, dirty) to 3 (dry, well aerated).

3. Results

3.1. Seasonal rainfall and nematode excretion patterns

There were considerable contrasts in the amounts and distributions of rainfall over the four years of the trial (Fig. 1). Rainfall in the 1987/88 winter–spring season – referred to as the wet winter – was well above average with a good distribution. But during the following two seasons – the dry winters – it was...
Fig. 1. Monthly rainfall (a) averaged across the four sites in north-west Syria, egg counts of gastro-intestinal nematodes (b), and larval counts of lungworms (c) in faeces of untreated (solid symbols) and treated (open symbols) ewes in 10 farm flocks over four years. Each vertical arrow indicates two treatments separated by 14 days.

well below average, with a poor distribution in the 1988/89 season and a better distribution in 1989/90. In 1990/91 – the average winter – the rainfall was somewhat below average with a good distribution. During the four years the total annual rainfall was respectively, 517, 226, 242 and 275 mm at Tel Hadya near Gammarri, 465, 201, 205 and 259 mm at Al-Bab, 489, 245, 207 and 268 mm at Al-Tah and
507, 222, 164 and 292 mm at Souran, close to Al-Taybeh.

Mean annual levels of parasite infection were generally low, even in untreated flocks, but there were marked seasonal patterns, with the lowest levels during the dry, hot summers and the highest levels during the cool, moist winters (Fig. 1). The wet winter 1987/88 with high rainfall had lower peak egg counts of gastrointestinal nematodes than the first dry winter 1988/89. In the second dry winter the egg counts remained low, whereas the larval counts were moderate. The treated ewes had substantially lower egg and larval counts than untreated ewes, but the seasonal pattern was still apparent in the former. The predominant lungworms were the protostrongyles Cystocaulus ocreatus, followed by Muellerius capillaris; D. filaria did not exceed 10% of the total larvae.

3.2. Ewe live weight and body condition scores

Lambing between November and January resulted in the decrease in ewe live weight followed by a gradual recovery in spring when pasture growth resumes, and into summer and autumn when flocks graze cereal stubbles (Fig. 2). The live weights, live weight changes and BCS of the untreated and treated ewes were similar ($P > 0.05$) at mating in each summer of the trial. Averaged across untreated and treated flocks, summer live weights decreased from 51.3 ($\pm 3.0$ SD) kg in 1987 and 49.9 ($\pm 4.0$) kg in 1988 to 48.1 ($\pm 3.5$) kg in 1989 and 48.4 ($\pm 5.7$) kg in 1990. The ewes’ live weight losses over three months in summer were smaller in 1987 (0.2 $\pm 2.26$ kg) and 1988 (0.5 $\pm 0.15$ kg) than in 1989 (3.6 $\pm 3.90$ kg) and 1990 (2.9 $\pm 2.20$ kg). The BCS in summer averaged over the two groups was 1.8 $\pm 0.1$ in 1987, 2.2 $\pm 0.2$ in 1988, 2.1 $\pm 0.2$ in 1989 and 2.7 $\pm 0.2$ in 1990. In contrast to the values in summer, significant ($P < 0.01$) differences in live weight and BCS between untreated and treated ewes were found in spring in all years except 1989/90 and 1990/91 in the case of BCS (Table 1).

3.3. Production traits

There were statistically significant ($P < 0.01$) differences between flocks and years for ewe deaths, sales, survival and fertility but effects due to treatments were statistically insignificant ($P > 0.05$). Averaged across the untreated and treated groups, deaths were 6.0 $\pm 6.2$, 6.9 $\pm 6.1$, 4.5 $\pm 5.4$ and 3.7 $\pm 4.0$, sales were 5.3 $\pm 7.8$, 0.6 $\pm 2.0$, 21.5 $\pm 18.6$ and 9.2 $\pm 11.0$, and survivals were 86.6 $\pm 7.5$, 87.6 $\pm 7.2$, 68.0 $\pm 19.4$ and 84.3 $\pm 11.8$ for 1987/88, 1988/89, 1989/90 and 1990/91, respectively. The corresponding fertility rates were 70.4 $\pm 13.1$, 91.0 $\pm 6.1$, 65.0 $\pm 14.9$ and 75.3 $\pm 20.9$ respectively.

![Fig. 2. Live weights of untreated (open symbols) and treated (solid symbols) ewes in 10 farm flocks in north-west Syria over four years.](image-url)
Table 1
Live weight and body condition score (BCS) of untreated and treated ewes in spring, birth and weaning weight and daily live weight gain of lambs and overall ewe performance [Means (standard deviations); *P* is the level of significance)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Year of trial (starting 1st June)</th>
<th>1987/88</th>
<th>1988/89</th>
<th>1989/90</th>
<th>1990/91</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spring live weight (kg)</strong></td>
<td>Untreated</td>
<td>47.2 (2.1)</td>
<td>47.1 (3.9)</td>
<td>41.1 (3.4)</td>
<td>43.4 (5.6)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>48.8 (3.5)</td>
<td>48.6 (3.3)</td>
<td>42.3 (2.3)</td>
<td>43.8 (5.5)</td>
</tr>
<tr>
<td></td>
<td><em>P</em></td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Spring BCS</strong></td>
<td>Untreated</td>
<td>1.89 (0.2)</td>
<td>2.17 (0.1)</td>
<td>2.04 (0.3)</td>
<td>2.29 (0.4)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>1.99 (0.3)</td>
<td>2.30 (0.1)</td>
<td>2.08 (0.3)</td>
<td>2.31 (0.3)</td>
</tr>
<tr>
<td></td>
<td><em>P</em></td>
<td>0.01</td>
<td>0.01</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Lamb birth weight (kg)</strong></td>
<td>Untreated</td>
<td>5.0 (0.8)</td>
<td>nd</td>
<td>4.6 (0.7)</td>
<td>4.5 (0.4)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>5.4 (0.5)</td>
<td>nd</td>
<td>5.1 (0.7)</td>
<td>4.7 (0.4)</td>
</tr>
<tr>
<td></td>
<td><em>P</em></td>
<td>0.01</td>
<td>–</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Lamb daily live weight gain (g)</strong></td>
<td>Untreated</td>
<td>167 (30)</td>
<td>nd</td>
<td>176 (55)</td>
<td>212 (51)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>180 (36)</td>
<td>nd</td>
<td>170 (60)</td>
<td>212 (36)</td>
</tr>
<tr>
<td></td>
<td><em>P</em></td>
<td>ns</td>
<td>–</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Lamb weaning weight, at 56 days (kg)</strong></td>
<td>Untreated</td>
<td>14.4 (1.3)</td>
<td>nd</td>
<td>14.0 (3.0)</td>
<td>16.4 (2.8)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>15.5 (2.4)</td>
<td>nd</td>
<td>14.6 (3.2)</td>
<td>16.6 (1.8)</td>
</tr>
<tr>
<td></td>
<td><em>P</em></td>
<td>0.01</td>
<td>–</td>
<td>0.01</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Ewe productivity</strong></td>
<td>Untreated</td>
<td>9.7 (4.2)</td>
<td>nd</td>
<td>9.4 (4.4)</td>
<td>14.0 (4.0)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>11.0 (4.6)</td>
<td>nd</td>
<td>10.4 (4.0)</td>
<td>14.3 (4.0)</td>
</tr>
<tr>
<td></td>
<td><em>P</em></td>
<td>ns</td>
<td>–</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

*ns = Not significant (*P* > 0.05).

Lambs of treated ewes were significantly (*P* < 0.01) heavier at birth than lambs of untreated ewes but their daily live weight gains were similar (Table 1). Except in 1990/91, lambs of treated ewes at weaning were significantly (*P* < 0.01) heavier than lambs of untreated ewes. However, overall ewe productivity was similar in untreated and treated ewes (*P* > 0.05).

3.4. Supplementary feeding

The farmers started feeding in September and by November many were offering at least 10 MJ metabolizable energy (ME) daily to each ewe. In December and January peak levels of supplementary feeding were found, in the range 12–16 MJ ME. There were statistically significant (*P* < 0.05) differences between years in the levels of supplementary feeding offered to ewes in winter, with less being offered in the second dry winter 1989/90 than in the first two years (Table 2). Whereas the peak level of supplementation reached 16 MJ ME in January in the first two winters, the peak in the second dry winter was only 12 MJ but recovered to 14 MJ in the last winter. The amounts of supplementary feed offered in summer were substantially lower and did not differ significantly (*P* > 0.05) between years.

3.5. Stepwise regression analysis

The results from the stepwise regression analysis for key variables are shown in Table 3. In both untreated and treated ewes sales were negatively correlated with spring live weight, level of supplementary feeding in winter and the prevalence of *D. filaria*. Fertility was positively related to ewe survival, and was affected by the proportion of goats and the level of winter feeding in untreated ewes. How-
Table 2  
Daily amount of supplements (MJ metabolizable energy) offered to each ewe in winter and summer for each year of the trial

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>12.1</td>
<td>11.7</td>
<td>8.5</td>
<td>10.3</td>
<td>2.57</td>
<td>*</td>
</tr>
<tr>
<td>Summer</td>
<td>2.0</td>
<td>1.7</td>
<td>1.2</td>
<td>0.8</td>
<td>1.38</td>
<td>ns</td>
</tr>
</tbody>
</table>

* Standard deviation (square root of the error mean square).

* * = Statistically significant (P < 0.05).

Table 3  
Components* of the best predictive models for ewe and lamb performance in untreated and treated groups of ewes in 10 flocks in north-west Syria

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Group</th>
<th>Regression equation</th>
<th>( R^2 )</th>
<th>Max ( R^2 ) (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>Untreated</td>
<td>1.52 – 0.02 Spring weight – 0.02 Winter feed – 0.7 Dictyocaulus*</td>
<td>0.24</td>
<td>0.67 (16)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>1.61 – 0.02 Spring weight – 0.02 Winter feed – 1.0 Dictyocaulus</td>
<td>0.40</td>
<td>0.56 (16)</td>
</tr>
<tr>
<td>Fertility</td>
<td>Untreated</td>
<td>0.30 + 0.4 Survival – 0.008 Goats* + 0.02 Winter feed</td>
<td>0.47</td>
<td>0.75 (19)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>– 0.28 + 1.1 Survival + 0.9 Marshallagia*</td>
<td>0.60</td>
<td>0.89 (19)</td>
</tr>
<tr>
<td>Survival</td>
<td>Untreated</td>
<td>– 0.04 + 0.37 Fertility + 0.0008 Rain + 0.15 Summer BCS</td>
<td>0.46</td>
<td>0.71 (19)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>0.38 + 0.55 Fertility + 0.0003 Rain – 0.5 Marshallagia</td>
<td>0.70</td>
<td>0.85 (19)</td>
</tr>
<tr>
<td>Spring weight</td>
<td>Untreated</td>
<td>43.3 + 0.8 Summer feed + 1.5 Housing – 20.2 Nematodirus*</td>
<td>0.31</td>
<td>0.52 (13)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>39.8 + 1.6 Summer feed + 0.02 Rain – 35.6 Cystocaulus*</td>
<td>0.40</td>
<td>0.63 (13)</td>
</tr>
<tr>
<td>Spring BCS</td>
<td>Untreated</td>
<td>1.87 + 0.002 Flock size + 0.02 Goats – 0.9 Dictyocaulus</td>
<td>0.52</td>
<td>0.63 (13)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>1.47 + 0.002 Flock size + 0.02 Goats + 0.15 Housing</td>
<td>0.51</td>
<td>0.71 (13)</td>
</tr>
<tr>
<td>Lamb daily gain (g)</td>
<td>Untreated</td>
<td>2.8 + 97.2 Spring BCS – 15.7 Nematodirus</td>
<td>0.63</td>
<td>0.92 (18)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>– 212.2 + 93.6 Spring BCS + 4.05 Summer weight</td>
<td>0.56</td>
<td>0.90 (18)</td>
</tr>
<tr>
<td>Lamb weaning weight, 56 days (kg)</td>
<td>Untreated</td>
<td>8.6 + 4.6 Spring BCS – 9.8 Nematodirus – 2.3 Lungworms*</td>
<td>0.64</td>
<td>0.91 (18)</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td>– 7.9 + 4.4 Spring BCS + 0.3 Spring weight</td>
<td>0.53</td>
<td>0.89 (18)</td>
</tr>
<tr>
<td>Ewe productivity</td>
<td>Untreated</td>
<td>– 32.04 + 0.57 Summer weight + 0.78 Fertility + 4.55 Summer BCS</td>
<td>0.66</td>
<td>0.94 (21)</td>
</tr>
<tr>
<td>(kg lamb/ewe exposed)</td>
<td>Treated</td>
<td>– 28.72 + 0.37 Summer weight + 16.85 Fertility + 4.89 Spring BCS</td>
<td>0.73</td>
<td>0.92 (21)</td>
</tr>
</tbody>
</table>

* \( R^2 \) is the percentage of the variability explained by the model, and Max \( R^2 \) is the maximum value obtained using all possible independent variables (n).

* Prevalence expressed as a proportion.

* Proportion of goats to sheep.

* Expressed as larvae per gram faeces after the log transformation (see Section 2.7).

ever, in treated ewes fertility was positively affected by the presence of *M. marshalli*, an important nematode located in the abomasum. The regressions explained 47 and 60%, respectively, of the variability in fertility in untreated and treated ewes. Ewe survival was positively related to fertility and rainfall in both groups, and to summer BCS in the untreated group. Live weights in spring improved as the amount of supplements fed in summer increased, whereas infections with parasites reduced the spring live weight of both groups. Regressions for the BCS of untreated and treated ewes in summer, which are not shown in Table 3, indicated that rainfall during the previous winter had a small but negative effect on BCS in summer. There was a consistent positive effect of ewe BCS in spring on lamb live weight gain and on weaning weight at 56 days, whereas the prevalence of certain species of nematodes in un-
treated ewes had a negative effect on weaning weight. In both groups ewe productivity responded positively to summer live weight and fertility.

4. Discussion

This trial used farm flocks over a series of years that included fortuitously one with above average, two with below average, and one with close to average winter/spring rainfall. It thereby provided an insight into the benefits from treating ewes for gastrointestinal and lungworm nematodes and the feeding strategies used by farmers during a period when their own production of barley would have been reduced. In addition, the seasonal excretion patterns of the parasites could be seen. However, the below average rainfall in two of the four years contributed to the low egg and larval counts even in untreated ewes. This somewhat compromised the value of the results for assessing the effects of such parasites on sheep productivity in a semi-arid area.

4.1. Seasonal patterns of egg and larval excretion

The predominant factor determining the marked seasonal patterns of egg and larval excretion was the winter/spring rainfall season, confirming studies by Altaif and Issa (1983) and Thomson and Orita (1988). A second factor was the lambing season which is associated with a peri-parturient rise in egg and larval counts (Jansen, 1968). Al-Khalidi and Al-Saeed (1991) report an increase in egg counts from January to a peak in April, which corresponds with the lambing season in northern Iraq. In the present trial peak lambing was somewhat earlier, in December–January.

A notable contrast between the four years was the difference in the peak egg and larval counts and the duration of the infections in 1987/88 – the wet winter – and in 1988/89 – the first winter with low rainfall (Fig. 1). Indeed, in the untreated ewes the peak egg counts in the dry winter were double those in the wet winter and the peak levels were sustained for longer in the dry winter. Lungworm larvae were also excreted for longer in the dry winter than in the wet winter, but the peak counts in the two winters were similar. This may have occurred because there was a build up of an adult parasite burden in the wet winter, which in turn resulted in a large number of inhibited larvae being carried through the summer. These caused a heavy infection level at the start of the following rainy season (Giangaspero et al., 1992). If correct, this explanation suggests that control of parasites is justifed in wet winters to prevent infection levels building up, but treatment is also important in the following winter, whether or not it has below average rainfall.

4.2. Benefits of treatment on productivity

The small benefits from controlling the parasites agree with the lower mortality in treated ewes reported by Pandey et al. (1984) and Sumner et al. (1995) and the improved birth weights and growth rates of offspring of treated ewes and does (Gatongi et al., 1997). In the present on-farm trial, however, the benefits from treatment were not statistically significant when expressed as ewe productivity (Table 1), although the additional lamb live weight weaned per ewe exposed to rams covered the cost of treatment.

4.3. Levels of supplementary feeding

High levels of supplementary feeding in winter are common in Syria and the amounts found in this trial are within the range reported by Thomson et al. (1989) and Opitz (1999). They were sufficient to cover the estimated ME needs of the ewes in late pregnancy and most of the needs in early lactation (AFRC, 1993). The lower levels of supplements offered in the second dry winter 1989/90 (Table 2) were associated with the marked decrease in the live weight of ewes at that time (Fig. 2), illustrating the dependency of ewes on supplementary feeding in winter.

The seasonal patterns of feeding suggest that farmers had good stocks of barley grain and straw from the 1988 harvest which were used in the first dry winter 1988/89. But for the second dry winter 1989/90 they only had limited stocks of grain and straw to sustain their animals and this resulted in the decrease in the amount of ME offered. In the fourth winter 1990/91, however, farmers fed slightly more
supplements again. Farmers sold more ewes in 1989/90, presumably to remove non-productive animals and to generate cash, some of which may have been used to purchase feed for the coming winter. Differences in the seasonal use of supplements demonstrate the coping strategies of farmers in a semi-arid area during years of below average rainfall and severe feed shortages.

4.4. Seasonal patterns of sheep productivity

The carry-over effect of one season to the next is illustrated when the productivity traits are examined in relation to winter rainfall. Ewe fertility, which was 70% in the wet winter 1987/88, was lower than expected given the ewes weighed on average 51.3 kg during the previous mating period in June–August 1987. Other studies showed that at a similar live weight (Thomson and Bahhady, 1988) and BCS (Treacher and Filo, 1995), ewe fertility above 90% would be expected. During the first dry winter ewe fertility was 91%, suggesting that the BCS of the ewes during the previous mating period had been optimal following a spring with good pastures. Fertility in the second dry winter dropped markedly even though the ewes were in moderate body condition when they were mated following the first dry winter. It then recovered somewhat in the winter of 1990/91. The poor association between ewe fertility and BCS suggests that either factors other than body condition score were affecting fertility, or that the precision of measuring BCS was poor in these trials. Filo and Treacher (1995) found BCS to be a useful predictor of fertility in trials under carefully controlled conditions.

The overall levels of ewe mortality were remarkably low for these harsh conditions and confirm other values reported for Syria (Opitz, 1999; Thomson et al., 1989). The low sales in the first dry year 1988/89 allowed a build-up of the flock inventory, whereas high sales occurred during the second dry year 1989/90 when farmers sold unproductive animals, presumably to raise cash and to save on feed costs. The interplay of these losses resulted in a similar survival rate in the first two years, a decrease in the third year after the second winter of low rainfall, and recovery in the last year after a winter of near average rainfall.

4.5. Experimental design

Working with 10 flocks which served as replicates allowed a better expression of flock diversity and removed the confounding effect of differences in flock management which were large, especially levels of winter feeding. But the low number of sheep in the untreated and treated groups, usually 20–30 head in each and the large amount of variation between flocks as shown by the standard deviations in Table 1, resulted in many of the differences between flocks being statistically insignificant. Another weakness of the experimental design was the risk of re-infection of treated ewes because they were mixed with untreated control ewes, particularly at night while confined in a pen or housed. However, the treatment of the sheep not involved in the trial, as well as all the goats, would have reduced this risk. Indeed, this may have reduced infection levels in untreated sheep. In each village the flocks used in the trial would have been exposed to some challenge while grazing the sparse communal pastures used by other village flocks. The substantially lower egg and larval counts in the treated ewes shows that the two double treatments were effective and suggests that rapid re-infection did not occur. Thus, deficiencies in the experimental design used are not seen as a reason for the low productivity response to treatment.

4.6. Stepwise regression analysis

The stepwise regression analysis was useful for identifying the main factors influencing flock productivity (Table 3). In each pair of equations the same predictor is found for both the untreated and treated groups at least once, in two pairs there are two predictors and in another two pairs three predictors in common. This would be expected since the differences between the performance of the two groups was small (Table 1). However, the equations have to be interpreted with caution and several of them have limited predictive value because of the low proportion of the total variation accounted for by the regressions.

In both untreated and treated groups, a low level of supplementary feeding in winter and poor live weight in spring resulted in high sales. This hap-
pened in 1989/90. An infection with *D. filaria* also reduced sales. Moreover, in both groups the positive relationship between fertility and survival and between survival and fertility indicates that good management, including culling to ensure flocks contained a high proportion of productive ewes, was beneficial. Good rainfall also increased survival, suggesting that ewes would be heavier in spring because of better pasture, which in turn would reduce sales. Somewhat surprisingly, summer BCS did not enter the regressions as a significant predictor of fertility as would be expected from other studies (Thomson and Bahhady, 1988; Treacher and Filo, 1995).

Supplementing ewes in summer benefited live weight in spring but a parasitic infection was detrimental (Table 3), suggesting that strategic use of both supplements in summer and an anthelmintic are justified. The improvement in spring BCS as flock size and the proportion of goats in the flock increased indicates that management may improve as flocks get larger and contain more goats. Indeed, in larger flocks and those with more goats fewer of the ewes need to be milked during the suckling period to supply household needs. Interactions between the nematodes in goats and sheep are possible since El-Moukdad (1981) found *N. filicollis* and to a lesser extent *M. marshalli* in goats in Syria. However, the importance of flock size and the proportion of goats may be less that suggested here as they do not enter any other of the regressions.

The BCS in spring was an important factor since it benefited both lamb daily live weight gain and live weight at weaning at 56 days, whereas both these variables were reduced by the presence of parasites in the untreated ewes. This suggests that, as expected, good feeding of ewes in spring from pastures, supplements or both, improved milk yield, whereas parasites reduced it. Summer live weight and fertility were the predominant factors associated with overall ewe productivity, with BCS in summer and spring also contributing.

Among all the regression equations, the predictors of overall ewe productivity accounted for the highest amount of variation, with an $R^2$ of 0.66 and 0.73, respectively, in the case of untreated and treated ewes. When all the 21 independent variables were included to predict ewe productivity ($R^2$ Max in Table 3), 94 and 92% of the total variation was accounted for. Even though this is a high level of precision to predict ewe productivity, the number of measurements needed at the flock level to achieve it would be too costly for widespread use.

The different species of gastrointestinal and lungworm nematodes appeared in nine out of the 16 regressions and in all but one case they had a detrimental effect (Table 3). *D. filaria*, *M. marshalli* and *N. filicollis* appeared in the regressions more frequently than the lungworms in general and *C. ocreatus*. *M. capillaris* was not used in the stepwise regression analysis because of its low prevalence. Thus, it appears that the nematodes probably did affect productivity even at the low levels of infection and prevalence. Moreover, *N. filicollis* consistently appeared to affect lamb performance and ewe productivity in untreated ewes, even at the low egg counts seen. Significantly, the strongyles entered none of the equations which suggests that they had little effect on ewe productivity at the infection levels encountered. In untreated ewes lungworms had a negative effect on ewe productivity at the infection levels encountered. In untreated ewes lungworms had a negative effect on the live weight of lambs when 56 days old. Altaif (1983) reported a 41% live weight response to treatment between April and August in Awassi ewes infected with *T. circumcincta* and *D. filaria*.

5. Conclusions

A trial extending over 6–8 years would have permitted a clearer interpretation of the effects of seasonal variations in rainfall on ewe productivity. Such studies, however, are costly and demand considerable resources beyond the reach of most research programs in the region. Despite the trial’s limited duration and the presence of two dry years, the annual offtake of each ewe increased by up to 1 kg live weight of weaned lamb, sufficient to cover the cost of the anthelmintic used. That farmers in the area were already voluntarily applying anthelmintics suggests that the benefits were apparent to them. The low frequency of treatment not only removed the potential detrimental effects of the parasites but also reduced the risk of resistance to the anthelmintic developing. An essential advantage of the trial was that it was conducted with farm flocks and therefore
other farmers in the area would have obtained similar results had they applied the treatments.

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References


