Effects of the scab mite *Psoroptes ovis* on the haematology and live mass of Merino and Dorper sheep

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ABSTRACT

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Five Merino and five Dorper sheep were artificially infested with the sheep scab mite *Psoroptes ovis* and the effect of infestation on their haematology, serum protein levels and live mass recorded for a period of 14 weeks. The reaction of the Merino sheep to infestation was more severe than that of the Dorper sheep. Haematological values fluctuated within the normal range during the assessment period. The mean haemoglobin concentration of the Merino sheep declined until antiparastic treatment was administered 10 weeks after infestation, after which it gradually increased. The lymphocyte counts of both breeds of sheep declined from 2 weeks to 10 weeks post-infestation, but increased after treatment, while the highest eosinophil counts were recorded in the Merino sheep at the height of the acute disease 8–10 weeks post-infestation. Serum albumin values for both breeds and serum globulin values for the Merino sheep were higher than normal during the entire 14-week observation period. A decrease in serum albumin and an increase in serum globulin concentration occurred at the height of infestation in both breeds. The mean live mass of a second group of five infested Merino sheep decreased by 6.4 kg over a 16-week period compared to a gain of 4.56 kg for five infested Dorper sheep.

Keywords: Dorper sheep, haematology, live mass, Merino sheep, *Psoroptes ovis*, sheep scab

INTRODUCTION

The sheep scab mite, *Psoroptes ovis* produces a proliferating dry scab-like lesion with a moist periphery causing intense irritation on sheep (Kirkwood 1980). Infested animals nibble at the infected patches and scratch themselves continually (Tarry 1974). The duration and frequency of scratching and rubbing and associated mouthing increase during the course of infestation (Corke, Broom & Taylor 2001). In addition to dermatological and behavioural changes, haematological changes accompany the expansion and regression of lesions (O'Brien, Robinson, Gray & O'Reilly 1995). Infestation can also have a marked effect on the live mass of sheep (Kirkwood 1980), and can result in significant economic losses in production, with reduced fleece and leather quality, lower conception rates, poor lamb growth, and frequent mortality (Bates 1996; Kirkwood 1986).

The present study was conducted to determine the haematological and live mass changes in Merino and Dorper sheep artificially infested with *P. ovis*.

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MATERIALS AND METHODS

Donor sheep

Infective material was collected from scab-infested sheep in the central Free State Province, South Africa and transferred directly onto the skins of two healthy Merino sheep. This material was kept in place by twisting an elastic band around the fleece directly above the site of infestation. These sheep were quarantined to prevent infestation of other sheep, and when lesions became established, approximately 6 weeks later, the sheep were used as a source of infective material.

Experimental sheep and infestation procedures

Five dewormed, healthy, year-old Merino wethers and five matching Dorper wethers were purchased from a scab-free farm during March 1997 and moved to a holding facility. On arrival the sheep were tagged for identification and vaccinated against enterotoxaemia. They were fed a ration of alfalfa hay and maintenance pills (Senwesco, Viljoenskroon), with water supplied *ad libitum*.

Approximately 2 weeks after purchase the sheep were each infested on the skin of their backs with 15 ovigerous female *P. ovis*, 15 males, two attachment pairs and four eggs collected from a donor sheep, and thereafter kept separately in two quarantine camps. Infestation was confirmed on all the sheep 1 week after placement of the mites. Ten weeks after infestation the sheep were each treated with a single 1.5-mℓ injection of the endectocide Dectomax® [Pfizer Animal Health Division (Pty) Ltd, South Africa] administered subcutaneously, to rid them of mites.

Blood samples

Commencing 2 weeks after infestation, blood samples were taken every fortnight for 14 weeks in evacuated blood collection tubes from the jugular veins of the sheep prior to feeding. The tubes to be used for haematology contained heparin as anticoagulant; haemoglobin concentration, white blood cell and differential white blood cell (WBC) counts were determined by means of a Technicon H1 blood analyser.

The tubes to which no anticoagulant had been added, were centrifuged and the serum collected and diluted with 20 µℓ B-2 Barbital Buffer and 5 µℓ serum. The relative percentages of serum albumin and serum globulin were determined using a Paragon Electrophoresis SPE kit [Beckman Instruments (Pty) Ltd, South Africa]. The data were subjected to an analysis of variance (ANOVA) to assess the significance of differences occurring in the haematological and serum protein values, during the course of infestation and between the Merino and Dorper sheep. The mean fortnightly values were subjected to a t-test.

Live mass

Ten healthy, dewormed, scab-free, year-old Merino and ten matching Dorper sheep were purchased during September 1997. On arrival at the holding facility all the sheep were tagged for identification and their mass measured on an electronic scale. Subsequently the two breeds were housed separately for approximately 3 weeks, in two camps, approximately 1 ha in size containing natural pasture. During this 3-week period both groups were fed 200–250 g of maintenance pills per sheep per day and 720 g of alfalfa hay per sheep per day, with water supplied *ad libitum*.

Early in October 1997 the mass of each sheep was again measured and five Merino and five Dorper sheep were randomly selected and each infested with 30 ovigerous female *P. ovis*, two males and two attachment pairs of mites collected from donor sheep. The remaining sheep in each group were used as controls. The two groups of infested sheep and the two sets of controls were each housed in separate quarantine camps, approximately 1 ha in size, containing natural pasture, and were fed a daily ration of alfalfa hay and maintenance pills.

Once a week the infested sheep were closely observed for clinical signs of sheep scab, and were individually examined every fortnight for the presence of scab lesions from which the affected surface area was calculated. The mass of the infested and control sheep was measured again at 3 weeks and 6 weeks after infestation and subsequently at fortnightly intervals for the 16-week duration of the experiment. At each occasion the mass of the control sheep was measured first to prevent cross-infestation between the groups. At the end of the 16-week period 1.5 mℓ of the endectocide Dectomax was administered to each of the infested sheep, by subcutaneous injection, to rid them of mites.

The mean body masses of the four groups were subjected to a one-way ANOVA. Differences between the mean body mass of the Merino and the Dorper sheep were determined by a t-test. The program PRISM™ (GraphPad, Statistical Software, Inc.) was used for statistical analysis of the data.

RESULTS

Haematology

The various haematological parameters remained within the limits considered normal for sheep.

Haemoglobin (Fig. 1A)

The haemoglobin concentrations of the Merino sheep decreased until treatment at 10 weeks post-infestation and rose gradually thereafter. Those of the Dorper sheep decreased initially but subsequently increased followed by a steep rise after treatment. The values for the two breeds differed significantly 8 weeks after infestation ($P = 0.001$) as well as over the remainder of the 14-week observation period ($P = 0.014$).

WBC (Fig. 1B)

The WBC counts of the Merino sheep decreased 10 weeks post-infestation, but increased after treatment, whereas those of the Dorper sheep declined throughout the observation period.

Lymphocytes (Fig. 1C)

Lymphocyte counts of both sheep breeds declined from 2–10 weeks post-infestation and increased after treatment, albeit temporarily in the Merinos. The differences between the two breeds were not significant ($P = 0.755$).

Monocytes (Fig. 1D)

Counts were at their lowest at treatment 10 weeks post-infestation and rose rapidly thereafter. The difference between the two breeds was not significant ($P = 0.507$).

Neutrophils (Fig. 1E)

Neutrophil counts of the Merino sheep dropped at 10 weeks post-infestation and increased after treatment. Those of the Dorper sheep declined gradually throughout the period of observation. The difference between the two breeds was significant ($P = 0.001$).

Eosinophils (Fig. 1F)

The highest eosinophil counts were recorded in the Merino sheep 8 weeks post-infestation. The counts of the Dorper sheep were stable for the first 6 weeks after infestation and, with the exception of week 10, declined thereafter. The eosinophil counts of the two breeds differed significantly ($P = 0.005$) during the first 6 weeks after infestation.

Serum proteins

The serum albumin concentrations of both breeds and the serum globulin concentration of the Merino sheep exceeded the levels generally considered normal for sheep.

Albumin (Fig. 2A)

The lowest serum albumin concentrations were recorded in both breeds of sheep 12 weeks post-infestation and increased thereafter. The difference between the two breeds was highly significant ($P = 0.001$).

Globulin (Fig. 2B)

The serum globulin concentrations essentially followed the same pattern in the two breeds, reaching their highest levels 2 weeks after treatment and then declining. The peak globulin concentration recorded 12 weeks post-infestation, corresponded to the time when the clinical condition of the Merino sheep appeared to be at its worst. The values for the two breeds differed significantly ($P < 0.05$).

Live mass

Merino sheep

On arrival the mean live mass of the Merino sheep was 26.97 kg and had increased to 28.48 kg on the day of infestation (approximately 3 weeks later). A week after infestation the first signs of scab were observed and all the infested sheep developed lesions. At 2 weeks post-infestation the mean size of the lesion was 1 cm^2, and at 8 weeks the lesions had expanded to a mean size of 342 cm^2, with a moist periphery containing large numbers of mites. Twelve weeks after infestation the scab extended over a large portion of the body (mean 2 068 cm^2), the wool had become ragged and stained and the sheep were visibly irritated and continually scratching. At 16 weeks large parts of the body were devoid of wool, and the animals were clearly very weak.

The mean live mass of the infested sheep decreased from 27.32 kg to 20.92 kg during the course of infestation, whereas that of the controls increased from 29.64 kg to 33.08 kg (Fig. 3A). The initial mean live mass of the infested sheep and that of the controls did not differ significantly ($P = 0.2402$). The first significant difference occurred at 12 weeks post-infestation ($P = 0.0072$), and at 16 weeks the difference was highly significant ($P < 0.0001$).

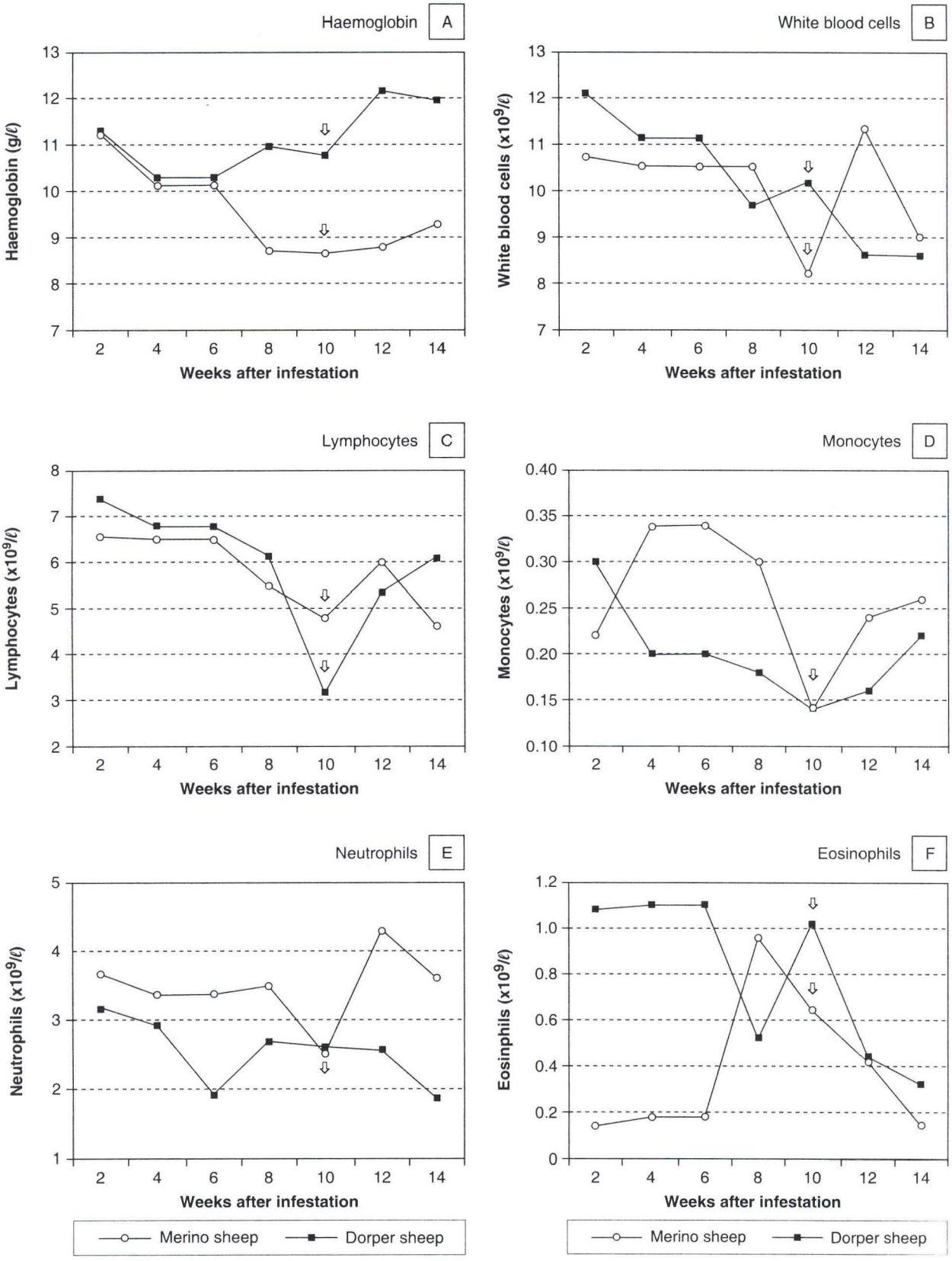

FIG. 1 Mean (A) haemoglobin concentration (g/dℓ); (B) white blood cell counts (x10⁹/ℓ); (C) lymphocyte counts (x10⁹/ℓ); (D) monocyte counts (x10⁹/ℓ); (E) neutrophil counts (x10⁹/ℓ); and (F) eosinophil counts (x10⁹/ℓ) of Merino and Dorper sheep infested with *Psoroptes ovis*. ⇩ = Treatment with an endectocide

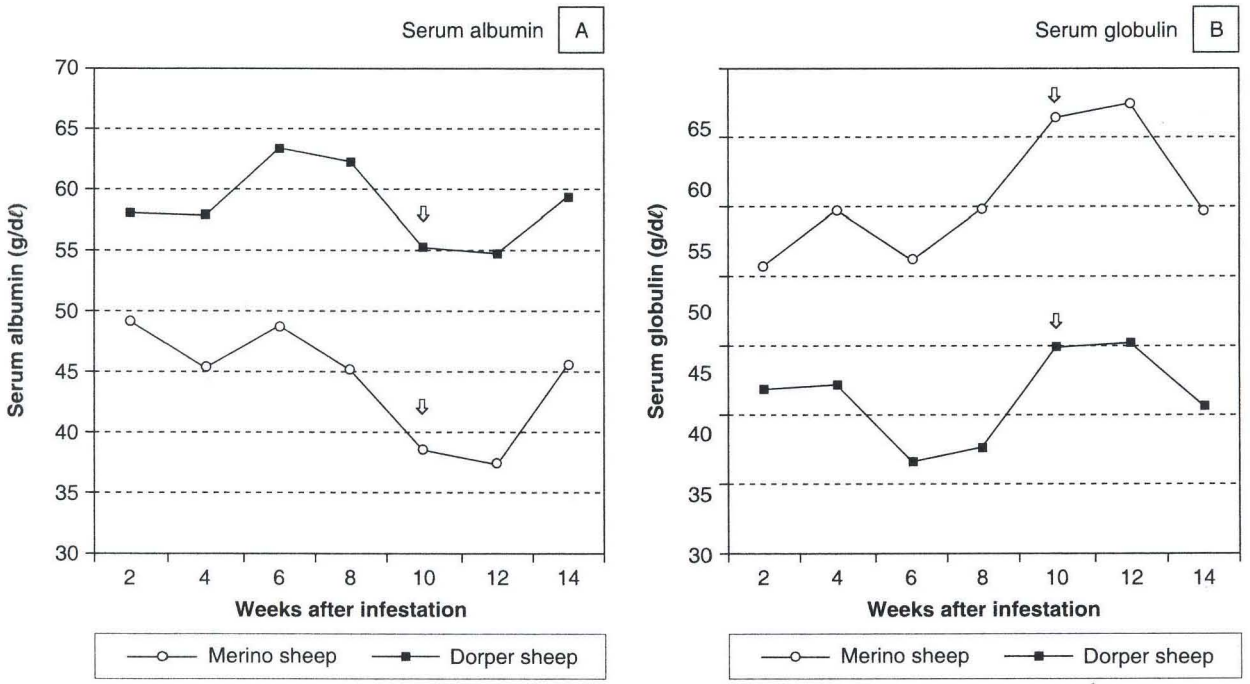

FIG. 2 Mean concentrations of (A) serum albumin (g/dℓ); and (B) serum globulin (g/dℓ) of Merino and Dorper sheep infested with *Psoroptes ovis*. ⇩ = Treatment with an endectocide

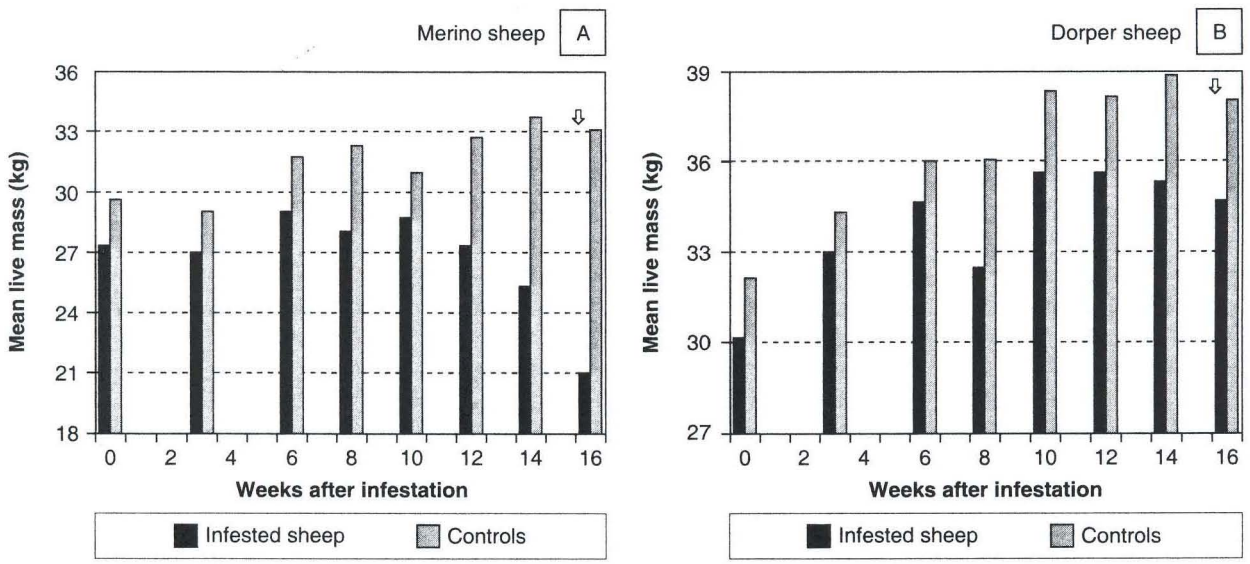

FIG. 3 Mean live mass of (A) Merino sheep and (B) Dorper sheep infested with *Psoroptes ovis* compared to uninfested controls. ⇩ = Treatment with an endectocide

Dorper sheep

On arrival the mean live mass of the Dorper sheep was 28.97 kg and had increased to 31.16 kg on the day they were infested approximately 3 weeks later. Although all the infested sheep initially developed lesions, those on three disappeared and they had to be re-infested during the 4th week of the experiment. At 2 weeks post-infestation the mean lesion size was 0.46 cm^2, and this increased to 59 cm^2 and 149 cm^2 at 8 and 12 weeks post-infestation respectively. At 8 weeks the infested sheep displayed signs of uneasiness and irritation, and tufts of wool were visible in their teeth. At the termination of infestation at 16 weeks, loss of fleece was minimal and the sheep appeared healthy.

The mean live mass of the infested sheep increased by 4.56 kg from 30.16 kg to 34.72 kg, and that of the controls by 5.88 kg from 32.16 kg to 38.04 kg (Fig. 3B). The mean live mass of the two groups of Dorper sheep did not differ significantly at any occasion ($P > 0.005$). The differences between the Merino and Dorper sheep were highly significant ($P = 0.0001$).

DISCUSSION

Haematology

Unfortunately no uninfested sheep were kept as controls during this experiment and the haematological tests were only initiated 2 weeks after mites had been placed on the sheep. However, the findings correspond to those of similar experiments performed on adult Suffolk-cross sheep in Ireland and Hereford calves in the United States of America (Stromberg & Guillot 1987b; O'Brien *et al.* 1995).

The feeding behaviour of *P. ovis* is still not entirely clear. The mouthparts of the mites can penetrate to the inner layer of the *stratum corneum* of the epidermis, but apparently no deeper (Sinclair & Filan 1989). The chelicerae are laterally compressed, with relatively long digits, probably used for abrading the host tissue (Rafferty & Grey 1987). The distal region of the hypostome is developed into a pair of fan-like structures, the pseudoruttella, similar to the proboscis of the housefly, and apparently assists with lapping up fluids (Rafferty & Grey 1987; Bates 1997). At one stage it was assumed that the mites, feeding on the outer epidermal layers, ingested mainly lipids (Sinclair & Kirkwood 1983), or that these served as a source of nutriment before dermal vesicles formed (Sinclair & Filan 1989). However, it is now thought that although lipid is ingested it is not digested and that the mites graze the skin around the moist periphery of the scab lesion, taking in serum components present in the surface exudates and skin secretions associated with the lesion (Bates 1997).

Both *Psoroptes cuniculi* and *P. ovis* feeding on rabbits and *P. ovis* feeding on cattle ingest erythrocytes (DeLoach & Wright 1981; Wright & DeLoach 1981). This apparently does not occur in sheep (Rafferty & Gray 1987) and consequently is unlikely to be the cause of the decrease in haemoglobin concentration of the Merino sheep in the present study. A similar reduction in haemoglobin concentration has been recorded in Suffolk-cross sheep in Ireland, and it was suggested that this could result from a suppression of erythropoiesis (O'Brien *et al.* 1995). A mild non-regenerative anaemia has been observed in calves infested with *P. ovis* (Stromberg & Guillot 1987a), as well as a decrease in serum iron and in total iron binding capacity, indicative of anaemia associated with chronic inflammation (Stromberg, Fisher, Guillot, Pruett, Price & Green 1986).

The lymphocyte counts of both groups of sheep declined during the first 8 weeks of infestation, with a fairly pronounced drop during the acute stage of the disease at 10 weeks. In Ireland lymphocyte counts declined in both infested and in control sheep and the decline was partly ascribed to the stress of frequent handling, coupled with additional stress during the acute stage of the disease (O'Brien *et al.* 1995). The lymphocyte counts of calves infested with *P. ovis* as well as those of control calves, decreased during the first 5 weeks of infestation. This was attributed to stress during their adjustment to stanchioning, but whereas the counts of the control calves then rose, the counts of the infested animals continued to decline until treatment at 7 weeks and only increased thereafter (Stromberg & Guillot 1987b). The difference in lymphocyte counts between the two groups of calves after 5 weeks of infestation probably reflected continued stress in the infested calves as a result of chronic dermatitis (Stromberg & Guillot 1987b).

Neutrophils are considered to be a sensitive indicator of both the progressive and regressive phase of *P. ovis* infestation in cattle (Stromberg & Guillot 1987b). A decrease in neutrophils in the peripheral blood is closely associated with mite activity and may be caused by the rapid efflux of these cells from the circulating granulocyte pool. Although neutrophils are not a dominant feature of the inflammatory reaction in the dermis of calves (Stromberg & Fisher 1986), their migration into the scab over an extensive surface area in infested cattle could lead to neutropaenia (Stromberg & Guillot 1987b). A rapid decrease in neutrophil numbers has been recorded in calves between 1 and 3 weeks post-infestation, followed by an equally rapid increase to normal levels 1 week after treatment at 7 weeks (Stromberg & Guillot 1987b). In the present study the number of circulating neutrophils decreased at the peak of infestation in the Merino sheep and, as in the calves, increased after treatment.

An increase in the numbers of circulating eosinophils has long been associated with parasitic infes-

tations (Nelson, Bell, Clifford & Keirans 1977). The eosinophil counts in the Merino sheep could be associated with the severity of the clinical reaction of the animals, with the highest values 8 and 10 weeks after infestation. The eosinophil counts of the Dorper sheep were already high 2 weeks post-infestation and with the exception of week 10, when a temporary increase occurred, they declined from weeks 6–14. In Scotland the superficial lymph nodes of the carcasses of lambs infested with *P. ovis* were enlarged and had a greenish tinge to the cortex caused by an increase in eosinophils (Cochrane 1994). This supports the hypothesis that the cutaneous response to the mites is at least in part a hypersensitivity reaction (O'Brien *et al.* 1995).

Serum proteins

No reason for the initial elevated serum albumin levels of both the Merino and Dorper sheep can be given. Mite infestation possibly caused the progressive decrease in serum albumin in the Merino sheep as well as the slight decrease in the Dorper sheep 10 and 12 weeks after infestation. A decline in serum albumin concentration in sheep infested with *P. ovis* has previously been recorded and was ascribed to the effects of the disease and possibly to the anorexia accompanying severe sheep scab (O'Brien *et al.* 1995). A decrease in serum albumin concentration is a feature of several helminth infections of the gastro-intestinal tract of sheep and cattle (Urquhart, Armour, Duncan, Dunn & Jennings 1996). This decrease has been attributed to a leakage of serum proteins through the more permeable hypertrophic or damaged epithelium of the parasitized gut, and, because of its smaller molecular size, serum albumin is selectively depleted. A similar phenomenon may take place in the dermis in the region of the moist periphery of the scab lesion.

An increase in serum globulin concentration can indicate an antibody response to the presence of an antigen. In Ireland artificial infestation of adult sheep of mixed breeds with *P. ovis* resulted in an increase in serum globulin concentration 3 weeks later (O'Brien *et al.* 1995). A delay in the return of globulin levels to normal, after the animals had been dipped in an acaricide, was ascribed to the possible persistence of dead mites and mite particles in the fleece, acting as a continuing antigenic stimulus (O'Brien *et al.* 1995). The serum globulin levels of the Merino sheep in the present study increased steadily to peak at 12 weeks after infestation, whereas the Dorper sheep had only slightly elevated levels in the 10th and 12th weeks after infestation. Serum globulin concentrations in both breeds decreased slightly 4 weeks after the termination of infestation. Not only was the mean lesion size on the skin of the Dorper sheep significantly smaller than that on the Merino sheep, but also their hairy coats were shorter and less dense than the fleece of the Merino sheep. This could facilitate shedding of dead mites or mite material and the total antigenic challenge would thus presumably be lower. The differences in serum globulin levels between the two breeds support this contention.

Live mass

The intense irritation experienced by the Merino sheep during the course of infestation obviously interrupted their feeding, and whilst being fed they would frequently stop to bite or scratch. In the United Kingdom the duration of rubbing and scratching by artificially infested sheep increased throughout infestation and there was a positive correlation between the time spent rubbing and the surface area of the scab lesions (Corke *et al.* 2001). These activities must affect the time devoted to feeding and hence the amount of feed ingested, and where healthy and infested sheep are kept together, hamper the ability of the latter to compete for feed (Kirkwood 1980).

Hereford heifer calves infested with *P. ovis* had significantly lower daily live mass gains than uninfested control animals, and their maintenance energy requirements increased by > 50 % (Cole & Guillot 1987). They also tended to have a lower dry mass digestibility than control animals (Cole & Guillot 1987), similar to that noted in calves during cold stress (Christopherson & Kennedy 1983).

Calves with severe *P. ovis* infestation may have difficulty in consuming sufficient feed to meet maintenance energy requirements and therefore may be susceptible to hypothermia (Cole & Guillot 1987). Cold stress appears to decrease digestibility in ruminants as a result of an increase in the rate of passage of ingesta through the digestive tract, possibly due to increased thyroid activity associated with cold exposure (Christopherson & Kennedy 1983). Loss of hair and a damaged integument could reduce thermal insulation and thus further increase the effect of cold stress. It is possible that sheep infested with *P. ovis* will react in a similar fashion to calves, particularly Merino sheep on which the development of lesions and hence loss of wool is greatest during the cold winter months (Meintjes 1999), thus increasing the likelihood of cold stress.

The feed that the sheep received prior to infestation was sufficient to ensure an increase in the mean live mass of the Merino sheep by 1.51 kg and that of the Dorper sheep by 2.19 kg. In addition the live mass of both control groups increased during the 16-week study period.

During the early stages of disease the live mass of the infested Merino sheep increased, but as the size of the lesions increased so did the levels of discomfort and possibly energy output, and as a result their live mass, and probably feed consumption, declined. Significant losses in mass by the Merino sheep were first recorded at 12 weeks post-infestation, corresponding to peak development of lesions. The reaction of the Merino sheep to infestation was similar to that recorded in 9-month-old fully fleeced Cheviot sheep artificially infested with *P. ovis* (Kirkwood 1980). These sheep also gained mass during the first 5 weeks of infestation, but this tailed off and by 14 weeks they had gained only 1.1 kg compared to a 14.6 kg gain by uninfested control sheep (Kirkwood 1980).

The development of lesions on the Dorper sheep was considerably slower and much less extensive than that on the Merino sheep and the differences in live mass between the infested and control Dorper sheep were never significant. Live mass gains in calves are generally not affected until infestation with *P. ovis* covers more than 15 % of an animal's body surface (Cole, Guillot & Purdy 1984), and a similar proportion of damaged skin might be applicable in sheep before live mass gain is affected.

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REFERENCES

BATES, P.G. 1996. The biology of *Psoroptes ovis*, the sheep scab mite. *Proceedings of a Conference on Sheep Scab (Psoroptic mange), Tralee, Co Kerry, Ireland*, 27th–29th March 1996: 4–6.

BATES, P.G. 1997. The pathogenesis and ageing of sheep scab lesions. Part 1. *State Veterinary Journal*, 7:11–15.

CHRISTOPHERSON, R.J. & KENNEDY, P.M. 1983. Effect of the thermal environment on digestion in ruminants. *Canadian Journal of Animal Science*, 63:477–496.

COCHRANE, G. 1994. Effects of *Psoroptes ovis* on lamb carcases. *Veterinary Record*, 134:72.

COLE, N.A., GUILLOT, F.S. & PURDY, C.W. 1984. Influence of *Psoroptes ovis* (Hering) (Acari: Psoroptidae) on the performance of beef steers. *Journal of Economic Entomology*, 77: 390–393.

COLE, N.A. & GUILLOT, F.S. 1987. Influence of *Psoroptes ovis* on the energy metabolism of heifer calves. *Veterinary Parasitology*, 23:285–295.

CORKE, M.J., BROOM, D.M. & TAYLOR, M.A. 2001. Changes of behaviour in sheep affected by psoroptic mange. *Abstracts of the 18th International Conference of the World Association for the Advancement of Veterinary Parasitology, Stresa, Italy*, 26–30 August 2001: 192.

DELOACH, J.R. & WRIGHT, F.C. 1981. Ingestion of rabbit erythrocytes containing ^{51}Cr-labelled hemoglobin by *Psoroptes* spp. (Acari: Psoroptidae) that originated on cattle, mountain sheep, or rabbits. *Journal of Medical Entomology*, 18:345–348.

KIRKWOOD, A.C. 1980. Effects of *Psoroptes ovis* on the weight of sheep. *Veterinary Record*, 107:469–470.

KIRKWOOD, A.C. 1986. History, biology and control of sheep scab. *Parasitology Today*, 2:302–307.

MEINTJES, T. 1999. The bio-ecology of the sheep scab mite *Psoroptes ovis* (Acari: Psoroptidae) Hering (1835). M.Sc. dissertation, University of the Free State.

NELSON, W.A., BELL, J.F., CLIFFORD, C.M. & KEIRANS, J.E. 1977. Interaction of ectoparasites and their hosts. *Journal of Medical Entomology*, 13:389–428.

O'BRIEN, D.J., ROBINSON, A.B., GRAY, J.S. & O'REILLY, P.F. 1995. Haematology and blood chemistry during the course of psoroptic scabies in sheep. *Veterinary Research Communications*, 19:39–48.

RAFFERTY, D.E. & GRAY, J.S. 1987. The feeding behaviour of *Psoroptes* spp. mites on rabbits and sheep. *Journal of Parasitology*, 73:901–906.

SINCLAIR, A.N. & KIRKWOOD, A.C. 1983. Feeding behaviour of *Psoroptes ovis*. *Veterinary Record*, 112:65.

SINCLAIR, A.N. & FILAN, S.J. 1989. Lipid ingestion from sheep epidermis by *Psoroptes ovis* (Acari: Psoroptidae). *Veterinary Parasitology*, 31:149–164.

STROMBERG, P.C. & FISHER, W.F. 1986. Dermatopathology and immunity in experimental *Psoroptes ovis* (Acari: Psoroptidae) infestation of naïve and previously exposed Hereford cattle. *American Journal of Veterinary Research*, 47: 1551–1560.

STROMBERG, P.C., FISHER, W.F., GUILLOT, F.S., PRUETT, J.H., PRICE, R.E. & GREEN, R.A. 1986. Systemic pathologic responses in experimental *Psoroptes ovis* infestation of Hereford calves. *American Journal of Veterinary Research*, 47:1326–1331.

STROMBERG, P.C. & GUILLOT, F.S. 1987a. Bone marrow response in cattle with chronic dermatitis caused by *Psoroptes ovis*. *Veterinary Pathology*, 24:365–370.

STROMBERG, P.C. & GUILLOT, F.S. 1987b. Hematology in the regressive phase of bovine psoroptic scabies. *Veterinary Pathology*, 24:371–377.

TARRY, D.W. 1974. Sheep scab: its diagnosis and biology. *Veterinary Record*, 95:530–532.

URQUHART, G.M., ARMOUR, J., DUNCAN, J.L., DUNN, A.M. & JENNINGS, F.W. 1996. *Veterinary Parasitology*, 2nd ed. Oxford: Blackwell Science Ltd.

WRIGHT, F.C. & DELOACH, J.R. 1981. Feeding of *Psoroptes ovis* (Acari: Psoroptidae) on cattle. *Journal of Medical Entomology*, 18:349–350.