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Late Fall Transmission of *Nematodirus battus* (Nematoda: Trichostrongyloidea) in Western Oregon

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Studies on *Nematodirus battus* Crofton and Thomas, 1951, have shown a marked seasonality in the pattern of transmission (Thomas and Stevens, 1956, Veterinary Record **68:** 471–475; Baxter, 1957, Veterinary Record **69:** 1007–1009; Thomas, 1959, Parasitology **49:** 387–410; Gibson, 1963, Research in Veterinary Science **4:** 258–268). The life cycle normally involves only 1 parasitic generation per year. The infective third-stage larvae develop over the summer within eggs deposited on pasture (Gibson, 1958, Journal of Comparative Pathology **68:** 338–344). Eggs are sensitized by low temperatures during fall and winter; larval hatching follows in the presence of adequate moisture and proper osmotic conditions as the temperature rises above 10 C (Thomas and Stevens, 1960, Parasitology **50:** 31–49; Christie, 1962, Parasitology **52:** 297–313; Parkin, 1976, Parasitology **73:** 343–354). This set of conditions, conducive to hatching, is regularly present only during spring (Parkin, 1976, loc. cit.); thus, hatching of eggs is concentrated into

TABLE I. *Weekly mean fecal egg counts for* N. battus *and other* Nematodirus *spp. in tracer lambs.*

	Trial day									
	−19*	−5†	16	23	28	35	42	49	56	63
N. battus	0	0	0	41 ± 13.7‡	99 ± 33.0	91 ± 30.4	90 ± 36.7	107 ± 43.6	48 ± 21.5	30 ± 17.3
Nematodirus spp.	21 ± 7.0	0	0	0	6 ± 2.1	53 ± 17.8	48 ± 19.7	62 ± 25.2	54 ± 24.1	0

* Pretreatment.
† Posttreatment.
‡ Mean ± SE.

a few weeks during this time. Outbreaks of clinical nematodiriasis are determined by the timing and magnitude of the seasonal hatch of larvae and the presence of young, susceptible lambs.

On occasion, deviations from this typical pattern have been reported. Completion of the life cycle has been recorded during other times of the year, particularly in the fall (Borgsteede, 1983, Veterinary Record **112:** 554; McKellar et al., 1983, Veterinary Record **112:** 309; Hollands, 1984, Veterinary Record **115:** 526–527). Larval availability during fall has been attributed to 3 different mechanisms: (1) eggs hatching within the same year as deposited (Gibson and Everett, 1981, Research in Veterinary Science **31:** 323–327); (2) eggs deposited during fall, overwintering and hatching the following fall (Hollands, 1984, loc. cit.); and (3) eggs hatching in spring, followed by long-term survival of the larvae through the summer (Borgsteede, 1983, loc. cit.).

Nematodirus battus was only recently documented in Oregon (Hoberg et al., 1986, Proceedings of the Helminthological Society of Washington **53:** 80–88). Consequently, there are no epizootiological data to assess the potential impact of this nematode in North America. Therefore, a study was initiated to determine whether transmission of *N. battus* in western Oregon follows the typical pattern seen in the United Kingdom and Western Europe or if the life cycle could be completed during other times of the year. Preliminary results are reported herein.

The pasture chosen for study is located at the Veterinary Medical Animal Isolation Laboratory (VMAIL) at Oregon State University. This pasture is 3 acres and consists of fescue (*Festuca* spp.), bent-grass (*Agrostis* spp.), rye-grass (*Elymus* spp.), and subclover (*Trifolium* sp.). It has been contaminated with *N. battus* at least since late 1984.

Eleven lambs (mixed breed; 7–9 mo old) were brought to VMAIL and housed in indoor isolation stalls. Individual fecal samples were taken and counts of eggs per gram (e.p.g.) performed using saturated NaCl flotation. Two animals were then killed and necropsied to confirm the absence of *N. battus*. The remaining 9 lambs were treated twice, at weekly intervals, with fenbendazole at 5 mg/kg. Posttreatment fecal samples were then examined.

On 12 November 1985, 1 wk following the second anthelmintic treatment, the 9 lambs were placed on the contaminated pasture. Fecal samples were collected weekly beginning on day 16 and e.p.g. counts performed. Differentiation of eggs of *N. battus* from those of other *Nematodirus* spp. was based on the criteria of Dunn (1978, Veterinary helminthology, 2nd ed., William Heineman Medical Books Ltd., London, 323 p.). On day 36, 3 lambs (Group 1) were removed from pasture, killed, and necropsied. Also on day 36, 3 lambs (Group 2) were transferred back to and maintained in indoor isolation stalls for 3 wk, then killed and necropsied. On day 66, the remaining 3 lambs (Group 3) were removed from pasture, killed, and necropsied.

At necropsy the small intestine was ligated *in situ* and removed from each animal. The anterior 12 m was separated from the remaining small intestine and the 2 sections processed separately. Each section was opened longitudinally and the mucosal surface stripped and washed. The contents and washings were sieved through a 400-mesh (37.5-μm) screen. For the posterior section, all material retained on the screen was backwashed into containers and fixed in 10% neutral buffered formalin. For the anterior sections, all material retained was placed in 0.8% saline from which live worms were recovered, identified, and frozen for other purposes. After this initial examination, the contents were fixed as before and brought to a known volume from which 2 5% aliquots were saved. Nematodes were later removed from each set of samples for identification. Intensity of infection for each lamb was calculated by adding together the totals from the

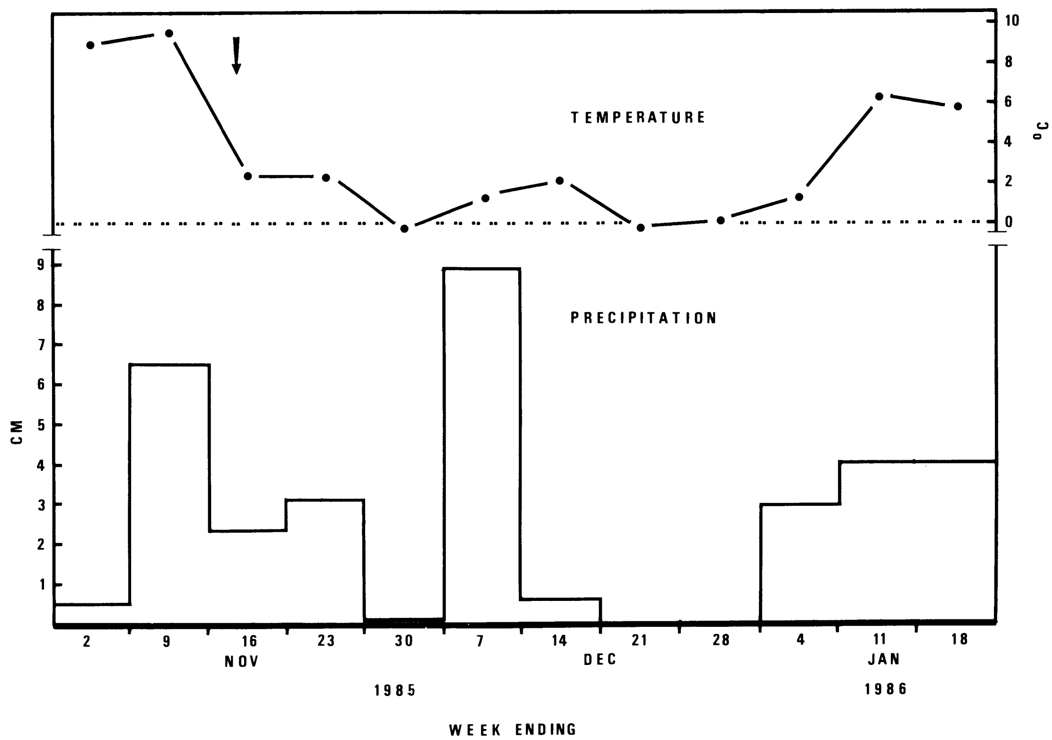

FIGURE 1. Mean weekly temperature and total weekly precipitation recorded at Hyslop Field Laboratory during late October through December 1985 and January 1986. Arrow indicates turnout of sheep onto pasture.

anterior (live worms recovered plus 1 5% aliquot) and posterior samples for each lamb. For the final 3 tracers, the 5% aliquots from the anterior sections were collected before removal of any live nematodes from the sample and total intensity calculated accordingly.

Meteorological data for the months of October–December 1985 and January 1986 were supplied by the Oregon State University Climatic Research Institute, Corvallis, Oregon. The values for precipitation and temperature were recorded at Hyslop Field Laboratory approximately 12.5 km from the study site.

The weekly mean air temperature and precipitation are illustrated in Figure 1. Values for temperature were slightly lower than normal for November and December and about average for January. Values for precipitation were about average for November and January, but were approximately half the normal for December.

Table I shows the weekly mean fecal egg counts observed during the study period. In pretreatment fecal exams, eggs of *N. battus* were not observed in any of the samples and specimens of this parasite were not found in either of the 2 lambs necropsied prior to anthelmintic treatment. Post-treatment fecal e.p.g. counts were negative for all species of *Nematodirus* and remained negative until day 23 when fecal flotations on all lambs were positive for *N. battus*. The counts remained at a relatively low level reaching a maximum peak of 200 e.p.g. In England and Norway, a seasonal fluctuation in the pattern of fecal egg counts has been demonstrated. Egg counts in lambs that began grazing in May were high in late spring, declined over the summer, and were either negative or very low throughout the rest of the grazing season (Thomas, 1959, loc. cit.; Helle, 1969, Veterinary Record **84:** 157–160; Boag and Thomas, 1975, Reseach in Veterinary Science **19:** 263–268). Yearling lambs and adults have also been shown to pass low numbers of *N. battus* eggs at times during summer and fall (Thomas, 1959, loc. cit.; Gibson, 1963, loc. cit.). The egg counts seen in this study are comparable to those for lambs over 5 mo of age late in the grazing season.

The species composition of *Nematodirus* for each lamb is shown in Table II. Overall, *N. battus* accounted for approximately 59% of the total

TABLE II. *Species composition of* Nematodirus *recovered from lambs at necropsy.*

Lamb no.	Day of necropsy	*N. battus*			*N. filicollis*			*N. spathiger*			*Nematodirus* spp.
		Males	Females	L4*	E4†	Males	L4	E4	Males	L4	Females
287	36	1,155	1,250	160	300	1,054	220	100	0	0	1,225
288	36	739	898	340	0	574	200	0	1	0	744
289	36	1,457	1,602	261	220	810	140	81	0	0	1,381
290	58	2,063	1,832	160	40	2,062	80	40	0	0	2,912
281	59	1,088	1,385	340	0	274	360	0	3	40	300
294	59	552	445	60	360	302	0	40	0	0	552
280	66	284	1,002	0	100	3	20	1	0	0	3
285	66	2,082	1,635	162	801	569	220	100	0	0	806
286	66	456	376	161	61	286	680	365	0	0	10

* Late fourth-stage larvae.
† Early fourth-stage larvae.

numbers of *Nematodirus* in the lambs. The other species present were *N. filicollis* (Rudolphi, 1810) and *N. spathiger* (Railliet, 1896), although the latter was represented by only a few specimens. The numbers of *N. battus* reported here are higher than those generally reported in animals toward the end of the grazing season (mean intensity ± SE: Group 1: 2,804 ± 460.9; Group 2: 2,775 ± 773.3; Group 3: 2,373 ± 1,157.77) (Reid and Armour, 1975, Research in Veterinary Science **18:** 307–313; Mitchell et al., 1985, Research in Veterinary Science **38:** 197–201). However, the intensity was lower than that recorded in the few reports of clinical nematodiriasis acquired in the fall, although the proportions of *N. battus* to *N. filicollis* were essentially the same (McKellar et al., 1983, loc. cit.; Hollands, 1984, loc. cit.; Hosie, 1984, Veterinary Record **115:** 666–667). The lower burdens may be due to the older animals involved in the present study (7–9 mo old) as compared to those exhibiting clinical disease (5 mo old). However, the relatively heavy infections seen in the 3 groups of tracers indicate that age resistance against *N. battus* is not complete.

Nematodirus battus has a minimum prepatent period of 15 days (Thomas, 1959, Parasitology **49:** 374–386). Therefore, the lambs in the present study must have acquired the infection sometime during the first to second week on pasture (mid to late November), as all lambs were positive by fecal flotation on day 23 (Table I). Although weather conditions were seasonally mild preceding the study, mean daily temperature was only 2.3 C during the time the lambs acquired their infections (Fig. 1). Consequently, the infection of lambs in November during a period of unseasonably low temperatures indicates that larval *N. battus* were capable of surviving the cold conditions present in western Oregon during late fall. *Nematodirus battus* larvae have been shown to be capable of extended survival at low temperatures (up to 475 days at 5 C) and during periods of desiccation (Parkin, 1976, loc. cit.; Boag and Thomas, 1985, Journal of Parasitology **71:** 383–384). Winters in this part of Oregon are usually warmer than the fall conditions reported here. Summer temperatures average approximately 22 C and precipitation approximately 4 cm. These climatologic conditions are well within the range of conditions *N. battus* larvae can tolerate. Therefore, long-term survival of larvae may occur in this region resulting in year-round transmission of this parasite. Whether this will supplement or replace the typical seasonally defined peaks of transmission as described elsewhere is currently unknown. The relationship this pattern has to clinical disease and the mechanism by which larvae become available on pasture are under investigation.

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