Effect of nematode infections on productivity of young and adult cattle on commercial dairy farms

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STELLINGEN

1. De meeste economische verliezen veroorzaakt door nematoden infecties bij rundvee treden niet op in de leeftijdscategorie waarvoor vanuit de veterinaire parasitologie de meeste aandacht bestaat.
   Dit proefschrift

2. Maagdarm- en longworminfecties zijn, na de factor voeding, de belangrijkste oorzaak voor de grote variatie in de groei van jongvee tijdens de opfok tot melkgevende vaars.
   Dit proefschrift

3. Niet op alle bedrijven is het ontwormen van melkkoeien op economische gronden gerechtvaardigd.
   Dit proefschrift

4. De behoefte aan een vaccin tegen maagdarmwormen wordt ondersteund door de positieve relatie tussen de in het eerste weideseizoen gemeten antilichaam titer tegen Ostertagia spp. en het voor leeftijd gecorrigeerde lichaamsgewicht na het tweede weideseizoen.
   Dit proefschrift

5. De waarde van sero-epidemiologisch onderzoek wordt door veel veterinair parasitologen onderschat.

6. De invloed van maagdarm- en longworminfecties op de productiviteit van vee wordt door veel zootechnici onderschat.

7. Het advies om naast inscharen op nieuw ingezaaid weiland kalveren ook te voorzien van een bolus tegen maagdarmworminfecties is economisch ongezond.
   Speciale uitgave van 'Veeteelt', "Management; sleutel voor een gezond melkveehouderijbedrijf", door J.Noordhuizen, Oct.1988, p.23

8. Wijzigingen in het landbouwbeleid van de rijke landen als bijdrage om het wereldvoedselprobleem te helpen oplossen, zijn veeleer probleemverschuivend dan probleem-oplossend van karakter.
   H.J.J.Stolwijk, 1988. Het westerse landbouwbeleid lost wereldvoedselprobleem niet op. Landbouwk.Tijdschr., 100: 21-24.

9. Opstallen van kalveren is, als ingrijpende verandering van het leefmilieu, de belangrijkste aanleiding tot het uitbreken van een BRSV-infectie (pinkengriep).

10. De niet-uniforme benadering van de Atrofische Rhinitis problematiek bij het varken door de regionale gezondheidsdiensten heeft grote consequenties voor de betrokken varkenshouders in die regio's.

11. De eisen die worden gesteld aan stellingen, die géén betrekking mogen hebben op het onderwerp van het proefschrift èn wetenschappelijk verdedigbaar moeten zijn, zijn alleen gerechtvaardigd wanneer in het voorstel voor een promotie-onderzoek voldoende tijd is ingeruimd voor het maken van zulke stellingen.

12. Voor de stam muizen, waarin van het rund afkomstige genen ingebracht zijn, zou de naam DN-ABUIS niet misstaan.

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CONTENTS

I. GENERAL INTRODUCTION

Nematode parasitism occurs in animals of all age classes, irrespective of practised management, on almost every farm in the Netherlands (Kloosterman, 1971; Borgsteede, 1977; Boon et al., 1984, 1986). The important genera are Ostertagia spp., Cooperia spp., Dictyocaulus viviparus, Nematodirus spp. and Trichostrongylus spp. Relative importance of the different genera differs with host age, mainly because of acquired immunity. Against Nematodirus spp. a strong host resistance develops within one grazing season (Kloosterman, 1971; Borgsteede, 1977). Therefore this genus is rarely found in animals of more than one year old, provided these animals had access to contaminated pasture during that first year. The same, but to a lesser extent, applies for Cooperia spp. and especially Dictyocaulus viviparus (Jarrett et al., 1957; Smith and Archibald, 1968; Borgsteede, 1977; Pott et al., 1978). Ostertagia spp. and Trichostrongylus spp. are generally the dominant genera found in adult cattle (Hong et al., 1981; Bairden and Armour, 1981; Borgsteede and v.d.Burg, 1982; Vercruysse et al., 1986). Occasionally other nematodes are found, but these are regarded to be economically less important.

On commercial dairy farms cattle can be divided into roughly three age categories; first-season grazing calves, second-season grazing yearlings and adult cows. Therefore the interest in nematode parasitism in relation to production will be briefly reviewed separately for these age-groups.

First-season grazing calves

Calves, entering their first grazing season, form the age class that is most susceptible to nematode infections. Clinical parasitism is rarely seen in older cattle. Obvious signs of disease are inappetence, dull hair coat, diarrhoea, weight gain depressions and in case of lungworm infections also coughing and increased respiratory rates (Jarrett et al., 1957; Anderson et al., 1965; Jansen et al., 1977; Armour and Ogbourne, 1982). For this reason most work on nematode infections refers to calves. Numerous authors reported about epidemiological, immunological, (patho-) physiological and productivity aspects with respect to nematode infections in calves. Many authors reviewed the existing knowledge (a.o. Armour and Ogbourne, 1982; Jorgensen and Ogbourne, 1985). The body of this knowledge became available through trials using experimental infections or controlled grazing experiments. Although results of this work revealed much about the effects of parasitism on the host, this information is not necessarily applicable to natural field situations encountered on commercial dairy farms. One of the main reasons for this is the (necessarily) restricted number of variables investigated in controlled experiments and the use of extreme situations, i.e. comparing heavily infected to non-infected calves. Nevertheless, based on results from such controlled experiments many authors proposed control strategies to prevent production losses due to nematodiasis in calves. One of the most well-known strategies was developed in Weybridge in England, the so-called

'dose and move' system (Michel, 1969). Another was the development of a lungworm vaccine by Glasgow workers in the late fifties. Other strategies involve anthelmintic treatments given once by means of a slow release or pulse release device, continuously at low levels in feed or drinking water or given at timed intervals based on knowledge of epidemiological patterns of infection (a.o. Downey et al., 1974; Jones, 1981; Taylor et al., 1985; Downey and O'Shea, 1985; Vercruysse et al., 1987; Jorgensen et al., 1987; Armour et al., 1987). Very recently Herd (1988) reviewed the control strategies based on anthelmintic treatments. Farm management measures are also mentioned as providing a means to control nematode infections. Among these are date of turnout, grazing on aftermath, stocking rate, and supplementary feeding (Oostendorp and Harmsen, 1968; Borgsteede, 1977; Nansen et al., 1978; Jacobs and Fox, 1985; Nansen et al., 1987; Eysker et al., 1988). Although all of these control measures have been shown to work sufficiently well in controlled grazing experiments, it remains doubtful to what extent these measures help controlling nematode parasitism on commercial farms (Michel et al., 1981; Jorgensen, 1983). Knowledge about frequency distributions of levels of infection encountered on commercial dairy farms and to what extent these levels of infection can be related to observed and measurable production losses should be taken into account when control strategies are evaluated. Also, such information should be related to practised management. These data can then be used for economic evaluations, both nation-wide and on farm level, providing a rational (and practical) basis for control strategies including the use of anthelmintics (Morris and Meek, 1980).

Second-season grazing yearlings

Compared to the effects of nematode infections in calves, the effects in older age groups, such as second-season grazing yearlings, have received little attention. This is surprising, because it has been shown that various production characteristics, such as milk production and reproductive performance, may depend on growth pattern and final body weights reached by yearlings (v.Adrichem and Shaw, 1977b; Sejrsen, 1978; Amir et al., 1978; Boxem, 1981; Prosl et al., 1983; Block et al., 1985; Holste et al., 1986; O'Kelly et al., 1988). Table 1 shows that substantial returns in growth performance during a second grazing season can be found after treatment of yearlings. In a few of the studies summarized, weight gain advantages in treated yearlings were, compared to controls, as large as often found in calves. A few authors described the epidemiological pattern of nematode infections in second-season grazing yearlings (Armour et al., 1979; Holtenius et al., 1983; Entrocasso et al., 1986c).

Several aspects need to be considered when studies are done with second-year cattle. Firstly, exposure to infection in the first year as calf appears to be important, both in terms of parasitology as in terms of growth performance. The former is demonstrated by, for example, lower worm burdens, lower egg output and stunted worms. The latter is demonstrated by higher growth rates observed in yearlings with previous experience compared to helminth naive yearlings (Smith and Archibald, 1968; Borgsteede et al., 1985). Unfortunately, several authors did not mention whether their animals had experienced nematode infections and if so, to

TABLE 1: Summary of results of studies investigating second season grazing cattle including observations on weight gains.

REFERENCE:	EXPERIMENTAL GROUPS: first grazing season (FGS)	housing period (HP)	second grazing season (SGS)	WEIGHT GAINS DURING[1] (in kg.): FGS	HP	SGS	CUMULATIVE GAINS (in kg.):	REMARKS:
Smith and Archibald, 1968 (Canada)	1. grazing pasture infected previous season		grazing pasture grazed by group 1.	0	0	0	0	SGS lasted only 4-5 weeks. Group 1 developed clinical PGE[2] with two deaths during FGS, group 2 during SGS. The latter showed signs similar to group 3 naive calves.
	2. grazing pasture not grazed for two years		in the preceding year together with;	+37.9	+20.5	-23.1	+35.3	
			3. helminth naive controls	--	--	-17.7		
v.Adrichem, 1970 (Netherlands)		1. controls			0	0	0	Calves were purchased at the end of the first grazing season and allocated on EPG (av. 150) and body weight. Calves had also a mean of 17 liver fluke eggs.
		2. thiabendazole at housing			+18.2	+32.6	+50.8	
		3. twice phenothiazine and thrice hexachlorophene during housing			+10.6	+30.6	+41.2	
		4. thiabendazole and thrice hexachlorophene during housing			+18.1	+29.1	+47.2	
v.Adrichem and Shaw, 1977a (Belgium)	1. controls	controls	controls	0	0	0	0	Animals used were twin bull calves randomly assigned to one of the groups. Controls harboured a moderate level of infection during FGS.
	2. cambendazole fortnightly	cambendazole at five week intervals	cambendazole fortnightly	+12.4	+21.2	+15.5	+49.2	
v.Adrichem and Shaw, 1977b (Belgium)	1. controls	controls	controls		0	0	0	Animals used were twin female calves randomly assigned to one of the groups. No data given about FGS, but between the age of 4 and 12 months weight gain advantage was +20.2 kg. Controls harboured a moderate infection.
	2. cambendazole fortnightly	cambendazole if EPG > 20	cambendazole fortnightly		+18.0	-2.0	+16.0	
Borgsteede et al., 1981 (Netherlands)			1. controls			0		No information on previous experience. Last animal was housed by mid-July. During housing period up to the end of September advantage increased to +22 kg.
			2. MSRB treated yearlings			+7.0		
Prosl et al., 1983 (Austria)	1. controls		controls, grazed the same pasture as calf	0	0	0		?: no data given, but MSRB treated animals calved at av. 21 days earlier than controls, who performed slightly better during the second grazing season.
	2. MSRB treated		MSRB treated, grazed the same pasture as calf	+34.8	-7.4	-0 ?		
Conder et al., 1983 (England)			1. controls			0		liveweight gain advantages ranged from -0.6 to +39.0 kg. (in three herds this was significant). In two herds clinical PGE occurred.
			2. MSRB treated			+15.1		
	(trials on 7 commercial farms, done in two different years and using both male and female yearlings with previous experience)							

..... Table 1 continued:

REFERENCE:	EXPERIMENTAL GROUPS: first grazing season (FGS)	housing period (HP)	second grazing season (SGS)	WEIGHT GAINS DURING[1] (in kg.): FGS	HP	SGS	CUMULATIVE GAINS (in kg.):	REMARKS:
Güldenhaupt and Bürger, 1983 (Germany)	(trials conducted on 5 farms using female, male and castrated male yearlings)		1. controls 2. MSRB treated			0 +13.3		weight gain advantages per farm ranged from 23 g/day to 169 g/day (in one herd this was significant).
Weiss and Bürger, 1984 (Germany)		Exp.I	1. controls 2. MSRB treated yearlings			0 +15.6		Castrated male yearlings and only in Exp.I also female yearlings. Av. body weights at start of season were in Exp.I 195 kg. and in Exp.II 474 kg.
		Exp.II	1. controls 2. MSRB treated yearlings			0 +2.9		
Gibbs and Kitsos, 1985 (U.S.A.)		Exp.I	1. controls 2. MSRB treated yearlings			0 -5.5		In Exp.I 18 month old heifers with previous experience used. In Exp.II 15 month old heifers used of which majority was helminth naive.
		Exp.II	1. controls 2. MSRB treated yearlings			0 +7.7		
Borgsteede et al., 1985 (Netherlands)	1. controls		controls	0	0	0	0	Groups 1 and 2 showed clinical PGE in the FGS and had to be treated. Herbage infestation level was generally lower in the SGS than in the FGS.
	2. controls		MSRB treated	0	0	+3.0	+3.0	
	3. MSRB treated		controls	+20.0	+3.9	+1.1	+25.0	
	4. MSRB treated		MSRB treated	+20.0	+3.9	+16.0	+39.9	
	5. kept indoors		controls	+44.0	-5.2	-38.0	+0.8	
	6. kept indoors		MSRB treated	+44.0	-5.2	-22.0	+16.8	
Entrocasso et al., 1986ab (Scotland)	1. controls		controls	0		0		? because during the winter housing period metabolism studies with pair-feeding were performed. Controls suffered from clinical type I and type II PGE.
	2. MSRB treated		MSRB treated	+20	?	+22	?	
	3. fenbendazole fortnightly		fenbendazole fortnightly	+20		-4		

1. weight gains are given as the difference from the control group (in kg.).
2. PGE is parasitic gastroenteritis.
The first grazing season has generally a length of about 4 to 5 months, while the second grazing season has a length of about 6 to 7 months.

what extent. Secondly, exposure to nematode infection during the second year may depress growth performance of yearlings despite of previous experience and thus a certain level of acquired immunity (Borgsteede et al., 1985). Thirdly, some authors concluded that nematode infections picked up during the first year can cause long lasting physiological damage resulting in depressed growth rates when circumstances are suboptimal even when at that time exposure to infections is negligible (v.Adrichem and Shaw, 1977a; Entrocasso et al., 1986b). And fourthly, the immunological consequences of picking up infective larvae by immune animals (hypersensitivity reactions) are supposed to be capable of reducing productivity of such animals. Besides growth performance other traits can be studied, such as carcass evaluations or length of fattening periods needed to reach desired slaughter weights (Entrocasso et al., 1986b; Garriz et al., 1987; Taylor, 1987).

Adult dairy cows

This group is the most important one if it comes to direct monetary incomes for the farmer. Quite a few workers have attempted to elucidate the impact of nematode parasitism on milk production. The body of this work started in the early seventies with reports from Todd, Bliss and coworkers (see Table 2). Since then, numerous authors published results concerning this subject. In Table 2 a summary of results of the majority of trials reported in the literature is given. This summary is restricted to anthelmintic treatment trials which included untreated control groups in each herd investigated, and to trials using experimental infections.

TABLE 2: Summary of results of trials studying the effect of anthelmintic treatment(s)[1]- or experimental infection(s) on milk production in dairy cattle.

STUDIES USING ANTHELMINTIC TREATMENT(S):

ANTHELMINTIC USED:	TOTAL NUMBER OF HERDS:	COWS:	STAGE OF LACTATION WHEN TREATED:	OVERALL RESPONSE[2]-: (treated vs. controls)	REFERENCE (country):
coppersulfate phenothiazine thiabendazole	34	1028	av. 130 days in lactation	+0.99 kg/day **[3]- (within 8 days)	Todd et al., 1972 Wisconsin, U.S.A.
coumaphos	22	1003	av. 155 days in lactation	+32.7 kg ** (over 60 days)	Bliss & Todd, 1973 Wisconsin, U.S.A.
thiabendazole	12	488	at calving	+192.0 kg + (over 305 days)	Bliss & Todd, 1974 Wisconsin, U.S.A.
coumaphos	1	36	varying stages	+1.7 kg/day (directly after treatment)	Brown & Maniscalco, 1974 Texas, U.S.A.
coumaphos	1	72	varying stages	.. no increase .. (over 56 days)	Beatty et al., 1975 Mississippi, U.S.A.
...various...	(21 trials)		...various...	3 of 21 trials showed significant responses	New Zealand Society of Animal Production, 1975 New Zealand

..... Table 2 continued:

ANTHELMINTIC USED:	TOTAL NUMBER OF HERDS:	COWS:	STAGE OF LACTATION WHEN TREATED:	OVERALL RESPONSE[2]: (treated vs. controls)	REFERENCE (country):
thiabendazole (T) coumaphos (C)	9	267	at calving (T) and 60-90 days later (C)	+242.4 kg * (over 305 days)	Bliss & Todd, 1976 Vermont, U.S.A.
thiabendazole (T) coumaphos (C)	.	400 (2 trials)	ca. 4 weeks prior to calving (T) or at calving (C)	-283 kg NS (T) +0.07 kg/day NS (C) (over 305 days or 60 days respect.)	Harris & Wilcox, 1976 Florida, U.S.A.
tetramisole levamisole	1	260 (2 trials)	varying stages and varying multiple treatment-schemes	ca. +200 kg * (over trial)	McQueen et al., 1977 New Zealand
thiabendazole	12	190	at calving	+399 kg (over 305 days)	Pouplard, 1978 Belgium
coumaphos	14	332	at calving and weekly first 90 days	+349.1 kg (Penn.) +488.1 kg (N.Car.) (over 305 days)	Todd et al., 1978 Pennsylvania & N.-Carolina, U.S.A.
fenbendazole	10	335	only when <150 days in lactation	+0.25 kg/day NS (over 42 days)	Barger, 1979 Australia
fenbendazole	9	268	in the dry period	+173 kg (full lactation of 270-305 days)	McBeath et al., 1979 England
fenbendazole thiabendazole	3	110	varying stages	+1.31 kg/day (over 84 days)	Hamann & Heeschen, 1980 Germany
thiabendazole	2	418	at calving	-80.8 kg mature cows +113.9 kg heifers (over 305 days)	Elsinghorst et al., 1981 The Netherlands
morantel tartrate	13	217	at calving	+255 kg NS (over 305 days)	Frechette & Lamothe, 1981 Quebec, Canada
albendazole	1	340	varying within 90 days after calving	+0.60 kg/day ** (over 90 days)	Grisi & Lima, 1981 Brazil
fenbendazole thiabendazole	1	125	1 week prior, or till 1 week after or 3 months after calving	+341.0 kg (over 305 days)	Grzywinski & Stadnicki, 1981 Poland
thiabendazole	1	96	at calving	-126 kg NS (over 305 days)	Thomas & Rowlinson, 1981 England
fenbendazole	8	442	at calving and monthly during whole lactation	+30.9 kg NS (over 300 days)	Barger & Lisle, 1982 Australia
morantel tartrate (MSRB-bolus)	1	210	within one month after turnout - varying stages	+376 kg * (over 305 days)	Bliss et al., 1982 England
levamisole	.	160 (2 trials)	at calving and 8 weeks later	-110 kg NS +965 kg * (over 305 days)	Fisher & MacNeill, 1982 British Columbia, Canada
coumaphos	1	546	1 to 5 weeks post partum	.. no significant increase .. (over 305 days)	Glenn et al., 1982 California, U.S.A.
thiabendazole	2	247 (4 trials in 2 years)	at calving	+204 kg * (over 305 days)	Kloosterman & Albers, 1982 The Netherlands
thiabendazole fenbendazole levamisole	120	9166	at calving	+42 kg * (over 305 days)	Michel et al., 1982 Great Britain
morantel tartrate	1	32	av. 66 days in lactation	+1.48 kg/day ** (over 28 days)	Signorini & Girardello, 1982 Italy

..... Table 2 continued:

ANTHELMINTIC USED:	TOTAL NUMBER OF HERDS:	COWS:	STAGE OF LACTATION WHEN TREATED:	OVERALL RESPONSE[2-]: (treated vs. controls)	REFERENCE (country):
fenbendazole	1	116	within 2 weeks after calving	+154 kg * (over 140 days)	Mathews et al., 1983 Australia
levamisole	9	1278 (2 years)	at calving	positive response NS	Fox & Jacobs, 1984 England
albendazole	20	341	at calving	+1.1 kg/day *? (over ... days)	Gouffe et al., 1984 France
thiabendazole	6	793	at calving	-104 kg NS (cows) +252 kg NS (heifers) (over 305 days)	Fetrow et al., 1985 Pennsylvania, U.S.A.
thiabendazole	1	10	varying stages	+0.8 kg/day NS (over 58 days)	Fox et al., 1985 England
levamisole	3	172	varying stages	transient response (over 90 days)	Prokopic et al., 1985 Czechoslovakia
coumaphos (C) thiabendazole (T)	3	685	av. 30 days in lactation (C), or within 2 weeks before calving (T)	+138 kg NS (C) -34 kg NS (T) (full lactation)	Miller et al.,1986 California, U.S.A.
coumaphos	1	28	av. 40 days in lactation and 30 days later and when EPG increased	+0.75 kg/day NS (full lactation)	Takagi & Block, 1986 Quebec, Canada
febantel	7	807	at calving	+97.6 kg * (full lactation)	O'Farrell et al., 1986 Ireland
oxfendazole	47	5556	twice in the dry period	+51.5 ** (full lactation of at av. 251 days)	Bisset et al., 1987 New Zealand
levamisole	88	1296	within 1 week prior to calving	+235.3 kg * (over 6 months)	Block et al., 1987 Quebec, Canada

STUDIES USING EXPERIMENTAL INFECTIONS:

INFECTION USED:	TOTAL NUMBER OF COWS:	STAGE OF LACTATION WHEN INFECTED:	OVERALL EFFECT OF INFECTION:	REFERENCE (country):
single infection with 200,000 L3 of gastro-intestinal nematodes (Haemonchus, Ostertagia, Cooperia, Trichostrongylus, Nematodirus)	48	varying stages	-1.22 kg/day (over 30 days)	Bliss & Todd, 1977 Wisconsin, U.S.A.
trickle infection with 5,000 L3 mixture of Cooperia and Ostertagia 3 times/week for 9 weeks	12	first infection 3 weeks after calving	-2.16 kg/day + (over 9 week period of infection)	Barger & Gibbs, 1981 Maine, U.S.A.
single infection with 225,000 L3 Cooperia and 25,000 L3 Ostertagia	48 (heifers)	at calving	no effect (full lactation)	Kloosterman & Albers, 1982 The Netherlands
single infection with 200,000 L3 Ostertagia	66	at calving	no effect (full lactation)	Kloosterman et al., 1985 The Netherlands

1. : Only trials summarized which included a not treated group in each herd.
2. : Between brackets the time-span is given over which the response was measured.
3. : Levels of significance are: NS - not significant; + - $P < 0.10$; * - $p < 0.05$; ** - $P < 0.01$. Otherwise level of significance was not stated in the original reference.

Table 2 shows that in the vast majority of summarized trials positive milk yield responses to anthelmintic treatment were found, irrespective of statistical significance. Despite this, a strong controversy exists among scientists whether adult dairy cows should be treated or not. Some aspects related to this controversy can be considered:

Anthelmintic treatment is only necessary if an infection with nematodes is present and if the infection limits (economical) production. Several authors showed that gastrointestinal nematode infections are widespread among adult cows (Yazwinski and Gibbs, 1975; Randall and Gibbs, 1977; Grisi and Todd, 1978; Borgsteede and v.d.Burg, 1982; Vercruysse et al., 1986). Although nematode parasitism is present in virtually every herd, it is very common to find enormous variations in milk yield response to treatment between herds, ranging from negative responses to more than +1000 kg. per lactation per herd (Todd et al., 1978; McBeath et al., 1979; Frechette and Lamothe, 1981, Barger and Lisle, 1982; Michel et al., 1982). Some authors pointed towards a lack of knowledge about a possible relationship between level of infection and treatment response. For instance Glenn et al. (1982) did not find an effect of anthelmintic treatment on milk production in one herd of dry-lot cattle in California. Faecal samples of a maximum of 13% of the cows in that herd contained nematode eggs, examined by means of a sugar flotation technique. Average EPG never exceeded a value of 0.22 . They concluded that there was "... a need for critical examination of parasite infection on a herd by herd basis". Herd (1982) stated in a review that "... there is a need to formulate control programmes in which the application of treatment is related to the immune status of the cattle and to expected levels of parasitism in the environment". Similar remarks were made by Baker (1979), Thomas et al. (1984) and Fetrow et al. (1985). Thusfar only Frechette and Lamothe (1981), Michel et al. (1982) and O'Farrell et al. (1986) tried to demonstrate a relationship between egg output (the first two) or pepsinogen values (the latter) and milk yield response to anthelmintic treatment, and failed to do so. A reason for this failure may be that these infection parameters are not sensitive enough to estimate levels of infection in adult cattle. Particularly egg output is found to be of minor value for that purpose (Michel, 1968; Borgsteede, 1982).

Another aspect is timing of anthelmintic treatment in relation to stage of lactation and in relation to seasonal occurrence of infections. Most authors believe that a greater economical benefit of anthelmintic treatment is obtained by treating early in lactation, mainly because of the phenomenon of a peri-parturient relaxation of immunity and consequently a post-parturient rise in egg output. However, seasonal patterns in occurrence of infections do not have to coincide with an optimal treatment time in lactation. Also, many authors suppose that effect of treatment is larger in heifers than in mature cows, possibly because of a lower acquired immunity in the younger heifers.

Method of calculating and analysing effect of treatment, including allocation of animals to treatment groups, is another important factor. Milk production is a highly variable trait and dependent on such factors as nutrition, breed, age, season of calving and heritage. Michel and Mulholland (1981), Thomas and Rowlinson (1981) and Fox and Jacobs (1984) discussed some of these matters in relation to designing trials and effects of different methods of calculating.

Furthermore anthelmintic drugs may have effects not related to a removal of worm burdens, for instance on host physiology and metabolism. Fox et al. (1985) reported a positive effect of thiabendazole on thyroid function in cows, while it is known that thyroid function is important in enhancing lactation. Another example is levamisole, which is known to possess immunomodulatory properties and therefore has been investigated as a possible drug for use in the control of bovine mastitis (Anderson, 1984). On the other hand, the positive responses summarized in Table 2 were obtained with many different anthelmintic drugs.

Yet another and highly disregarded aspect is the quality of management and the level of production on a farm. Bliss and Todd (1973) found the higher treatment responses in the 'better managed' herds, without giving detailed information for such a qualification.

Finally, to circumvent some of the above mentioned aspects as well as the indirect way of measurement when clinical trials are performed, a few authors have attempted to prove a production limiting effect of nematode parasitism using experimental infections (see Table 2). Bliss and Todd (1977) as well as Barger and Gibbs (1981) found substantial milk production losses in experimentally infected cows compared to not infected cows. In the Netherlands no such effects were found in two studies (Kloosterman and Albers, 1982; Kloosterman et al., 1985). There is no straightforward explanation, but these different results may be due to larval strain differences in pathogenicity, to type of infection or to differences in previous experience with nematode infections.

Despite these considerations many authors reported that the commercial industry gave blanket recommendations to treat adult dairy cattle. In England Michel et al. (1981) found an increase in the use of anthelmintic drugs since the first reports of Todd, Bliss and coworkers appeared. In connection with the common finding that such treatments can result in highly variable milk production increases between herds, it should be attempted to investigate possible relationships between level of infections found on commercial dairy farms and treatment responses in order to rationalize this use of anthelmintic drugs.

In the following chapters the results of a survey on (initially) 100 commercial dairy farms in the Netherlands are described. This survey was carried out in the years 1985/86 and 1986/87 and it was partly cross-sectional, partly longitudinal and included some clinical trials. The main purpose was to estimate the impact of nematode parasitism on performance of first-season and second-season grazing calves and yearlings as well as on milk production in adult cows on commercial farms, and to investigate in particular the relationship between the level of parasitism and some production parameters with herd as the experimental unit, a relationship which can form a basis for a more rational approach to control nematode infections in the field. In both years the same farms were approached for participation, not only for practical reasons but also to investigate whether the same levels of nematode infection continue within farms over subsequent years. The Department of Animal Husbandry of the Agricultural University Wageningen, the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty Utrecht, the Department of Infectious Diseases and Immunology of the same Faculty and the Department of Parasitology of

the Central Veterinary Institute Lelystad participated in this survey.

In chapters II, III, IV and V results regarding the effect of nematode parasitism on growth performance of first-season grazing calves are presented. Chapters II and IV present results with respect to the grazing seasons of 1985 and 1986, respectively. Chapters III and V deal with the growth performance of calves during winter housing after the first grazing season in relation to experienced nematode infections, and included each year a clinical trial in which half of each herd on a number of farms was treated with an anthelmintic drug to assess indirectly the impact of nematode parasitism. Chapters VI and VII give results concerning second-grazing season yearlings. Chapter VI is focussed on the relationship between level of exposure to nematode infections and growth performance up to the end of the second year, and includes the years 1985 (when yearlings were for the first time at pasture as calf) and 1986. Chapter VII deals with the growth performance of yearlings/heifers during winter housing after the second grazing season. This study included also a clinical trial in which half of each herd investigated was treated after housing. Since many yearlings calved during winter housing it was decided, to collect milk production data from these animals in the autumn of 1987, to see whether anthelmintic treatment resulted in increased milk production during the first lactation and to investigate possible relations with the level of exposure these animals experienced during the previous grazing seasons. The chapters VIII and IX give results of two trials with adult cows, in which on each of a number of farms dry cows were treated with an anthelmintic drug or left untreated as controls during the housing periods of 1985/86 and 1986/87, respectively. Main purpose of these two trials was to see whether a relationship existed between the effect of treatment on milk production and the level of exposure to nematode infection during the grazing season.

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II. EFFECT OF NATURALLY OCCURRING NEMATODE INFECTIONS ON GROWTH PERFORMANCE OF FIRST-SEASON GRAZING CALVES

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ABSTRACT

Liveweight of calves on 89 dairy farms was measured at the end of the grazing season and related per herd to the level of exposure to nematode infection during the grazing season. There were significant between herd variations in antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus as well as in pepsinogen values. All but 6 herds (93.1%) had gastrointestinal nematode infections, as measured by faecal egg counts in September. Faecal samples of 17 herds (19.3%) contained lungworm larvae in September. Liveweight of calves per herd deviated from -68.1 kg. to +84.1 kg. from the for age adjusted population mean after their first grazing season. Growth performance up to the time of liveweight measurements was significantly correlated negatively with several serological and parasitological parameters. Data could be fitted by means of both linear and segmented curvilinear regression. Antibody titre against Cooperia spp. and gastrointestinal nematode egg output measured in September accounted for 3.1% ($P < 0.10$) and 6.7% ($P < 0.05$), respectively, of the variation in growth performance between herds. Certain infection parameters, when combined, accounted for 9.2% of this variation; these were antibody titre against Cooperia spp. and larval counts for both gastrointestinal nematodes and lungworm. Adding certain management factors to these infection parameters resulted in a model explaining 27.6% of the observed variation in growth performance between herds. These factors were supplementary feeding, lungworm vaccination, anthelmintic treatment at housing, date of housing and herd age.

INTRODUCTION

It is well established that nematode infections may cause weight gain depressions accumulating to as much as 50 kg. per animal at the end of the

grazing season, compared to calves which are either not infected, treated frequently or otherwise kept at low levels of infection (Henriksen et al., 1976; Entrocasso et al., 1986; Callinan and Riffkin, 1987; Taylor, 1987; Nansen et al., 1988). These weight gain depressions result from a voluntary reduction in feed intake as well as from effects of nematodes on metabolism and digestibility (Steel, 1978; Holmes, 1986; Kroonen et al., 1986; Kloosterman and Henken, 1987). Verstegen (1987) reported 6-7% increased maintenance requirements in parasitized animals. These results originate mainly from trials using experimental infections or from controlled grazing experiments. Often extreme situations with high levels of infection were used. Such extreme situations, accompanied by distinct clinical outbreaks, are fairly rare in practice. Besides, the available knowledge on integrated control measures has, until now, not widely been put into practice on commercial dairy farms (Michel et al., 1981; Jorgensen, 1983). Therefore, experimental findings are not readily applicable in normal daily practice on farms. Also, nation-wide evaluations of the economic impact of nematode infections, based on experimental studies alone, may be biased. Large surveys involving many farms were conducted in the Netherlands (Oostendorp and Harmsen, 1968; Kloosterman, 1971; Borgsteede, 1977). These studies, however, relied heavily on observations on egg output. Kloosterman (1971) could not demonstrate a relation between egg output and growth rate of calf-herds. With the development of serological techniques (Keus et al., 1981; Boon et al., 1982), large cross-sectional surveys became more feasible and attractive (Bain and Symington, 1986; Boon et al., 1984, 1986). Such surveys yield data on the frequency-distribution of levels of infection on commercial dairy farms as well as data on the effects of these levels of infection on, for instance, actual growth performance of calves in uncontrolled circumstances, with or without accounting for certain management practices.

The present study was conducted on 89 dairy farms. Levels of nematode infection in first-season grazing calves were estimated by serological as well as parasitological techniques, and related to growth performance measured at the end of the grazing season. In addition certain management factors were evaluated.

MATERIALS AND METHODS

Farms and calves

In this study 89 farms participated. These farms were all situated around the city of Utrecht and belonged to the Veterinary Practice of the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty in Utrecht. Average farm size was 24.6 ha. (range: 9-50). Per farm a mean number of 15 calves (range: 4-41), 15 yearlings (range: 3-42), and 52 cows (range: 22-114) were present.

It was chosen to investigate only calves which were pastured together as one herd in an attempt to avoid variation originating from different management practices and different infection patterns within herds. Consequently, the herds investigated consisted of at average 9 calves (range: 4-24) on each farm.

The majority of calves were of the Dutch Friesian breed, Holstein Friesian breed or crossbreds of these two. About 6% were of the Meusse-Rhine-IJssel (MRIJ) breed and about 8% were of other breeds. The latter were distributed over 38% of the farms, while calves of the MRIJ-breed were mainly concentrated on 7% of the farms. Calves were, when liveweights were assessed, at average 10.4 months old (range: 4.6-22.4 months).

Measurement of growth performance

After the first grazing season liveweight of all calves of the 89 herds was assessed by measuring the heart girth, i.e. the circumference (cm.) of the chest directly behind the forelegs (Vos and Vos, 1967). Figure 1 presents schematically the timing of measurements in relation to grazing and housing periods. On the majority of these farms calves were also actually weighed. Because results of both measurements correlated very well ($r = 0.96$) and because on a number of farms weighing was impossible due to housing circumstances, it was decided to use only the heart girth measurements.

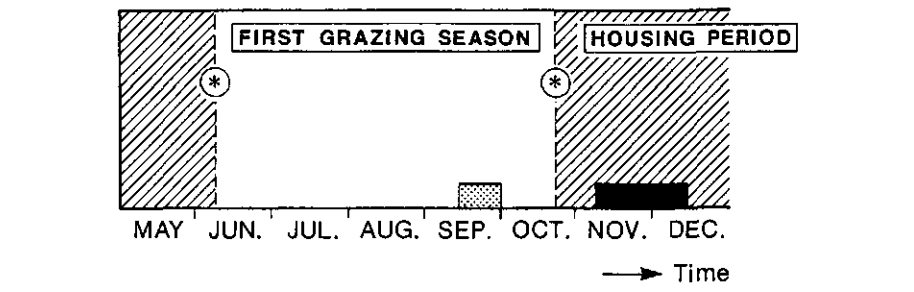


Figure 1: Sampling periods and observations relative to grazing season and housing period.

The estimated weights were adjusted for age and breed of the calves, and expressed as the liveweight deviation from the overall population mean. Between herd variation of this deviation was significantly greater than the within herd variation ($F = 10.6$, $P < 0.001$). Therefore all subsequent calculations were done with the average herd weight deviation from the age adjusted population mean (HWDM).

Faecal examinations

At the end of September 1985 (Figure 1) faecal samples were taken from freshly deposited pats (as many as possible) on pasture grazed by the calf-herds under investigation. On each farm these samples were thoroughly

mixed and split into two parts. One sample per herd was used to determine a mean herd level of egg output. Egg output was estimated by counting gastrointestinal nematode larvae per gram faeces (LPG-GI) after culturing, combined with larval identification (Borgsteede and Hendriks, 1973, 1974). The other sample was used for a lungworm larval count (per 30 grams of faeces) (LPG-Dv), using a Baermann-technique.

Serological examinations

From 5 randomly chosen calves in each herd, if that number was available, blood samples were taken. Sampling took place twice (Figure 1). Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus, as well as pepsinogen values were determined as described earlier by Keus et al. (1981), Boon et al. (1982) and Berghen et al. (1987). Sera were analysed soon after each sampling period. ELISA-tests, done in different periods, showed variation in overall levels without affecting the relative order of titres found. This was due to the use of different batches of reagents (e.g. conjugate, antigen, standard sera etc.). A separate analysis was done to allow comparisons between sampling periods.

Management practices

In the autumn of 1985 each farmer was visited to obtain data on farm, herd and general management by means of a questionnaire, e.g. total farm area, number of calves, yearlings, cows, pasture management, total area grazed by calves, date of turnout, date of housing, supplementary feeding, lungworm vaccination, anthelmintic treatments at pasture and/or after housing, etc.

Calculations and statistics

All continuous data were tested for normality and, with respect to serological and growth performance data, for homogeneity of variance. Pepsinogen values were transformed according to the formula $Y = \ln (X)$. LPG-GI was transformed according to $Y = {}^{10}\log (X+1)$. LPG-Dv was classified, because of a non-normal distribution which included many zero-counts.

Management data were either categorical or continuous variables. The latter were tested for normality. If a clear non-normality existed, these variables were classified into categorical data (if possible dichotomous), or in some cases transformed. Date of housing was classified into three classes: before October - 'early'; from October to mid November- 'middle'; after mid November - 'late'. Grazing intensity, referred to as calfdays per ha., was calculated as the natural logarithm of 'the herd size multiplied by the length of the grazing period (days) and divided by the total area grazed (ha.)'. Supplementary feeding is the average amount of concentrates (kg.) given per calf per day during the grazing season.

All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985), with herd as the experimental unit. The following steps were performed;

I. Effect of each single infection parameter on HWDM was analysed by means

of both linear and segmented curvilinear regression. The latter was fitted, using the model:

$$Y_i = p - c.(I_i - x_0)^2 + e_i,$$

where; Y_i = the per herd weight deviation in the i^{th} herd from an age-adjusted population mean (HWDM in kg. per calf),

p = constant weight deviation (referred to as plateau),

c = regression coefficient; if $I_i \leq x_0$ then $c = 0$,

I_i = infection parameter in the i^{th} herd,

x_0 = threshold level for infection parameter, above which growth performance can be described by a curvilinear relation,

e_i = residual error term.

In case of non-continuous data analysis of variance was used.

The next step attempted to fit infection parameters into one model, using:

$$Y_i = u + I_{1i} + ..+ I_{ji} + e_i,$$

where; Y_i = the per herd weight deviation in the i^{th} herd from an age-adjusted population mean (HWDM in kg. per calf),

u = overall mean,

I_{ji} = infection parameter j in herd i (j = 1, ..., 10).

e_i = residual error term.

For ease of interpretation no interactions between infection parameters were investigated.

II. Relationships between management variables and either HWDM or the infection parameters were investigated by means of linear regression or analysis of variance. Relations showing statistical significance at the 10% level were used for further analysis. However, in case of variables showing significant relationships with some of the infection parameters it was assumed, that it was possible they also influenced the infection parameters with which no significant relations were demonstrated.

III. Finally, infection parameters and management variables were combined in one model:

$$Y_i = u + I_i" + M_{1i} + ..+ M_{ki} + (I_j \times M_k)_i + e_i,$$

where; Y_i = the per herd weight deviation in the i^{th} herd from an age-adjusted population mean (HWDM in kg. per calf),

u = overall mean,

$I_i"$ = 'predicted' per herd weight deviation in herd i based on the combination of infection parameters found in step I,

M_{ki} = management variable k in herd i (k = 1, ..., 20),

$(I_j \times M_k)_i$ = interaction of infection parameter j with management variable k in herd i (j = 1, ..., 10; k = 1, ..., 20),

e_i = residual error term.

To facilitate interpretation only two-way interactions were evaluated.

RESULTS

Table 1 presents the results of the larval identifications. The predominant species were of the Ostertagia and Cooperia oncophora type. In 6.9% of the herds no gastrointestinal nematode larvae were found. At average a geometric mean of 28.4 LPG were present. Actual LPG-GI varied between 0 and 740 LPG. In faecal samples of 17 herds (19.3%) lungworm larvae were found with a maximum of 182 larvae per 30 grams of faeces.

TABLE 1: Identification of larval types found in faecal samples collected in September 1985 (n=87).

	Number of herds with faecal sample containing:					Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%	
Ostertagia spp.	9	36	26	13	1	2	78 (89.7)
Cooperia oncophora	9	4	22	29	23	0	78 (89.7)
Cooperia punctata	48	36	0	2	1	0	39 (44.8)
Trichostrongylus spp.	58	28	1	0	0	0	29 (33.3)
Oesophagostomum spp.	79	8	0	0	0	0	8 (9.2)
Haemonchus spp.	77	5	2	3	0	0	10 (11.5)

Nematodirus spp. eggs were found in 1 herd. **Trichuris** eggs were found in 7 herds. **Moniezia** spp. eggs were found in 9 herds.

Table 2 shows that antibody titres against D. viviparus and Cooperia spp. decreased between September and December ($P < 0.10$ and $P < 0.05$, respectively). Antibody titres against Ostertagia spp. increased during this period ($P < 0.05$), whereas pepsinogen values decreased over the same period ($P < 0.001$). From Table 3 it is clear that antibody titres correlated strongly with eachother. All correlations between antibody titres and pepsinogen values were significant, but the strength of the correlation between antibody titres against D. viviparus or against Cooperia spp. and pepsinogen value was decreased in December. LPG-GI

TABLE 2: Descriptive statistics for the serological parameters (n=89).

	SEPTEMBER 1985				DECEMBER 1985			
	mean	s.d.	min.	max.	mean	s.d.	min.	max.
Dictyocaulus titre	4.10	1.20	1.3	6.9	3.82	0.87	1.1	6.3
Cooperia titre	3.64	1.41	0.5	6.9	3.31	0.85	1.2	5.2
Ostertagia titre	5.55	1.50	1.8	8.5	5.94	0.80	4.1	7.8
Pepsinogen value	1263.1	616.5	314	3545	696.5	330.1	183	2058

correlated significantly with all serological parameters measured in September. When LPG-GI in September was related to parameters measured in December only the correlations with the antibody titres against Cooperia and Ostertagia remained significant. Herds with a positive LPG-Dv showed, compared to herds with negative counts, significantly higher antibody titres against lungworm (4.82 vs. 3.93, $P < 0.01$), and against Cooperia spp. (4.29 vs. 3.48, $P < 0.05$), and higher pepsinogen values (1451 mU vs. 1012 mU, $P < 0.01$), all measured in September.

TABLE 3: Pearson correlation coefficients for the relationships of the serological parameters with eachother within sampling periods (n=89) and with the gastrointestinal nematode larval count (LPG-GI) (n=87).

	SEPTEMBER 1985				DECEMBER 1985			
	Dict. titre	Coop. titre	Ost. titre	Pep. value	Dict. titre	Coop. titre	Ost. titre	Pep. value
Dictyocaulus titre	--	.762 ***	.715 ***	.352 ***	--	.552 ***	.655 ***	.279 **
Cooperia titre		--	.762 ***	.467 ***		--	.746 ***	.260 *
Ostertagia titre			--	.407 ***			--	.419 ***
LPG-GI	.402 ***	.519 ***	.363 ***	.529 ***	.076 NS	.314 **	.302 **	.172 NS

NS = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001 .

From Figure 2 it can be seen that growth performances up to the end of the first grazing season varied enormously between herds. HWDM ranged from -68.1 kg. to 84.1 kg. for individual herds.

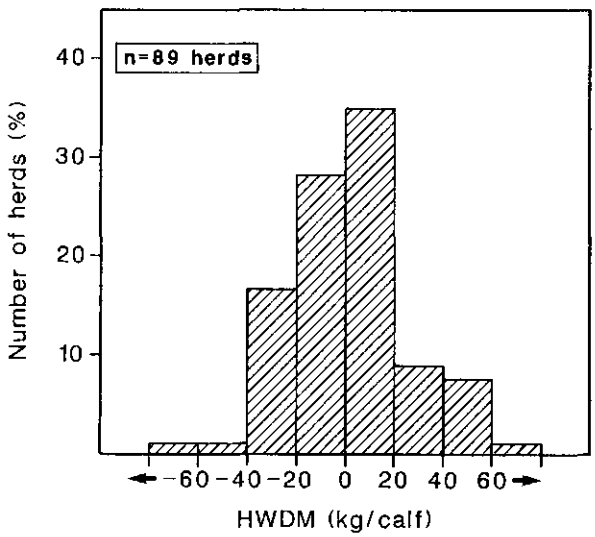


Figure 2: Frequency distribution of the mean herd weight deviations from an age-adjusted population mean (HWDM) after the first grazing season.

Several serological and parasitological parameters showed significant relations with HWDM (Table 4). The most pronounced relations were found with antibody titre against Cooperia spp. in September (r = -0.176), with LPG-GI (r = -0.258), and with antibody titre against Ostertagia spp. and pepsinogen value measured after housing (r = -0.178 and -0.178, respectively). LPG-Dv was also negatively related to HWDM recorded after the grazing season (F = 2.62, P < 0.10). Herds with more than 10 larvae/30 grams of faeces averaged a HWDM of -18.6 kg., herds with 1 to 10 larvae +0.6 kg., and zero-counts +4.5 kg.

TABLE 4: Regression of the weight deviations from the population mean measured after housing (HWDM) on the parameters estimating nematode infection (n=89).

	LINEAR REGRESSION:					SEGMENTED CURVILINEAR REGRESSION:					
	u	b	MSE_r	r^2(%)	sign.	p	x_0	c	MSE_r	r^2(%)	sign.
SEPTEMBER 1985											
Dict.titre	11.11	-2.24	682.1	1.06	NS	5.10	3.74	2.80	668.2	4.20	+
Coop.titre	13.78	-3.26	668.1	3.10	+	4.96	3.54	2.88	665.0	4.66	*
Ost.titre	11.94	-1.80	682.0	1.08	NS	4.90	3.35	0.42	688.6	1.28	NS
Pep.value	50.12	-6.89	678.5	1.59	NS	5.09	6.77	14.43	668.5	4.15	+
LPG-GI	15.31	-9.18	650.1	6.67	*	9.88	-0.02	3.06	656.2	5.93	*
DECEMBER 1985											
Dict.titre	-3.36	1.39	688.0	0.21	NS	1.49	3.35	-0.55	696.9	0.12	NS
Coop.titre	17.77	-4.79	672.9	2.41	NS	6.37	2.11	2.09	673.6	3.43	+
Ost.titre	36.66	-5.84	667.6	3.18	+	1.63	7.09	-24.55	694.7	0.40	NS
Pep.value	57.17	-8.69	667.7	3.17	+	11.45	4.59	2.78	673.2	3.48	+

All estimates are given in kg./calf per herd. For explanation of models used see section Material and Methods. MSE_r is the residual mean square error. r^2-value given for the segmented curvilinear regression was calculated by fitting observed HWDM on HWDM 'predicted' by the segmented curvilinear relation. NS = not significant; + = P<0.10; * = P<0.05 .

Despite such significant negative linear relations between infection parameters and growth performance, it may be that growth performance is only affected by parasitism if infections are above a certain threshold level. Therefore segmented curvilinear regressions were applied on the data, by which such threshold levels might be found. For some of the infection parameters the resulting 'predicted' HWDM could also significantly be fitted to the observed HWDM (Table 4). Both linear and curvilinear regression resulted in similar residual mean square errors. Linear and curvilinear regression for the relation with antibody titre against Cooperia measured in September is graphically presented in Figure 3. The threshold titre-value above which weights decrease progressively with increasing titres was 3.54 (see Table 4 and Figure 3).

Combining infection parameters (not accounting for effects of management variables) in an attempt to explain the variation in HWDM, resulted in significantly increased r^2 values. Under the conditions set by the present study, using linear relations between infection parameters and HWDM, the best model involved antibody titre against Cooperia spp., LPG-GI and LPG-Dv, all measured in September (r^2 = 9.17%, P < 0.01). When results of segmented curvilinear regression of HWDM on antibody titres were used,

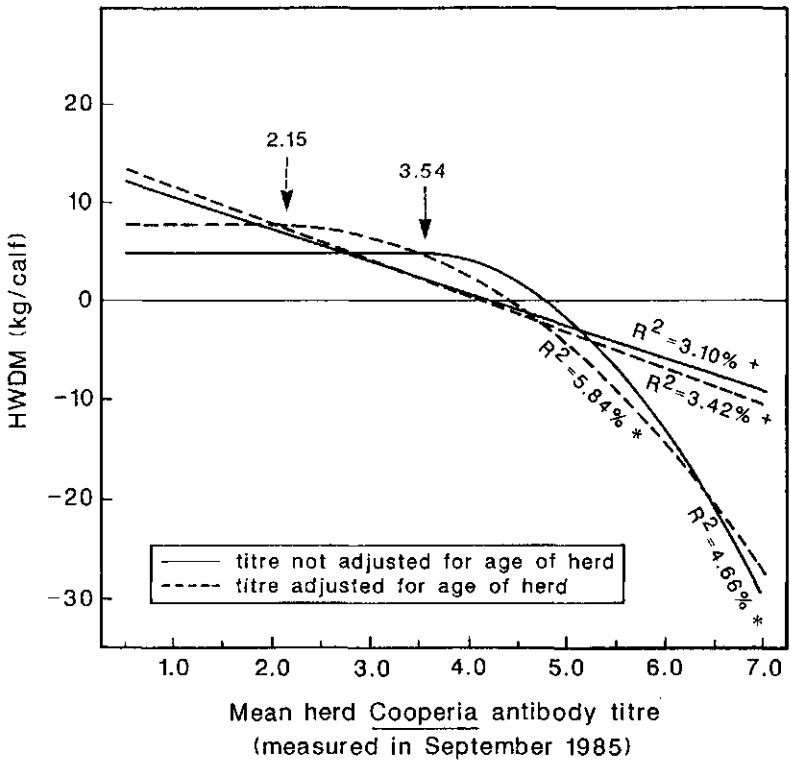
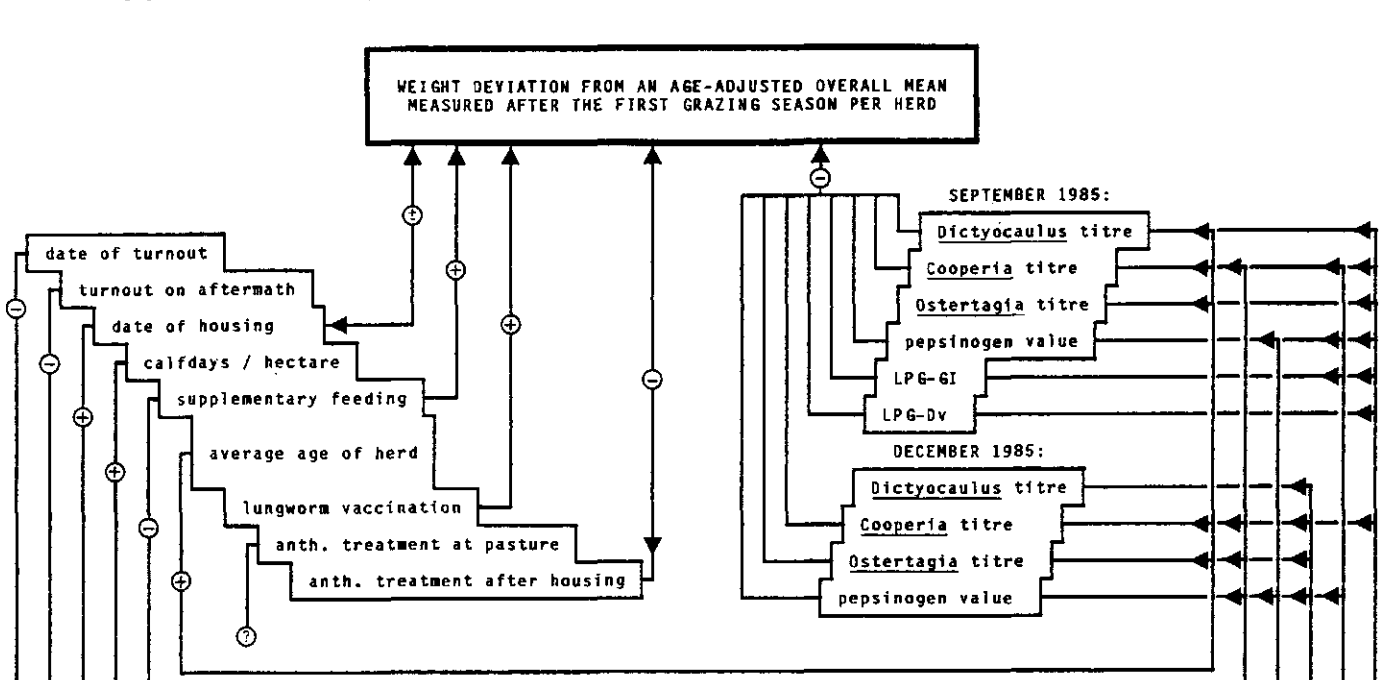


Figure 3: Linear and segmented curvilinear relationship between the mean herd weight deviation from an age-adjusted population mean (HWDM) and the mean herd antibody titre against Cooperia spp. in September.

the best model involved antibody titre against Cooperia spp. and D. viviparus as well as LPG-GI and LPG-Dv, all measured in September (r^2 = 12.62%, P < 0.001).

The significant relations between farm, herd and management characteristics and infection parameters or HWDM are given in Figure 4. Rotational grazing schemes (such as: setstocking, rotations with or without returning to earlier grazed pastures, rotations on aftermath, number of rotations etc.) did not have significant effects on either the infection parameters or HWDM. In herds housed early (n=11) or late (n=15) HWDM recorded was -12.6 kg. and -8.5 kg., respectively. HWDM recorded in the other herds averaged +7.0 kg. This difference was significant (P < 0.05). The serological parameters measured in December were also significantly related to date of housing. Housing later meant higher titres and higher pepsinogen values (P < 0.05). Per kg. of concentrate supplementarily fed at pasture, HWDM increased with 10.9 kg. (r = 0.259, P < 0.05). Supplementary feeding apparently influenced some infection parameters as well, but this effect was largely due to age of herds. Firstly, younger calves received more supplementary feeding than older animals (r = -.488, P < 0.001). Secondly, antibody titres showed significant positive correlations to age, while it could not be

Figure 4: Relationships between the mean herd weight deviations from an age-adjusted population mean (HWDM), management practices and infection parameters.



Arrows indicate the direction of a relationship, while the sign of a relationship is given by - or +.
?: no significant relations were found with 'anthelmintic treatment at pasture', but it can be assumed that this does influence the level of infection.

demonstrated that this was due to differences in date of turnout (i.e. length of grazing period). This was particularly the case with antibody titres against Cooperia spp. and Ostertagia spp. ($r = 0.364$, $P < 0.001$ and $r = 0.309$, $P < 0.01$ in September and; $r = 0.269$, $P < 0.05$ and $r = 0.230$, $P < 0.05$ in December). The relation between antibody titre against Cooperia spp. and HWDM after titres were adjusted for age of herd is shown in Figure 3. The correlation coefficient for the relation between age and antibody titre against Dictyocaulus was 0.202 ($P < 0.10$) in September and 0.124 in December (N.S.). Calves in lungworm vaccinated herds (32.6% of all herds) were 10.5 kg. heavier than those in not vaccinated herds ($P < 0.10$), but no relations could be found with the infection parameters measured. Coughing was observed more frequently in herds which were not vaccinated compared to vaccinated herds ($P < 0.05$). Herds treated with an anthelmintic at housing (44.9% of all herds) weighed 11.6 kg. less than herds not treated at housing ($P < 0.05$). The other variables mentioned in Figure 4 appeared to affect only the level of the infection parameters measured.

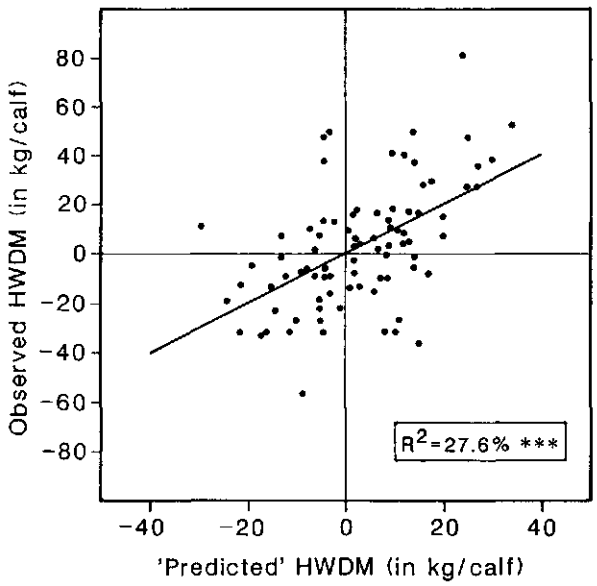


Figure 5: The correlation between observed and 'predicted' HWDM, calculated by a linear model including three infection parameters and four management factors (see text).

In Figure 5 observed HWDM is compared with the resulting 'predicted' HWDM based on a combination of infection parameters and management variables. The infection parameters involved, were: antibody titre against Cooperia, LPG-GI and LPG-Dv. Antibody titre was adjusted for age and the linear relations between infection parameters and HWDM were used. Management variables implemented, were: supplementary feeding, lungworm vaccination, treatment after housing, and date of housing. All factors

within the model were separately at least significant at the 10% level. The model explained 27.6% of the total variation in HWDM. Estimated effects on HWDM of each of the separate variables involved in the model, remained at about the same level as mentioned above. When segmented curvilinear relations between some of the infection parameters and HWDM were used 29.4% of the total variation could be explained. The variables involved were the same, except that antibody titre against D. viviparus also added to the model.

DISCUSSION

Based on existing knowledge, it was expected that nematode infections affect growth performance of calves considerably on commercial dairy farms. However, under uncontrolled field circumstances many other factors play an important role. These factors may exert effects either directly on growth performance or on level of exposure to infection or on both. For example supplementary feeding at pasture may partially compensate for the weight gain depressions caused by parasitic infections (Kloosterman, 1971; Verstegen et al., J.Anim.Sci., accepted). On the other hand it may also decrease uptake of infective larvae by a decreased herbage intake. Pasture management (e.g. stocking rates, rotational grazing systems, date of turnout and housing, grazing on aftermath) affects the level of exposure to nematode infection (Armour, 1980; Nansen et al., 1988). It can also affect growth performance directly when grass availability on pasture decreases substantially (Nansen, 1987). In the case of aftermath grazing, weight gains are improved by the availability of high quality and palatable herbage (Oostendorp and Harmsen, 1968). Such management practices present great difficulties in examining relationships between level of infection and production on commercial farms.

In the present study it was shown that a simple combination of infection parameters, all measured once in September, could explain about 9% of the variation in growth performance of calves. Apparently the combination of parameters can explain more than every single parameter can do. Parameters involved were antibody titres as well as faecal larval counts. Since egg output fluctuates more in time compared to titres, it was not expected to find a significant relationship between egg output and HWDM. Kloosterman (1971) could not demonstrate such a relationship. In 1978 and 1979 surveys were conducted on 51 and 49 dairy farms, respectively (Kloosterman et al., 1981). A significant negative correlation between egg output in late summer and growth performance was found only in 1979. A reason for these different results may be the date of turnout. Herds were turned out considerably later in 1979 compared to 1978. In the present study date of turnout was comparable to that in 1979. Antibody titre against Ostertagia spp. did not appear to contribute significantly to the combined estimation of the level of exposure. This may be due to the fact that host immunity against this nematode develops rather slowly compared to Cooperia and especially Dictyocaulus (Smith and Archibald, 1968; Pott et al., 1978). Another reason, however, is that all three nematode infections are present on almost all farms, and where conditions are favourable for one species they generally will be so for the other species. This is supported by the strength of the correlations

between the various serological and parasitological parameters. Some cross-reactivity will have been present, but this can not completely account for the strong correlations found. Keus et al. (1981) demonstrated a certain degree of genus-specificity in the antigen-antibody reactions. This is supported by the differences in strength of the correlations between pepsinogen values and titres, especially in December.

HWDM could also be fitted to some of the infection parameters by means of segmented curvilinear regression, particularly with some of the serological parameters. Although in these cases the fit between the data was slightly improved, this was statistically not significant compared to the fit obtained with linear regression. Still, it is possible that growth performance is only affected by nematode infections when these infections reach a certain threshold level. Such threshold levels should be found below levels considered as the border between subclinical and clinical infections, and above levels which can be considered too low to affect growth performance. A threshold titre-value of 3.54 for antibody titre against Cooperia appears to meet these requirements satisfactorily. However, in the present study all infection parameters (except LPG-Dv) were logarithmically transformed before used in analyses. Kloosterman et al. (1974) found a linear relationship between growth and the logarithm of the number of larvae administered. In experimental infections a linear relationship also has been found frequently between the logarithm of number of larvae administered and antibody titres resulting from such infections. On the other hand, the same authors concluded that a curvilinear relationship could have been present in their data.

With respect to management practices it was demonstrated that a distinction could be made between factors affecting growth performance and factors affecting exposure to infection. The latter were not considered relevant for a model which includes infection parameters estimating the level of exposure. However, factors affecting both level of infection and growth should be investigated more closely. For instance, supplementary feeding was found to influence both HWDM and some of the serological infection parameters. It could be established that the latter was associated with herd age. Younger calves received more supplementary feeding at pasture than older animals. Also antibody titres appeared to be related to age, independent of date of turnout, i.e. length of grazing period up to time of sampling. Some age related immunity, as measured by antibody titres, may develop in cattle. Such a phenomenon has been demonstrated in sheep with Haemonchus infections (Urquhart et al., 1966). Michel et al. (1979) demonstrated that acquired resistance to Ostertagia ostertagi developed more rapidly in 20-month-old cattle than in calves. Noteworthy here, is the fact that an effect of age could neither be demonstrated on pepsinogen values nor on faecal larval counts.

Date of housing, anthelmintic treatment at housing, and vaccination against lungworm significantly influenced growth performance. These factors did not affect the infection parameters. With respect to the lower weight gains recorded in herds housed early or treated at housing, it may be speculated that farmers took these measures in response to reduced bodily condition of the animals, and that these animals were not completely recovered by the time liveweights were recorded. Jorgensen et al. (1978), in a follow-up of the grazing experiment conducted by Henriksen et al. (1976), found higher growth rates during the housing period in groups

affected most by nematode infection during the previous grazing period compared to groups affected least. However, some of the initial liveweight differences at housing were still evident at the end of the housing period. When housed very late reduced availability of grass probably played a major role in affecting weight gains (Nansen, 1987).

In the present study lungworm vaccination appeared to prevent severe outbreaks of parasitic bronchitis, although it did not affect the infection parameters measured. Vaccinated herds were on average 10 kg. per calf heavier and, according to the questionnaire, coughed significantly less during the grazing season than unvaccinated herds. Boon (1979) showed that coughing of calves at pasture is mainly caused by lungworm infections.

Combining management factors with infection parameters, measured in September, into one model to explain the between herd variation in HWDM, increased the amount of explained variation from 9% to 28%. However, some of the involved management factors were measures taken by farmers to prevent or in response to the occurrence of nematode infections. Lungworm vaccination or not and anthelmintic treatment at housing or not exemplify this. Thus, serological and parasitological examinations, used to relate growth performance and level of exposure to nematode parasites, likely underestimate the total impact of nematode infections.

The present study, although not accounting for climatic conditions, showed that large cross-sectional surveys can produce sufficient qualitative and quantitative data to explain reduced weight gains caused by nematode infections in first-season grazing calves. The results obtained in such surveys can be used to rationalize the use of anthelmintic drugs in practice, especially in relation to the occurrence of subclinical infections, and to evaluate economic losses caused by nematode infections. More studies will be needed however. For instance to elucidate which kind of model for the relation between infection level and growth performance is more realistic, linear or segmented curvilinear regression. Comparison of both in a cost-evaluation results in quite different estimates of the annual losses caused by nematode infections (Ploeger and Kloosterman, 1988). Furthermore it appears that single infection parameters account for only part of the total impact of infections on production and that some management practices can be related to the occurrence of nematode infections accounting for again another part of that total impact. Very interesting is also what happens after the first grazing season on commercial farms during the housing period as well as the subsequent second grazing season. Several authors reported about the long lasting effects of nematode infections (Jorgensen et al., 1978; Entrocasso et al., 1986; Taylor, 1987).

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III. EFFECT OF NEMATODE INFECTIONS ON GROWTH PERFORMANCE OF CALVES AFTER STABLING ON COMMERCIAL DAIRY FARMS

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ABSTRACT

Growth performance of calves was assessed on 32 farms during winter housing. Nematode infection was measured by antibody titres, pepsinogen values, and faecal examinations. Half of each herd was treated with ivermectin after stabling. Treatment significantly increased growth rate by an average of +0.059 kg./day ($P < 0.01$). Effect of treatment varied between herds from -0.078 to +0.210 kg./day. Only a few of the infection parameters correlated weakly, but positively, to the effect of treatment on growth performance per herd. Untreated control groups showed very different growth rates between herds, ranging from 0.250 to 0.936 kg./day. This was strongly correlated to several infection parameters. Groups with the highest values for the infection parameters gained approximately 50 kg. less over a 4-month period during winter housing than groups with the lowest values for those infection parameters.

INTRODUCTION

The effects of naturally occurring nematode infections on growth performance of calves were shown to last during a subsequent stabling period (van Adrichem and Shaw, 1977; Jorgensen et al., 1978; Entrocasso et al., 1986). Some compensatory growth has been found to occur after stabling in groups of calves which were severely affected by nematode infections (Jorgensen et al., 1978). Ploeger et al. (submitted) demonstrated, in a study on 89 commercial dairy farms, that nematode parasitism significantly reduced growth performance of calves during the first grazing season. This effect was related to the level of infection calves were exposed to.

The present paper describes the effect of naturally occurring nematode infections on growth performance of calves on 32 of these 89 farms during the following housing period. Two approaches were followed: firstly, the effect of ivermectin treatment after housing on growth performance in relation to the level of exposure to nematode infection was investigated, and; secondly, the growth performance of the untreated control groups was compared between herds in relation to those levels of exposure.

MATERIALS AND METHODS

Farms and calves

Thirty-two farms, none of which applied treatment at housing, were approached to participate in the present study. All of these farms were situated around the city of Utrecht and belonged to the Veterinary Practice of the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty Utrecht. At average 9 calves were present in each herd (range: 4-18). Some other characteristics are given in Table 1. The majority of calves were of the Dutch Friesian or Holstein Friesian breed or crossbreds of these two (89.3%). About 5% of the calves were of the Meusse-Rhine-IJssel breed. Breeds were equally divided over treatment groups.

TABLE 1: Comparison of ivermectin-treated and control calves at the time of treatment.

	CONTROL GROUP	IVERMECTIN-TREATED GROUP
number of calves	147	154
age ± s.d. (days)	343 ± 92.1	332 ± 84.8
mean body weight ± s.d. (kg.)	286.8 ± 58.8	280.9 ± 60.8
mean heart girth ± s.d. (cm.)	154.1 ± 12.4	153.1 ± 12.6

Anthelmintic treatment

Half of each herd was treated with ivermectin (Ivomec®, M.S.D.Agvet) injected subcutaneously at the manufacturer's recommended dose (0.2 mg/kg liveweight). The other half was injected with vehicle solution (control group). On each farm calves were randomly allocated to the ivermectin treated or control group. Treatment was given in November/December (see Figure 1).

Measurement of growth performance

Growth performance of all calves was estimated, 1): by measuring the heart girth, i.e. circumference (cm.) of the chest directly behind the forelegs (Vos and Vos, 1967), and 2): by actually weighing calves. The latter was done on only 24 farms. Figure 1 presents the schedule of measurements. Both performance parameters were expressed as average daily gain, cm./day for heart girth (ADG-HG) or kg./day for body weight (ADG-BW), between December and March. The relevant traits investigated, were; growth performance of control calves on each farm, and the effect of ivermectin treatment. The latter was expressed as the difference between the treated and the control group in each herd. In Table 1 treatment groups are compared with eachother with respect to initial body weight, heart girth and age.

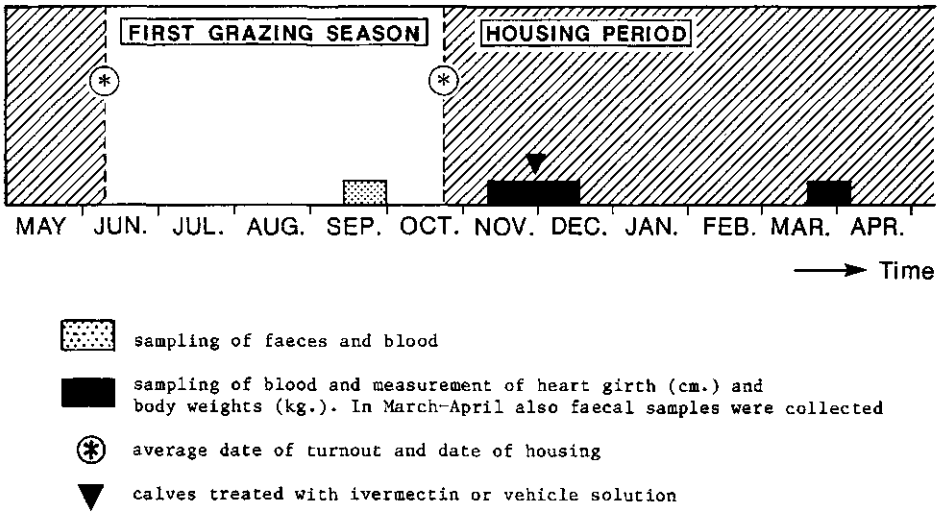

Figure 1: Sampling periods, treatments and observations relative to grazing season and housing period.

Faecal examinations

At the end of September 1985 (Figure 1) faecal samples were taken from freshly deposited pats (as many as possible) on pasture grazed by the calves. In March 1986 faecal samples were taken rectally from all calves on each farm. In September samples were thoroughly mixed per herd and per ivermectin treated or control group on each farm in March. Egg output per herd or group was estimated by counting larvae per gram faeces (LPG) after culturing, combined with larval identification (Borgsteede and Hendriks, 1973 and 1974). Presence of lungworm larvae (per 30 grams of faeces) was determined using a Baermann technique, except in March because it was not expected to find any lungworm larvae at that time.

Serological examinations

In September and December blood samples were taken from 5 randomly chosen calves per herd, where available. At the end of March all calves in each herd were sampled (see Figure 1). Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus, as well as pepsinogen values were determined using techniques described by Keus et al. (1981), Boon et al. (1982) and Berghen et al. (1987). Sera were analysed soon after each sampling period. Despite standardization procedures ELISA-tests, done in different periods, showed variation in overall levels without affecting the relative order of titres found. This was due to the use of different batches of reagents (e.g. conjugate, antigen, standard sera etc.). A separate analysis was done to allow comparisons between sampling periods.

Statistics

Data were tested for normality and, with respect to serological and growth performance data, for homogeneity of variance. Pepsinogen values were transformed according to the formula Y = ln (X). Gastrointestinal larval counts were transformed according to Y = $^{10}\log$ (X+1). All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985).

TABLE 2: Identification of larval types found in faecal samples collected in September 1985 (n=32).

	Number of herds with faecal sample containing:						Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%		
Ostertagia spp.	4	12	9	6	1	0	28	(87.5)
Cooperia oncophora	3	1	9	11	8	0	29	(90.6)
Cooperia punctata	18	14	0	0	0	0	14	(43.8)
Trichostrongylus spp.	25	7	0	0	0	0	7	(21.9)
Oesophagostomum spp.	29	3	0	0	0	0	3	(9.4)
Haemonchus spp.	30	0	0	2	0	0	2	(6.3)

Trichuris eggs were found in 2 herds. **Moniezia** spp. eggs were found in 5 herds.

TABLE 3: Identification of larval types found in faecal samples collected in March 1986 from ivermectin-treated and control groups (n=32).

	Number of herds with faecal sample containing:						Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%		
CONTROL CALVES								
Ostertagia spp.	1	18	8	3	2	0	31	(96.9)
Cooperia oncophora	3	2	5	7	15	0	29	(90.6)
Cooperia punctata	20	12	0	0	0	0	12	(37.5)
Trichostrongylus spp.	11	19	1	1	0	0	21	(65.6)
Oesophagostomum spp.	22	9	1	0	0	0	10	(31.3)
Bunostomum spp.	28	4	0	0	0	0	4	(12.5)
IVERMECTIN-TREATED CALVES								
Ostertagia spp.	20	8	2	1	1	0	12	(37.5)
Cooperia oncophora	1	1	1	2	8	19	31	(96.9)
Cooperia punctata	32	0	0	0	0	0	0	(0.0)
Trichostrongylus spp.	31	1	0	0	0	0	1	(3.1)
Oesophagostomum spp.	32	0	0	0	0	0	0	(0.0)
Bunostomum spp.	32	0	0	0	0	0	0	(0.0)

Nematodirus spp. eggs were found in 3 untreated groups and in 2 treated groups. **Moniezia** spp. eggs were found in 5 untreated groups and in 1 treated group.

RESULTS

Tables 2 and 3 present results of larval identifications in September and in March. Results for the control groups in March resembled those found in September for the whole herd. The main differences between these periods were the lower egg output recorded in March (20.7 vs. 27.3

TABLE 4: Descriptive statistics for the serological parameters and the effect of treatment on these parameters (n=32).

	SEPTEMBER 1985				DECEMBER 1985				MARCH 1986				
	mean	s.d.	min.	max.	mean	s.d.	min.	max.		mean	s.d.	min.	max.	sign. of difference
Dictyocaulus titre	4.10	1.21	1.5	6.1	3.84	0.84	1.1	5.4	C:	3.28	0.53	2.2	4.3	
									IT:	3.02	0.46	2.1	3.8	P<0.001
Cooperia titre	3.71	1.65	0.5	6.1	3.57	0.76	2.4	5.2	C:	3.23	0.71	1.4	4.8	
									IT:	2.66	0.50	1.2	3.7	P<0.001
Ostertagia titre	5.53	1.45	3.1	8.5	6.11	0.73	4.9	7.7	C:	4.88	0.79	3.4	6.5	
									IT:	4.25	0.55	3.0	5.5	P<0.001
Pepsinogen value	1315.3	563.7	577	2818	732.6	382.6	183	2058	C:	1012.0	415.5	222	1848	
									IT:	719.2	284.0	120	1189	P<0.001

C = control groups; IT = ivermectin-treated groups.

geometric mean LPG, N.S.), and that more herds were excreting eggs of the genera Trichostrongylus and Oesophagostomum. Ivermectin treatment affected egg output of all species found, except for Cooperia oncophora. 97% of the treated groups still excreted eggs of the Cooperia oncophora type. For Ostertagia spp. this was 38% compared to 97% in the control groups. Egg output in treated groups was generally lower than in control groups (av. 10.4 vs. 20.7 geometric mean LPG, $P < 0.05$). In September 7 out of 32 herds were found excreting low numbers of lungworm larvae.

Table 4 gives the results of the serological examinations. In March mean antibody titres of the control groups were significantly lower when compared to December ($P < 0.05$). Mean herd pepsinogen values were higher in March ($P < 0.01$). In March, treated groups showed lower antibody titres and pepsinogen values compared to the control groups ($P < 0.001$).

ADG-BW of control groups varied between herds from 0.250 to 0.936 kg./day (av. 0.602 kg./day). Ivermectin treated groups gained at average 0.059 kg./day more (range: -0.078 to +0.210 kg./day) during the housing period than control groups ($P < 0.01$). For heart girth effect of treatment was +0.007 cm./day ($P=0.103$).

In Table 5 regression coefficients for the relation between growth performance of untreated controls and infection parameters are given. Particularly antibody titres against Cooperia spp. and against Ostertagia spp., measured in December and March, were significantly correlated negatively with growth performance of control groups. When statistical significance was found, regression coefficients were at least -0.120 kg./day. Results obtained with heart girth measurements were in the same direction as those of the body weight recordings. Weaker relations were found between the effect of ivermectin treatment on growth performance and the infection parameters (Table 6). Only a few infection parameters tended to correlate positively to this treatment effect.

Age of the control groups was strongly correlated with ADG-HG ($r = -0.615$, $P < 0.001$), but not with ADG-BW. The effect of treatment on ADG-HG was also affected by herd age ($P < 0.10$), as opposed to treatment effect

TABLE 5: The regression coefficients of the relationships between the growth performance of the untreated control groups and the infection parameters.

	ADG-BW (kg./day)			ADG-HG (cm./day)		
	b	r^2(%)		b	r^2(%)	
SEPTEMBER 1985						
Dictyocaulus titre	-.001	0.01	NS	-.005	1.53	NS
Cooperia titre	-.013	1.27	NS	-.009	11.29	+
Ostertagia titre	-.006	0.23	NS	-.008	7.11	NS
pepsinogen value	-.168	12.68	+	-.025	5.71	NS
LPG-GI	-.080	6.26	NS	-.013	3.40	NS
DECEMBER 1985						
Dictyocaulus titre	-.011	0.20	NS	-.007	1.76	NS
Cooperia titre	-.141	28.62	**	-.019	9.83	+
Ostertagia titre	-.160	26.92	**	-.021	11.25	+
pepsinogen value	-.006	0.03	NS	-.017	4.81	NS
MARCH 1986						
Dictyocaulus titre	-.082	5.04	NS	-.018	4.53	NS
Cooperia titre	-.120	19.94	*	-.028	20.21	**
Ostertagia titre	-.140	34.09	**	-.035	38.36	***
pepsinogen value	-.147	12.34	+	-.041	23.50	**
LPG-GI	-.212	24.01	*	-.022	6.76	NS

LPG-GI: Gastrointestinal nematode larval count.
NS = not significant; + = P<0.10; * = P<0.05; ** = P<0.01; *** = P<0.001

TABLE 6: The regression coefficients of the relationships between the effect of ivermectin-treatment on growth performance and the infection parameters.

	TREATMENT EFFECT ON:					
	ADG-BW (kg./day)			ADG-HG (cm./day)		
	b	r^2(%)		b	r^2(%)	
SEPTEMBER 1985						
Dictyocaulus titre	.001	0.02	NS	.004	3.44	NS
Cooperia titre	.005	0.91	NS	.004	7.96	NS
Ostertagia titre	.013	5.77	NS	.003	2.49	NS
pepsinogen value	.077	14.99	+	.004	0.66	NS
LPG-GI	.019	1.99	NS	.003	0.84	NS
DECEMBER 1985						
Dictyocaulus titre	.013	1.64	NS	-.005	3.77	NS
Cooperia titre	.039	12.26	+	.005	2.92	NS
Ostertagia titre	.036	7.72	+	.004	1.35	NS
pepsinogen value	.019	1.93	NS	.007	3.14	NS

LPG-GI: Gastrointestinal nematode larval count.
NS = not significant; + = P<0.10

on ADG-BW. When ADG-HG was adjusted for age of herd, its regression on infection parameters resulted in almost equal estimations when compared to those of ADG-BW. This is illustrated in Figure 2 for the relation between ADG of control groups and antibody titre against Ostertagia spp. in March.

Weight deviation of calves from an age-adjusted overall mean in December, used as a covariate, did not affect the relationships between infection parameters and ADG-HG, ADG-BW or effect of ivermectin treatment on ADG.

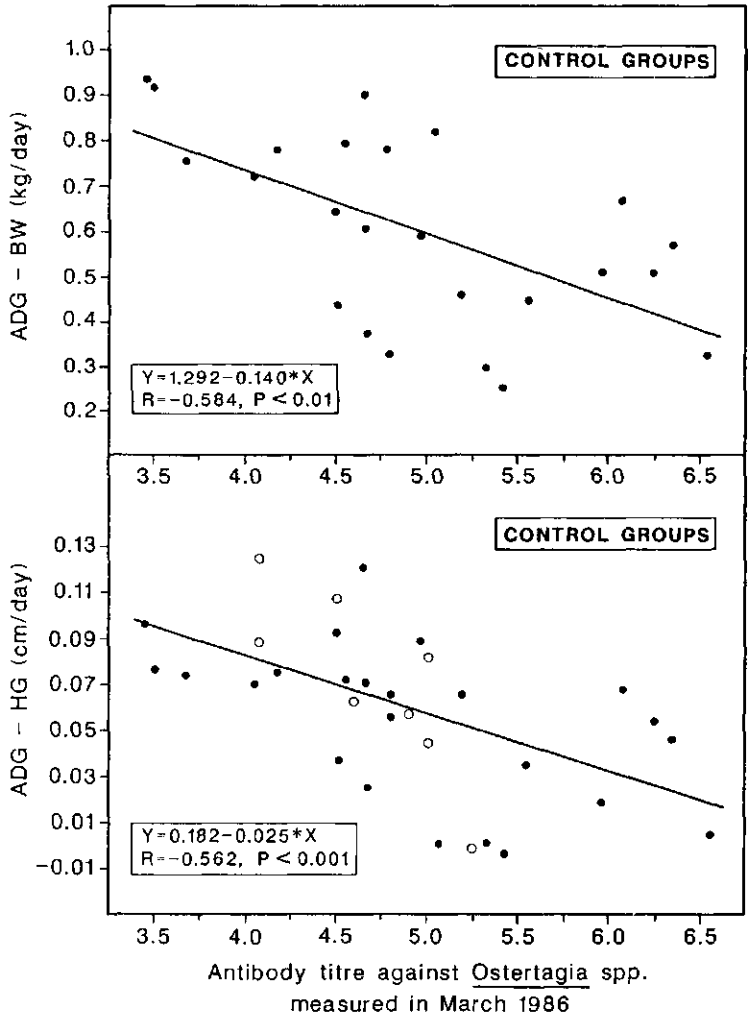

Figure 2: The regression of growth rates (ADG-BW and ADG-HG) on the mean herd antibody titre against Ostertagia spp. in March, measured in the control groups (ADG-HG is adjusted for age of calves).

DISCUSSION

From the present study it is concluded that anthelmintic treatment after housing increases average daily weight gain of calves which harboured naturally nematode infections. Similar results were reported by others (van Adrichem, 1970; Preston et al., 1983). In March treated groups and control groups differed in antibody titres, pepsinogen values, egg output and identifications of larval types, which indicated that treatment significantly reduced the level of infection in most herds. The average increase in daily weight gain, however, about +0.06 kg./day, was not impressive and only amounted to a weight gain advantage of approximately 7 kg. for treated calves over the observation period of 4 months. Ivermectin treatment increased heart girth by +0.007 cm./day. Findings of Vos and Vos (1967) and results of the present study indicated that 1 cm. of heart girth of calves, at an age of approximately 1 year, represents about 5.5 kg. body weight. Therefore, on basis of heart girth, treatment increased daily weight gain by +0.04 kg./day. Because of variability in measurements due to technical or biological errors (e.g. gut-fill), this gain is considered to be similar to the +0.06 kg./day gain based on body weight.

Between herds, the effect of anthelmintic treatment on ADG-BW varied from -0.078 to +0.210 kg./day. Only a small part of this variation could be explained by nematode infections, as shown by the weak, but positive, correlations. Possibly, interactions occurred with level and quality of feed provided on the farms. It was not possible to take these factors into account. However, Parkins et al. (1982) investigated the effect of a low protein diet on the performance of winter-housed calves which had been exposed to different levels of infection during the grazing season. In all groups they found very low growth rates, which differed only slightly between groups. A similar situation may have occurred on several farms in the present study, which may have prevented a large treatment effect on growth performance and consequently a stronger relation between this effect of treatment and the level of infection. This hypothesis is supported by the fact that control groups of herds showing the highest values for the infection parameters showed by far the lowest growth rates.

Very interesting was the enormous variation in growth performance between the untreated control groups, ranging from 0.250 to 0.936 kg./day. These growth rates correlated strongly with several infection parameters. Regression coefficients indicated that per unit increase of infection parameter growth rates declined by around 0.15 kg./day. This seems to be very high. On basis of this figure it can be calculated that groups with the highest levels of infection gained approximately 50 kg. less than groups with the lowest levels of infection.

Borgsteede et al. (1985) and Entrocasso et al. (1986) found that growth rates between groups of calves exposed to different levels of infection in the grazing season did not differ during winter housing. Tornquist and Tolling (1987), however, reported growth rates after housing which were higher in calves protected by a MSRB bolus during the grazing season, than in untreated calves. In three different years they found that weight gain advantages built up by the end of the grazing season by MSRB calves doubled during the subsequent housing period. This amounted to around +20 kg. over the housing period. In only one of these years control calves showed clinical parasitic gastroenteritis. On the other hand the same

authors could not demonstrate such differences in weight gain in three other years. The results found in the present study may have been effected by a poor plane of nutrition of calves on several farms, or conversely by excessively rich nutrition of calves on other farms (growth rates in excess of 0.8 kg./day). In view of the existing knowledge about possible detrimental effects of infection on growth it should, however, be clear that herds can suffer losses of several tens of kilograms per head during a housing period if infection levels are high. Tornquist and Tolling (1987) concluded that worm burdens consisting almost solely of arrested larvae and as low as 25,000 early L4, sufficed to reduce performance. In the present study no post-mortem studies could be done. Van Adrichem and Shaw (1977), using twin bull calves, found a difference in growth rate during winter housing of 0.126 kg/day in favour of calves treated fortnightly while pastured and at five week intervals when housed. The untreated twin calves in that study harboured only a moderate infection during the grazing season.

Finally, it was shown that measuring growth performance either by weighing calves or by measuring heart girth produced quite similar results. This finding agrees with Vos and Vos (1967), who showed the usefulness of heart girth measurements in assessing liveweights. It was necessary to adjust ADG-HG for age of calves, as opposed to ADG-BW, because final heart girth is reached earlier in life compared to final liveweights (Vos, 1969). An 1-cm increase in heart girth represents increasingly more kg. of liveweight when calves grow older.

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IV. EFFECT OF NEMATODE INFECTIONS ON GROWTH PERFORMANCE OF CALVES ON COMMERCIAL DAIRY FARMS

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ABSTRACT

Liveweight of calves on 86 dairy farms was measured at the end of the grazing season and related per herd to the level of exposure to nematode infection estimated in October and December. There were significant between herd variations in antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus as well as in pepsinogen values. On average 20.5 LPG (geometric mean) were found in October. Faecal samples of 20.5% of the herds contained lungworm larvae. Liveweight of calves deviated per herd from -59.8 kg. to +52.2 kg. from an age-adjusted population mean after their first grazing season. Growth performance was significantly related negatively to several serological and parasitological parameters. Data were fitted by means of both linear and segmented curvilinear regression. By combining infection parameters 19% of the variation in growth performance between herds could be explained. Infection parameters involved were antibody titre against Cooperia spp., egg output and lungworm larval count. It was found that antibody titres were significantly correlated positively to herd age, while pepsinogen values and egg output were negatively correlated to age. Combining supplementary feeding and anthelmintic treatment during the grazing season with the infection parameters into one model explained approximately 30% of the observed variation in growth performance between herds. It was shown that these findings were consistent with those of a similar study conducted on the same farms a year earlier, although there were clear differences between the years. Finally, significant positive relations were found between the levels of exposure to nematode parasites within farms between two consecutive years.

INTRODUCTION

In a cross-sectional survey, conducted in 1985 and involving 89 dairy farms, significant relations were demonstrated between growth performance of calf-herds and their exposure to nematode parasites (Ploeger et al., submitted). This investigation also showed the feasibility of cross-

sectional surveys on commercial farms as a means to collect useful data to evaluate economic losses caused by nematode infections, and to rationalize control strategies. This study was repeated on 86 of these farms in 1986, to investigate; 1) whether the relations found in 1986 would be consistent with those found in 1985, 2) the differences between two years, and 3) whether high or low levels of exposure to nematode parasites per farm continued over the years.

The present paper describes the results of this repeated study.

MATERIALS AND METHODS

Because the present study was basically the same as the study of Ploeger et al. (submitted), the reader is referred to that earlier 1985 study for detailed information about materials and methods used. The following sections are mainly restricted to the information about materials and methods which were different from that previous study. Where appropriate, reference is made to the used techniques and to the statistical analyses applied.

Sampling periods

Figure 1 presents schematically the timing of measurements relative to the grazing season and the housing period. Both sampling periods started two weeks later in 1986 than in 1985.

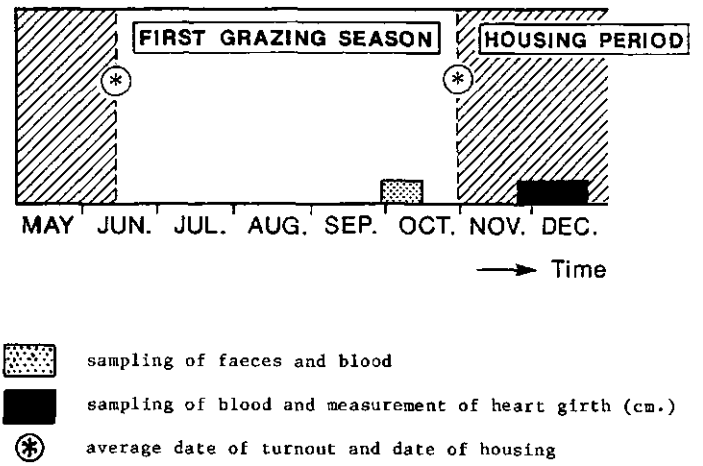


Figure 1: Sampling periods and observations relative to grazing season and housing period.

Measurement of growth performance

After the first grazing season liveweight of all calves of the 86 herds was only assessed by measuring the heart girth, i.e. the circumference (cm.) of the chest directly behind the forelegs (Vos and Vos, 1967). In the previous year it was shown that heart girth was strongly correlated to body weight, confirming the findings of Vos and Vos (1967). Estimated weights, based on heart girth, were adjusted for age and breed of the calves and per herd expressed as the deviation from the overall population mean (HWDM = Herd Weight Deviation from the population Mean).

Faecal and serological examinations

Egg output was estimated by counting gastrointestinal nematode larvae per gram faeces (LPG-GI) after culturing, combined with larval identification (Borgsteede and Hendriks, 1973, 1974). Lungworm larvae, if present, were counted (per 30 grams of faeces) (LPG-Dv) using a Baermann-technique.

Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus, and pepsinogen values were determined as described earlier by Keus et al. (1981), Boon et al. (1982) and Berghen et al. (1987). A separate analysis was done to allow comparisons of antibody titre levels between sampling periods and between the years 1985 and 1986.

Management practices

Each farmer was asked to complete a questionnaire about farm, herd and general management to see whether radical changes in management had occurred in 1986 compared to 1985 and to obtain data specifically concerning the 1986 grazing season.

Meteorological data

Data about the weather conditions, which prevailed in 1985 and 1986, were obtained from annual reports of the Royal Dutch Meteorological Institute (K.N.M.I., 1986, 1987). These data are only used in the Discussion, where appropriate.

Calculations and statistics

The same calculations were performed as in the 1985 study. Pepsinogen values were transformed according to the formula $Y = \ln(X)$. LPG-GI was transformed according to $Y = {}^{10}\log(X+1)$. LPG-Dv was classified, because of a non-normal distribution which included many zero-counts.

All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985), with herd as the experimental unit. The 10% level was considered as the threshold level for significance. It was attempted to collect faeces and blood samples in each herd in all periods. Due to practical circumstances this was not always possible and therefore the number of herds used in analyses may vary. Analysis of the data followed the same steps as used in the 1985 study, which shortly were;

I. Effect of each single infection parameter on HWDM was analysed by

means of both linear and segmented curvilinear regression. In case of non-continuous data analysis of variance was used. The next step attempted to fit infection parameters into one model. For ease of interpretation no interactions between infection parameters were investigated.

II. Relationships between management variables and either HWDM or the infection parameters were investigated by means of linear regression or analysis of variance. Effect of interactions between different management variables as well as effect of interactions between management variables and infection parameters on HWDM were evaluated also.

III. Finally, it was attempted to combine infection parameters and management variables into one model, to explain the observed variation in HWDM between herds. To facilitate interpretation only two-way interactions were evaluated.

In addition to these steps, in which data concerning the 1986 grazing season were analysed, relations between the levels of exposure to nematode parasites in 1985 and those in 1986 were investigated.

RESULTS

Table 1 presents the results of the larval identifications. The predominant species were of the Ostertagia and Cooperia oncophora type. In 8.8% of the herds no gastrointestinal nematode larvae were found. Note that 17 herds (21.3%) excreted Nematodirus eggs. On average a geometric mean of 20.5 LPG-GI were present. Actual LPG-GI varied between 0 and 801 LPG. In faecal samples of 16 herds (20.5%) lungworm larvae were found with a maximum of 420 larvae per 30 grams of faeces.

TABLE 1: Identification of larval types found in faecal samples collected in October 1986 (n=80).

	Number of herds with faecal sample containing:					Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%	
Ostertagia spp.	15	27	21	8	6	3	65 (81.3)
Cooperia oncophora	13	7	17	15	22	6	67 (83.8)
Cooperia punctata	47	29	2	2	0	0	33 (41.3)
Trichostrongylus spp.	54	24	1	1	0	0	26 (32.5)
Oesophagostomum spp.	78	2	0	0	0	0	2 (2.5)
Haemonchus spp.	71	7	2	0	0	0	9 (11.3)
Bunostomum spp.	79	1	0	0	0	0	1 (1.3)
Strongyloides papillosus	79	1	0	0	0	0	1 (1.3)

Nematodirus spp. eggs were found in 17 herds. **Trichuris** eggs were found in 1 herd.

Table 2 shows that antibody titre against Cooperia spp. decreased between October and December ($P < 0.001$). Antibody titres against Ostertagia spp. and D. viviparus increased slightly during this period (NS). Pepsinogen values decreased over the same period ($P < 0.01$). From Table 3 it is clear that antibody titres correlated strongly with eachother. Almost all correlations between antibody titres and pepsinogen values were significant. LPG-GI correlated significantly with most serological parameters.

TABLE 2: Descriptive statistics for the serological parameters.

	OCTOBER 1986 (n=81)				DECEMBER 1986 (n=86)				sign. of difference between periods
	mean	s.d.	min.	max.	mean	s.d.	min.	max.	
Dictyocaulus titre	3.96	1.31	1.2	7.1	4.09	0.88	2.0	5.7	NS
Cooperia titre	3.25	1.26	0.3	6.2	2.78	1.10	0.1	6.0	***
Ostertagia titre	5.40	1.52	2.0	8.2	5.64	1.03	2.7	8.6	NS
Pepsinogen value	1186.6	499.5	263	3559	1069.7	546.9	263	2926	**

TABLE 3: Pearson correlation coefficients for the relationships of the serological parameters with eachother within sampling periods and with the gastrointestinal nematode larval count (LPG-GI).

	OCTOBER 1986 (n=81)				DECEMBER 1986 (n=86)			
	Dict. titre	Coop. titre	Ost. titre	Pep. value	Dict. titre	Coop. titre	Ost. titre	Pep. value
Dictyocaulus titre	--	.807 ***	.878 ***	.283 *	--	.562 ***	.475 ***	.221 *
Cooperia titre		--	.819 ***	.302 **		--	.556 ***	.290 **
Ostertagia titre			--	.310 **			--	.119 NS
LPG-GI	.165 NS	.258 *	.230 *	.286 *	.265 *	.403 ***	.299 **	.140 NS

NS = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001 .

Herds with a positive LPG-Dv showed, compared to LPG-Dv negative herds, higher antibody titres against lungworm (4.40 vs. 3.79, $P < 0.10$), against Cooperia spp. (3.58 vs. 3.16, NS), against Ostertagia spp. (6.23 vs. 5.14, $P < 0.05$), higher pepsinogen values (geometric means: 1287 mU vs. 1005 mU, $P < 0.05$), and a higher egg output (geometric means: 50.7 vs. 16.5 LPG-GI, $P < 0.05$) in October. In December herds which had a positive LPG-Dv in October still showed significantly higher antibody titres against lungworm (4.55 vs. 3.93, $P < 0.05$) and against Cooperia spp. (3.25 vs. 2.68, $P < 0.10$).

From Figure 2 it can be seen that growth performance up to the end of the first grazing season varied enormously between herds ($F = 7.11$, $P < 0.001$). HWDM ranged from -59.8 kg. to 52.2 kg. HWDM was significantly related to several serological and parasitological parameters (Table 4). The most pronounced relationships were found with antibody titre against Cooperia spp. in October ($r = -0.226$), and with LPG-GI ($r = -0.253$). Segmented curvilinear regressions resulted also in significant relations between HWDM and the infection parameters with generally higher r^2-values compared to the linear relations (see Table 4). Linear and curvilinear regression is illustrated in Figure 3 for the relation between HWDM and the antibody titre against Cooperia spp. in October. HWDM was also negatively related to LPG-Dv ($F = 6.62$, $P < 0.01$). Herds with more than 10 larvae/30 grams of faeces averaged a HWDM of -27.6 kg (n=7), with 1 to 10 larvae -4.8 kg. (n=9), and zero-counts +3.2 kg. (n=62).

Combining infection parameters into one model to explain the variation in HWDM, resulted in significantly increased r^2-values. Using linear relations, the best model involved antibody titre against Cooperia spp. as

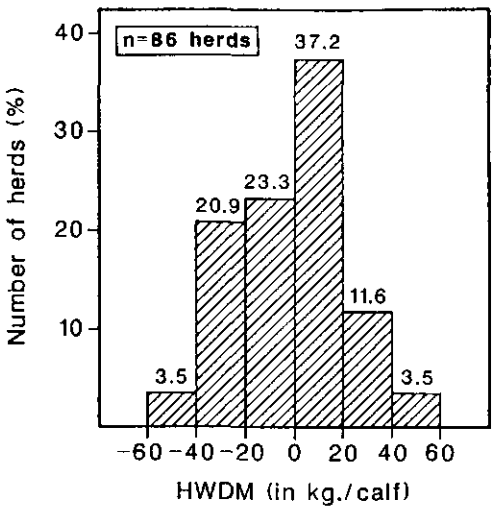


Figure 2: Frequency distribution of the mean herd weight deviations from an age-adjusted population mean (HWDM) after the first grazing season.

TABLE 4: Regression of the weight deviations from the population mean measured after housing (HWDM) on the parameters estimating nematode infection per herd.

	LINEAR REGRESSION:					SEGMENTED CURVILINEAR REGRESSION:					
	u	b	MSE_r	r^2(%)	sign.	p	x_0	c	MSE_r	r^2(%)	sign.
OCTOBER 1986 (n=81)											
Dict.titre	12.67	-3.32	503.6	3.68	+	3.33	2.24	0.83	507.9	4.10	+
Coop.titre	12.80	-4.08	496.0	5.13	*	3.10	2.69	2.31	493.2	6.86	*
Ost.titre	13.75	-2.64	506.6	3.10	NS	2.98	4.65	1.46	501.1	5.37	*
Pep.value	52.21	-7.56	512.5	1.97	NS	3.76	6.34	7.71	511.5	3.42	+
LPG-GI	9.36	-7.76	492.6	6.42	*	0.38	2.39	137.80	504.8	5.34	*
DECEMBER 1986 (n=86)											
Dict.titre	10.43	-2.67	517.8	1.07	NS	0.88	4.68	14.31	519.0	2.03	NS
Coop.titre	7.19	-2.77	514.1	1.78	NS	1.81	2.82	4.00	489.3	7.63	*
Ost.titre	0.26	-0.13	523.4	0.00	NS	-1.14	6.90	-12.43	512.1	3.33	+
Pep.value	15.70	-2.39	521.4	0.39	NS	1.56	5.59	1.16	527.4	0.43	NS

All estimates are given in kg./calf per herd. For explanation of models used see section Material and Methods. MSE_r is the residual mean square error. r^2-value given for the segmented curvilinear regression was calculated by fitting observed HWDM on HWDM 'predicted' by the segmented curvilinear relation. For LPG-GI n=80. NS = not significant; + = P<0.10; * = P<0.05 .

well as LPG-GI and LPG-Dv (r^2 = 18.6%, $P < 0.001$), all measured in October. Using these same infection parameters, but replacing the linear relation between HWDM and antibody titre against Cooperia by the segmented curvilinear relation, the r^2-value became 21.0% ($P < 0.001$).

The farm, herd and management characteristics which were significantly (at least $P < 0.10$) related to the infection parameters or to HWDM are

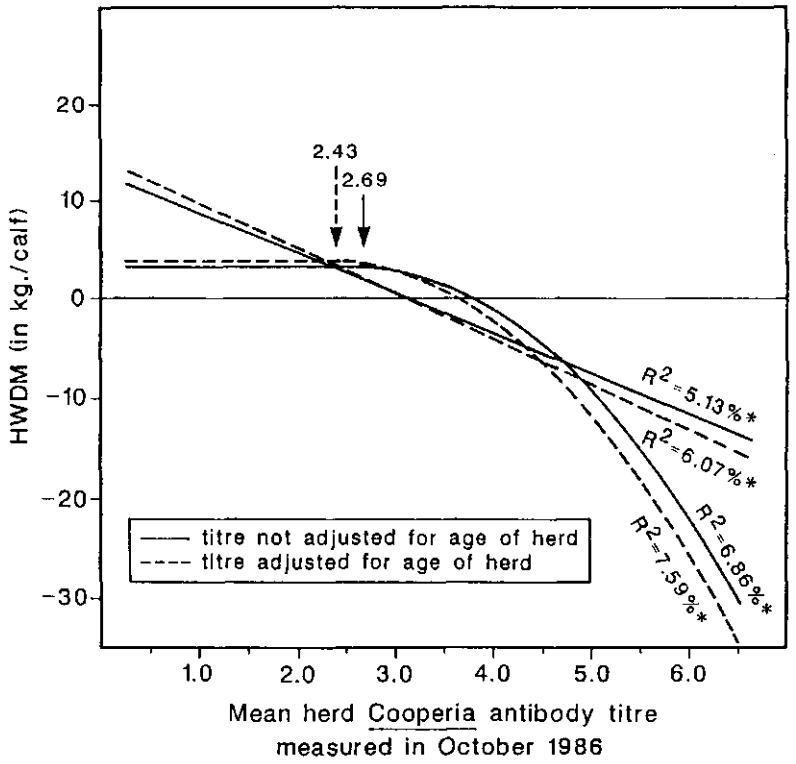
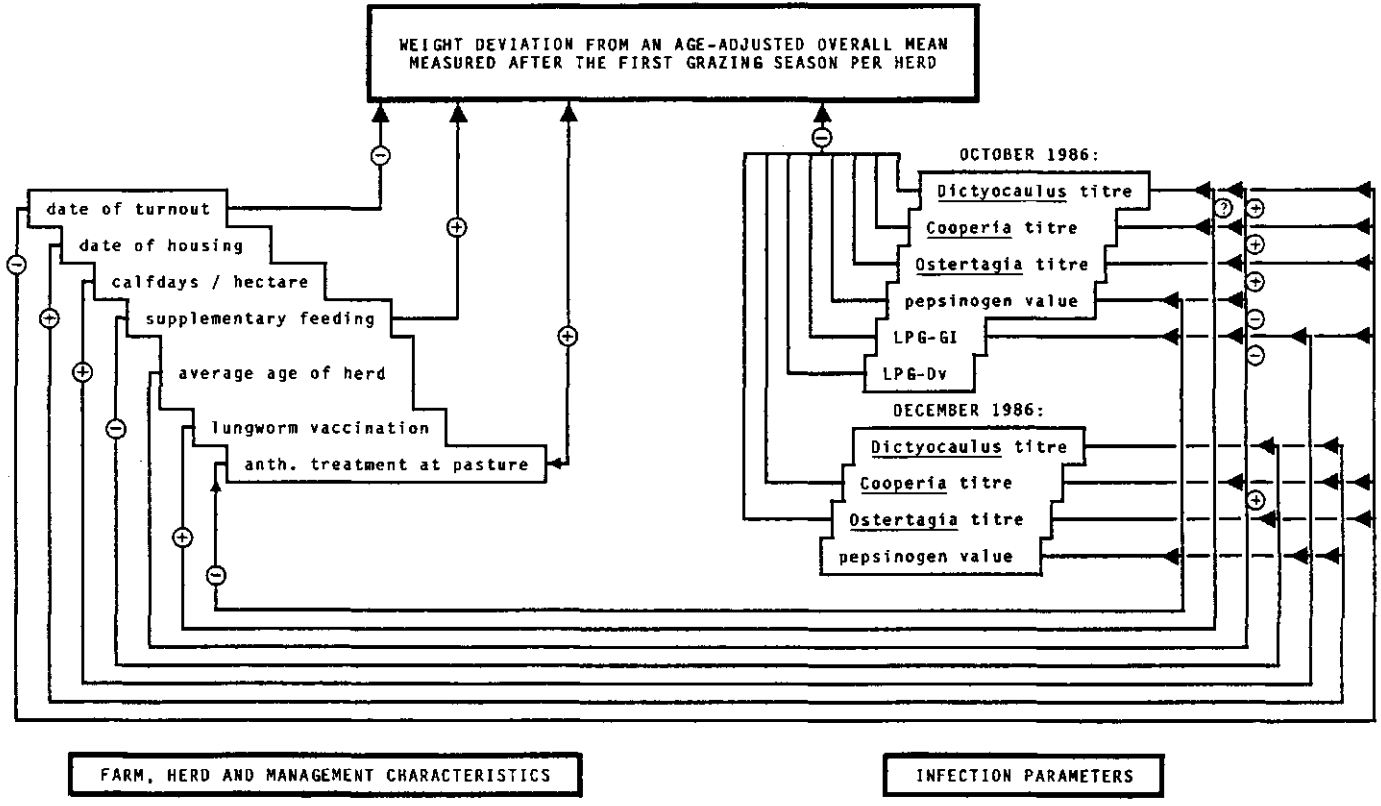


Figure 3: Linear and segmented curvilinear relationship between the mean herd weight deviation from an age-adjusted population mean (HWDM) and the mean herd antibody titre against Cooperia spp. in October.

given in Figure 4. Some of the management practices given in Figure 4 were not significantly related to HWDM in 1986 as opposed to 1985. Calves in herds housed early (9.8% of the herds) weighed 4.0 kg. less than calves in herds housed from October to mid-November (53.7%) and 10.0 kg. less than calves in herds housed after mid-November (36.6%). Calves in lungworm vaccinated herds (26.5% of the herds) weighed 8.1 kg. less than calves in not vaccinated herds. Herds treated after housing (37.3% of the herds) weighed 3.7 kg./calf more than herds not treated after housing. All these differences were not significant. However, herds housed early were more frequently treated after housing than herds housed later (75.0% vs. 33.8%, $P < 0.05$). Coughing of calves was observed more frequently in herds not vaccinated ($P < 0.05$). Herds in which coughing was observed, were more frequently treated after housing ($P < 0.05$) and were also more frequently treated at pasture ($P < 0.001$).

HWDM decreased with a later date of turnout ($P < 0.10$). Herds treated with an anthelmintic at pasture weighed 16.9 kg. more than herds not treated during the grazing season ($P < 0.001$). Herds turned out earlier were more frequently treated at pasture than herds turned out later ($P < 0.01$). HWDM increased with 8.2 kg. per kg. of concentrates supplementarily

Figure 4: Relationships between the mean herd weight deviation from an age-adjusted population mean (HWDM), management practices and infection parameters.



Arrows indicate the direction of a relationship, while the sign of a relationship is given by - or +.
?: the effect of lungworm vaccination on antibody titre against Dictyocaulus was not significant, but vaccinated herds had clearly higher titres. Herd-age was both negatively and positively related to the infection parameters, which is shown in the right half of the figure for each infection parameters separately.

fed to each calf during the grazing season ($r = 0.235$, $P < 0.05$). Younger herds received more supplementary feeding than older herds ($P < 0.01$).

The mentioned management practices were all significantly related to infection parameters, including those practices which were related directly to growth performance (see Figure 4). However, no statistically significant interaction terms were found. Figure 5 demonstrates the effect of anthelmintic treatment during the grazing season on the relation between antibody titre against Cooperia and HWDM. Regression coefficients differed ($b = -1.29$ for herds treated at pasture vs. $b = -5.05$ for herds not treated), but this was not significant. Figure 5 also shows the clear effect of anthelmintic treatment at pasture on HWDM.

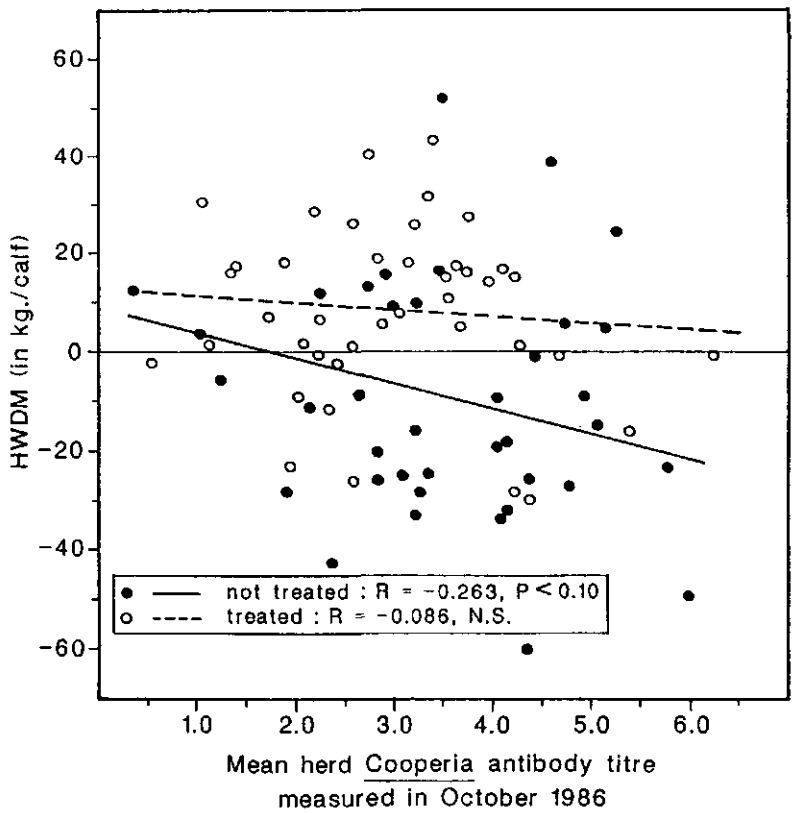


Figure 5: Effect of anthelmintic treatment during the grazing season on the mean herd weight deviation from an age-adjusted population mean (HWDM) and the effect of this treatment on the linear relation between HWDM and the mean herd antibody titre against Cooperia in October.

Antibody titres were correlated positively to herd-age (titre against Dictyocaulus, $r = 0.245$, $P < 0.05$; Cooperia, $r = 0.268$, $P < 0.05$; Ostertagia, $r = 0.194$, $P < 0.10$; see Figure 4), independent of length of grazing period up to time of sampling. Pepsinogen values and LPG-GI were

correlated negatively to age of herd ($r = -0.179$, $P = 0.109$; $r = -0.236$, $P < 0.05$; respectively). The effect of herd-age on the relation between antibody titre against Cooperia spp. and HWDM is shown in Figure 3.

Combining infection parameters (measured in October) and management characteristics into one model explained about 30% of the variation in HWDM. Variables included were antibody titre against Cooperia, LPG-GI, LPG-Dv, supplementary feeding and anthelmintic treatment at pasture. For the infection parameters linear relations with HWDM were assumed and antibody titre and LPG-GI were adjusted for age. In Figure 6 the 'predicted' HWDM, calculated by this model, is fitted to the observed HWDM. The separate effects of the variables used in the model on HWDM, after adjustment for the effects of the other variables, remained at about the same magnitude as mentioned above. Replacing the linear relation between antibody titre against Cooperia and HWDM by the segmented curvilinear relation did not change these results significantly.

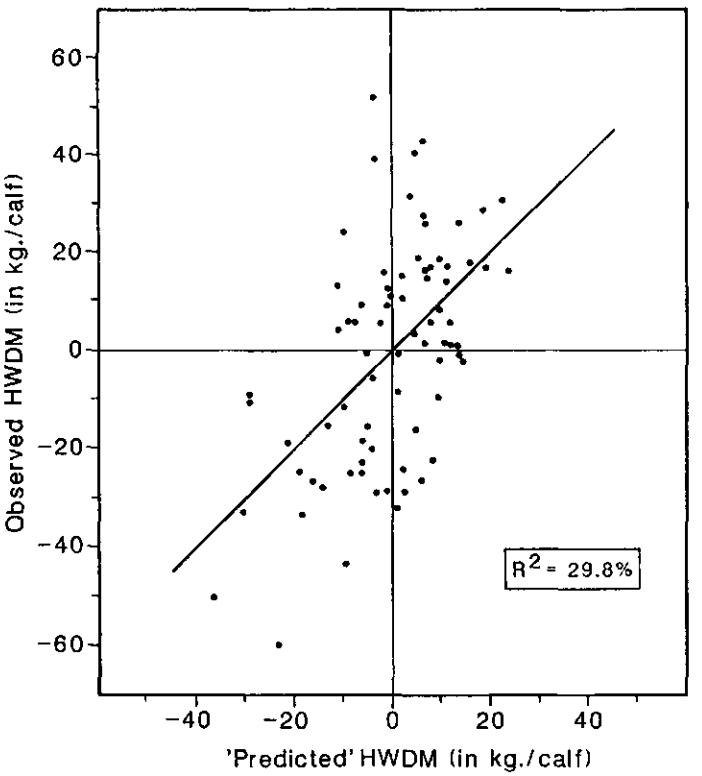


Figure 6: The correlation between observed and 'predicted' HWDM, calculated by a linear model including three infection parameters and four management factors (see text).

TABLE 5: Pearson correlation coefficients for the relations between the infection parameters measured in 1986 and the same parameters measured in 1985 on the same farms.

	OCTOBER 1986					DECEMBER 1986			
	Dict. titre	Coop. titre	Ost. titre	Pep. value	LPG-GI	Dict. titre	Coop. titre	Ost. titre	Pep. value
SEPTEMBER 1985	.241 *	.284 *	.050 NS	.155 NS	.419 ***	.189 +	.337 **	.351 **	.110 NS
DECEMBER 1985	-.202 +	-.010 NS	-.235 *	.133 NS	--	-.177 NS	.135 NS	.018 NS	.400 ***

NS = not significant; + = P < 0.10; * = P < 0.05; ** = P < 0.01; *** = P < 0.001

The correlation coefficients for the relations between the infection parameters measured in 1985 and those measured in 1986 are given in Table 5. The relations between the parameters measured in September 1985 and those in 1986 were positive and stronger than those between the parameters measured in December 1985 and those of 1986. Furthermore, it was found that all serological parameters in September 1985 were significantly correlated positively to LPG-GI in October 1986. No significant relation for LPG-Dv between both years was found.

Analysis of variance revealed that the main effects sampling period (within year) and year were significant in the case of antibody titre against Cooperia and pepsinogen value. For the latter the interaction term between sampling period and year was also significant. Antibody titre against Cooperia was lower in the December periods compared to September 1985 or October 1986 ($P < 0.10$), and titres were lower in 1986 than in 1985 ($P < 0.05$). Pepsinogen values were higher in 1986 compared to 1985 ($P < 0.001$). This was due to the fact that pepsinogen values did not decrease significantly between October and December 1986, whereas they did between September and December 1985.

On 37.5% of the farms where coughing was observed in the calf-herd during the 1985 season, coughing was also observed in the 1986 season. On 11.9% of the farms where no coughing was observed in 1985, coughing was observed in 1986. These percentages differed significantly ($P < 0.01$). In 1985 coughing was observed on 48.8% of the farms and in 1986 on 24.4%.

Of the farmers who vaccinated their calves against lungworm in 1985, 55.6% vaccinated also in 1986. Of the farmers who did not vaccinate in 1985, 12.7% vaccinated their calves in 1986. These percentages were significantly different ($P < 0.001$).

On 74.4% of the farms where calves were treated with an anthelmintic drug at pasture during 1985, calf-herds were also treated at pasture during 1986. On 23.3% of the farms where herds were not treated at pasture during 1985, calf-herds were treated at pasture during 1986. These percentages differed significantly ($P < 0.001$). A similar result was found for the management practice 'treatment at housing' (52.8% and 23.9%, respectively; $P < 0.01$).

Analysis of variance revealed that the levels of the infection parameters measured in the 1986 season did not differ significantly between farms where calf-herds were vaccinated both in 1985 and in 1986 and farms where herds were vaccinated in only one of these years or where no

vaccinations were given in both years. A similar result was obtained when this was analysed for the management practices 'anthelmintic treatment at pasture' or 'anthelmintic treatment after housing'.

HWDM of calf-herds recorded after the 1986 season was significantly correlated positively to HWDM of calf-herds on the same farms recorded after the 1985 grazing season ($r = +0.580$, $P < 0.001$).

DISCUSSION

In the present study 30% of the variation in growth performance (HWDM) could be explained by combining three infection parameters and two management variables. The infection parameters were measured in October, while most herds were still pastured. Parameters involved were antibody titre against Cooperia, LPG-GI and LPG-Dv. Management practices contributing to the explained variation were supplementary feeding and whether calves were treated at pasture or not. Generally, these results as well as the enormous variation found in HWDM between herds confirmed the findings of Ploeger et al. (submitted). Kloosterman et al. (1981) found similar between herd variations in HWDM in two surveys, conducted in 1978 and 1979, from as low as -80 kg. to +40 kg.

There were, however, differences between the results of the 1986 study and the comparable 1985 study. Differences with respect to occurrence and level of exposure to nematode parasites were; 1) somewhat lower antibody titres in 1986, the difference being significant in the case of antibody titre against Cooperia; 2) pepsinogen values were significantly higher in December 1986 than in the comparable period of 1985; 3) in 1986 17 herds (21.3%) excreted Nematodirus eggs, as opposed to only one herd (1.1%) in 1985, while in 1986 sampling started about two weeks later; 4) in 1985 strong correlations were found between LPG-GI and the serological parameters, while in 1986 these correlations were much weaker; 5) correlations between antibody titres and pepsinogen values were also weaker in 1986 than in 1985; 6) in 1986 an average geometric mean LPG-GI of 20.5 was found with a maximum of 801 LPG-GI, compared to 28.4 and 740 in 1985; 7) the relationship between LPG-Dv and antibody titre against Dictyocaulus was less pronounced in October 1986 than in September 1985, while only in 1986 a significant relationship existed between LPG-Dv and Dictyocaulus titre in December; 8) in 1985 coughing was observed on 48.8% of the farms and in 1986 on 24.4%.

These differences, generally, indicate that in 1986 infections occurred later in the grazing season when compared to 1985, and that accordingly sampling, though at average two weeks later in 1986, took place relatively earlier in the sequence of the seasonal infection pattern. This is possibly reflected in the stronger relationships found between infection parameters and HWDM (r^2 = 19% in 1986 vs. 9% in 1985, with in both years the same infection parameters involved).

The weather conditions recorded in 1985 and 1986 strongly support the idea of a later occurrence of infections in the 1986 season compared to the 1985 season. In 1985 a wet summer and a dry autumn were recorded. Particularly during the months June and August rainfall was above average. Temperatures, on average, did not deviate much from those normally recorded. In 1986, however, a prolonged dry period was recorded between

mid-June and mid-August. Temperatures recorded in June and July were also higher than normal. September 1986 was a very cold month.

With respect to management practices two variables were found to influence HWDM significantly in 1986. One of these, i.e. anthelmintic treatment at pasture, can be regarded as strongly related to nematode infections. However, it was surprising to find that where calves were treated at pasture growth performance was significantly better. Such treatments are often given therapeutically, rather than preventively. There was no indication that this practice was different on the farms investigated in the present study. Kloosterman et al. (1981) found that herds treated at pasture weighed 21 kg. and 20 kg. less at the end of the first grazing season in two similar surveys. Ploeger et al. (submitted) did not find significant differences in the 1985 season. On the other hand, treatments given to prevent the build-up of high levels of pasture infectivity have been shown to prevent substantial weight gain losses (Jones, 1981; Armour et al., 1981; Borgsteede et al., 1981; Thomas and Bell, 1988; Eysker et al., 1988). The results of the present study, therefore, suggest that the treatments given at pasture, unintentionally or not, did prevent the build-up of a high pasture infectivity.

Partly because of the relatively late seasonal build-up of larval availability on pasture in 1986, the effect of treatment on HWDM may have been confounded with an effect of lungworm vaccination. Calves at pasture were treated mainly because coughing was observed and less because of weight gain depressions, which in case of subclinical infections are scarcely recognized by farmers. The latter also helps to explain why no statistically significant interactions between treatments and infection parameters were found. Assuming that pasture infectivity during the first part of the grazing season was low in 1986, boostering of immunity against lungworm may have been less than in the preceding year, when vaccinated herds gained significantly more than unvaccinated herds. When larval challenge increased, vaccination did prevent clinical outbreaks, judged by the low coughing frequency observed, but acquired immunity was not sufficient to prevent some weight gain depressions. On the other hand, in unvaccinated herds, suffering from lungworm infections, anthelmintic treatment was given cutting off further infections and in addition controlling the build-up of high pasture infectivity with respect to gastrointestinal nematode infections. These factors may all have contributed to the fact that calves in vaccinated herds weighed 8.1 kg. less than calves in unvaccinated herds, a result that was opposite to that observed in 1985.

The second management practice significantly influencing HWDM was supplementary feeding. In 1985 it was found that one kg. of concentrates per calf per day supplementarily fed during the grazing season, significantly increased the HWDM with 10.9 kg. In the present study this was 8.2 kg. No interactions were found with infection parameters nor were there any consistent relations between the amount of concentrates fed and the infection parameters. This suggests that in practice the effects of supplementary feeding and the level of exposure on HWDM are additive and that supplementary feeding will be given rather independently of the occurrence of nematode infections. In the present study as well as in 1985 (Ploeger et al., submitted) it was found that younger calves received more supplementary feeding than older calves. Kloosterman et al. (1981) found

that condition scores depend on the age of calves. Younger calves are generally scored as poor, which may be the reason for the fact that more supplementary feed is given to younger animals.

Other management practices were not significantly related to HWDM. However, some of these may influence infection levels or, reversely, may be influenced by the occurrence of infections. For instance HWDM, although not significant, differed with date of housing in the present study. Of the early housed herds 75% were treated at housing as opposed to 34% of herds housed later. Early housed herds did weigh 4 to 10 kg. less than the other herds. A similar result was obtained in 1985.

Age of herd was significantly correlated to all infection parameters measured in October, except LPG-Dv. Antibody titres increased with age, while pepsinogen values and LPG-GI decreased with age. This supports the idea of an age-related development of immunity. Ploeger et al. (submitted) also found significant positive correlations between age and antibody titres. Michel et al. (1979) demonstrated that acquired resistance developed more rapidly in older than in younger calves. Smith (1970) found that 15-month-old yearlings showed a greater resistance to gastrointestinal nematode parasitism compared to 3-month-old calves. When infection parameters were adjusted for age, the negative relationships between these parameters and HWDM became stronger (see Figure 3).

Both linear and segmented curvilinear regression could be used to fit HWDM to infection parameters. Which model should be regarded as the most realistic one was discussed previously (Ploeger et al., submitted). On statistical grounds there are no clear objections against the use of linear models. Biologically the question remains whether it is realistic to assume that growth depressions per unit of infection parameter (e.g. per titre-unit) will be the same at very low levels as at high levels. This is also important for the development of control strategies to prevent production losses caused by nematode infections. Donald (1985) stated that it is not necessary, perhaps even undesirable, to reduce infection rates to the lowest possible level because of threshold levels of infection below which production losses are not readily measurable. Control strategies should be based on cost-benefit evaluations of expected returns, not only on a short term basis but also based on returns achieved on longer terms. Ploeger and Kloosterman (1988) showed that estimates of economic losses when based on segmented curvilinear relations were much lower compared to estimates based on linear relations. They also showed preliminary results indicating the importance of a development of acquired immunity in the first grazing season with respect to growth performance in the second season.

Another important aspect to consider is whether high or low levels of exposure continue within a farm over the years, i.e. whether nematode parasitism on farms is a structural problem or not. A structural nature of the problem is conceivable, because of the use of permanent pastures on commercial dairy farms and the capability of infective larvae to overwinter on pasture. Carrier-animals may also play a role when first-season grazing calves are grazed on pastures grazed by older cattle. In the present study significant positive correlations were found between levels of exposure to nematode parasites in 1985 and those in 1986. The highest correlation coefficient found (i.e. $r = +0.419$ for LPG-GI between years), indicated that up to 18% of the variation in levels of exposure in 1986 may be explained by the levels of exposure in the preceding year. Perhaps farmers

accommodated some of their management practices in 1986 in response to the results obtained in 1985. However, from the questionnaire and from impressions obtained during farm-visits this did not seem to have occurred. Likely, these positive relations between years reflect the habit to graze calf-herds on the same pastures each year. Nonetheless, a large part of the variation in levels of exposure in 1986 could not be explained by the observed levels of exposure in 1985. Weather conditions may have caused a difference in level of exposure between years or may have induced some alterations in management practices differing between farms, although the farms were all located around the city of Utrecht. Also, not all farmers who, for instance, vaccinated the calf-herd against lungworm in 1985, did so in 1986. Another reason may be found in the timing of sampling periods with respect to the course of infection.

It was also found that management practices like vaccination against lungworm and treating with an anthelmintic drug when applied in two consecutive years, did not result in significantly lower levels of exposure to nematode parasites compared to when this was not the case. Thus, it appeared that the effects of such management practices on nematode parasitism were rather short-lived and did not constitute a structural approach to the control of parasitism by the farmers. Very interesting is the significant positive correlation for HWDM between years. It demonstrates that part of the observed variation in growth performance between calf-herds is of a structural origin. The plane of nutrition will be mainly responsible for that positive correlation between years. In view of the positive correlations found for the levels of exposure to nematode parasites between years and of the significant negative relations between HWDM and levels of exposure within years, it may be assumed that parasitism is also one of the structural differences between farms.

Summarizing, results of the 1986 study confirmed the usefulness of cross-sectional surveys on commercial dairy farms in collecting information about the effects of nematode infections on growth performance. Boon et al. (1984, 1986) showed earlier the feasibility of such studies. Including observations on growth performance as done by Ploeger et al. (submitted) and as done in the present study, results in data which can be used to evaluate nation-wide economic losses as well as to rationalize the use of anthelmintics in practice. Moreover, it was shown that such type of studies can be done in different years under different circumstances with satisfactorily consistent results between years. This is also due to the fact that particularly gastrointestinal nematode infections follow a rather stereotyped epidemiological pattern (Armour and Ogbourne, 1982; Lancaster and Hong, 1987; Eysker and v.Miltenburg, 1988). Still, differences between years in patterns do occur, resulting in differences in the strength of relationships found when such surveys are conducted at fixed points in time, without taking account of weather conditions. Finally, it was shown that nematode parasitism on commercial farms is in part a structural problem, continuing over consecutive years, despite management practices directed against the negative effects of parasitism. Although the relations were not very strong between years, it can be speculated that it is possible to identify farms where serious nematode parasitism occurs each year and that a structural approach to control this parasitism might be more beneficial to these farms on the long term than the vaccinations and anthelmintic treatments applied at present.

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V. EFFECT OF NEMATODE INFECTIONS ON GROWTH PERFORMANCE OF CALVES DURING WINTER HOUSING ON DAIRY FARMS

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ABSTRACT

Growth performance of calves was estimated by means of heart girth measurements on 48 farms during winter housing (from December to the end of March). Level of exposure to nematode infection was measured by antibody titres, pepsinogen values, and faecal examinations. Half of each herd was treated with albendazole after housing. All infection parameters measured in March were significantly lower in the treated groups than in the untreated control groups. Treatment increased growth rate by an average of +0.007 cm./day (N.S.), i.e. +0.036 kg./day. Effect of treatment varied from -0.075 to +0.100 cm./day between herds. This effect of treatment on the growth performance per herd was significantly correlated positively to pepsinogen value ($r = 0.321$, $P < 0.05$ measured in October; $r = 0.265$, $P < 0.10$ measured in December). Control groups showed very different growth rates between herds, ranging from 0.023 to 0.170 cm./day, i.e. 0.112 to 0.874 kg./day. This variation was strongly related to several infection parameters, particularly those measured in October. The most pronounced correlation was found between the average daily gain of the control groups and the mean herd antibody titre against Ostertagia spp. measured in October ($r = -0.413$, $P < 0.01$). These results were consistent with those of a similar study conducted on commercial dairy farms a year earlier.

INTRODUCTION

In a previous study it was shown that growth performance of calves during winter housing varied enormously between herds, from 0.250 to 0.936 kg./day, and that this was significantly related to the level of nematode infections calves were exposed to during the previous grazing season (Ploeger et al., submitted). In the same study anthelmintic treatment increased growth performance, but the effect of treatment was only weakly related to the level of infection.

The present paper reports findings of a similar study on commercial dairy farms, which was conducted to investigate whether results would be consistent between years or not.

MATERIALS AND METHODS

Because the present study, conducted in 1986/87, was basically the same as the study of Ploeger et al. (submitted), conducted in 1985/86, the reader is referred to that earlier study for detailed information about materials and methods used. The following sections are mainly restricted to information about materials and methods which differed from those in the previous study. Where appropriate, reference is made to the used techniques.

Farms and calves

Forty-eight farms, none of which applied treatment at housing, were approached to participate in the present study. Twenty-five of these farms were also involved in the previous study by Ploeger et al. (in preparation). This fact had no significant influence on the results of the present study. All farms were approached through the Veterinary Practice of the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty Utrecht. At average 8 calves were present in each herd (range: 3-20). The majority of calves were of the Dutch Friesian or Holstein Friesian breed or crossbreds of these two (87.4%). About 6% of the calves were of the Meusse-Rhine-IJssel breed. Breeds were equally divided over treatment groups.

Sampling periods

Figure 1 presents schematically the timing of measurements and treatments relative to the grazing season and housing period.

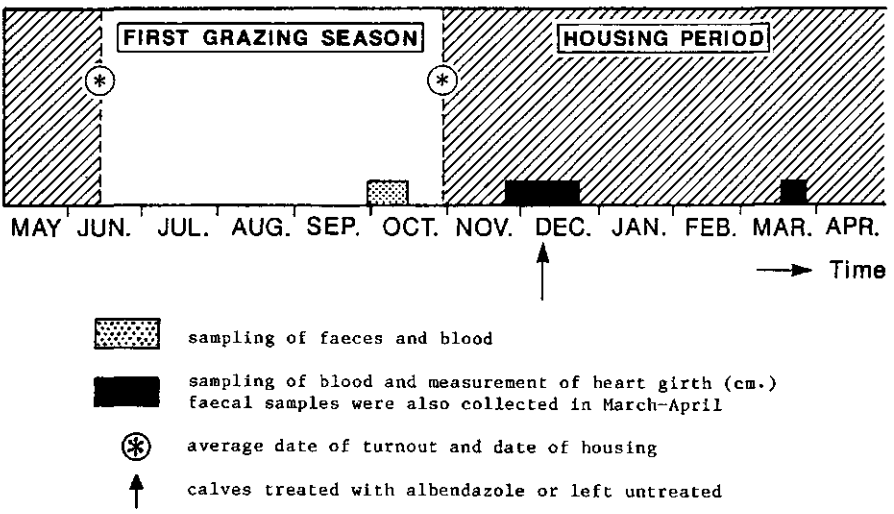

Figure 1: Sampling periods, treatments and observations relative to grazing season and housing period.

Anthelmintic treatment

Half of each herd was treated orally with albendazole (Valbazen®, SmithKline Diergeneeskundige Produkten B.V.) at the manufacturer's recommended dose (7.5 mg/kg liveweight). The other half was left untreated (control group). On each farm calves were randomly allocated to the albendazole-treated or the control group. Treatment was given in November/December (see Figure 1).

Measurement of growth performance

Growth performance of all calves was estimated by measuring the heart girth, i.e. circumference (cm.) of the chest directly behind the forelegs (Vos and Vos, 1967), and expressed as average daily gain (ADG-HG in cm./day). The relevant traits investigated, were: growth performance of control calves on each farm, and the effect of albendazole treatment. Effect of treatment was expressed as the difference between the treated and control groups. In Table 1 treatment groups are compared with eachother with respect to age, initial heart girth and estimated body weight.

TABLE 1: Comparison of albendazole-treated and control calves at the time of treatment.

	CONTROL GROUP	ALBENDAZOLE TREATED GROUP
number of calves	199	205
age ± s.d. (days)	328 ± 87.7	324 ± 87.6
mean heart girth ± s.d. (cm.)	150.0 ± 13.1	148.7 ± 13.3
estimated body weight ± s.d. (kg.)[1]	275.3 ± 64.6	268.9 ± 65.2

[1] according to findings of Vos and Vos (1967).

Faecal and serological examinations

Egg output per herd or per treatment group was estimated by counting larvae per gram of faeces (LPG-GI) after culturing, combined with larval identification (Borgsteede and Hendriks, 1973, 1974). Lungworm larvae were counted (per 30 grams of faeces) (LPG-Dv) using a Baermann-technique.

Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus, as well as pepsinogen values were determined using techniques described by Keus et al. (1981), Boon et al. (1982) and Berghen et al. (1987).

Statistics

Data were tested for normality and, with respect to serological and growth performance data, for homogeneity of variance. Pepsinogen values were transformed according to the formula $Y = \ln (X)$. Gastrointestinal larval counts were transformed according to $Y = {}^{10}\log (X+1)$. All statistical analyses were performed using the Statistical Analysis System

(S.A.S., 1985).

RESULTS

Tables 2 and 3 present results of the larval identifications in October and in March. From the results in March it appeared that more herds were excreting eggs of the genera Trichostrongylus, Oesophagostomum and Bunostomum during the housing period, as is indicated by the differences between the larval counts in October and in March (control groups). Egg output in the control groups recorded in March, was higher than in October (31.6 vs. 21.4 geometric mean LPG-GI, N.S.). Compared to the control groups

TABLE 2: Identification of larval types found in faecal samples collected in October 1986 (n=44).

	Number of herds with faecal sample containing:					Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%	
Ostertagia spp.	4	16	12	7	4	1	40 (90.9)
Cooperia oncophora	6	6	12	9	10	1	38 (86.4)
Cooperia punctata	21	19	2	2	0	0	23 (52.3)
Trichostrongylus spp.	27	16	1	0	0	0	17 (38.6)
Oesophagostomum spp.	43	1	0	0	0	0	1 (2.3)
Haemonchus spp.	38	5	1	0	0	0	6 (13.6)
Bunostomum spp.	43	1	0	0	0	0	1 (2.3)
Strongyloides papillosus	43	1	0	0	0	0	1 (2.3)

Nematodirus spp. eggs were found in 7 herds.

TABLE 3: Identification of larval types found in faecal samples from albendazole-treated and untreated control groups collected in March 1987 (n=46).

	Number of herds with faecal sample containing:					Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%	
CONTROL CALVES							
Ostertagia spp.	3	29	7	5	2	0	43 (93.5)
Cooperia oncophora	8	2	0	10	25	1	38 (82.6)
Cooperia punctata	26	20	0	0	0	0	20 (43.5)
Trichostrongylus spp.	11	29	3	2	0	0	34 (73.9)
Oesophagostomum spp.	36	10	0	0	0	0	10 (21.7)
Haemonchus spp.	45	1	0	0	0	0	1 (2.2)
Bunostomum spp.	41	5	0	0	0	0	5 (10.9)
ALBENDAZOLE-TREATED CALVES							
Ostertagia spp.	2	4	4	9	11	16	44 (95.7)
Cooperia oncophora	20	8	9	6	2	1	26 (56.5)
Cooperia punctata	41	5	0	0	0	0	5 (10.9)
Trichostrongylus spp.	39	6	1	0	0	0	7 (15.2)
Oesophagostomum spp.	43	3	0	0	0	0	3 (6.5)
Haemonchus spp.	46	0	0	0	0	0	0 (0.0)
Bunostomum spp.	45	1	0	0	0	0	1 (2.2)

Nematodirus spp. eggs were found in 2 control groups.

all genera, except Ostertagia spp., were found less frequently in the treated groups. Egg output in treated groups was significantly lower than in control groups (7.6 vs. 31.6 geometric mean LPG-GI, $P < 0.001$). In October 21.4% of the faecal samples contained lungworm larvae with a maximum of 22 per 30 grams of faeces. No lungworm larvae were found in March.

Table 4 gives the results of the serological examinations. In March average antibody titres against Dictyocaulus and against Ostertagia of the control groups were significantly lower compared to December ($P < 0.01$ and $P < 0.10$, respectively). Antibody titre against Cooperia for these groups was higher in March ($P < 0.001$). Mean herd pepsinogen values were also higher in March, but this was not significant. Anthelmintic treatment resulted in significantly lower antibody titres and pepsinogen values compared to the control groups. This was most pronounced for the antibody titres against Cooperia and against Ostertagia.

TABLE 4: Descriptive statistics for the serological parameters and the effect of treatment on these parameters.

	OCTOBER 1986 (n=44)				DECEMBER 1986 (n=48)				MARCH 1987 (n=48)					
	mean	s.d.	min.	max.	mean	s.d.	min.	max.		mean	s.d.	min.	max.	sign. of difference
Dictyocaulus titre	4.12	1.39	1.2	7.1	4.13	0.92	2.0	5.7	C:	3.60	0.74	2.2	5.1	
									AT:	3.35	0.70	2.2	5.0	P<0.01
Cooperia titre	3.32	1.36	0.3	6.2	2.87	1.09	0.7	6.0	C:	3.61	1.15	1.6	7.4	
									AT:	2.84	0.85	1.4	5.2	P<0.001
Ostertagia titre	5.52	1.63	2.0	8.2	5.65	0.85	3.9	7.2	C:	5.38	0.86	4.0	7.6	
									AT:	4.96	0.68	3.6	6.6	P<0.001
Pepsinogen value	1229.3	544.1	263	3559	1107.3	590.9	327	2926	C:	1302.5	609.4	160	2684	
									AT:	1133.5	581.2	100	2739	P<0.05

C = control groups; AT = albendazole-treated groups.

ADG-HG of control groups varied between herds from 0.023 to 0.170 cm./day (av. 0.106 cm./day). This equals 0.112 to 0.874 kg./day with an average of 0.533 kg./day, according to findings of Vos and Vos (1967). Albendazole-treated groups gained at average 0.007 cm./day more than the control groups (range: -0.075 to +0.100 cm./day) ($P = 0.121$). Estimated in kg./day this is similar to +0.036 kg./day (range: -0.303 to +0.524 kg./day). Over the entire period this amounted to a difference in body weight between treated and control groups of approximately +4.0 kg.

Age of the control groups was strongly correlated with ADG-HG ($r = -0.518$, $P < 0.001$). The effect of treatment on ADG-HG was not significantly influenced by herd-age.

In Table 5 regression coefficients are given for the relation between growth performance and the infection parameters. Particularly antibody titres, measured in October, were significantly correlated negatively with growth performance of the control groups. Adjusting ADG-HG for age of herd did not, in general, influence the established relations significantly. Figure 2 graphically illustrates the relation between ADG-HG of the control groups and the mean herd antibody titre against Ostertagia spp. in October. Weaker relations were found between the

TABLE 5: The regression coefficients of the relationships between the level of exposure to nematode infections and either the growth performance of the control groups or the effect of treatment on growth performance during the following housing period.

	ADG-HG of CONTROL GROUPS (cm./day) not adjusted for age: b	r^2(%)		adjusted for age: b	r^2(%)		EFFECT OF TREATMENT ON ADG-HG (cm./day) b	r^2(%)	
OCTOBER 1986 (n=44)									
Dictyocaulus titre	-.011	15.02	**	-.009	13.70	*	.005	5.11	NS
Cooperia titre	-.011	16.08	**	-.008	11.83	*	.002	0.96	NS
Ostertagia titre	-.010	18.74	**	-.008	17.08	**	.001	0.35	NS
pepsinogen value	-.020	4.77	NS	-.026	12.39	*	.021	10.30	*
LPG-GI	-.001	0.01	NS	-.008	2.72	NS	.004	0.98	NS
DECEMBER 1986 (n=48)									
Dictyocaulus titre	-.009	4.59	NS	-.006	2.78	NS	.003	0.66	NS
Cooperia titre	-.008	5.37	NS	-.006	3.70	NS	.003	0.90	NS
Ostertagia titre	-.000	0.00	NS	-.002	0.21	NS	.000	0.00	NS
pepsinogen value	-.010	2.43	NS	-.007	1.94	NS	.013	7.01	+
MARCH 1987 (n=48)									
Dictyocaulus titre	-.002	0.13	NS	-.001	0.01	NS		n.d.	
Cooperia titre	-.007	4.31	NS	-.003	1.53	NS		n.d.	
Ostertagia titre	-.004	0.80	NS	-.001	0.07	NS		n.d.	
pepsinogen value	-.015	6.39	+	-.014	8.38	*		n.d.	
LPG-GI	-.002	0.14	NS	-.007	1.95	NS		n.d.	

n.d. = not done. NS = not significant; + = P<0.10; * = P<0.05; ** = P<0.01

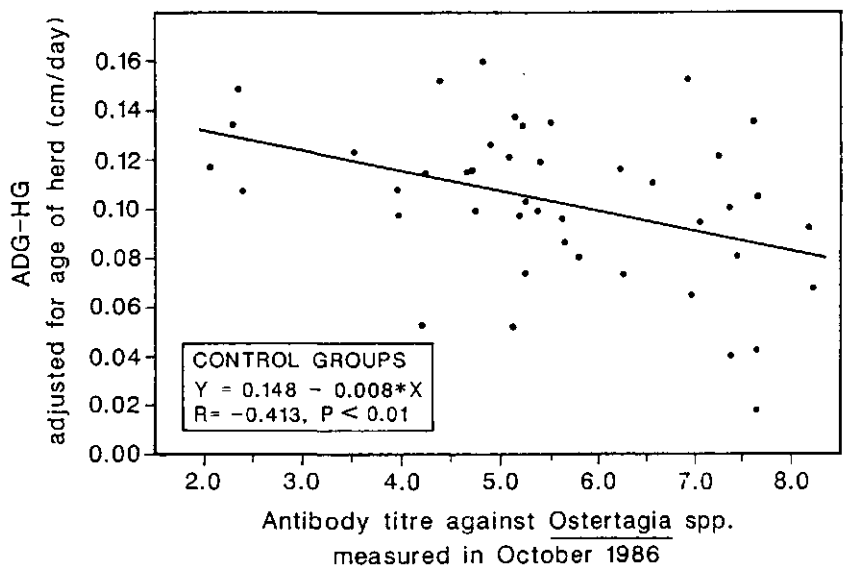

Figure 2: The regression of growth rates (ADG-HG) in the control groups during winter housing on the mean herd antibody titre against Ostertagia spp. in October.

infection parameters and the effect of albendazole treatment on growth performance. This treatment effect was only significantly correlated positively to pepsinogen value. There were no significant relations between LPG-Dv and ADG-HG of the control groups or the effect of treatment on ADG-HG.

DISCUSSION

In general, the results of the present study confirm the findings of a similar study reported previously (Ploeger et al., submitted). On average, anthelmintic treatment after stabling, though not significantly, increased average daily gain. This increase varied considerably between herds. Although the correlations between the effect of treatment on ADG-HG and the infection parameters were weak and mostly not significant, this variation in response to treatment may be related to the different levels of exposure to infection during the previous grazing season. There were significant correlations with the pepsinogen values, and the signs of the regression coefficients were consistently positive as opposed to those found for the relations between ADG-HG of the control groups and the infection parameters. In the present study albendazole was used, whereas in the study of Ploeger et al. (submitted) ivermectin was used. The similarity of the findings in both studies supports the hypothesis that the positive treatment effects were the result of the anthelmintic activity of these compounds, and not of some general growth promoting effect or of an effect on other pathogens, although ivermectin is also active against ectoparasites (Preston et al., 1983). Furthermore, in both studies treatment also resulted in significantly lower antibody titres, pepsinogen values and faecal egg output in the treated groups compared to the control groups.

Overall, the effect of treatment on ADG-HG was not impressive, being approximately +0.036 kg./day. One of the reasons is the fact that not all herds involved in this study, had a high level of infection. Interference of the nutritional status of the calf-herds with effect of anthelmintic treatment is another and very important factor. Kloosterman et al. (1973) and Parkins et al. (1982) presented results indicating that feeding levels can interfere with effects of different levels of nematode infection. Steel (1978) suggested that plane of nutrition can influence the immunological competence of the host and that it can influence the pathogenicity of an infection. Such influences may mask a clear and straightforward relationship between response to anthelmintic treatment and level of infection. For instance, treatment of calves in herds exposed to high levels of infection but also on a high plane of nutrition, probably will not have as great an effect on growth performance as may be expected. Reversely, calves on a lower plane of nutrition exposed to low levels of infection may respond disproportionately well to treatment, due to increased pathogenicity of the infection or decreased resistance of the host. On the other hand a low plane of nutrition in itself may restrict a response in growth performance to treatment, even when the level of infection is very high.

Growth performance of the control groups, reflecting the situation when there is no interference, also varied enormously between herds, ranging

from 0.11 to 0.87 kg./day. Nutritional status of herds will be the major explicatory factor for this variation. However, naturally acquired nematode infections undoubtedly play a significant role. Several significant relations were found between ADG-HG of the control groups and infection parameters, particularly with the serological parameters measured in October. Based on the relationship between heart girth and body weight found by Vos and Vos (1967), these results can be calculated to a difference in growth rate of at least 0.25 kg./day between herds exposed to the lowest level of infection compared to herds exposed to the highest levels.

Striking is the fact that in the present study especially sampling in October, while calves were still pastured, produced significant results. In the comparable study of Ploeger et al. (submitted) sampling in September 1985 did not give such results, whereas sampling in December and in March, at the conclusion of the trial, did give significant results. Apparently timing of sampling is crucial. Although nematode infections generally follow a basic seasonal pattern from year to year, there is still a large variation between years, both in magnitude and time (Armour and Ogbourne, 1982; Lancaster and Hong, 1987; Eysker and v.Miltenburg, 1988). Comparing the data from both studies reveals that antibody titres were generally lower in October and December 1986 and that they were higher in March 1986 than in the comparable sampling periods in 1985. Pepsinogen values were in December as well as in March in the 1986 study higher than in the comparable periods in the 1985 study. Similar results were seen for LPG-GI, when compared between both years. Weather conditions were markedly different in 1986 compared to 1985 (K.N.M.I., 1986, 1987). Generally, in 1985 a wet summer and a dry autumn were recorded. Particularly during the months June and August rainfall was above average. In 1986, however, a prolonged dry period was recorded between mid-June and mid-August. Temperatures recorded in June and July were also higher than normal. September 1986 was a very cold month. This suggests that in 1986 the rise in numbers of trichostrongyle larvae on pasture occurred later, and that consequently calves picked up substantial numbers of infective larvae much later in the season than in 1985. Therefore the sampling period of October 1986 fell relatively early in that sequence of events. These conditions may have resulted in the, overall, somewhat lower antibody titres in October and December, but in higher burdens of arrested larvae during winter housing in the 1986 study. The latter may have resulted in the higher antibody titres, pepsinogen values and egg output in March (control groups) compared to October 1986 as well as compared to the previous year. The results of the present study, therefore, indicate that sampling periods should be carefully timed, taking account of the weather conditions during the grazing season.

In conclusion, it was shown that growth performance of calves during winter housing is affected by nematode infections picked up during the previous grazing season. This agrees with findings of others (v.Adrichem and Shaw, 1977; Jorgensen et al., 1978; Entrocasso et al., 1986; Taylor, 1987). Moreover, it was demonstrated that the growth rate of calves is significantly related negatively to the level of exposure to nematode infection on commercial dairy farms. These results were consistent with those found in a similar study on dairy farms a year earlier (Ploeger et al., submitted).

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VI. EFFECT OF NATURALLY OCCURRING NEMATODE INFECTIONS IN THE FIRST AND SECOND GRAZING SEASON ON THE GROWTH PERFORMANCE OF SECOND-YEAR CATTLE

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ABSTRACT

Liveweight of yearlings on 87 dairy farms was measured at the end of the second grazing season and per herd related to the level of exposure to nematode infection during the grazing season. There were significant between herd variations in antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus as well as in pepsinogen values. All herds were found positive for gastrointestinal nematode infections on basis of egg output in October. These results were similar to those found in yearling-herds on the same farms a year earlier. Liveweight of yearlings per herd deviated from -64.7 kg. to +94.4 kg. from an age-adjusted population mean after the second grazing season. This mean herd weight deviation was significantly related negatively to antibody titre against Ostertagia spp. (linear regression: $P < 0.05$; segmented curvilinear regression: $P < 0.01$) and to antibody titre against Cooperia spp. (segmented curvilinear regression: $P < 0.05$). Antibody titre against Ostertagia spp. measured in the first grazing season, when yearlings were calves, was significantly correlated positively to age-adjusted body weights at the end of the second grazing season. It was concluded that immunity built up during the first year had a positive effect on growth performance in the second year.

INTRODUCTION

The majority of studies investigating the effects of nematode parasitism on growth performance refers to calves in the first grazing season. However, cattle are normally pastured a second season before they calve for the first time. Significant positive correlations have been found between body weight at first calving and first lactation yield (v.Adrichem and Shaw, 1977b; Boxem, 1981). Yearlings are exposed to nematode infections in the second grazing season (Borgsteede, 1977; Armour et al., 1979; Borgsteede et al., 1985; Entrocasso et al., 1986b). Several authors demonstrated that these nematode infections may affect growth performance

of cattle negatively during the second year (Smith and Archibald, 1968; v.Adrichem, 1970; Conder et al., 1983; Borgsteede et al., 1985). On the other hand clinical parasitism is rarely seen in second-year cattle compared to first-year calves, due to development of an acquired immunity during the first grazing season. Smith and Archibald (1968) and Borgsteede et al. (1985) found that yearlings, which had previous experience with nematode infections, performed much better during the second year than yearlings with no or almost no previous experience. This suggests that the immunity built up during the first season has a significant positive effect on performance in the second season.

In the present study, the liveweights of yearlings after two consecutive grazing seasons are related to the level of exposure to nematode infections in both the first and second grazing season on 87 commercial dairy farms, with special reference to the second grazing season.

MATERIALS AND METHODS

Farms and yearlings

In this study 87 farms participated. These farms were all situated around the city of Utrecht and belonged to the Veterinary Practice of the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty in Utrecht. Average farm size was 25 ha. (range: 9-50). Per farm a mean number of 14 calves (range: 4-38), 13 yearlings (range: 4-38), and 48 cows (range: 20-105) were present.

It was chosen to investigate only yearlings which were pastured together as one herd in an attempt to avoid variation originating from different management practices and different infection patterns within herds. Consequently, the herds investigated consisted of at average 10 yearlings (range: 4 - 24) on each farm.

The majority of yearlings were of the Dutch Friesian breed, Holstein Friesian breed or crossbreds of these two (85.2%). About 5.9% were of the Meusse-Rhine-IJssel (MRIJ) breed and about 8.9% were of other breeds. The latter were distributed over 32.2% of the farms, while yearlings of the MRIJ-breed were distributed over 17.2% of the farms. Yearlings were, when liveweights were assessed, at average 21 months old (range: 10.2 - 30.7 months).

The majority of these yearlings were also investigated in the preceding year as calf. In the following sections information is mainly restricted to the observations done in the second year. Where appropriate, reference is made to observations done in the first year. Detailed information about that first year is given by Ploeger et al. (submitted[a]).

Measurement of growth performance

After the second grazing season liveweight of 853 yearlings in 87 herds was assessed by measuring the heart girth, i.e. the circumference (cm.) of the chest directly behind the forelegs (Vos and Vos, 1967). Figure 1 presents schematically the timing of measurements relative to grazing and housing periods. The average estimated body weight after the second grazing season was 453 kg. (range: 268 - 628 kg.).

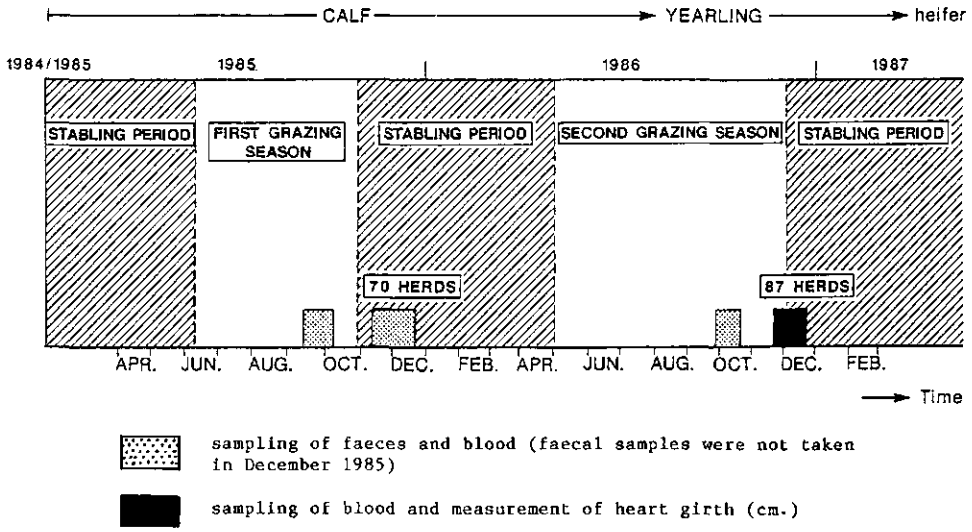

Figure 1: Sampling periods and observations relative to grazing seasons and housing periods.

The estimated weights were adjusted for age and breed of the yearlings, and expressed as the liveweight deviation from the overall population mean. These weight deviations were then related to the time-interval between date of heart girth measurement and date of calving, if known. The resulting relationship was used to adjust the weight deviations for stage of pregnancy. All subsequent calculations were done with the average herd weight deviation ($HWDM_y$: Herd Weight Deviation from the Mean in kg. per Yearling).

Faecal and serological examinations

Faecal samples and sera were collected as described by Ploeger et al. (submitted[a]). Sampling periods are given in Figure 1. Egg output was estimated by counting gastrointestinal nematode larvae per gram faeces (LPG-GI) after culturing, combined with larval identification (Borgsteede and Hendriks, 1973, 1974). Lungworm larvae were counted per 30 grams of faeces (LPG-Dv), using a Baermann-technique.

Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus, as well as pepsinogen values were determined as described earlier by Keus et al. (1981), Boon et al. (1982) and Berghen et al. (1987).

In the preceding year yearling-herds were sampled on the same farms participating in the present study. These samples were taken in the same periods (September and December 1985) as from the calf-herds investigated on those farms (Ploeger et al., submitted[a]). The same sampling procedures and the same faecal and serological techniques were applied, which resulted in additional information about the occurrence of nematode infections in the second grazing season in subsequent years. It was found that these

results, obtained in 1985, were similar to those obtained in 1986. Therefore, the results for the yearling-herds sampled in 1985 only will be given when these were significantly different from those in 1986.

The sera were analysed soon after each sampling period. A separate analysis was done to adjust antibody titres for technical variation due to the use of different batches of reagents (e.g. antigen, conjugate, etc.). This adjustment allowed comparing of antibody titres between sampling periods and between years.

Calculations and statistics

All continuous data were tested for normality and, with respect to serological and body weight data, for homogeneity of variance. Pepsinogen values were transformed according to the formula Y = ln (X). LPG-GI recorded in the second grazing season was transformed according to Y = ln (X+1). LPG-Dv was classified, because of a non-normal distribution which included many zero-counts.

All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985), with herd as the experimental unit. The 10% level was considered as the threshold level for significance. The following steps were performed;

I. Effect of each single infection parameter, measured in the second grazing season, on $HWDM_y$ was analysed by means of both linear and segmented curvilinear regression. The latter was fitted according to the model described previously by Ploeger et al. (submitted[a]). In case of non-continuous data analysis of variance was used.

II. Since $HWDM_y$ reflects the cumulative performance up to the end of the second grazing season, including the growth performance during the first season, the effect of level of exposure measured in the first as well as in the second year on $HWDM_y$ was investigated using multiple regression analysis.

In addition, relationships between the levels of exposure to nematode parasites for yearling-herds in 1985 and those for the yearling-herds on the same farms in 1986 were evaluated.

RESULTS

The results of the larval identifications in faecal samples collected in October 1986 are given in Table 1. All herds were found excreting nematode eggs, with an average of 24.4 LPG-GI (range 1 - 196). Ostertagia spp. and Cooperia oncophora were found in the majority of herds. In faecal samples of five herds (6.3%) lungworm larvae were found. Larval identifications, egg output and number of herds excreting lungworm larvae were similar to the findings in yearling-herds on the same farms in the previous year. The most pronounced differences between both years were found for the larval identifications. In 1985 larval types of the genera Trichostrongylus and Oesophagostomum were found in 71.3% and 39.1% of the herds, respectively. In 1986 these percentages were 58.2% and 12.7%, respectively. Also, larval types of the genus Bunostomum were not found in faecal samples in 1985.

All serological parameters showed a significant between herd variation ($P < 0.001$). Descriptive statistics for the serological parameters (on

TABLE 1: Identification of larval types found in faecal samples collected in October 1986 (n=79).

	Number of herds with faecal sample containing:						Total number of positive farms (%):*	
	0%	1-25%	25-50%	50-75%	75-99%	100%		
Ostertagia spp.	3	31	18	9	16	2	76	(96.2)
Cooperia oncophora	16	18	12	12	18	3	63	(79.7)
Cooperia punctata	38	36	4	1	0	0	41	(51.9)
Trichostrongylus spp.	33	35	6	5	0	0	46	(58.2)
Oesophagostomum spp.	69	10	0	0	0	0	10	(12.7)
Bunostomum spp.	71	8	0	0	0	0	8	(10.1)
Haemonchus spp.	75	3	1	0	0	0	4	(5.1)

* On eight farms no faecal samples were taken.

TABLE 2: Descriptive statistics for the serological parameters.

	OCTOBER 1986 (n=79)				DECEMBER 1986 (n=87)				sign. of difference between periods
	mean	s.d.	min.	max.	mean	s.d.	min.	max.	
Dictyocaulus titre	4.74	0.86	2.3	6.9	3.95	0.83	2.5	6.9	***
Cooperia titre	4.68	0.92	2.0	7.0	4.08	0.82	2.0	5.8	***
Ostertagia titre	6.93	1.00	3.3	8.8	6.37	0.92	4.6	9.0	**
Pepsinogen value	1552	487	695	2820	1472	523	233	2520	+

NS = not significant; + = P<0.10; ** = P<0.01; *** = P<0.001 .

herd basis) measured in the second grazing season are given in Table 2. Antibody titres decreased significantly from October to December. Pepsinogen values decreased also significantly, but to a lesser extent compared to antibody titres.

In 1985 similar results were obtained in yearling-herds for the antibody titres against Cooperia and Ostertagia. Significant differences between 1986 and 1985 were: 1) antibody titre against Dictyocaulus in December 1986 was lower than in December 1985 (av.= 4.53) ($P < 0.05$), and; 2) in 1985 average pepsinogen values were 1873 mU in September and 974 mU in December, whereas in 1986 for the comparable periods 1552 mU and 1472 mU, respectively, were recorded. For the pepsinogen values both the effect of sampling period (within year) and the effect of year were significant ($P < 0.001$ and $P < 0.01$, respectively). Also, the interaction between sampling period and year was significant ($P < 0.001$).

In Table 3 the correlation coefficients are given for the relations of the serological parameters with eachother as well as with LPG-GI. Antibody titres strongly correlated with eachother in October, whereas the correlations were weaker in December. Correlations between antibody titres and pepsinogen values were mostly significant but weak. LPG-GI was only significantly correlated to antibody titre against Cooperia spp. measured in both October and December, and to pepsinogen value measured in December. Because faecal samples of only 5 herds contained lungworm larvae, no statistical analyses were performed involving this infection parameter.

No significant correlations were found for the single infection

TABLE 3: Pearson correlation coefficients for the relationships of the serological parameters with eachother within sampling periods and with the gastrointestinal nematode larval count (LPG-GI).

	OCTOBER 1986 (n=79)				DECEMBER 1986 (n=87)			
	Dict. titre	Coop. titre	Ost. titre	Pep.-value	Dict. titre	Coop. titre	Ost. titre	Pep.-value
Dict. titre	--	.642 ***	.515 ***	.239 *	--	.307 **	.422 ***	-.072 NS
Coop. titre		--	.665 ***	.334 **		--	.269 *	.272 *
Ost. titre			--	.326 **			--	-.075 NS
LPG-GI	.024 NS	.201 +	.123 NS	.119 NS	.019 NS	.250 *	.166 NS	.216 +

NS = not significant; + = P<0.10; * = P<0.05; ** = P<0.01; *** = P<0.001 .

parameters between years (from calf to yearling), except for the mean herd pepsinogen values measured in December in both years ($r = 0.264$, $P < 0.05$). Correlations for the single infection parameters measured in yearling-herds in September 1985 and in yearling-herds in October 1986 on the same farms, were significantly positive: for antibody titres against Dictyocaulus, Cooperia, Ostertagia, and for pepsinogen values correlation coefficients were +0.183 ($P = 0.106$), +0.348 ($P < 0.01$), +0.203 ($P < 0.10$) and +0.328 ($P < 0.01$), respectively. Also, antibody titre against Ostertagia measured in yearling-herds in December 1985 was significantly correlated to the same parameter measured in yearling-herds in December 1986 ($r = +0.221$, $P < 0.05$).

Individual weight deviations of yearlings varied significantly between herds compared to within herds ($F = 6.41$, $P < 0.001$). The frequency distribution of $HWDM_y$ is shown in Figure 2. $HWDM_y$ ranged from -64.7 kg. to +94.4 kg. per yearling per herd.

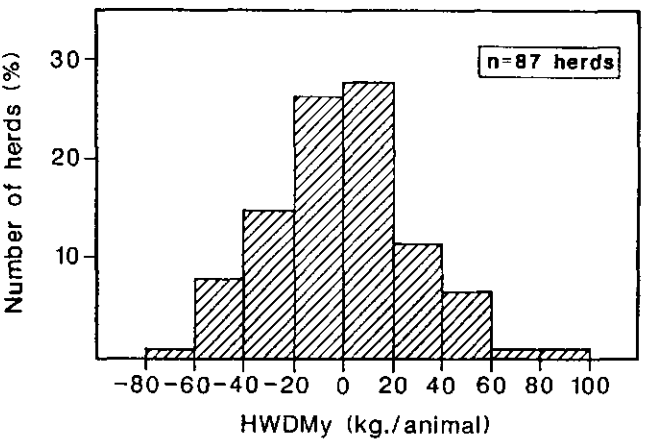

Figure 2: Frequency distribution of the mean herd weight deviations from an age-adjusted population mean ($HWDM_y$) after the second grazing season.

TABLE 4: Regression of the weight deviations from the population mean measured after housing ($HWDM_y$) on the parameters estimating nematode infection per herd.

	LINEAR REGRESSION:					SEGMENTED CURVILINEAR REGRESSION:					
	u	b	MSE_r	r^2(%)	sign.	p	x_0	c	MSE_r	r^2(%)	sign.
OCTOBER 1986 (n=79)											
Dict.titre	6.70	-1.94	791.7	0.35	NS	-1.09	4.73	3.48	793.7	1.41	NS
Coop.titre	22.52	-5.34	770.0	3.09	NS	1.05	4.57	7.30	746.7	7.24	*
Ost.titre	49.14	-7.45	738.2	7.09	*	5.71	5.71	3.42	731.6	9.12	**
Pep.value	59.17	-8.49	786.4	1.03	NS	-2.88	7.88	-10439	777.4	2.20	NS
LPG-GI	-3.02	0.22	794.4	0.01	NS	-3.15	4.07	-15.28	795.8	1.14	NS
DECEMBER 1986 (n=87)											
Dict.titre	3.80	-1.11	895.3	0.10	NS	-0.85	4.92	-4.49	903.4	0.37	NS
Coop.titre	14.43	-3.69	886.9	1.03	NS	2.99	2.34	0.98	896.6	1.13	NS
Ost.titre	-2.12	0.24	896.1	0.01	NS	-1.10	6.88	-2.01	904.0	0.31	NS
Pep.value	66.30	-9.33	880.3	1.77	NS	4.74	6.55	9.76	887.4	2.14	NS

All estimates are given in kg./animal per herd. For explanation of models used see section Material and Methods. MSE_r is the residual mean square error. r^2-value given for the segmented curvilinear regression was calculated by fitting observed $HWDM_y$ on $HWDM_y$ 'predicted' by the segmented curvilinear relation. NS = not significant; * = P<0.05; ** = P<0.01 .

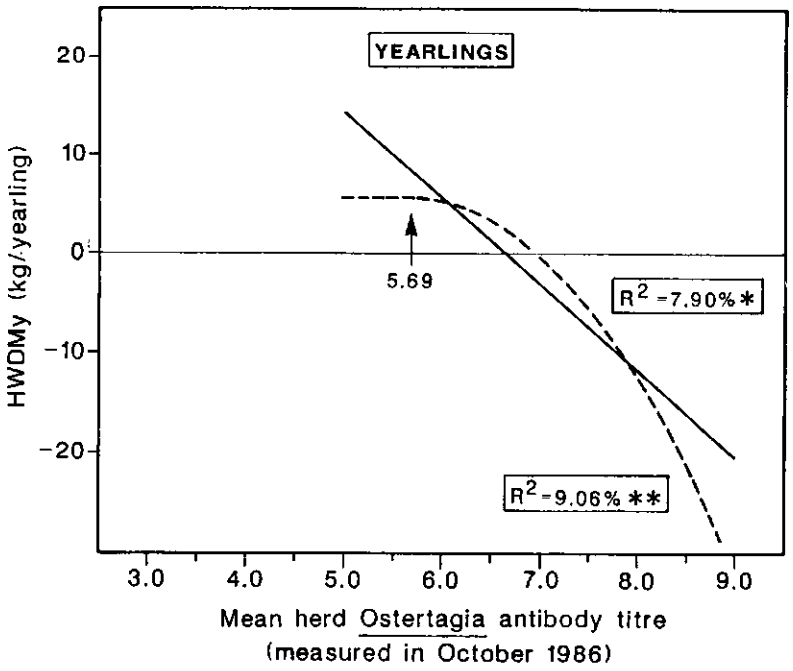

Figure 3: Linear and segmented curvilinear relationship between the mean herd weight deviation from an age-adjusted population mean ($HWDM_y$) and the mean herd antibody titre against Ostertagia spp. in October 1986.

In Table 4 the results of regression analyses are given of the relation between $HWDM_y$ and the infection parameters, measured in the second year. With respect to linear regression only the relation with antibody titre against Ostertagia spp. in October was significant ($P < 0.05$). Using segmented curvilinear regression, significant relations were found with antibody titre against Ostertagia spp. and against Cooperia spp. in October ($P < 0.01$ and $P < 0.05$, respectively). The regression of $HWDM_y$ on Ostertagia titre is shown in Figure 3. With respect to this figure note that one herd is left out, because it showed an antibody titre of 3.3, far below the titre-values found in all other herds. $HWDM_y$ for this herd was +4.0 kg. Comparing regression lines of Figure 3 and Table 4, it appears that exclusion of this observation mainly influenced the estimates of the linear regression.

Multiple regression analysis of the effects of level of exposure to nematode infection in both first and second grazing season on $HWDM_y$, showed that regression coefficients for the infection parameters, measured in the first season, were positive. The regression coefficients for the infection parameters, measured in the second season, were negative, except for LPG-GI (Table 5). $HWDM_y$ was significantly related to antibody titres against Ostertagia spp. measured in the second as well as in the first season ($P < 0.05$). In Figure 4 this is illustrated by means of a classification in above and below average titres in both years. Multiple regression analyses applied on infection parameters measured after the respective grazing seasons (December periods) did not result in significant and consistent relations.

TABLE 5: Multiple regression of the mean herd weight deviation from the overall mean ($HWDM_y$), recorded after the second grazing season, on the infection parameters measured in the first grazing season (as calf) and in the second season (as yearling).

	intercept		b_1 (first year)		b_2 (second year)		r^2(%)	sign. of model
Dictyocaulus titre	-12.33	NS	5.85	+	-2.51	NS	4.70	NS
Cooperia titre	3.64	NS	4.03	NS	-4.01	NS	3.37	NS
Ostertagia titre	32.63	NS	5.14	*	-8.82	*	10.41	*
Pepsinogen value	-23.55	NS	7.50	NS	-4.14	NS	1.21	NS
LPG-GI	-11.51	NS	1.94	NS	2.58	NS	1.18	NS

b_1 and b_2: regression coefficients
NS = not significant; + = $P < 0.10$; * = $P < 0.05$

DISCUSSION

In the second grazing season yearlings were exposed to nematode infections on all farms as indicated by the faecal examinations in the present study. Others also found that second-year cattle are exposed to infection (Borgsteede, 1977; Armour et al., 1979; Borgsteede et al., 1985). The serological parameters showed that there were significant differences between herds in level of exposure to these infections.

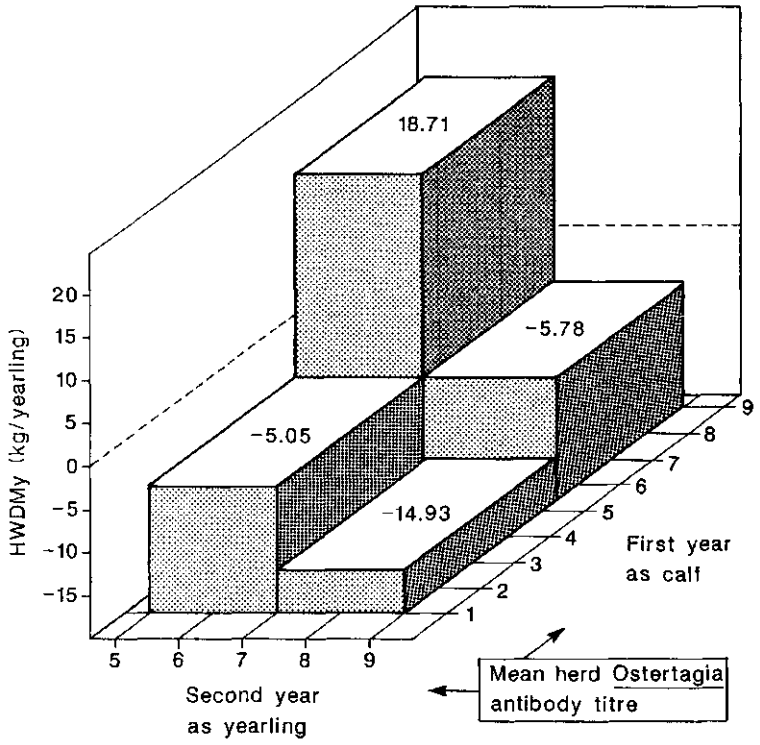

Figure 4: The mean herd weight deviation from an age-adjusted population mean ($HWDM_y$) at different levels of exposure to infection, as measured by antibody titres against Ostertagia spp. in the first and second grazing season.

The results of the faecal and serological examinations in 1986 were, in general, very similar to those in yearling-herds on the same farms in 1985. Nonetheless, there were two noteworthy differences between both years. Firstly, larval types of the genus Trichostrongylus were found in more herds in 1985 than in 1986. This finding may indicate that infections were slightly older in September 1985 than in October 1986, although no differences were found with respect to Cooperia oncophora between both years. Borgsteede (1977) concluded that in the first half of the second grazing season Ostertagia spp. and Cooperia spp. were the most frequent types found, while in the second half of that season Trichostrongylus spp. replaced Cooperia spp. with respect to frequency found. Secondly, the pepsinogen values did not decrease as much from October to December 1986 as from September to December 1985, which suggests that intake of infective larvae was higher during the autumn 1986 than during the autumn 1985. The weather conditions recorded in 1985 and 1986 support these findings. In 1986 a prolonged and extremely dry period was recorded by the Royal Dutch Meteorological Institute from mid-June to mid-August (K.N.M.I., 1987). September 1986 was relatively cold, in fact one of the coldest Septembers of this century. In 1985 a wet summer and a dry autumn were recorded (K.N.M.I., 1986). Antibody titres, however, did not reflect a late intake

of infective larvae in 1986. Antibody titres were significantly lower in December than in October 1986. The same was found in 1985. Perhaps ingested larvae in the autumn 1986 became arrested in their development once established in the digestive tract. This would suggest that larvae arrested in the early L4-stage are not capable of eliciting an antibody response as measured in the present study. Kloosterman et al. (1985) concluded that antibody titres in adult cows seem to efficiently reflect the resumption of development of larvae during winter housing. In the present study as well as in the study of Kloosterman et al. (1985) antibody titres were determined, using crude saline extracts of adult worms as antigen.

The level of exposure to nematode infection during the second year significantly influenced $HWDM_y$ negatively, irrespective of previous experience in the first season. Herds with above average antibody titres against Ostertagia in October in the second year, weighed on average 17.2 kg./animal less after the second grazing season than herds with below average antibody titres (see Figure 4). Others also found that growth performance of second-season grazing yearlings can be reduced by nematode infections (Smith and Archibald, 1968; v.Adrichem, 1970; v.Adrichem and Shaw, 1977a; Conder et al., 1983; Güldenhaupt and Bürger, 1983; Borgsteede et al., 1985). On the other hand, several authors could not demonstrate significant effects of nematode infections in some groups of second-year cattle (v.Adrichem and Shaw, 1977b; Prosl et al., 1983; Weiss and Bürger, 1984; Entrocasso et al., 1986a). Reasons for these different results may be numerous, e.g. levels of exposure in the first grazing season may differ, levels of exposure in the second season may differ, different management practices, differences in the plane of nutrition of cattle, etc. In the present study, levels of immunity built up in the first year may have been, in the majority of herds, not sufficient to prevent weight gain losses from occurring during the second year. Perhaps the control measures taken by farmers in the first grazing season, though not always as efficiently as could be, keep nematode infections at levels which are not sufficient to provoke the build-up of a good immunity. In the Netherlands much effort is done to prevent the negative effects of nematode infections in calves. For instance, calf-herds on approximately 60% of the farms are turned out late on mown pasture in the Netherlands (Eysker et al., 1983; Ploeger, unpublished results). Also, the weather conditions in the first half of the second grazing season in 1986, as described above, may have played a significant role by reducing the larval challenge at pasture during that period, resulting in decreased resistance to the effects of ingested larvae later in the season. Larval identifications in faecal samples showed that 80% of the herds excreted Cooperia oncophora larvae in October 1986. Borgsteede et al. (1985) did not find any Cooperia spp. larvae in second-year cattle, which were grazed in the first season as untreated control calves, from May onwards as opposed to second-year cattle kept indoors in their first year.

Segmented curvilinear regression of $HWDM_y$ on the infection parameters measured in the second grazing season, resulted in significant relations with antibody titres against Ostertagia and against Cooperia, both measured in October. Similar results were obtained for calves in the first grazing season, although segmented curvilinear regression did not significantly improve the fit between the data compared to linear regression (Ploeger et

al., submitted[ac]). Little is known about the shape of the relationship between antibody titres, estimating level of exposure to nematode infection, and growth performance. A linear relationship assumes that weight gains are affected negatively by nematode infections starting upwards from the lowest antibody titre. Also, it assumes that the magnitude of weight gain depressions per titre-unit is the same over the whole range of antibody titres, from low to high. Therefore, the value of a linear model may be questioned. Segmented curvilinear relationships assume that there are threshold titres below which the levels of exposure are not sufficient to reduce growth performance significantly, and above which growth performance is increasingly affected per titre-unit. The use of both methods in an economical assessment of monetary losses results in quite different estimates (Ploeger and Kloosterman, 1988). Therefore, the choice between these models will have important implications for the evaluation and use of control strategies on commercial dairy farms.

$HWDM_y$ was also significantly related to the antibody titre against Ostertagia spp. measured in the first grazing season. Surprising was that the sign of this relationship suggests that the level of exposure in the first grazing season had a significant positive effect on body weights achieved at the end of the second year. Herds in which above average antibody titres were measured in the first year as calf, were on average 16.5 kg./animal heavier at the end of the second grazing season compared to herds with below average titres in the first year (see Figure 4). Ploeger et al. (submitted[a]) demonstrated significant negative relations between growth performance as calf and several infection parameters measured in that first year. Although the relation between antibody titre against Ostertagia in the first year and growth performance as calf was not significant, the sign of this relation was also negative. These negative relations in the first year were found to extend into the subsequent housing period (Ploeger et al., submitted[b]). Therefore, the observed differences in body weight after the second grazing season could not already have been present at the beginning of that second season. Consequently, yearling-herds exposed to the above average levels of infection in the first season gained more during the second season than herds with less previous experience. This finding may be explained by two phenomena. Firstly, compensatory growth may have occurred in herds which were underweight at the beginning of the second season. However, it seems unlikely that this could have been responsible for such improved growth rates that herds being underweight at the beginning of the season, gained on top of the actual compensating gain 16.5 kg./animal more by the end of the season. Secondly, immunity built up during the first year may prevent reduced growth rates, caused by nematode infections in the second year. This effect of acquired immunity will only become manifest if there is sufficient larval challenge. From the results of the faecal and serological examinations it may be concluded that there was sufficient challenge in the second year. The hypothesis of an effect of acquired immunity is in agreement with findings of Smith and Archibald (1968) and those of Borgsteede et al. (1985).

Finally, almost no significant relations were found between the level of exposure in the first year as calf and in the second year as yearling. The positive correlation found for pepsinogen values measured after the grazing seasons between years may be due to an allergic reaction to ingested larvae

in animals which are supposed to be immune (Armour et al., 1979). Also, no significant interaction between the antibody titres against Ostertagia, which were measured in the first and second year, on $HWDM_y$ was found, suggesting that the negative effect of the level of exposure in the second year on $HWDM_y$ occurred independent of previous experience. These results indicate that, apart from an effect of acquired immunity, the epidemiology and control of nematode infections in both age-groups can be dealt with separately. This reflects the habit on commercial dairy farms to graze calves and yearlings separately, which also agrees with the significant positive correlations found between infection parameters measured in yearling-herds on the same farms in subsequent years. As for yearling-herds, significant positive correlations were demonstrated between subsequent years for the infection parameters measured in calf-herds on the same farms participating in the present study (Ploeger et al., submitted[c]).

It may be concluded that controlling nematode infections in first-year calves will not necessarily result in improved weight gains over two consecutive grazing seasons on commercial dairy farms. Moreover, the results of the present study strongly suggest that calves should be allowed to build up immunity. However, the build-up of immunity, sufficient to prevent the weight gain losses caused by nematode infections in the second year as were demonstrated in the present study, should be balanced against the growth depressing effects of infective larvae picked up during the first year. This may be difficult to achieve with the at present available measures to control nematode parasitism. Therefore, it may be worthwhile to intensify the efforts to develop a vaccine against gastrointestinal nematodes.

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VII. EFFECT OF ANTHELMINTIC TREATMENT OF SECOND-YEAR CATTLE ON GROWTH PERFORMANCE DURING WINTER HOUSING AND FIRST LACTATION YIELD

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ABSTRACT

The effect of nematode infections on growth performance during winter housing and on first lactation yield was investigated in heifers on 69 farms. Presence of gastrointestinal nematode infections was confirmed in all herds by means of faecal examinations, during the second grazing season as well as in the subsequent housing period. Significant differences in antibody titres and pepsinogen values were found between herds. Half of each herd was treated with albendazole after housing. Treatment resulted in significantly reduced egg output, antibody titres against Ostertagia and Cooperia, and pepsinogen values in treated groups compared to untreated control groups on each farm. Albendazole-treated groups gained on average 0.007 cm./day (i.e. 0.05 kg./day) more than control groups during the housing period ($P \leq 0.10$), varying between herds from -0.060 to +0.137 cm./day. The difference between the lowest and highest growth rate for the control groups was 0.212 cm./day (i.e. 1.5 kg./day). Albendazole-treated heifers produced 195.4 kg. milk per 305-day lactation more than untreated heifers ($P < 0.01$). Per herd the milk yield response to treatment was +313.8 kg. milk ($P < 0.01$), varying from -876 to +1950 kg. No consistent relationships between infection parameters and the production parameters were found on herd by herd basis. It was found that milk production of untreated heifers increased with 10.5 kg. milk per kg. extra body weight, adjusted for age, measured after the second grazing season ($P < 0.05$). It is suggested that nematode infections occurring in the first two years of life negatively influence milk production by reduced weight gains.

INTRODUCTION

Heifers, exposed to nematode infections during their first and second grazing season, are supposed to possess a good acquired immunity (Armour et al., 1979; Borgsteede et al., 1985). Despite this immunity it has been found that heifers carry low to moderate worm burdens (Hong et al., 1981; Bairden and Armour, 1981; Borgsteede and v.d.Burg, 1982). Conflicting evidence has been reported about the negative effects of such worm burdens on the first lactation yield (Pouplard, 1978; McBeath et al., 1979; Michel et al., 1982; Prosl et al., 1983; Kloosterman and Albers, 1982; Fetrow et al., 1985). Besides the actual presence of infection, milk production of heifers may be influenced by the previous experience with nematode

infections. Van Adrichem and Shaw (1977) showed that first lactation yield was significantly correlated positively to body weight at calving adjusted for age at calving. They also showed that animals kept at lower levels of infection, by means of anthelmintic treatments during the first and second grazing season, weighed significantly more at calving compared to untreated controls. Furthermore, in the same study no differences were found in growth performance between the treated and untreated animals during the housing period after the second grazing season. Ploeger et al. (submitted[d]) demonstrated that both previous experience and actual exposure to nematode infection influenced growth performance of animals during their second grazing season on commercial dairy farms.

In the present study heifers, on the same commercial dairy farms used in the study of Ploeger et al. (submitted[d]), were investigated during winter housing after their second grazing season. On each farm the herd was divided into a treated and a control group after housing. Effect of treatment on growth performance over the housing period and on the first lactation yield was investigated. These data were related to the level of nematode parasitism estimated by means of faecal and serological examinations and to age-adjusted body weights achieved after the second grazing season.

MATERIALS AND METHODS

Farms and heifers

In this study 69 farms were involved. All these farms participated in a previous study investigating the effect of nematode infections on growth performance of yearlings in their second grazing season (Ploeger et al., submitted[d]). The heifers were pastured together as one herd during that second grazing season. At average 10 heifers were present in each herd (range: 4 - 21). The majority of heifers were of the Dutch Friesian breed, Holstein Friesian breed or crossbreds of these two (85.5%). About 6.3% were of the Meusse-Rhine-IJssel (MRIJ) breed and about 8.2% were of other breeds. Breeds were equally divided over treatment groups, both with respect to the body weight as to the milk production data. Some other characteristics are given in Table 1.

TABLE 1: Comparison of albendazole-treated and control heifers at the time of treatment.

	CONTROL GROUP	ALBENDAZOLE TREATED GROUP
number of heifers	314	348
age ± s.d. (days)	630 ± 87.4	634 ± 86.8
mean heart girth ± s.d. (cm.)	180.1 ± 9.6	180.6 ± 9.2
estimated body weight ± s.d. (kg.)[1]	447.1 ± 63.0	450.4 ± 61.4

[1] according to findings of Vos and Vos (1967).

Anthelmintic treatment

Half of each herd was treated orally with albendazole (Valbazen®, SmithKline Diergeneeskundige Produkten b.v.) at the manufacturer's recommended dose (7.5 mg/kg liveweight). The other half was left untreated (control group). On each farm heifers were randomly allocated to the albendazole-treated or control group. Treatment was given in November/ December (see Figure 1).

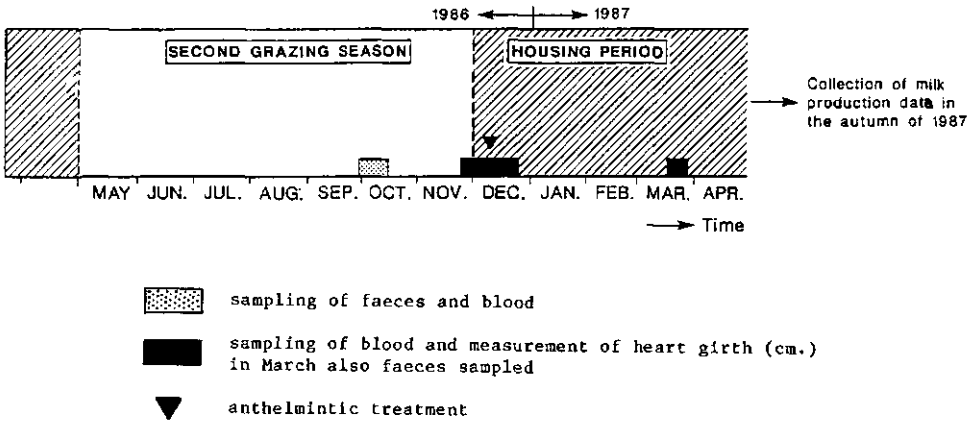

Figure 1: Sampling periods, anthelmintic treatment and observations relative to grazing season and housing period.

Measurement of growth performance

Growth performance of all heifers was estimated by measuring the heart girth, i.e. the circumference (cm.) of the chest directly behind the forelegs (Vos and Vos, 1967), and expressed as average daily gain (ADG-HG in cm./day). Figure 1 presents the schedule of measurements. Age, breed and expected calving date were recorded from each animal's identification card. The relevant traits investigated, were: growth performance of control heifers on each farm and the effect of albendazole treatment. The latter was expressed as the difference between treated and control groups in each herd. In Table 1 treatment groups are compared with eachother with respect to age, average heart girth and average estimated body weight. The latter was calculated according to Vos and Vos (1967).

The estimated body weights, in December, were adjusted for age, breed and stage of pregnancy (Ploeger et al., submitted[d]), and expressed as the body weight deviation from the overall population mean. Subsequent calculations were done with the average herd weight deviation from the population mean ($HWDM_y$ in kg. per yearling).

Milk production data

In the autumn 1987 milk production data, including milk fat and protein percentages, were collected at the local milk registration organisations. From each heifer the cumulative data of the first registration date past 100 days in lactation were taken. Age, breed and month of calving were recorded as well. Because not all heifers on the 69 farms calved between December 1986 and autumn 1987 or achieved at least 100 days in lactation, several herds had to be excluded from analysis. In total, data from 166 controls and 181 treated heifers in 47 herds were available, with at least 2 control and 2 treated animals in each herd.

Faecal and serological examinations

Faecal samples and sera were collected as described by Ploeger et al. (submitted[c]). Sampling periods are given in Figure 1. Egg output was estimated by counting gastrointestinal nematode larvae per gram faeces (LPG-GI) after culturing, combined with larval identification (Borgsteede and Hendriks, 1973, 1974). Lungworm larvae were counted per 30 grams of faeces (LPG-Dv), using a Baermann-technique.

Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus, as well as pepsinogen values were determined as described earlier by Keus et al. (1981), Boon et al. (1982) and Berghen et al. (1987). Sera were analysed soon after each sampling period. ELISA-tests, done in different periods, showed variation in overall levels without affecting the relative order of titres found. This was due to the use of different batches of reagents (e.g. conjugate, antigen, standard sera etc.). A separate analysis was done to adjust titres for this technical variation, to allow comparing between sampling periods.

Calculations and statistics

All continuous data were tested for normality and, with respect to serological and production data, for homogeneity of variance. Pepsinogen values were transformed according to the formula $Y = \ln(X)$. LPG-GI recorded in the second grazing season was transformed according to $Y = \ln(X+1)$. LPG-Dv was classified, because of a non-normal distribution which included many zero-counts.

Of 662 heifers 226 (34%) calved between December 1986 and March 1987. This had a pronounced influence on ADG-HG as is illustrated in Figure 2. The main reason for this effect of calving-date on ADG-HG is that lactation negatively influences body condition, at least during the first months of lactation. Overall, with respect to calving-date, heifers were equally distributed over both treatment groups. However, within farms a highly unequal distribution was seen. Because the herd was the experimental unit, ADG-HG was adjusted for date of calving. This was done by subtracting the 'predicted' ADG-HG values, obtained by the relationships between date of calving and ADG-HG, from the observed values. These relationships are shown in Figure 2. Before calculating these relationships heifers were divided into two groups, one group calving after the second heart girth measurement in March and one group calving before that date. For the former a correlation coefficient of +0.092 was found ($n = 326$, $P < 0.10$). It was

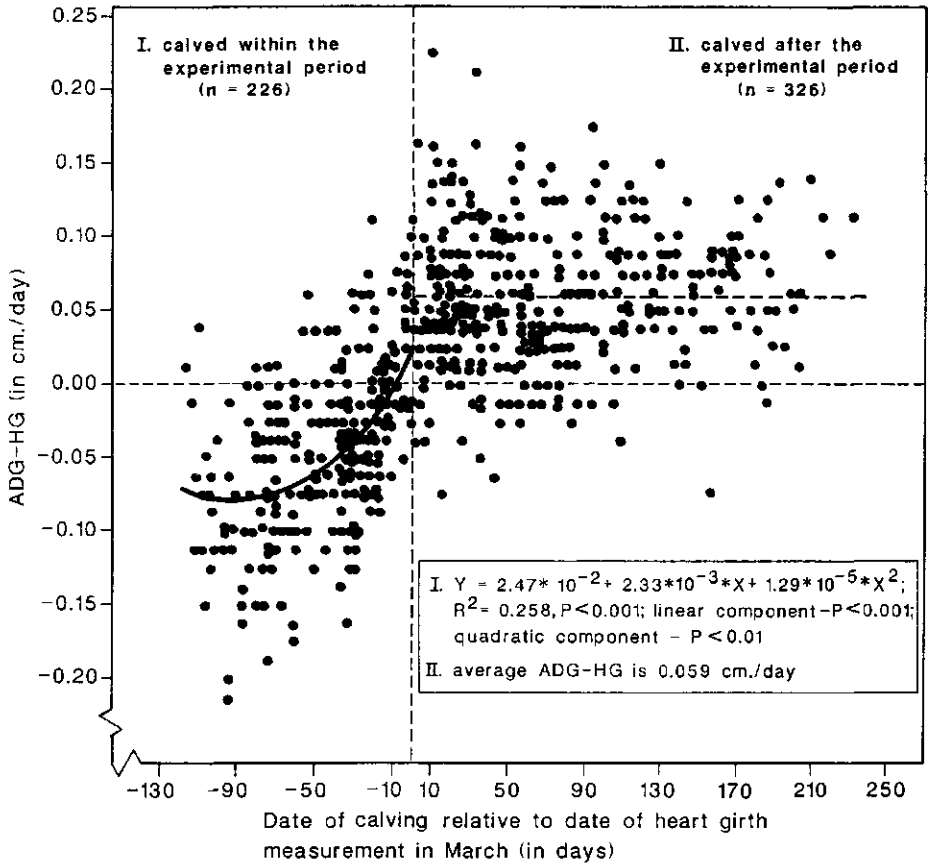

Figure 2: Growth performance during winter housing (ADG-HG) of heifers, calving within or after the experimental period from December 1986 to March 1987.

assumed that this weak relationship was more likely due to age per se than to date of calving. For the latter a non-linear relation was found (see Figure 2). This curvilinear relation may be explained by the fact that milk production is physiologically most demanding during the first months of lactation. The reason that both lines do not fit on eachother at the time of calving may be due to the variability in the data, but also to calving itself.

Milk production data were all corrected for age at calving, season of calving, breed, length of lactation and mean herd level of production to a standardized 305-day production according to correction factors obtained at the Zootechnical Institute of the Veterinary Faculty Utrecht and which are normally used in the Netherlands.

All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985), with herd as the experimental unit.

RESULTS

The results of the larval identifications in faecal samples collected in October and March are presented in Tables 2 and 3. In October Ostertagia spp. and Cooperia oncophora were the predominant larval types found. In March increased percentages of other genera were found in the control groups compared to October. From the larvae found in faecal samples from the untreated groups the majority was of the Cooperia oncophora type in 52.3% of the herds in March. Albendazole treatment had a clear effect on the larval identifications. For all genera the percentage of groups found positive were decreased, except for Ostertagia spp. and Haemonchus spp. In

TABLE 2: Identification of larval types found in faecal samples collected in October 1986 (n=62).

	Number of herds with faecal sample containing:					Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%	
Ostertagia spp.	2	25	14	7	12	2	60 (96.8)
Cooperia oncophora	10	15	10	11	14	2	52 (83.9)
Cooperia punctata	28	29	4	1	0	0	34 (54.8)
Trichostrongylus spp.	28	27	5	2	0	0	34 (54.8)
Oesophagostomum spp.	56	6	0	0	0	0	6 (9.7)
Haemonchus spp.	60	2	0	0	0	0	2 (3.2)
Bunostomum spp.	56	6	0	0	0	0	6 (9.7)

In 7 herds no faecal samples were collected.

TABLE 3: Identification of larval types found in faecal samples collected in March 1987 from albendazole-treated and untreated heifers.

	Number of herds with faecal sample containing:					Total number of positive farms (%):	
	0%	1-25%	25-50%	50-75%	75-99%	100%	
CONTROL GROUPS (n=65)							
Ostertagia spp.	6	31	14	7	2	5	59 (90.8)
Cooperia oncophora	16	9	6	11	23	0	49 (75.4)
Cooperia punctata	35	27	1	2	0	0	30 (46.2)
Trichostrongylus spp.	15	33	13	4	0	0	50 (76.9)
Oesophagostomum spp.	35	29	1	0	0	0	30 (46.2)
Haemonchus spp.	60	5	0	0	0	0	5 (7.7)
Bunostomum spp.	47	16	2	0	0	0	18 (27.7)
ALBENDAZOLE-TREATED GROUPS (n=67)							
Ostertagia spp.	2	6	3	3	23	30	65 (97.0)
Cooperia oncophora	47	11	1	2	6	0	20 (29.9)
Cooperia punctata	63	4	0	0	0	0	4 (6.0)
Trichostrongylus spp.	54	13	0	0	0	0	13 (19.4)
Oesophagostomum spp.	67	0	0	0	0	0	0 (0.0)
Haemonchus spp.	58	6	3	0	0	0	9 (13.4)
Bunostomum spp.	62	5	0	0	0	0	5 (7.5)

In two herds no faecal samples were taken from control heifers, and in two other herds no faecal samples from both groups were taken.

86.2% of the treated groups the majority of larvae found were of the Ostertagia type. Average LPG-GI was 27 (range: 1 - 196) in October. In March average LPG-GI was 45.8 (range: 1 - 240) for the control groups and 11.8 (range: 0 - 186) for the treated groups. This difference between treatment groups was highly significant ($P < 0.001$). Lungworm larvae were found in faecal samples from three herds in October and from two treated groups in March.

TABLE 4: Descriptive statistics for the serological parameters and effect of albendazole treatment on these parameters.

	OCTOBER 1986 (n=62)				DECEMBER 1986 (n=69)				MARCH 1987 (n=69)					
	mean	s.d.	min.	max.	mean	s.d.	min.	max.		mean	s.d.	min.	max.	sign. of difference
Dictyocaulus titre	4.79	0.77	3.4	6.8	4.00	0.86	2.5	6.9	C:	4.16	0.68	2.7	5.5	
									AT:	4.05	0.72	2.6	5.7	NS
Cooperia titre	4.80	0.84	2.7	7.0	4.09	0.81	2.0	5.8	C:	4.31	1.10	2.4	7.0	
									AT:	3.82	1.08	2.1	7.8	***
Ostertagia titre	7.02	0.93	5.4	8.8	6.41	0.92	4.6	9.0	C:	6.40	0.66	5.0	7.9	
									AT:	5.95	0.58	4.8	7.3	***
Pepsinogen value (mU)	1571	447	729	2752	1520	526	533	2520	C:	1678	638	499	3060	
									AT:	1297	551	191	2509	***

C = control groups; AT = albendazole treated groups.
NS = not significant; *** = $P < 0.001$.

The serological findings are given in Table 4. Within each sampling period the between-herd variation was significantly higher than the within-herd variation ($P < 0.001$). Mean herd antibody titres were significantly higher in October compared to December ($P < 0.01$). Mean herd antibody titres in December did not differ significantly from those found in the control groups in March. Pepsinogen levels did not differ significantly between October, December or March (control groups). Albendazole-treated groups showed significantly lower antibody titres against Cooperia and Ostertagia and pepsinogen values compared to control groups in March.

In Table 5 the correlation coefficients are given for the relations of the serological parameters with eachother within sampling periods. The correlations between antibody titres against Dictyocaulus viviparus and pepsinogen values were not significant. Antibody titre against Ostertagia correlated significantly to pepsinogen value in October ($P < 0.05$) and March ($P < 0.05$), but not in December. Antibody titre against Cooperia correlated significantly to pepsinogen value in October ($P < 0.05$) and December ($P < 0.05$), but not in March. None of the serological parameters correlated significantly to the LPG-GI in October and in March.

The individual variation in actual growth performance between December and March is illustrated in Figure 2. After adjustment for the effect of calving-date, i.e. days in lactation, the difference between highest and lowest growth rate observed for the control groups was 0.212 cm./day. The frequency distribution of ADG-HG, adjusted for calving-date, for the control groups is

TABLE 5: Pearson correlation coefficients for the relationships of the serological parameters with eachother within sampling periods.

	OCTOBER 1986 (n=62)			DECEMBER 1986 (n=69)			MARCH 1987 (n=69)[1]		
	Coop. titre	Ost. titre	Pep.- value	Coop. titre	Ost. titre	Pep.- value	Coop. titre	Ost. titre	Pep.- value
Dict.titre	.571 ***	.439 ***	.112 NS	.293 *	.435 ***	-.120 NS	.261 *	.344 **	-.202 +
Coop.titre		.566 ***	.253 *		.311 **	.238 *		.583 ***	-.018 NS
Ost.titre			.324 *			-.062 NS			.266 *

1 correlation coefficients refer to the serological parameters measured in the control groups.
NS = not significant; + = P < 0.10; * = P < 0.05; ** = P < 0.01; *** = P < 0.001 .

given in Figure 3. Albendazole-treated groups gained on average 0.007 cm./day more than control groups (P = 0.108), varying from -0.060 to +0.137 cm./day between herds. ADG-HG of the heifers, after adjustment for date of calving, was significantly positively correlated with age (P < 0.01). After age-correction albendazole-treated groups gained on average 0.007 cm./day more than the control groups (P < 0.10).

Only the regressions of growth rate of control groups on mean herd pepsinogen level and on LPG-GI, both determined in March, were significant (b = -0.017, r^2 = 4.14%, P < 0.10; and b = +0.007, r^2 = 6.23%, P < 0.05; respectively). For effect of albendazole treatment on growth performance only the regression on antibody titre against Dictyocaulus viviparus in October was significant (b= -0.013, r^2 = 8.76%, P < 0.05). After data were corrected for age, significant regressions were found for growth rate of control groups on antibody titre against Cooperia in October (b = -0.010, r^2 = 5.00%, P < 0.10), on pepsinogen value and on LPG-GI, both in March (b = -0.018, r^2 = 4.88%, P < 0.10; b = +0.007, r^2 = 5.71%, P < 0.10; respectively). For effect of albendazole treatment the regression on antibody titre against Dictyocaulus in October became slightly weaker (b = -0.012, r^2 = 7.70%, P < 0.05).

In Figure 4 the frequency distribution of the adjusted 305-day lactation yield is given for both control and albendazole-treated heifers. Individually, treatment resulted in an increase of 195.4 kg. milk. Analysis of variance showed that both farm effect and treatment effect were significant (P < 0.001 and P < 0.01, respectively). No significant differences between treated and control heifers were found for percentages fat and protein (-0.032% and -0.017%, respectively).

Per herd, treatment effect on milk production varied from -876 to +1950 kg./heifer/305-day lactation. The average mean herd response to treatment was +313.8 kg. milk (P < 0.01). Of the 47 herds 32 (= 68%) showed a positive response to treatment. Mean herd response to treatment was only significantly related to antibody titre against Dictyocaulus viviparus in December (b = -327.1, r^2 = 10.9%, P < 0.05).

Milk production in the control groups was significantly correlated to $HWDM_y$, recorded after the second grazing season (r = 0.335, P < 0.05). Per

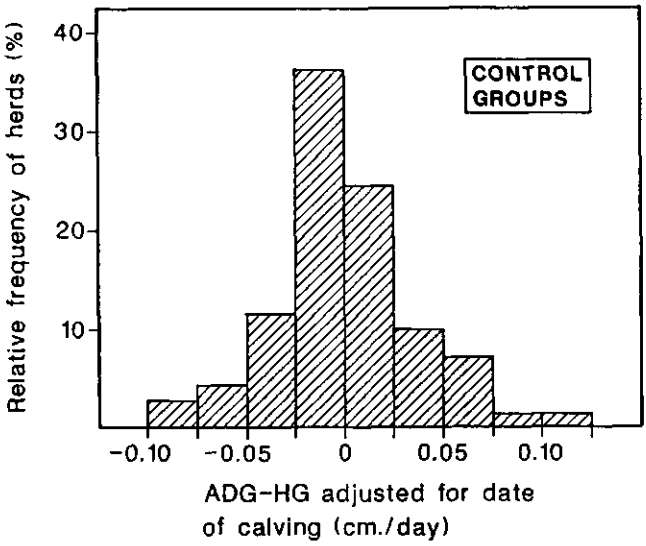

Figure 3: Frequency distribution of growth rates (ADG-HG), adjusted for date of calving, measured in the untreated heifers per herd.

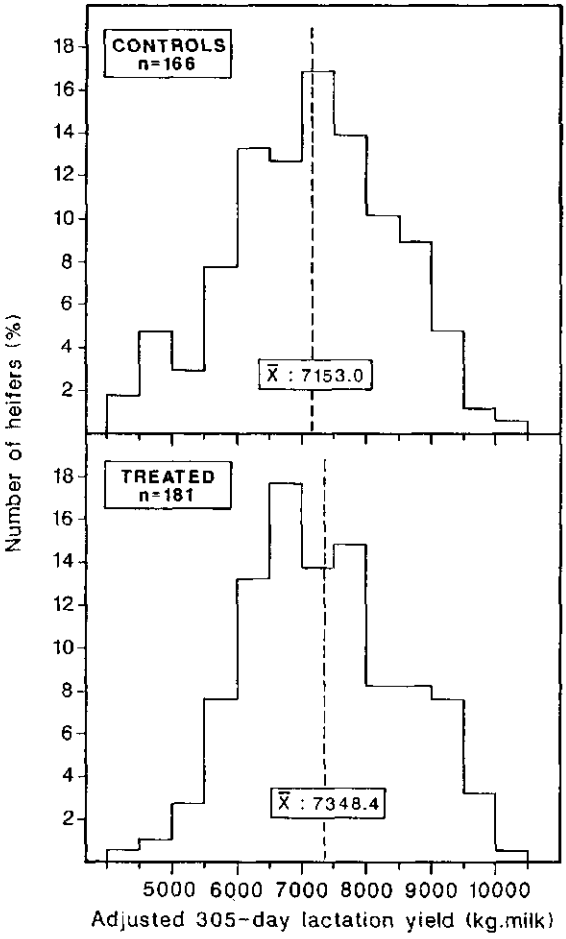

Figure 4: Effect of albendazole treatment in heifers on the first lactation yield.

kg. extra body weight milk production increased with 10.5 kg./305-day lactation. This relation is graphically presented in Figure 5. A similar but not significant result was obtained for the albendazole-treated groups in each herd (b = +7.20, r = 0.227, N.S.).

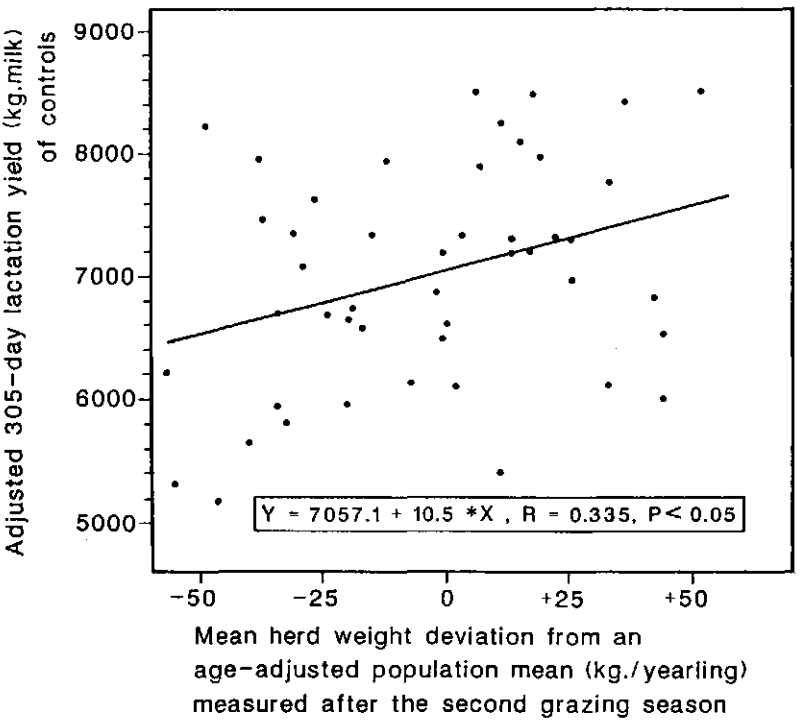

Figure 5: Linear regression of the first lactation yield on the mean herd weight deviation from an age-adjusted population mean ($HWDM_y$ in kg./yearling) measured after the second grazing season.

DISCUSSION

Anthelmintic treatment of heifers after the second grazing season increased both growth performance and the first lactation yield. Growth performance increased by 0.007 cm./day, which can be estimated as approximately +0.05 kg./day according to Vos and Vos (1967). Over the observed period this amounted to some 5 to 6 kg. body weight advantage in favour of the treated heifers. Anthelmintic treatment resulted in significantly decreased antibody titres against Ostertagia and Cooperia, pepsinogen values and egg output in March. These findings agree with results of Williams et al. (1977), Downey (1978) and Borgsteede (1979). Treatment did not result in significantly decreased antibody titres against

lungworm. Also, in March lungworm larvae were only found in faecal samples of 2 treated groups. Downey (1978) demonstrated that albendazole was highly effective against Dictyocaulus. These results indicate that no lungworm burdens were present at housing, suggesting that the heifers developed a solid immunity against lungworm during the previous grazing seasons. The finding of lungworm larvae in 2 treated groups may have been due to reinfection via the hay during the housing period. So, it is reasonable to assume that the slightly increased growth performance observed for the treated compared to the untreated heifers, was due to a decreased level of gastrointestinal nematode parasitism.

Between herds the effect of treatment on growth performance varied from -0.060 to +0.137 cm./day, which can be estimated as -0.42 to +0.96 kg./day. Growth performance of control groups varied also considerably between herds with a difference between smallest and largest gain of 0.212 cm./day. This figure can be estimated, according to Vos and Vos (1967), as approximately 1.5 kg/day. For heifers of at average 21 months old this is quite a difference. These results are very difficult to explain. Differences in the plane of nutrition will account for most of the variation in growth performance between herds. The infection parameters varied also significantly between herds. However, no consistent relationships were found between the infection parameters and the effect of albendazole treatment on growth rate, or the growth rate of the control groups. Technical variation inherent to heart girth measurements may have caused some variability, but it is unlikely that this could have resulted in such a large between herd variation as observed in the present study. Perhaps stage of lactation influenced the level of resistance to nematode infection of heifers. It has been found that such an acquired immunity is largely lost by heifers early in lactation (Michel et al., 1979). In the present study not all heifers calved during the period of observation and moreover, the distribution of heifers with respect to calving-date was not always similar between treatment groups within herds. Therefore, lactation may have interfered with a possible straightforward relation between level of infection and growth performance. Petrie et al. (1984) suggested also that heifers may acquire more infective larvae late in the grazing season due to a periparturient suppression in immunity. In the present study, both the weather conditions recorded (K.N.M.I., 1987) and the results of the faecal and serological examinations support the hypothesis that substantial numbers of larvae may have been ingested relatively late in the grazing season in 1986. In 1986 a prolonged and extremely dry period was recorded from mid-June to mid-August. Pepsinogen values were in December as high as in October, while they were highest in March. Egg output in control groups was higher in March compared to October. Furthermore, egg output, antibody titres against Ostertagia and Cooperia and pepsinogen values were significantly lower in treated than in untreated groups in March.

Interesting results were obtained regarding the subsequent milk production in the first lactation. On an individual basis anthelmintic treatment resulted in a significant increase of 195.4 kg. milk per 305-day lactation. Per herd this increase was 313.8 kg. The difference between these figures is puzzling. It suggests that the effect of treatment was largest in the smaller herds, or at least in herds in which few heifers participated in the trial. No consistent relations were found between the mean herd milk yield response to treatment and the infection parameters. A

significant negative relation was found with antibody titre against lungworm in December, which is difficult to explain. Against lungworm infections a solid immunity is built up during the first year(s) at pasture, which agrees with the faecal and serological findings in the present study. Perhaps the significant negative relation resulted from the need to maintain this immunity against incoming larvae at the expense of production (Bairden and Armour, 1981). That herds were exposed to lungworm infections was confirmed by the finding of lungworm larvae in faecal samples taken in October as well as in faecal samples taken in March. The same may apply for gastrointestinal nematode infections, although no significant relations with the relevant infection parameters were found.

Milk production of the control heifers was significantly positively correlated to the age-adjusted body weight ($HWDM_y$) after the second grazing season. Although $HWDM_y$ does not give the exact weights at calving, this result suggests that heifers may produce 10.5 kg. more milk over the first lactation per kg. of extra body weight at calving. This is in agreement with findings of Boxem (1981), who found an increase of 8.5 kg. milk per kg. extra body weight at calving. In previous studies on the same farms as used in the present study, it was shown that nematode infections occurring in the first and second year influenced growth performance (i.e. $HWDM_y$) significantly (Ploeger et al., submitted[abd]). Therefore it can be speculated, that these nematode infections during the first and second grazing season influence milk production negatively by reduced body weights at calving. A similar conclusion was drawn by Van Adrichem and Shaw (1977), who also found a significant positive correlation between body weight at calving, adjusted for age, and subsequent milk yield in heifers. Prosl et al. (1983) did not find differences in milk production between heifers treated with a MSRB-bolus, in the first as well as in the second grazing season, and untreated heifers. However, the MSRB-treated heifers calved on average 19 days earlier.

For the treated groups in the present study, it was found that per kg. of extra body weight heifers produced 7.5 kg. milk more, which was lower than the figure found for the untreated heifers. This may have been due to higher milk yield responses to anthelmintic treatment in heifers which were underweight compared to heifers with higher age-adjusted body weights.

Summarizing, significant positive effects of anthelmintic treatment were found on growth performance as well as on milk production. Treatment also reduced the levels of gastrointestinal nematode infection significantly. No consistent relations could be demonstrated between the levels of infection and growth performance during winter housing or milk production on herd by herd basis. It is concluded from the significant and positive correlation found between body weights after the second grazing season and first lactation yield, that nematode infections occurring in the first two years of life negatively influence milk production by reduced weight gains. Further investigations are needed, particularly on the effect of calving and lactation on immunity to nematode infections.

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VIII. EFFECT OF ANTHELMINTIC TREATMENT OF DAIRY CATTLE ON MILK PRODUCTION RELATED TO SOME PARAMETERS ESTIMATING NEMATODE INFECTION

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ABSTRACT

On 31 farms blood samples were taken from adult dairy cattle in September 1985, while pastured, and in November/December 1985, when stabled, to assess serum pepsinogen levels and level of nematode antibody titres. Faecal samples taken in September were examined to establish presence of parasites by means of egg counts and larval identification. During the stabling period dry cows were either treated with ivermectin or with a placebo in alternate sequence of expected calving-date. As a result 285 cows were treated with ivermectin while 242 cows served as controls. Anthelmintic treatment resulted in a significant increase in the 305-day milk production of 205.1 kg ($P < 0.01$). Fat and protein percentage were not significantly influenced by anthelmintic treatment. There was a significant between herd variation in nematode antibody titres and in pepsinogen values. The mean herd milk production response to treatment correlated positively with the mean herd Ostertagia antibody titre measured in September 1985 ($r = 0.364$, $P < 0.05$).

INTRODUCTION

In the past two decades numerous authors have dealt with the impact of gastrointestinal nematode infections on milk production in adult dairy cattle. Of these authors a few worked with experimental infections in adult dairy cattle, whereas the majority used anthelmintic treatment as a means to study the effect of infections on milk production. Overall, results did not present unequivocal evidence of a negative influence of these worm infections on milk yield. Since the work of Todd and Bliss and co-workers (1972, 1973, 1974, 1976) that showed an increase in milk yield after anthelmintic treatment of cows, some authors reported the same while others could not find such an increase. Yet most of the work done showed positive responses, although in most cases no statistical significance could be demonstrated. As a result a continuing controversy exists about the effect of nematode infection on milk production. Several factors play a role in this controversy.

Several authors showed gastrointestinal nematode infection to be widespread among adult cows (Yazwinski and Gibbs, 1975; Randall and Gibbs, 1977; Grisi and Todd, 1978; Borgsteede and Van der Burg, 1982; Vercruysse

et al., 1986). However, a relationship between level of infection and treatment response has not been shown thusfar. Some authors have drawn attention to this point (Glenn et al., 1982; Herd, 1982; Thomas et al., 1984; Fetrow et al.,1985). Baker in 1979 said this to be the most overlooked fact. A reason for this lack of knowledge might be that infection parameters used are not sensitive enough in adult cows. Frechette and Lamothe (1981) and Michel et al. (1982), investigating 13 and 120 herds respectively, could not demonstrate such a relationship using faecal egg counts as a parameter of infection. Recently O'Farrell et al. (1986) also could not demonstrate such a relationship when blood pepsinogen values were used.

Secondly, milk yield is a highly variable trait and so are milk production responses to treatment. This is not only true for individual cows but it is also very common to find on one farm a large positive response of several hundreds of kilograms of milk whereas on another farm the response may even be negative (Todd et al., 1978; McBeath et al., 1979; Frechette and Lamothe, 1981; Barger and Lisle, 1982; Michel et al., 1982). It is evident that number of observations and method of comparing groups can influence the final results of trials (Michel and Mulholland, 1981; Thomas and Rowlinson, 1981; Fox and Jacobs, 1984).

Thirdly, timing of treatment with respect to stage of lactation may be important. Although most authors describing treatment during lactation reported positive responses, most of them suggest that a greater economical benefit may be achieved by treatment early in lactation. Also, with respect to timing of treatment, one should consider the seasonal occurrence of infections (Baker, 1979).

The present study focusses on the relationship between milk yield response to anthelmintic treatment and level of nematode infections, assessed either by level of antibody titres, pepsinogen values or egg output.

MATERIALS AND METHODS

Farms and cows

In this study 31 farms participated, all situated around the city of Utrecht and belonging to the Veterinary Practice of the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty in Utrecht. These farms were selected out of 100 on basis of pepsinogen values in September 1985 in an effort to form a group of herds with a relatively low and one with a relatively high level of nematode infection. The farms had a mean of 56 cows, ranging between 22 and 114, which calve throughout the year. With respect to number of cows and level of actual milk production (mean of 5731 kg.) these farms resembled the overall figures of all farms in the Netherlands (L.E.I./C.B.S., 1987).

All cows in the trial calved between December 1985 and June 1986 during the stabling period. A few cows were treated in the summer grazing period. Data from these cows did not differ significantly from the other cows, hence they were included. Specifics with respect to age, breed and month of calving are given in Table 1.

TABLE 1: Number of cows according to age at calving, breed and season of calving over treatment groups.

AGE AT CALVING*		2.05-4.00		4.00-7.00		7.00-		
BREED**		black	red	black	red	black	red	
MONTH OF CALVING								TOTAL
Dec - Feb	controls	22	3	40	10	4	3	82
	treated	29	8	36	7	4	1	85
Mar - May	controls	38	4	74	10	17	2	145
	treated	56	11	79	9	21	2	178
Jun - Aug	controls	5	0	7	1	1	1	15
	treated	8	0	7	1	6	0	22
	TOTAL	158	26	243	38	53	9	527

* 2.05 means 2 years and 5 months old.
** black: Holstein Friesians, Dutch Friesians and crossbreds of these.
red : Maas-Rijn-IJssel breed, crossbreds of this breed with Holstein Friesians and a few other breeds or crossbreds.

Anthelmintic treatment

The anthelmintic drug used was ivermectin (Ivomec®, M.S.D.Agvet) injected subcutaneously at the manufacturer's recommended dose (0.2 mg/kg liveweight). Anthelmintic and placebo solution (i.e. the vehicle for ivermectin without the active drug) were given in colour-coded bottles to the farmer in sufficient amounts to treat cows dried off during the stabling period. With these, an administration form with instructions was given, which was carefully explained to the farmers. Cows were treated at least one month before the expected calving-date or when they were dried off, because of a withdrawal period of 28 days for ivermectin. On each farm cows were alternately allocated to the anthelmintic treatment or to the control group in order of expected calving-date. Control animals were subcutaneously injected with the placebo. At the end of the trial 285 animals had been treated with ivermectin and 242 cows served as non-treated controls. The difference between numbers of treated and control cows is merely coincidental and could only be explained by culling of cows.

Milk production data

In the autumn of 1986, when all cows in the experiment were at least 100 days in lactation, milk production data including milk fat and protein percentages were collected at the local milk registration organisations. Age, breed and previous lactation performance were recorded at the same time. From each cow the cumulative data of the first registration date past 100 days in lactation were taken, so that at average each cow was 112 days in lactation. Collection of these data was done again at the end of the lactation period or, when this exceeded 305 days, at 305 days. At this time data of 219 control and 250 treated cows were available.

Faecal examinations

At the end of September 1985 prior to the commencement of the trial period, faecal samples were taken from freshly deposited pats (as many as possible) on pasture grazed by adult cows at that time. On each farm these samples were thoroughly mixed and split into two parts. One sample per farm was used to assess a mean herd level of egg output. Because of the expectation that EPG's would be very low, egg output was measured by counting larvae per gram faeces (LPG) after culturing, combined with larval identification. These examinations were done at the Central Veterinary Institute in Lelystad, according to their routinely used methods (Borgsteede and Hendriks, 1973, 1974). The other sample was used for examining presence of lungworm larvae (per 30 grams). This was done at the Department of Helminthology and Entomology of the Veterinary Faculty Utrecht.

Serological examinations

From 5 randomly chosen cows in each herd blood samples were taken. Sampling took place twice, in September 1985 together with faecal sampling and also at the commencement of the trial in November 1985 after all cows had been stabled. The following parameters were assessed in the serum obtained from these samples. Firstly, antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus were determined by means of an ELISA technique (Keus et al., 1981; Boon et al., 1982), using crude antigens from adult worms. Secondly, pepsinogen values were assessed in each sample following the method described by Berghen et al. (1987).

Sera were analysed soon after each sampling period. ELISA-tests, done with a time-span of several months in between, showed variation in overall levels without affecting the relative order of titres found. This was due to the use of different batches of reagents (e.g. conjugate, antigen, standard sera, etc.). A separate analysis was done to allow comparing between sampling periods.

Management data

In the autumn of 1985 each farmer was visited to obtain data on farm, herd and general management by means of a questionnaire.

Statistics

Current and previous milk production data were all corrected for age at calving, season of calving, breed, length of lactation and mean herd level of production to a standardized 305-day production according to correction factors normally used in the Netherlands. Finally all subsequent calculations and statistics were based on the differences between current and previous lactation yields to stabilize genetic variation.

Serological data were tested for normality on an individual basis and for homogeneity of variance in case mean herd titres had to be used. Only pepsinogen values were not normally distributed and were transformed according to the formula $Y = \ln (X)$.

Data obtained from faecal examinations were based on a herd sample and

were tested for normality. Larval counts were logarithmically transformed according to $Y = {}^{10}\log (X+1)$.

Management data were either categorical or continuous variables. The latter were tested for normality. If non-normality existed, these variables were classified into categorical data.

All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985).

RESULTS

Descriptive statistics for mean herd antibody titres against Cooperia spp., Ostertagia spp. and Dictyocaulus viviparus and for pepsinogen values are given in Table 2. All serological parameters showed a strongly significant between herd variation compared to the within herd variation ($P < 0.01$ for antibody titres against Dictyocaulus viviparus and $P < 0.001$ for all other parameters, in September as well as in November). From Table 2 it is apparent that variation between herds was larger in September than in November. Comparison between sampling periods revealed that antibody titres against Dictyocaulus viviparus and against Cooperia spp. increased ($P < 0.05$), while antibody titres against Ostertagia spp. decreased (N.S.) from September onwards. Mean herd pepsinogen levels decreased significantly ($P < 0.001$).

TABLE 2: Descriptive statistics for the serological parameters measured on a herd basis (n = 31).

	SEPTEMBER				NOVEMBER			
	mean	s.d.	min.	max.	mean	s.d.	min.	max.
Dictyocaulus titre	3.92	0.44	2.8	4.6	4.11	0.38	3.3	4.9
Cooperia titre	3.65	0.75	1.4	4.6	3.97	0.46	3.0	5.1
Ostertagia titre	6.04	1.07	3.8	8.0	5.81	0.60	5.0	7.3
Pepsinogen value	1968	701	731	2918	950	297	455	1699

Pepsinogen value is the untransformed value in mU.

Selection of farms on basis of their mean herd pepsinogen level in September 1985 did not affect the distribution of the mean herd antibody titres compared to the frequency distribution of all 100 farms examined initially.

Gastrointestinal nematode larval counts per herd varied between 1 and 16 LPG (mean 3.4). No lungworm larvae were found. Table 3 shows the results of the larval identifications. Ostertagia spp. were the most prevalent type found.

Table 4 presents the correlation coefficients between the serological parameters measured in September on pasture and in November after housing. Within each sampling period it appears that for the pepsinogen values only the correlations with Ostertagia antibody titres were significant ($P < 0.05$). No significant relations between coprological parameters and serological parameters were found.

TABLE 3: Identification of larval types in faecal samples collected in September 1985 (n=29).

Species:	Number of herds with % of larvae in faecal sample found: 0%	1-25%	25-50%	50-75%	75-99%	100%	Total number of positive farms (%):*
Ostertagia spp.	0	4	11	8	5	1	29 (100.0)
Cooperia oncophora	13	7	7	1	1	0	16 (55.2)
Cooperia punctata	12	16	1	0	0	0	17 (58.6)
Trichostrongylus spp.	6	16	4	3	0	0	23 (79.3)
Oesophagostomum spp.	7	19	2	1	0	0	22 (75.9)

* On two farms no faecal samples were taken.

TABLE 4: Coefficients of correlation of the serological parameters with eachother within and between sampling periods in 1985 (n = 31). Coefficients are above the diagonal, whereas the corresponding significancies can be found below the diagonal.

	SEPTEMBER				NOVEMBER			
	Dict. titre	**Coop. titre**	**Ost. titre**	**Pep.-value**	**Dict. titre**	**Coop. titre**	**Ost. titre**	**Pep.-value**
SEPTEMBER								
Dict. titre	-	.414	.358	.286	.204	.146	.180	.079
Coop. titre	*	-	.513	.214	.079	.060	.196	.417
Ost. titre	*	**	-	.452	.125	.044	.237	.215
Pep.-value	NS	NS	*	-	-.083	-.090	.280	.086
NOVEMBER								
Dict. titre	NS	NS	NS	NS	-	.496	.328	.215
Coop. titre	NS	NS	NS	NS	**	-	.706	.132
Ost. titre	NS	NS	NS	NS	NS	***	-	.362
Pep.-value	NS	*	NS	NS	NS	NS	*	-

NS = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001 .

Overall response to anthelmintic treatment, measured after 100 days of lactation, consisted of a significant increase of 205.1 kg. milk/cow/305 days of lactation ($P < 0.01$), as is shown in Figure 1. Analysis of variance on individual data demonstrated significant effects on the difference between current and previous lactation of age at calving ($P < 0.001$), production level of individual cows ($P < 0.001$), farm ($P < 0.001$) and of interactions between treatment and farm ($P < 0.05$) and between treatment and level of production ($P < 0.05$). Figure 2 graphically presents the effect of interaction between level of production of individual cows and treatment on milk production. This is done by showing the effect of treatment on the relationship between previous and current lactation performance. No effect of month of calving and breed could be demonstrated on the difference between current and previous lactation, nor were there significant interactions of these with treatment effect.

No significant differences between treated and control cows for percentage fat and protein were found (-0.033% and +0.009%, respectively).

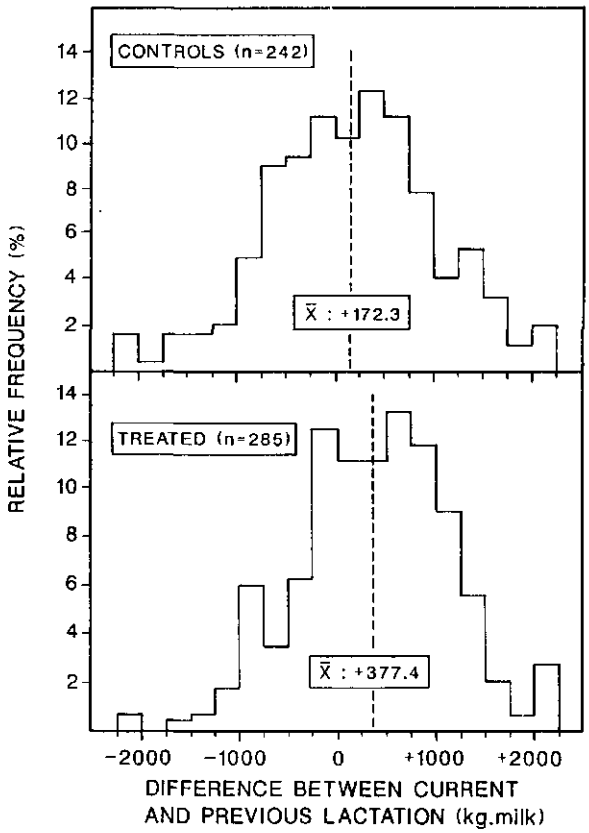


Figure 1: Effect of ivermectin treatment on the frequency distribution of the difference between current and previous lactation performance.

Milk production data collected at the end of the lactation period showed an increase of 143.5 kg. milk/cow/305 days of lactation in favour of the treated cows ($P < 0.10$). The difference with the earlier mentioned 205.1 kg. was largely due to the fact that about 11% of the cows were culled after the first 100 days. When data obtained after 100 days of lactation of these cows were left out, the figure of 205.1 kg. becomes 169.7 kg. ($P < 0.05$).

On a herd basis, the average treatment effect on milk production varied between -839 to 1287 kg./cow/lactation. Of the 31 farms 17 showed a positive response to anthelmintic treatment. Table 5 shows the coefficients of regression and correlation between the mean herd milk yield response to anthelmintic treatment and the serological parameters. Only the correlation between response and Ostertagia antibody titre measured in September 1985 was significant ($P < 0.05$). In Figure 3 this relationship is graphically presented with the 95% confidence interval. Based on this interval, probabilities of a positive mean herd response to anthelmintic treatment can be calculated when the Ostertagia antibody titre is known. It appears

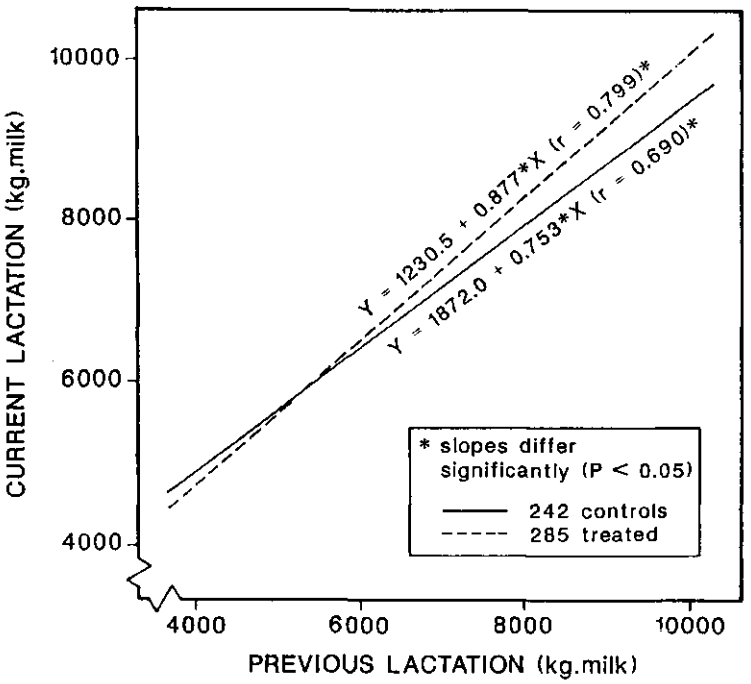


Figure 2: Effect of ivermectin treatment on the relationship between previous and current lactation performance.

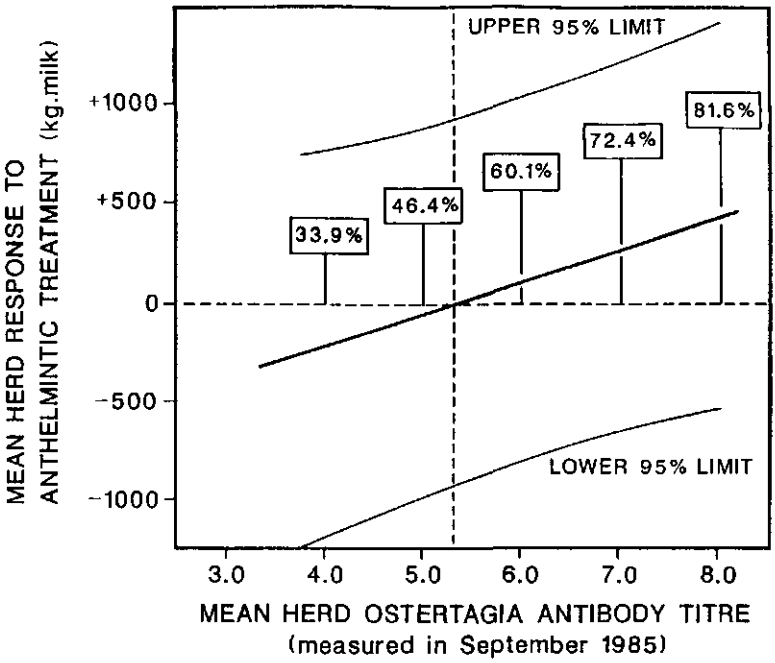
TABLE 5: Linear regression of the mean herd milk yield response to anthelmintic treatment on the serological parameters (n = 31).

	SEPTEMBER			NOVEMBER		
	regression coefficient ± s.e.	r^2 (%)	P	regression coefficient ± s.e.	r^2 (%)	P
Dict. titre	180.5 ± 196.5	2.83	NS	97.6 ± 233.2	0.60	NS
Coop. titre	107.4 ± 116.0	2.87	NS	246.0 ± 186.2	5.68	NS
Ost. titre	161.5 ± 76.7	13.25	*	143.5 ± 142.7	3.37	NS
Pep.-value	-13.9 ± 214.6	0.01	NS	353.8 ± 272.8	5.50	NS

Levels of significance (P) are; NS = not significant; * = P<0.05 .

that in this study at least 3 out of 4 herds with antibody titres of 7.0 or higher will benefit from an anthelmintic treatment. No significant relations were found between LPG and mean herd milk production response to anthelmintic treatment or with any of the results of the larval identification.

Contrary to what was found on an individual basis no significant effect of level of production on response to anthelmintic treatment was detected on a herd basis. In comparison to Figure 2 regression coefficients on a herd basis were for the not treated cows 0.960 (s.e.= 0.099) and for the treated cows 1.040 (s.e.= 0.086). Also, no significant relationships were



Percentages represent the chance of finding a positive mean herd response to anthelmintic treatment at that particular antibody titre.

Figure 3: Linear regression of the mean herd milk yield response to anthelmintic treatment on the antibody titre against Ostertagia spp. (n = 31).

found between the mean herd milk yield response and most of the other herd and management characteristics. The latter included date of housing prior to treatment, date of turnout in spring, quantity of concentrates fed, type of stable, and number of total stock present per hectare. Only the number of cows was significantly related to some of the serological infection parameters, namely mean herd antibody titre against Ostertagia spp. ($r = 0.371$, $P < 0.05$) and against Dictyocaulus viviparus ($r = 0.416$, $P < 0.05$), both measured in September 1985.

DISCUSSION

Treated cows significantly produced 205.1 kg of milk for a complete 305-day lactation more than non treated cows, based on the first 100 days of lactation. This level of increase, due to anthelmintic treatment, falls within the range often mentioned in the literature. When data of completed lactations were used, response to treatment was lower. This decrease in effect of treatment over a whole lactation period compared to the first 100 days was largely due to the culling of cows in mid or late lactation. So, at both collection dates virtually the same response was found. This

supports the finding of Todd and co-workers that the greater economical benefit of treatment will be achieved early in lactation (Todd et al., 1978). Possibly the effect of treatment measured at the end of the lactation period would have been greater if cows had not been pastured during the summer. On the other hand it was shown that the increase in milk production during the first 100 days persisted through the grazing season until the end of the lactation period.

On a herd basis the response to treatment varied considerably from as low as -839 to as high as +1287 kg. milk/cow/lactation, with only 17 herds showing a positive response. Apparently treatment had no effect on several farms. Todd et al. (1978) and Michel et al. (1982) also found that effect of treatment on milk yield was negligible on a number of farms. This might be due to differences in level of infection between herds.

Faecal examinations in this study revealed the presence of gastrointestinal nematode infections on all farms, with Ostertagia spp. being the most prevalent. The results in Table 3 are typical for the Netherlands. Since egg output is generally considered to be a poor indicator of infection level in adult cattle (Michel, 1968; Barth et al., 1981; Borgsteede, 1982), serology may provide a better means to discriminate between herds with respect to exposure to infection (Kloosterman, 1983; Kloosterman et al., 1985). Indeed serology showed a significant between herd variation in level of antibody titres and pepsinogen values, in September as well as in November. Relating this to the mean herd response to treatment, a significant positive correlation with the mean herd Ostertagia antibody titre measured in September was found. No significant relationships were demonstrated between mean herd response and any of the other serological parameters, which is perhaps not surprising.

Firstly, adult cows seem to have a stronger developed acquired immunity against lungworm and Cooperia infections than against Ostertagia infections. This is supported by the results of the present larval identifications and those of Borgsteede (1982) who found Ostertagia spp. to be the most prevalent larval type in adult cattle. Secondly, pepsinogen values are even within herds very variable, whereas antibody titres show a lower within herd variation and are thus useful in discrimating between herds. Further, although pepsinogen levels correlated significantly with Ostertagia antibody titres, they do not entirely reflect the same events (Kloosterman et al., 1985). Frechette and Lamothe (1981), Michel et al. (1982) and O'Farrell et al. (1986) also were not able to demonstrate significant correlations between mean herd response to treatment and faecal egg counts or pepsinogen values.

The correlation between mean herd Ostertagia antibody titre and mean herd response was not strong enough to allow a precise prediction of the effect of anthelmintic treatment on milk production. Nevertheless, with Figure 3 in mind, one can say that the chance of achieving a positive effect of treatment will be much greater in herds with the higher levels of antibody titres. A predictive 'index of parasitism', based on several serological parameters and perhaps combined with results of faecal examinations, might be a great help in deciding whether or not to treat herds. Such an index would provide a more economical and rational basis for control of nematode infections rather than to use treatment as a means in diagnosing subclinical worm parasitism (Todd et al., 1978). However, at

present the construction of such an index is not yet feasible.

Timing of sampling to estimate infection levels could prove to be very crucial, perhaps more so with respect to pepsinogen values than with antibody titres, the latter being more stable once elevated. The only infection parameter significantly correlated with the mean herd milk yield response to treatment, was measured in September. The variation between herds was greater in September than in November (Table 2). Kloosterman (1983) showed that levels of antibody titres in cows peak around August. At that time it is to be expected that variation between herds is largest. For yearlings and calves this peak fell in September and October respectively. Since these age-groups were also investigated, we had to compromise with respect to time of sampling due to practical circumstances.

Herd and management characteristics should be taken into account as well. In this study, however, these seemed not to play an important role. No influence of age, breed or month of calving could be demonstrated on the effect of treatment. Likewise no effect of some other management factors were found. Possibly the very complex interactions between such herd and management factors in influencing both epidemiology of infections and level of production interfere with this. An interesting result was the significant interaction between level of production and effect of treatment, based on individual data. This indicated that high producing cows benefitted more from treatment than low producing cows (Figure 2). So, one would expect to find that farms with a high level of production also would show a relatively higher response to treatment. Although there was a difference pointing into this direction, this was not significant. This is probably due to the rather low number of observations (31) in view of the enormous variation when calculations are based on mean herd values. Bliss and Todd (1973) reported that the 'better managed' herds showed the higher responses, however without stating the criteria for this qualification of management and without performing statistical analysis. Thomas et al. (1984) found that the treatment response in heifers was higher on farms where in the previous year heifers produced more compared to other farms. In the same study no such relationship seemed to exist for mature cows. Still, it can be speculated that gastrointestinal nematode infections will affect milk production relatively more in cows producing at the higher levels, in which the physiological relations will be more critical compared to low producing cows.

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IX. MILK YIELD INCREASE AFTER ANTHELMINTIC TREATMENT OF DAIRY CATTLE RELATED TO SOME PARAMETERS ESTIMATING HELMINTH INFECTION

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ABSTRACT

On 81 farms blood samples were taken from adult dairy cattle on pasture in October 1986 and after stabling in December 1986, to measure antibody titres against the nematodes Dictyocaulus viviparus, Cooperia spp. and Ostertagia spp. and the trematode Fasciola hepatica, and serum pepsinogen values. Faecal samples, collected in October, were examined to confirm the presence of parasites by means of egg counts and larval identifications. From December until the end of the stabling period dry cows were either treated with albendazole or left untreated in alternate sequence of calving-date. Treated cows produced 132.9 kg. milk/cow/lactation more than untreated cows ($P < 0.01$). Fat and protein percentage were not significantly influenced by anthelmintic treatment. Mean herd milk yield response to treatment varied from -899 kg. up to +1231 kg. milk/cow/lactation. There was a significant between herd variation in antibody titres against nematodes and in pepsinogen values. However, no significant correlations between these parameters and the mean herd milk yield response to treatment were found.

INTRODUCTION

Since Todd and Bliss and co-workers (1972, 1973, 1974, 1976) showed that milk yield of cows increases after anthelmintic treatment, numerous authors reported about the same subject. Combined, results presented conflicting evidence of a negative influence of helminth infections on milk production in dairy cattle. Nevertheless, an increase in the use of anthelmintics in adult cows was seen in Great Britain since the early seventies (Michel et al., 1981). This was partly due to the fact that most of the work done showed positive responses, although statistical significance was often absent. Between herds, however, variation in milk yield response to anthelmintic treatment is very large (McBeath et al., 1979; Frechette and Lamothe, 1981; Barger and Lisle, 1982; Michel et al., 1982). Several authors reported gastrointestinal nematode infection to be

widespread among adult cows (Grisi and Todd, 1978; Bairden and Armour, 1981; Borgsteede and Van der Burg, 1982; Vercruysse et al., 1986). However, Frechette and Lamothe (1981), Michel et al. (1982) and O'Farrell et al. (1986) could not demonstrate a relationship between level of infection and the mean herd milk yield response to treatment, using faecal egg counts or blood pepsinogen values. Recently, Ploeger et al. (Vet.Parasitol., accepted) using antibody titres measured by means of an ELISA-technique, were able to demonstrate such a relationship.

The present study was conducted to confirm the results found in that earlier study.

MATERIALS AND METHODS

Farms and cows

In this study 81 farms were involved, all situated around the city of Utrecht and belonging to the Veterinary Practice of the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty in Utrecht. The farms had a mean of 50 cows, ranging between 20 and 105, which calve throughout the year. All 1385 cows in the trial calved between November 1986 and June 1987 during the stabling period. Specifics with respect to age, breed and month of calving are given in Table 1.

TABLE 1: Number of cows according to age at calving, breed and season of calving over treatment groups.

AGE AT CALVING*		2.05-4.00		4.00-7.00		7.00-		
BREED**		black	red	black	red	black	red	
MONTH OF CALVING								TOTAL
Nov - Jan	controls	73	8	108	14	27	2	232
	treated	53	9	94	6	26	3	191
Feb - Mar	controls	82	4	137	9	40	2	274
	treated	62	9	144	11	48	3	277
Apr - Jun	controls	58	6	100	10	26	3	203
	treated	61	3	99	9	33	3	208
	TOTAL	389	39	682	59	200	16	1385

* 2.05 means 2 years and 5 months old.
** black: Holstein Friesians, Dutch Friesians and crossbreds of these.
red : Maas-Rijn-IJssel breed, crossbreds of this breed with Holstein Friesians and a few other breeds or crossbreds.

Anthelmintic treatment

The anthelmintic drug used was albendazole (Valbazen®, SmithKline Diergeneeskundige Produkten b.v.) given orally at the manufacturer's recommended dose (7.5 mg/kg liveweight). On each farm cows were alternately allocated to the anthelmintic treatment or to the not treated control group in order of expected calving-date. Cows were treated within one week before

the expected calving-date, for which members of our staff visited the farms every two weeks during the stabling period. At the end of the trial 676 animals had been treated with albendazole and 709 cows were left untreated. The difference between numbers of treated and control cows is due to the fact that visits started from December onwards, whereas some herds were already stabled in November. Cows which calved after stabling but before our fortnightly visits started, were included as controls. No effect of this on the results could be demonstrated.

Milk production data

In the autumn 1987, when all cows in the experiment were at least 100 days in lactation, milk production data including milk fat and protein percentage were collected at the local milk registration organisations. Age, breed and previous lactation performance were recorded at the same time. From each cow the cumulative data of the first registration date past 100 days in lactation were taken, so that at average each cow was about 112 days in lactation.

Faecal examinations

In the first half of October 1986, prior to the commencement of the treatment period, faecal samples were taken from freshly deposited pats (as many as possible) on pasture grazed by adult cows at that time. On each farm these samples were thoroughly mixed and split into two parts. One sample was used to assess a mean herd level of egg output. Because of the expectation that egg counts would be very low, egg output was measured by counting the number of larvae per gram faeces (LPG) after culturing, combined with larval identification. These examinations were done at the Central Veterinary Institute in Lelystad, using the methods of Borgsteede and Hendriks (1973, 1974). The other sample was used for examining presence of lungworm larvae (per 30 grams), using a Baermann-technique. This was done at the Department of Helminthology and Entomology of the Veterinary Faculty Utrecht.

Serological examinations

From 5 randomly chosen cows in each herd blood samples were taken, in October 1986 at the same time faecal samples were taken and again at the commencement of the trial after housing in December 1986. Antibody titres against Ostertagia spp., Cooperia spp. and Dictyocaulus viviparus were determined by means of an ELISA technique (Keus et al., 1981; Boon et al., 1982), using crude antigens from adult worms. Pepsinogen values were assessed in each sample following the method described by Berghen et al. (1987).

Because albendazole is also active against liver fluke, antibody titres against Fasciola hepatica were determined, in sera taken in December 1986, by means of an Indirect Haemagglutination (IHA) technique at the Central Veterinary Institute in Lelystad (Van Tiggele and Over, 1976). Doubling serum dilutions were used starting at 1:25. Titres $\leq$ 1:25 were classified as negative and titres $\geq$ 1:100 as positive for a liver fluke infection. Titres of 1:50 were regarded suspect. A herd was regarded positive when the

mean titre was $\geq$ 1:50 or when at least two sera within that herd showed titres $\geq$ 1:100. Some herds with one positive animal, but with a mean titre less than 1:50, were regarded as suspect. These criteria are routinely used at the Central Veterinary Institute.

Sera were analysed soon after each sampling period. ELISA-tests, done with a time-span of several months in between, showed variation in overall levels without affecting the relative order of titres found, due to the use of different batches of reagents (e.g. conjugate, antigen, standard sera, etc.). Also, it was desirable to compare results of the present study with those of Ploeger et al. (Vet.Parasitol., accepted). In that earlier study investigated herds had been selected based on pepsinogen values in September. In the present study no pre-selection was made. Therefore, a separate analysis was done using 100 herds in 1985 and 93 herds in 1986, including the investigated herds in both studies, to allow comparing of both years and of sampling periods within years.

Calculations and statistics

Current and previous milk production data were all corrected for age at calving, season of calving, breed, length of lactation and mean herd level of production to a standardized 305-day production according to correction factors normally used in the Netherlands. Finally, all subsequent calculations and statistics were based on the difference between current and previous lactation yield to stabilize genetic variation.

Serological data were tested for normality on an individual basis and for homogeneity of variance in case mean herd titres had to be used. Pepsinogen values were not normally distributed and were transformed according to the formula $Y = \ln (X)$. IHA antibody titres against Fasciola hepatica were classified as mentioned above.

Data obtained from faecal examinations were based on a herd sample and were tested for normality. Larval counts were logarithmically transformed according to $Y = {}^{10}\log (X+1)$.

All statistical analyses were performed using the Statistical Analysis System (S.A.S., 1985).

RESULTS

Descriptive statistics for the serological parameters are given in Table 2. It shows a strongly significant between herd variation compared to the within herd variation ($P < 0.001$). Mean herd antibody titre against Ostertagia spp. and pepsinogen levels decreased significantly between October and December ($P < 0.001$).

Gastrointestinal nematode larval counts per herd ranged from 1 to 134 LPG, with an average of 8.9 LPG. Results of the larval identifications are presented in Table 3. Clearly, Ostertagia spp. were the most prevalent type found. However, it was very striking to find 40.8% of the herds having a relatively high ($\geq$25%) percentage of Cooperia oncophora larvae in their egg output, indicating recent uptake of infective larvae. These herds also had a significantly higher egg output (17.6 vs. 2.9 LPG, $P < 0.001$). In one herd 2 lungworm larvae per 30 grams of faeces were found.

TABLE 2: Descriptive statistics for the serological parameters measured on a herd basis.

	OCTOBER (n=76)						DECEMBER (n=81)						sign. of difference between periods
	F	sign.	mean	s.d.	min.	max.	F	sign.	mean	s.d.	min.	max.	
Dictyocaulus titre	3.72	***	4.03	0.62	2.5	6.1	6.58	***	4.18	0.80	2.9	7.1	N.S.
Cooperia titre	4.08	***	3.95	0.68	2.3	5.4	5.60	***	3.74	0.72	2.2	5.7	+
Ostertagia titre	4.45	***	6.04	0.75	4.0	8.5	7.34	***	5.43	0.81	4.2	8.1	***
Pepsinogen value1)	--		1652	530	775	3295	--		1439	591	414	2805	
ln (Pep.-value)	4.20	***	7.34	0.29	6.65	8.08	9.64	***	7.13	0.48	5.96	7.91	***

1)Pepsinogen value is the untransformed value in mU.
ln (Pep.-value) is mean herd pepsinogen value after ln-transformation of individual values.
F-values give the ratio (between herd variance / within herd variance).
NS = not significant; + = P<0.10; *** = P<0.001 .

Correlation coefficients between the serological parameters revealed, that all antibody titres were correlated positively with eachother within both sampling periods (Table 4). The only significant correlation involving pepsinogen values is the one with antibody titres against Ostertagia spp. ($P < 0.05$) measured in October. Correlations within the sampling period of December were generally lower. No significant correlations between the serological parameters and LPG could be found. When egg outputs, consisting of at least 25% Cooperia oncophora larvae, are considered indicative for recent uptake of infective larvae, herds can be divided into two groups; a group with relatively 'old' infections (O) in October and a group with 'recent' infections (R). Figure 1 shows for both groups the average antibody titres against Cooperia and against Ostertagia measured in October and December 1986. The decrease in titre between both sampling periods is given also (Figure 1.C). Although within sampling period differences between groups (O vs. R) were not significant, the decrease in titre from October till December was only significant in the group with 'old' infections (O).

Results obtained in the separate analysis to compare levels of antibody titres and pepsinogen values between 1985 and 1986, as well as between sampling periods (sampling at pasture vs. after

TABLE 3: Identification of larval types in faecal samples collected in October 1986.

Species:	Number of herds with % of larvae in faecal sample found: 0%	1-25%	25-50%	50-75%	75-99%	100%	Total number of positive farms	(%):*
Ostertagia spp.	7	35	12	14	4	4	69	(90.8)
Cooperia oncophora	27	18	10	11	9	1	49	(64.5)
Cooperia punctata	25	30	11	9	1	0	51	(67.1)
Trichostrongylus spp.	22	36	13	5	0	0	54	(71.1)
Oesophagostomum spp.	49	25	0	2	0	0	27	(35.5)
Bunostomum spp.	63	10	3	0	0	0	13	(17.1)

* On five farms no faecal samples were collected.
In one herd 2 lungworm larvae per 30 grams faeces were found.

TABLE 4: Coefficients of correlation for the serological parameters within and between sampling periods in 1986. Coefficients are above the diagonal, whereas the corresponding significancies can be found below the diagonal.

	OCTOBER				DECEMBER			
	Dict. titre	Coop. titre	Ost. titre	Pep.-value	Dict. titre	Coop. titre	Ost. titre	Pep.-value
OCTOBER (n=76)								
Dict. titre	-	.657	.393	-.131	-.096	.094	-.082	-.262
Coop. titre	***	-	.401	-.154	-.017	.083	-.035	.015
Ost. titre	***	***	-	.239	.107	.147	-.173	.084
Pep.-value	NS	NS	*	-	.036	.165	-.121	.349
DECEMBER (n=81)								
Dict. titre	NS	NS	NS	NS	-	.222	.333	-.083
Coop. titre	NS	NS	NS	NS	*	-	.134	.121
Ost. titre	NS	NS	NS	NS	**	NS	-	-.089
Pep.-value	*	NS	NS	**	NS	NS	NS	-

NS = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001 .

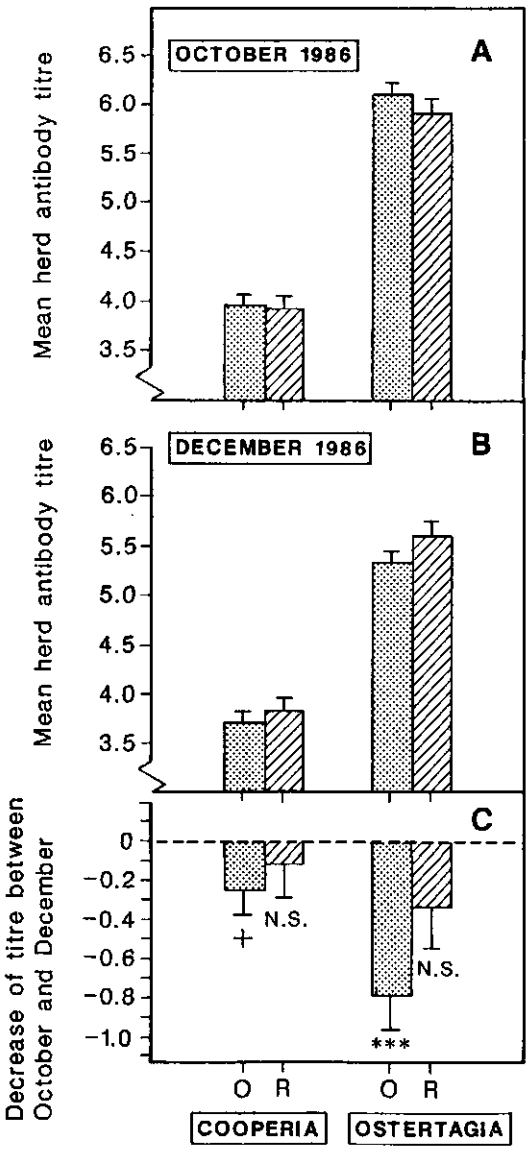
stabling), are given in Table 5. Analysis of variance showed a significant effect of year and sampling period on antibody titre against Cooperia (both effects; $P < 0.01$) and Ostertagia (both effects; $P < 0.001$) and on pepsinogen value ($P < 0.01$ and $P < 0.001$, respectively). For all three parameters values were higher in 1985 compared to 1986 and, within year, values were highest when measured during the grazing period. Furtheron, a significant interaction between year and sampling period was demonstrated for pepsinogen values ($P < 0.001$), indicating a lower decrease in pepsinogen values during the autumn in 1986 compared to 1985.

TABLE 5: Comparison of antibody titres and pepsinogen values measured in 1985 and 1986.

	SEPTEMBER 1985		NOVEMBER 1985		OCTOBER 1986		DECEMBER 1986	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Dictyocaulus titre	4.34	0.48	4.10	0.46	4.04	0.60	4.20	0.78
Cooperia titre	4.15 [a]	0.63	3.97 [b]	0.54	3.94 [b]	0.66	3.75 [c]	0.72
Ostertagia titre	6.43 [a]	0.98	5.77 [c]	0.59	6.00 [b]	0.76	5.44 [d]	0.82
Pepsinogen value	1909 [a]	532	963 [d]	328	1672 [b]	515	1427 [c]	580
number of herds	100		100		88		93	

different letter-superscripts within rows denote significant differences ($P < 0.05$) and are only presented when analysis of variance showed an overall statistical significance.

According to the criteria used at the Central Veterinary Institute 14.8% of the herds could be regarded positive for a liver fluke infection. A further 13.6% of herds could be classified as suspect, having at least one positive sample. No significant rankcorrelations were found between serological parameters measuring nematode infections and IHA-titres against liver fluke. Between total number of gastrointestinal nematode larvae (LPG) and antibody titres against liver fluke a significant positive rank-correlation was found ($r = 0.269$, $P < 0.05$). Analysis of variance showed



O: 'old' infections, indicated by egg output in which Cooperia oncophora larvae constitute less than 25% of the total egg output (45 herds).

R: 'recent' infections, indicated by egg output in which Cooperia oncophora larvae constitute at least 25% of the total output (31 herds).

least square mean ± s.e.

In the lower part of the figure (C) significancies are given for the null hypothesis: titre-decrease = 0 (in each group of herds).
Group means for the antibody titres were not significantly different within sampling period.

Figure 1: Antibody titres against Cooperia spp. and Ostertagia spp. in herds differing in the percentage of Cooperia oncophora larvae of the total number of larvae found in faecal samples collected in October.

that gastrointestinal nematode infections late in the autumn occurred most pronounced in the herds which were also suspected of having a liver fluke infection.

Treated cows produced 132.9 kg. milk/cow/305-days of lactation more than untreated cows ($P < 0.01$) (Figure 2). No interaction between month of calving and treatment could be demonstrated. Treated cows produced increasingly more than untreated cows with increasing level of production (+1.9% per kg.milk produced). This, however, was not significant. Response to treatment was neither related to breed nor to age of cows.

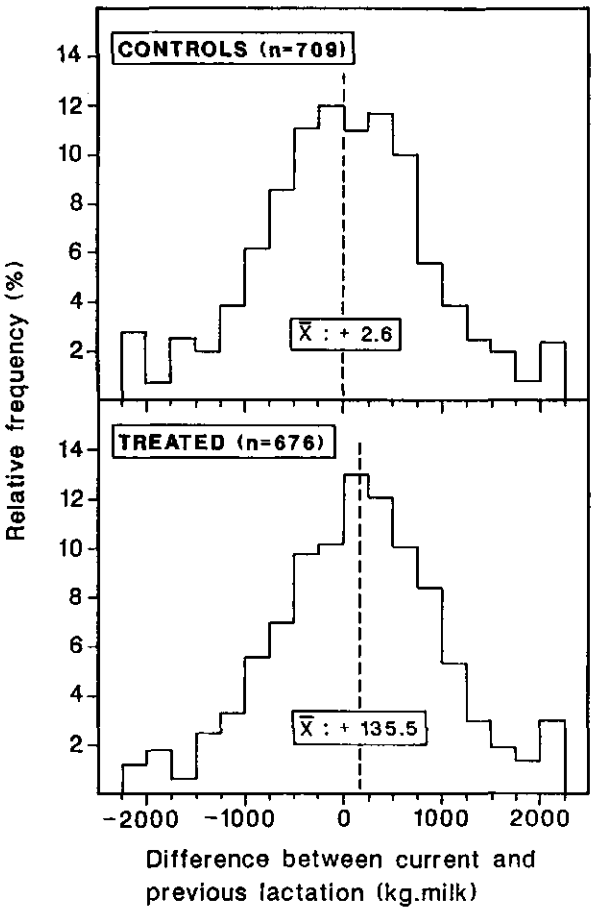
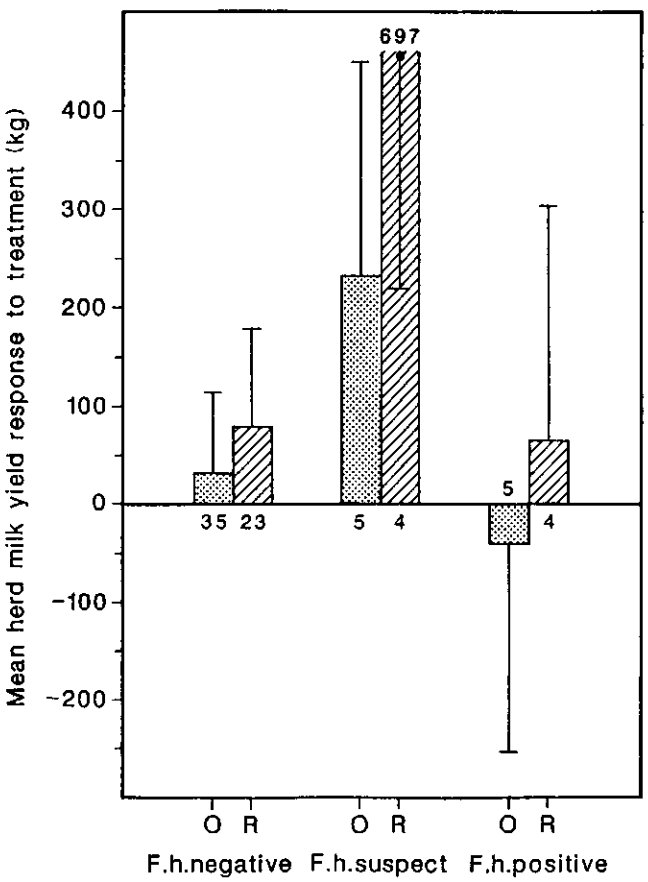


Figure 2: Frequency distribution of the difference between current and previous lactation yield for albendazole-treated and untreated control cows.

No significant differences between treated and control cows for percentage fat and protein were found (-0.029% and +0.008%, respectively).

Per herd the average treatment effect on the milk yield varied between -899 to 1231 kg./cow/lactation. Of the 81 farms 49 showed a positive

response to anthelmintic treatment. No significant correlations were found between the treatment response per herd and the serological parameters measuring nematode infection. No significant relation could be demonstrated between LPG and mean herd milk yield response to anthelmintic treatment. With respect to the results of the larval identifications, mean herd response to treatment was higher in the group of herds (R) with at least 25% Cooperia oncophora larvae in their egg output (158.1 vs. 48.8 kg.milk/cow/lactation, N.S.; see Figure 3).



O: 'old' infections, indicated by egg output in which Cooperia oncophora larvae constitute less than 25% of the total egg output (45 herds).
R: 'recent' infections, indicated by egg output in which Cooperia oncophora larvae constitute at least 25% of the total output (31 herds).
F.h. = Fasciola hepatica, see for criteria of classification Materials and Methods. Numbers in the figure give the number of herds in each class.

Figure 3: Mean herd milk yield response to albendazole treatment in groups of herds classified according to the antibody titre against Fasciola hepatica in December, and according to the percentage of larvae found in faecal samples in October identified as Cooperia oncophora larvae.

In Figure 3 mean herd treatment response is graphically presented by grouping herds firstly as negative, suspected or positive for Fasciola hepatica infection, and secondly according to the percentage of Cooperia oncophora larvae found in the larval identifications. Analysis of variance showed that herds, suspected of having a liver fluke infection, responded significantly better to the treatment (+287.4 kg.milk/ cow/lactation compared to 'negative' herds, $P < 0.05$; and +331.9 kg.milk/cow/lactation compared to 'positive' herds, $P < 0.10$). Figure 3 also shows that there was no significant interaction between the two criteria of grouping herds.

DISCUSSION

Comparing the results of the present study and those of 1985 (Ploeger et al., Vet.Parasitol., accepted) reveals some interesting differences between both years. Firstly, increase of milk production after anthelmintic treatment was lower in 1986 compared to 1985 (132.9 vs. 205.1 kg.milk/cow/lactation). Secondly, no significant correlations between mean herd milk yield response and parameters measuring nematode infections were found in 1986. In 1985 a significant correlation with antibody titre against Ostertagia spp. was demonstrated. Explanation of these differences may be found in the results of the serological and parasitological measurements.

The levels of antibody titres were significantly lower in 1986 compared to the previous year. Pepsinogen values measured in October 1986 were also lower than in September 1985. On the other hand, gastrointestinal nematode larval counts were in 1985 lower with a maximum of 16 LPG found in one herd participating in the trial (average of 3.4 LPG). In 1986 an average of 8.9 LPG with a maximum of 134 LPG was found. Further, pepsinogen values in 1986 did not decrease as dramatically between October and December as they did in the comparative period in 1985. In 1986 both sampling periods fell about two weeks later in the season than the 1985 sampling periods. Above mentioned differences in levels of antibody titres and pepsinogen values between both years, however, can not be fully explained by this time difference. Moreover, it may be expected to find an egg output of the same magnitude, if not lower, later in the grazing season. Eysker and Van Meurs (1982) found in a longitudinal study an increase in total LPG in June, followed by a decrease later in the summer. Whereas in the present study the serological findings in October indicated lower levels of exposure than in 1985, LPG's indicated otherwise. In 1985 a wet summer and a dry autumn were recorded (K.N.M.I., 1986). Particularly during the months June and August rainfall was above average. Temperatures did not deviate much from those normally recorded. In 1986, however, a prolonged dry period was recorded between mid-June and mid-August (K.N.M.I., 1987). Temperatures recorded in June and July were also higher than normal. So, these findings suggest that in 1985 more infective larvae were picked up and earlier in the grazing season, whereas in 1986 overall exposure may have been lower with uptake of larvae occurring later. The larval identifications are in agreement with these findings. In the egg output of 41% of the herds at least 25% of the larvae were identified as Cooperia oncophora. 28% of the herds had egg outputs in which these Cooperia larvae constituted the majority of larvae found. In 1985 these figures were 31% and 7% of the herds, respectively (Ploeger et al., Vet.Parasitol., accepted). Borgsteede

(1982) found 8.7% of 298 cows on 7 farms excreting Cooperia oncophora eggs. He demonstrated in the same study that Cooperia oncophora was identified more frequently when egg outputs were higher, which agrees with the present study.

Consequently, it could be speculated, assuming that overall exposure was lower in 1986, that especially herds experiencing 'recent' exposure (i.e. late infections in the autumn) might have responded better to the anthelmintic treatment in terms of milk production. Though not significant, they indeed averaged a mean herd milk yield response to treatment of 100 kg. more than the other herds with 'older' infections. Since antibody titres generally follow the pattern of larval uptake with a delay of some weeks, it was not surprising to find slightly lower titres in these herds in October, thus preventing the demonstration of a significant positive correlation between antibody titres and response to treatment. The difference in the decrease of titres between October and December between the 'old' and 'recent' groups supports this interpretation of the results.

In this study albendazole was used. Because this drug is also active against Fasciola hepatica infections, although the recommended dose rate for liver fluke is higher than used in the present study, this could interfere with the effect of treatment on milk yield due to nematode infections. Ross (1970) and Black & Froyd (1972) reported increases in milk production after treatment against fascioliasis. However, no significant interactions between the presence of liver fluke infections and the parameters measuring nematode infections on the mean herd milk yield response were found. Herds suspected of having a liver fluke infection showed at average the highest increases in milk production after treatment. The fact that the positive herds did not respond at least as high as the suspected herds, may have been due to whole herd anthelmintic treatments against liver fluke carried out by the farmers themselves. We were primarily interested in gastrointestinal nematode infections, so farmers were just asked not to treat animals with anthelmintics active against nematode worms.

In conclusion, the present study did not entirely confirm the findings of Ploeger et al. (Vet.Parasitol., accepted), but also it did not contradict those findings. It appears important to distinguish between two features of infection patterns. Firstly, the level of exposure and secondly, when in the season uptake of infective larvae takes place. A high level of exposure may result in a relatively large worm burden which lasts over a considerable time without being reflected in for instance egg output. This may have happened in 1985, resulting in the demonstration of a weak but positive correlation between level of exposure, as measured by antibody titres, and response to treatment. In 1986 exposure may have been appreciably less but occurring later. Such a pattern influences serological and parasitological findings, which should accordingly be interpreted with great care. In 1986, it appeared that only in herds acquiring late infections, infection may have reached levels sufficient for a clear milk yield response to treatment carried out during the stabling period.

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X. GENERAL DISCUSSION

The main purpose of the studies described in the previous chapters was to estimate the effect of gastrointestinal and lung nematode parasitism on performance of cattle on commercial dairy farms, and in particular to investigate the relationship between the level of that parasitism and growth performance in young or milk production in older stock.

In all studies significant negative effects of exposure to nematode infections on growth performance and milk production were found. Moreover, these negative effects were in the majority of cases significantly related to the level of exposure. The resulting data may be useful for economic evaluations of the production losses due to nematode infections and may consequently provide a basis for a rational and structural approach to the control of these infections on dairy farms. However, there are other requirements to be satisfied, besides a demonstration of whatever relationships exist between levels of infection and production, before it can be attempted to undertake such economic evaluations. Basically, these requirements are: 1) data should be collected in the field, rather than be obtained from experimental infection trials, controlled grazing experiments, or slaughterhouse surveys; 2) an adequate sample of farms should be realized, which represents reasonably well the total population in number of farms, distribution within a region or country, management practised, size of farms etc.; 3) data should include parameters estimating levels of infection, to establish frequency distributions of those levels; 4) data should include parameters measuring production (e.g. weight gain, milk production). It is proposed to discuss the findings described in the previous chapters in the perspective of this list of requirements, rather than to discuss in detail the findings for each age-categorie and each relationship found separately.

The first 4 requirements (the fifth being the demonstration of a relationship between levels of infection and production) to be satisfied, may impose restrictions on each of the others. This is simply due to the huge variability in both the parameters estimating levels of infection as well as the production parameters. Michel and Mulholland (1981), in Great-Britain, described the problems encountered in the organisation of a large collaborative trial involving commercial farms. In their effort to investigate the effect of anthelmintic treatment on milk production nearly 100 people were engaged in collecting data and samples and at least 25 laboratories were involved. In total 120 herds with an average of 168 cows in each were involved in this trial, of which the results were reported by Michel et al. (1982). This number of herds and cows was calculated by the authors to be needed, based on the demand to satisfy statistical significance at the 5%-level if a milk production response to treatment of at least +28 kg./305-day lactation was found. This value of +28 kg. was worth twice the cost of an anthelmintic dose. A few remarks should be made about this trial. Firstly, the study of Michel et al. (1982) was only investigating the adult cows. Secondly, the number of herds and cows was somewhat enlarged above the number actually required to meet the demands

set by the authors, because of the use of different anthelmintic drugs to make sure that the anthelmintic activity of these drugs was responsible for a milk production increase. Thirdly, the average number of 168 cows in each herd was far beyond the national average of 55 (Thomas et al., 1983). Fourthly, an expected increase of 28 kg. milk per lactation after treatment is rather low. From Table 2 in chapter I it can be seen that the majority of trials resulted in larger treatment responses. Finally, it can be stated that if a significant relationship exists between the level of exposure to infection and a treatment response per herd, the level of the overall treatment response is rendered less important. In view of all this and assuming that, in general, circumstances do not differ substantially between Great-Britain and The Netherlands, it appears that the numbers of herds and animals used in the present studies meet the requirement of an adequate sample size reasonably well.

All farms participating in the described studies, were approached through the Department of Herd Health and Ambulatory Clinic of the Veterinary Faculty Utrecht. Advantages of this were: 1) an easy access to the farms; 2) the possibility of visiting all farms in a relatively short period, facilitating comparisons of results between farms; 3) the possibility of visiting farms more than once within a year as well as in another year; and 4) the reduced demands for labour (e.g. personnel to be involved) and time. However, this may raise questions about whether these farms can be considered to represent the Dutch population of dairy farms. In the Table below some general characteristics about the size of the participating 100 farms (in 1985) are given.

	mean	s.d.	min.	max.
farm size (ha.)	24.8	8.4	9	50
number of cows (including heifers)	53	19.6	22	114
number of yearlings (>1 year)	15	6.4	3	42
number of calves (<1 year)	15	6.8	4	41

All farms were member of the national milk registration association. The national average of cows per farm was 41 in 1985 (Anonymous, 1987). However, at that time 60% of the total number of farms were member of that registration organisation. These 'member' farms are generally the larger farms. The average milk production on the farms investigated was 5700 kg./lactation. The overwhelming majority of cows was of the Dutch Friesian breed, Holstein Friesian breed or of a crossbred of these. For these cow breeds the average milk production recorded was about 5800 kg./lactation in the Netherlands. The variation in growth performance of calves between herds found in the described studies were very similar to earlier findings (Kloosterman, 1971; Kloosterman et al., 1981; Kloosterman, unpublished results 1978, 1979, 1981). No clear divergence in management practices on the investigated farms was found compared to management normally practised

in The Netherlands (Eysker et al., 1983; Boon et al., 1986; Anonymous, 1987).

The farms were all distributed around the city of Utrecht, which had several advantages, as mentioned above. However, it may be a disadvantage if such a sample of farms seriously affects frequency and occurrence of nematode infections compared to nation-wide. Comparing the data concerning nematode infection with previous findings in the Netherlands (Kloosterman, 1971; Borgsteede, 1977; Borgsteede, 1982; Borgsteede and v.d.Burg, 1982; Boon et al., 1984; Ploeger, unpublished results 1984; Boon et al., 1986; Kloosterman, personal communication) indicates that the results of the faecal and serological examinations described in the previous chapters were very similar to those found elsewhere.

Despite the advantages of the farms being distributed over a relatively small area, the large number of farms made it impossible to visit farms and collect samples and data on a regular basis, e.g. fortnightly or even monthly. Therefore the design of the complete study resembled more a cross-sectional type of survey, rather than a longitudinal type of study. With respect to the parameters estimating levels of infection such a design may present difficulties in interpreting the results.

Particularly parasitological parameters (e.g. egg output) are not very reliable when used as indicators for the level of nematode infection when samples are not taken often. Moreover, egg output is generally low in the case of older cattle, due to acquired immunity (Michel, 1968, Barth et al., 1981, Borgsteede, 1982). Serological measurements and in particular antibody titres, however, have been shown to provide useful information about the variation in levels of infection between herds of all age-categories (Kloosterman, 1983; Boon et al, 1982, 1984ab, 1986; Bain and Symington, 1986; Entrocasso et al., 1986b; Dorny et al., 1986). This is a prerequisite for such infection parameters to be used in cross-sectional surveys, as is that they should not fluctuate sharply in the course of time. Antibody titres meet the latter requirement also better than faecal egg counts, pepsinogens or haematological parameters like eosinophils. Another advantage of serological techniques is that they are far less laborious than parasitological techniques. From the results decribed in this thesis it can be concluded that in first-season grazing calves both parasitological and serological parameters reflect variation in levels of exposure to nematode infection during the first grazing season. This is emphasized by the consistency of results obtained in 1985 and 1986 (chapters II, III, IV and V). For older cattle it was shown that parasitological parameters lost their ability to estimate the level of exposure, but they were still useful in confirming presence of gastrointestinal nematode infections. Of course, the variation in levels of infection is less between cow-herds compared to calf-herds due to acquired immunity, which was in fact confirmed by the lower egg output and the larval identifications. Nevertheless, the measurement of antibody titres, particularly against Ostertagia spp., did show that there were significant between herd variations in exposure to infection in older cattle (chapters VI, VII, VIII and IX). This ability of antibody titre determinations renders them extremely valuable for studies in older cattle.

A second difficulty in cross-sectional surveys to be dealt with, is the timing of sampling to obtain the most valuable information. Although it is

well established that particularly gastrointestinal nematode infections are rather predictable in their occurrence (Michel, 1969; Armour and Ogbourne, 1982; Eysker and v.Miltenburg, 1988), there are two aspects to be considered. Firstly, an 'optimal' time of sampling (within a year) may be different for the different age-categories of animals. Kloosterman (1983) showed that antibody titres against Cooperia in calves, yearlings and cows reached peak-values at different times in the grazing season. In the present investigation it was desired to study the effects of parasitism in all age-categories. Therefore, the sampling period falling within the grazing season, was necessarily a compromise. Secondly, weather conditions play an important role in the seasonal pattern of infection (Lancaster and Hong, 1987), even to such an extent that these conditions can be used in modelling and simulation studies of the course of infection (Gettinby et al., 1979; Grenfell et al., 1987). In the present studies an effect of the time of sampling in relation to the results obtained for the different age-categories of animals could not be demonstrated, because it would have required sampling at regular time-intervals, i.e. at least monthly. The different weather conditions in 1985 and 1986, however, had significant effects on the results described in this thesis. This is clearly shown by: 1) the differences in levels of antibody titres, pepsinogen values, egg output and larval identifications for all age-categories of cattle between 1985 and 1986; 2) the difference in the strength of the relationships between growth performance of calves and levels of exposure to infection measured in the first grazing season in 1985 compared to 1986 (chapters II and IV); 3) the difference in the effects of some management practices (e.g. vaccination against lungworm, anthelmintic treatments) on growth performance of calves between years (chapters II and IV); and 4) the difference in the effect of anthelmintic treatment of cows on milk production in 1986 compared to 1985 (chapters VIII and IX).

To investigate the effects of nematode infections on production, growth performance of calves and yearlings and milk production of cows are the two most obvious parameters to consider. On commercial dairy farms essentially two approaches can be followed to investigate effects of nematode infections on these production traits. Firstly, relationships between the level of exposure and the level of production can be investigated. Secondly, clinical trials in which half the number of animals in a herd is treated with an anthelmintic drug are a well established means to measure the effects of infection, provided that reinfection after treatment is kept at a low level for some time. The latter approach was chosen to investigate the effects of infection on milk production, mainly because of three reasons: 1) it is unlikely that a direct relationship between level of exposure to infection and level of milk production can be demonstrated, due to the huge variation in the latter and the relatively smaller variation in the former when compared to the situation for calves; 2) numerous claims have been made that anthelmintic treatment of adult cows increases milk production, without actually investigating the relationship between the level of exposure and the magnitude of such a treatment effect; 3) for adult cows it is far more difficult to divide production in terms of time-intervals like a grazing season or a housing period compared to growth performance in young cattle, even though the actual exposure to free-living infective larvae occurs at pasture.

For growth performance in first-season grazing calves and in yearlings a relatively direct relationship with level of exposure can be investigated. Effects of nematode infections are more pronounced and variations between herds in level of exposure are greater in calves compared to cows. First-season grazing calves are the age-class which is most susceptible to nematode infections. Furthermore, growth performance is more easily measured at a fixed point in time, because body weights are strongly related to age during the first years of life. The main disadvantages of the limitations set by the design of the described studies on the measurements of growth performance might have been: 1) that no body weight data were collected for the first season grazing calves at turnout; and 2) that the growth performance data collected after the grazing season included a variable part of the subsequent housing period. On the other hand, it can be stated that, on average, the first grazing season constitutes a major part of the life-time of calves up to time of housing after that first season. Also, it has been shown that infections picked up during the grazing season may have long-lasting effects on performance, which implies that the body weight differences between herds at housing will, to a large extent, continue to be present over at least a few months (Jorgensen et al., 1978; Borgsteede et al., 1985; Entrocasso et al., 1986a; Tornquist and Tolling; 1987). The latter was indeed confirmed in the studies described in chapters III and V.

For yearlings in the second grazing season another aspect needs to be considered. Growth performance can be measured during the second grazing season to investigate the effects of the level of exposure to infection in that second year. This requires an additional body weight measurement at turnout before the second season. However, more interesting are the actually achieved body weights at first calving. Several authors demonstrated significant positive correlations between the body weight at first calving and the subsequent milk production in the first lactation (Bereskin and Touchberry, 1966; v.Adrichem and Shaw, 1977; Boxem, 1981). Also, the achieved body weights in relation to the age of the yearlings is of interest. The sooner animals calve for the first time the sooner they become productive for the farmer.

It was clearly demonstrated that for all three age-categories of animals in the present studies, significant negative relationships existed between the level of exposure to nematode infection and the level of production The significant positive correlation between the milk production response on anthelmintic treatment and the mean herd antibody titre against Ostertagia spp. found in 1985 (chapter VIII), is, to our knowledge, the first time that such a significant relationship has been demonstrated.

It appears that all requirements to evaluate economic losses (Kloosterman, 1984) were reasonably well satisfied. Results of these studies were used in preliminary calculations of the economic losses due to nematode infections on commercial dairy farms (Ploeger and Kloosterman, 1988). It showed that in the Netherlands most of the economic losses occur in older cattle. However, economic evaluations based on these results should be interpreted with caution for a number of reasons. The most important reasons are:

1) both linear and segmented curvilinear relations could be fitted between data (i.e. antibody titres) estimating the level of exposure and

data measuring growth performance for calves as well as yearlings (chapters II, IV and VI). From a statistical point of view linear relations should be adopted. However, a linear relation can be debated on the grounds of whether it is realistic to assume that production losses occurring at low levels of exposure are the same per titre-unit as at high levels of exposure. Moreover, it assumes that production is reduced from the lowest titres upwards, i.e. from the lowest level of exposure upwards. On the other hand, it appeared that when growth performance data were related to LPG-GI or to pepsinogen values segmented curvilinear regressions did not improve the fit between 'predicted' and observed growth performance. Little is known about the shape of the relationship between infection parameters and production parameters. Nevertheless, this shape may have profound effects on the magnitude of the calculated economic losses. Assuming a linear relationship increased the economic losses in calves and yearlings by a factor 3 and 2, respectively, compared to assuming segmented curvilinear relations;

2) as mentioned earlier, it may be questioned whether the sampling periods, particularly those within the grazing season, were optimal in producing the most accurate data;

3) from the relationships (significant or not significant) found between management practices and the growth performance of calves, some were associated with the occurrence of nematode infections (e.g. lungworm vaccination, anthelmintic treatments, date of housing; see chapters II and IV). This means that the costs and benefits of preventive as well as curative actions taken by the farmer, intentionally or unintentionally, should be included in economic evaluations. This is extremely difficult to assess (Ploeger and Kloosterman, 1988). Moreover, it will depend on the year in which it is assessed, as is clearly shown by the differences found between the years 1985 and 1986 (chapters II and IV);

4) it may be questioned to what extent economic losses, calculated for each age-categorie separately, are additive. A significant positive relation was demonstrated between antibody titre against Ostertagia in calves in the first grazing season and the achieved body weights after the second season (chapter VI). This suggested that, at least on commercial dairy farms, the level of exposure to nematode infection in the first year positively influences growth performance on the long term, at least to a certain extent, although it may influence growth performance negatively on a shorter term. The latter was indeed demonstrated to occur in the calves (chapters II and IV). Borgsteede et al. (1985) found similar results. Also, a significant positive correlation between milk production of heifers and achieved body weights after the second season was found (chapter VII), which strongly suggests that milk production is influenced by what happens in the first and second year of life. A related matter is whether calves and yearlings should be raised to grow at rates maximally attainable in stead of at optimal growth rates. It has been shown that a high growth rate may lead to decreased milk yields, due to the formation of fatty tissue in the developing udder at the expense of glandular tissue (Amir, 1974; Sejrsen and Larsen, 1977; Sejrsen, 1978). As a consequence Sejrsen (1978) stated that it seems reasonable that a critical limit for daily gain exists of about 700 to 750 g./day in the period before and around the onset of puberty. These daily gain figures are also advocated in the Netherlands as the optimal growth rate to be achieved in relation to age and body weight

at first calving and the milk production thereafter (Boxem, 1981);

5) as is indicated above, economic evaluations done in one year may depend on the previous history of the investigated animals. This may also apply with respect to the previous history of the area grazed by animals from the same age-categorie each year. In chapters IV and VI significant relations concerning the level of exposure to nematode infection, the majority of which were positive, were found within age-categories between 1985 and 1986. This suggests that there may be a structural origin for problems with nematode infections within farms and within age-categories continuing over subsequent years;

6) finally, there may be other production traits to consider than those investigated in this thesis, one of these being the reproductive performance of heifers and cows.

Although economic evaluations based on the described results are still very crude, some important implications arise from the results from such evaluations with respect to the approach of controlling nematode parasitism on commercial dairy farms. Firstly, it appeared that the measures (e.g. anthelmintic treatments) taken by farmers to control parasitism in first-season grazing calves (chapter IV) are not always of a rational and preventive nature. This is in agreement with the findings of Eysker et al. (1983). Secondly, it appeared that the acquired immunity built up during the first grazing season was not sufficiently developed to prevent the negative effects of exposure to infection in the subsequent second year (chapter VI), which is possibly due to the effort put into advocating grazing on aftermath and turning out calves late on mown pasture in the Netherlands (Oostendorp and Harmsen, 1968; Kloosterman, 1971; Borgsteede, 1977;Eysker et al., 1983; Ploeger, unpublished results, 1985, 1986). However, it appeared also that the level of acquired immunity built up in the first year positively influenced the growth performance in the second year. Therefore, control should not be based on strategies in which calves are not exposed, such as zero-grazing. This is in agreement with findings of Borgsteede et al. (1985). Thirdly, it appears that more attention should be given to older cattle in the Netherlands, since most of the economic losses occur in dairy cows (Ploeger and Kloosterman, 1988; chapters VI, VII, VIII and IX). Fourthly, the consistency of results obtained in 1985 and 1986 (chapters II, III, IV and V) and the fact that these were obtained by means of a cross-sectional type of survey indicate that it may be worthwhile to investigate the value of epidemiological modelling and simulation studies on the effects of nematode parasitism and the effects of control strategies over subsequent years. Recently, some interesting results were obtained by Smith et al. (1987), who used a mathematical model of the population biology of Ostertagia ostertagi in simulation studies comparing control strategies involving anthelmintic treatments.

Summarizing, the present studies demonstrated significant relations between the level of nematode parasitism and production of cattle. Additionally, it was shown that surveys of a cross-sectional type are extremely useful in collecting data to study such relations. For first-season grazing calves faecal (LPG's for gastrointestinal and lung nematodes) and serological examinations (especially antibody titre against Cooperia spp.) can be used in such surveys. Both types of data, estimating

nematode infections, contributed significantly to the relationship between level of exposure and growth performance (with the herd as the experimental unit). For older cattle, yearlings and cows, antibody titre determinations (particularly against Ostertagia spp.) are regarded as the most valuable in estimating the variation in level of exposure to nematode infection between herds. Faecal examinations may be used to confirm the presence of nematode parasites. Finally, significant negative relationships between the level of exposure to nematode infection and the level of production (growth performance and milk production) were demonstrated not only within age-categories (calves, yearlings/heifers, cows), but also between age-categories over subsequent years on commercial dairy farms.

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GENERAL SUMMARY

In this study relationships between levels of exposure to gastro-intestinal and lung nematode infections and production were investigated on commercial dairy farms in the Netherlands. Little was known about these relationships, particularly with respect to second-year cattle and adult cows. Knowledge about the effects of different levels of exposure to nematode infection on growth performance and milk production on commercial farms, may lead to estimations of the economic impact of nematode infections. This, in turn, may contribute to a better understanding of methods to control nematode parasitism.

The present work comprised 8 studies, involving a total of 100 farms and conducted in 2 subsequent years. Where possible, first-season grazing calves, second-season grazing yearlings, heifers and adult cows were investigated on each farm. The design of the present studies resembled a cross-sectional type of survey and included some longitudinal investigations. Parameters used to estimate nematode infection were: faecal egg output combined with larval identifications, faecal lungworm larval counts, antibody titres against the gastrointestinal nematodes Ostertagia spp. and Cooperia spp., antibody titre against the lung nematode Dictyocaulus viviparus, and serum pepsinogens. Parameters used to estimate production were: body weight and heart girth of calves and yearlings, and milk production in heifers and adult cows. Additionally, questionnaires were used to collect data about farm, herd and general management. The herd was the experimental unit in the statistical analyses.

From faecal examinations in late summer and in the housing period, it was concluded that gastrointestinal nematode infections occurred in each herd, irrespective of age. In faecal samples from calf-herds the most frequent larval types found were of the genera Ostertagia and Cooperia. In faecal samples from yearling-herds the most frequent larval types found were of the genera Ostertagia, Cooperia and Trichostrongylus. In faecal samples from adult cows the most frequent larval types found were of the genera Ostertagia and Trichostrongylus.

Faecal samples of approximately 20% of the calf-herds and 6% of the yearling-herds contained lungworm larvae.

From the serological examinations it was concluded that all parameters demonstrated significant between-herd-variation in level of exposure to nematode infection compared to the within-herd-variation. This was most pronounced for calf-herds and least pronounced, but still strongly significant, for cow-herds. The between-herd-variation was highest during the grazing period for all age-groups. Antibody titres showed, generally, higher between-herd-variations than pepsinogen values.

Significant differences in production parameters were demonstrated between herds, irrespective of age. Age-adjusted body weights of calves varied between herds from -68.1 to +84.1 kg./calf and from -59.8 to +52.2

kg./calf from the population mean after the first grazing seasons in 1985 and 1986, respectively. Growth rates of calves during winter housing varied per herd from 0.25 to 0.94 kg./day and from 0.11 to 0.87 kg./day in the respective years.

Age-adjusted body weights of yearlings after the second grazing season varied per herd from -64.7 to +94.4 kg./yearling from the population mean. Growth rates of yearlings during winter housing were strongly influenced by calving and lactation.

Significant relationships were found between infection parameters and growth performance of calves and yearlings.

Growth performance of calves during the first grazing season was negatively related to antibody titre against Cooperia spp., faecal gastrointestinal nematode egg output and faecal lungworm larval count. This was demonstrated in 1985 as well as in 1986.

Growth performance of calves during winter housing was negatively related to antibody titres against Ostertagia spp. and Cooperia spp., and to pepsinogen values.

Growth performance of yearlings during the second grazing season was negatively related to antibody titre against Ostertagia spp.

Anthelmintic treatment of calves and yearlings after housing, significantly increased weight gains during the housing period.

Anthelmintic treatment after stabling and during the housing period resulted in significantly increased milk production in cows and heifers. For adult cows a significant positive correlation was found between antibody titre against Ostertagia spp. and the milk yield response to anthelmintic treatment per herd.

Concerning the longitudinal aspects of the present study, it was concluded that:

1) level of exposure to nematode infection during the first grazing season, as measured by antibody titres against Ostertagia spp., positively affects growth performance during the second grazing season, due to acquired immunity;

2) milk yield in the first lactation is positively related to body weight achieved by the end of the second grazing season. Consequently, nematode infections in the first years of life negatively affect this milk yield by reduced weight gains;

3) levels of pasture contamination may continue over subsequent years, as suggested by significant positive correlations of single infection parameters between years for calf-herds and for yearling-herds on the same farms.

Management practices on the farms influenced both level of exposure to nematode infection and growth performance of calves during the first grazing season. Supplementary feeding, vaccination against lungworm, treatments with anthelmintics at pasture or at housing, and date of housing were the most significant factors contributing to the explained part of the between-herd-variation in growth performance of calves.

Finally, it was concluded that cross-sectional type of surveys are

extremely useful in collecting data to investigate relationships between levels of nematode infections in calves, yearlings and cows. Antibody titres are the most valuable infection parameters estimating level of exposure to infection in all age-groups, to be considered for use in such surveys. Faecal examinations reflect the level of exposure to nematode infection in calves, but are for that purpose less useful in yearlings and in cows.

Economical evaluations estimating the impact of nematode parasitism on production indicated that most of the economic losses occur in older cattle in the Netherlands. The value of such economic estimations based on results of the present study and some implications of these results for the use and value of control strategies were discussed.

SAMENVATTING

In dit onderzoek is gekeken naar de invloed van infecties met maagdarm- en longwormen op de productiviteit van vee op praktijkbedrijven in Nederland, met speciale aandacht voor de relatie tussen infectieniveau en de groei van jongvee en de melkproduktie van melkkoeien. Er was weinig bekend over zulke relaties in de praktijk, vooral met betrekking tot pinken en volwassen melkvee. Kennis van het effect van verschillende infectieniveau's op de groei en de melkproduktie is noodzakelijk om schattingen van de economische verliezen, veroorzaakt door infecties met nematoden, te kunnen maken. Deze schattingen kunnen bijdragen aan een beter begrip en rationeel gebruik van systemen ter bestrijding van (de gevolgen van) worminfecties onder praktijkomstandigheden.

Het onderzoek omvatte 8 afzonderlijke studies, waaraan in totaal 100 bedrijven deelnamen en werd uitgevoerd in 2 opeenvolgende jaren. Waar mogelijk werden op elk bedrijf zowel kalveren (eerste weideseizoen), pinken (tweede weideseizoen) als koeien in het onderzoek betrokken. Waarnemingen en metingen werden gedaan volgens de opzet van een epidemiologisch dwarsdoorsnede onderzoek, maar met de mogelijkheid om enige longitudinale aspecten van het effect van worminfecties op de produktiviteit te bestuderen. Parameters voor de bepaling van het voorkomen van en het niveau van infectie met nematoden, waren: faecale eiuitscheiding gecombineerd met larven differentiaties; longworm-larventelling in mestmonsters; antilichaam titers tegen de nematoden Ostertagia spp., Cooperia spp. en Dictyocaulus viviparus in serummonsters; en pepsinogeen waarden in serummonsters. Lichaamsgewicht, borstomvang en melkproduktie vormden de produktie parameters. Gegevens over de bedrijfsvoering werden verzameld middels enquete-formulieren en middels de bedrijfsbezoeken. De koppel werd als experimentele eenheid gezien in de statistische verwerking van de gegevens.

Uit de resultaten van het mestmonster-onderzoek, uitgevoerd in de herfst en tijdens de stalperiode in beide jaren van het onderzoek, kan geconcludeerd worden dat infecties met nematoden op elk bedrijf voorkomen, ongeacht de leeftijd van het vee. Bij de kalveren waren de meest voorkomende nematoden van de geslachten Ostertagia en Cooperia. Bij de pinken waren dat de geslachten Ostertagia, Cooperia en Trichostrongylus en bij de koeien Ostertagia en Trichostrongylus.
Longwormlarven werden aangetroffen in 20% van de mestmonsters afkomstig van koppels kalveren en in 6% van de mestmonsters afkomstig van koppels pinken.

Uit het serologisch onderzoek kan worden geconcludeerd, dat de verschillen in infectieniveau met maagdarm- en longwormen tussen bedrijven (i.e. koppels) significant groter zijn dan binnen bedrijven. Dit was het duidelijkst voor de kalveren en het minst duidelijk, hoewel eveneens sterk significant, voor de koeien. De variatie in de serologische waarnemingen tussen bedrijven was het grootst in alle leeftijdsgroepen wanneer gemeten in de weideperiode. Deze variatie tussen bedrijven was groter wanneer

gemeten met behulp van antilichaam titers dan met pepsinogeen waarden.

Productie, gemeten met behulp van lichaamsgewichten, borstomvang en melkproduktie, verschilde eveneens significant tussen de bedrijven voor alle leeftijdsgroepen.

De voor leeftijd gecorrigeerde lichaamsgewichten van kalveren verschilden per koppel tussen bedrijven van -68.1 tot +84.1 kg./kalf in 1985 en van -59.8 tot +52.2 kg./kalf in 1986 ten opzichte van het populatie gemiddelde, gemeten na het eerste weideseizoen. De groei van kalveren tijdens de daaropvolgende stalperiode varieerde per koppel van 0.25 tot 0.94 kg./dag in 1985/86 en van 0.11 tot 0.87 kg./dag in 1986/87.

De voor leeftijd gecorrigeerde lichaamsgewichten van pinken, gemeten na het tweede weideseizoen, varieerden per koppel van -64.7 tot +94.4 kg./pink ten opzichte van het populatie gemiddelde. De groei van pinken, dan wel vaarzen, tijdens de daaropvolgende stalperiode werd sterk beinvloed door afkalven en lactatie.

Significante verbanden werden gevonden tussen de infectie parameters en de voor leeftijd gecorrigeerde lichaamsgewichten van kalveren en pinken, gemeten na het weideseizoen.

Lichaamsgewicht van kalveren na het eerste weideseizoen, per koppel, was negatief gecorreleerd met de antilichaam titer tegen Cooperia spp., eiuitscheiding en longworm-larventelling. Dit werd zowel in 1985 als in 1986 gevonden.

De groei van kalveren tijdens de stalperiode was negatief gecorreleerd met de antilichaam titers tegen Ostertagia spp. en Cooperia spp., en met de pepsinogeen waarden.

Lichaamsgewicht van pinken na het tweede weideseizoen, per koppel, was negatief gecorreleerd met de antilichaam titer tegen Ostertagia spp.

Behandeling van kalveren en pinken na opstallen met een anthelminticum resulteerde in significant verbeterde groei tijdens de stalperiode.

Ontwormen van vaarzen en koeien in de droogstand voor het afkalven, resulteerde in een significante toename van de melkproduktie in de daaropvolgende lactatie. Deze toename in melkproduktie na behandeling met een anthelminticum in koeien was, per koppel, significant positief gecorreleerd met de antilichaam titer tegen Ostertagia spp. gemeten in de voorafgaande weideperiode.

De volgende conclusies konden worden getrokken met betrekking tot de longitudinale aspecten in het onderzoek:

1) het infectieniveau in het eerste weideseizoen, gemeten door middel van de antilichaam titer tegen Ostertagia spp., beinvloedt de groei tijdens het tweede weideseizoen positief op praktijkbedrijven, middels verworven immuniteit;

2) de melkproduktie van vaarzen was positief gecorreleerd met het voor leeftijd gecorrigeerde lichaamsgewicht na het tweede weideseizoen. Hieruit voortvloeiend, beinvloeden worminfecties voorkomend tijdens het eerste en tweede weideseizoen de melkproduktie van vaarzen negatief middels een negatief effect op de groei tijdens de eerste levensjaren;

3) het niveau van weidebesmetting met infectieuze larven in een jaar is deels afhankelijk van het niveau van weidebesmetting in het voorafgaande

jaar, zoals wordt gesuggereerd door de significant positieve correlaties voor afzonderlijke infectie parameters tussen jaren bij zowel kalveren als pinken binnen bedrijven.

De bedrijfsvoering beinvloedde zowel infectieniveau's als de groei van kalveren tijdens het eerste weideseizoen. Bijvoedering met krachtvoer, vaccinatie tegen longworm, anthelmintica-behandelingen tijdens de weideperiode en na opstallen, en de opstaldatum waren de meest in het oog springende factoren, die significant bijdroegen aan het verklaarde deel van de variatie tussen bedrijven in voor leeftijd gecorrigeerde lichaamsgewichten, gemeten na de weideperiode.

Tot slot kan geconcludeerd worden, dat de opzet van het onderzoek, dwars-doorsnede waarbij veel bedrijven bezocht kunnen worden in plaats van longitudinaal op een beperkt aantal bedrijven, zeer geschikt is om gegevens te verzamelen voor de bestudering van de relatie tussen infectieniveau en produktiviteit op praktijkbedrijven. Voor dit type onderzoek kunnen antilichaam titers beschouwd worden als de meest waardevolle parameters ter bepaling van het infectieniveau in alle leeftijdsgroepen ("sero-epidemiologie"). De eiuitscheiding en larventellingen, bepaald in mestmonsters, weerspiegelden bij kalveren het infectieniveau eveneens, maar zijn voor dat doel minder bruikbaar bij ouder vee, pinken en koeien.

Economische evaluaties van het effect van infecties met maagdarm- en longwormen op de productiviteit van jongvee en koeien geven aan, dat de meeste economische verliezen veroorzaakt door deze infecties in Nederland optreden in ouder vee. De waarde van zulke economische evaluaties, gebaseerd op de uitkomsten van dit onderzoek, en enige implicaties van de resultaten met betrekking tot de waarde en het gebruik van bestrijdingssystemen zijn bediscussieerd.

CURRICULUM VITAE

Harm Wildrik Ploeger werd op 18 februari 1959 geboren te Ede. In 1977 werd het Atheneum B diploma behaald aan de christelijke scholengemeenschap 't Loo te Voorburg. Vrijgesteld van militaire dienstplicht werd in datzelfde jaar begonnen met de studie Zoötechniek aan de toenmalige Landbouwhogeschool te Wageningen. In 1985 werd door de Stichting Landbouwhogeschool Fonds de prof.C.T.de Wit scriptieprijs toegekend aan de scriptie 'Resultaten van een sero-epidemiologische survey bij "first-season grazing" kalveren met betrekking tot het Bovine Respiratory Syncytial Virus en enkele nematoden', resultaat van een doctoraal-onderzoek bij de vakgroep Veehouderij. De studie werd afgerond in maart 1986. Van september 1985 tot december 1988 volgde een tijdelijk dienstverband als wetenschappelijk project-medewerker voor het onderzoek dat resulteerde in dit proefschrift.