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AN EPIDEMIOLOGICAL STUDY OF FOOT ROT IN PASTURED CATTLE

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MONRAD, J., A. A. KASSUKU, P. NANSEN and P. WILLEBERG: *An epidemiological study of foot rot in pastured cattle.* Acta vet. scand. 1983, *24*, 403—417. — Using 12 years of data from the common grazing areas at Store Vildmose on the incidence of foot rot in cattle, it was shown that the disease incidence varied significantly between the sections in which the animals were grazing. Differences also existed between breeds in their foot rot incidence. Extraordinarily wet summers were noted to influence foot rot in cattle, and a possible effect of soil pH was also observed.

foot rot; cattle; incidence; epidemiology; breed differences; climatic factors; lameness.

Foot rot is a multifactorial disease of the feet of cattle, characterized by erosions and foul-smelling lesions of the interdigital skin and of other soft tissues. *Gupta et al.* (1964) and *Blood et al.* (1979) listed different names used for this condition, such as winter foot-rot, stinky foot, foul-in-foot, fouls, infectious pododermatitis, panaris, panaritium, clit-ill, and interdigital phlegmon.

The first sign of the disease is slight lameness, which gradually becomes more serious as the condition progresses. The interdigital skin, coronet, pastern and fetlock are often swollen. The animal is anorexic, the affected limb is often held off the ground, and in severe cases pyrexia may be present. There is a marked drop in milk yield, followed by a loss of body condition. In case of complications arising from the disease, amputation of the claws or slaughter of the animal may be necessary (*Gupta et al.* 1964).

Foot rot in cattle may be accurately diagnosed by its characteristic location, fetid odour of the lesions, and the swelling of the interdigital area and heel bulbs. A careful examination of the hoof will enable the clinician to distinguish foot rot from nail punctures, bruising of the heels, traumatic injuries, laminitis, foot abscesses, and foot and mouth disease lesions (*Gupta et al.* 1964, *Blood et al.* 1979).

Berg & Loan (1975) reported that Fusobacterium necrophorum and Bacteroides melaninogenicus were predominant isolates from foot rot lesions in cattle. Furthermore, they experimentally reproduced the disease in cattle by introducing an inoculum of Bacteroides melaninogenicus and Fusobacterium necrophorum into the interdigital skin. The addition of soil to the inoculum was noted to aggravate the severity of the infection (*Berg* 1978). Some Gram-negative bacilli similar to Bacteroides nodosus and unidentified spirochaetes were found to have an additional etiological importance (*Gupta et al.* 1964).

The etiological bacteria of foot rot are cosmopolitan in distribution. They have been isolated as commensals from the faeces of cattle and a number of other animal species (*Simon & Harris* 1981). The skin of the feet of cattle and sheep are also known to harbour the bacteria.

These organisms are very sensitive to aerobic conditions. Two to 10 days exposure to atmospheric oxygen is lethal, and exposure to a temperature of 50—60° C kills the bacteria within 10—15 min (*Buxton & Fraser* 1977). However, Fusobacterium necrophorum may survive in swampy pastures for up to 11 months at 4° C, while B. nodosus survives longer in tissues of the host than in mud and moist pastures (*Garcia et al.* 1971, *Simon & Harris* 1981, *Egerton* 1981). *Simon & Harris* (1981) noted that many research workers reported that F. necrophorum survives in a microenvironment with a pH range of 6 to 9.

A number of predisposing factors have been incriminated to precede foot rot outbreaks (*Smedegaard* 1964). Rainfall and humidity above average have been reported to be among the predisposing factors (*Nylin* 1980).

Gupta et al. (1964), *Johnson et al.* (1969), *Blood et al.* (1979), and *Greenough et al.* (1981) noted that wet mud and faeces often soften and macerate the interdigital skin, facilitating entry of the pathogens into the tissue. Furthermore, they observed that stubble, stones, and frozen or dried mud may bruise the skin,

making it easy for the bacteria to gain entry into the interdigital tissues. Dry faeces and straw in layers around the coronet may create anaerobic conditions which are suitable for bacterial multiplication (*Gupta et al.* 1964).

Smedegaard (1963) reported that Jersey bulls had a lower incidence of related conditions than Red Danish and Friesian bulls. *Hollon & Branton* (1975) and *Frisch* (1976) observed that the incidence of foot rot decreased with increasing proportion of Bos indicus blood in Bos taurus crossbreds. The incidence of foot rot was even higher in purebred Bos taurus breeds. The wide interdigital space, which *Greenough et al.* (1981) consider to be hereditary, is also one of the predisposing factors.

The composition of some feed rations has also been associated with the disease. *Banting* (1978) observed an increase in the incidence of foot conditions where zinc was deficient in the feedstuffs and noted that oral zinc therapy could be used in controlling foot conditions. However, *Egerton* (1978) could not find any useful response to zinc therapy in ruminants with foot infections.

There are different views among research workers on the seasonal incidence of foot rot. *Greenough et al.* (1981) in United Kingdom, reported the presence of foot rot in cattle throughout the year with a higher frequency from October to March. *Nylin* (1980) and *Eddy & Scott* (1980) observed higher incidence of the disease from September to December. *Prentice & Neal* (1972) and *Eddy & Scott* reported that a higher frequency of foot rot in early lactation was common.

The aim of the present epidemiological study was to determine which contributory factors act under pastural conditions in Denmark.

MATERIALS AND METHODS

Location of study area

Store Vildmose is a swampy land covering an area of about 70 square kilometres in North Jutland, Denmark. Approximately 1,000 hectares of land were drained between 1920 and 1930 for use as a grazing area for cattle.

There are 4 feedlot groups in this area: "Ørne" and "Sandels" feedlot groups form the northern section, while the "Dam" and "Ring" feedlot groups form the southern section. The feedlots placed in the northern section are provided with windbreaks (Fig. 1).

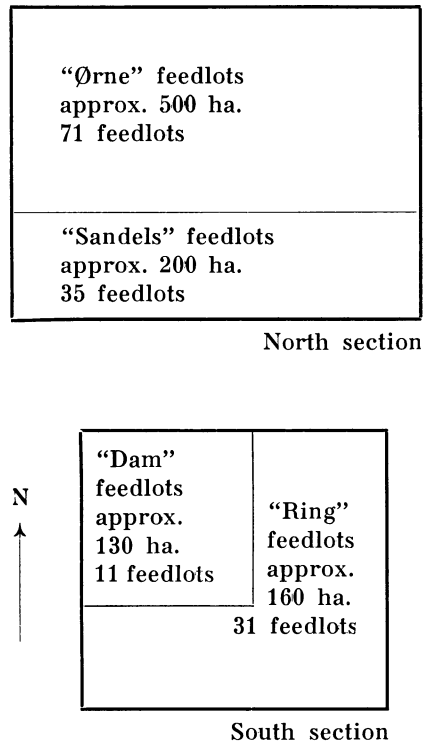

Figure 1. Schematic location and size of the feedlot sections in Store Vildmose and the number of feedlots available in 1970.

Management

From 1950 to 1960, parts of the area were enriched with lime, and the improved pastures sown. Towards the end of this period existing drainage was improved in the southern section, and this procedure was later repeated in the northern section. Enrichment of the soil with calcium was carried out after the drainage of the area. Lime was applied to the soil at the rate of 4 tons per hectare. The area was then used for grain production for the following 3 years. In the third year, the area was undersown with grass. Thus, improved pastures have gradually replaced poor quality pastures.

Cattle are usually put on pasture from mid-May to mid-October each year. Three or 4 herdsmen are charged with the responsibility of the day to day care of the animals. They promptly report any unusual event to the cattle owners.

Records of animals grazing in this area are kept at the Vildmose Supervisor's office. The animals are identified by eartag numbers and numbered metal chains. Records include age and breed of the individual animals. In addition, the number of cattle in each feedlot area, the number of cattle for each owner using a feedlot, and records of each individual head of cattle succumbing to foot rot and other diseases during the pasturing period are kept.

Recording of foot rot cases

The herdsmen's observations of foot rot cases were confirmed by a veterinary surgeon. The following information was then recorded: — The date of onset of foot rot signs, age, breed and identification number of the affected animal and the paddock in which the animal had been grazing. All cases occurring during the pasturing period were reported, apart from those that appeared when the cattle were in their first week on pasture. Recurrence of foot rot in the same animal at least 2 weeks after recovering from the previous foot rot condition was considered a new case.

Table 1. Breed distribution of the grazing cattle in Store Vildmose, 1970—1981.

	SDM		RDM		Jersey		Cross-breeds		Unknown breed		
Year	no.	%	no.	%	no.	%	no.	%	no.	%	Total
1970	1780	52.8	737	21.9	471	14.0	365	10.8	19	0.6	3372
1971	1808	57.8	658	21.0	399	12.8	256	8.2	7	0.2	3128
1972	1884	59.6	578	18.3	395	12.5	278	8.8	26	0.8	3161
1973	1900	58.3	568	17.4	393	12.1	387	11.9	12	0.4	3260
1974	1921	60.2	492	15.4	386	12.1	368	11.5	26	0.8	3193
1975	2043	66.3	439	14.2	242	7.8	360	11.7	0	—	3084
1976	2028	65.8	389	12.6	253	8.2	379	12.3	35	1.1	3084
1977	2021	67.1	415	13.8	264	8.8	294	9.8	16	0.5	3010
1978	1997	68.3	392	13.4	274	9.4	263	9.0	0	—	2926
1979	2069	72.5	309	10.8	238	8.3	236	8.3	0	—	2852
1980	1731	73.1	249	10.5	181	7.6	198	8.4	10	0.4	2369
1981	1694	72.6	231	9.9	208	8.9	153	6.6	46	2.0	2332
Total	22,876	64.0	5457	15.3	3704	10.4	3537	9.9	197	0.6	35,771

Population data

The data for the study have been collected from 1970 to 1981, during which period a total of 35,771 head of cattle have grazed for a season in this area. The breeds recorded are the Danish Friesian Dairy breed (SDM), Red Danish Dairy breed (RDM), Jersey breed, and cross-breeds.

The proportion of each breed in the area for each year is shown in Table 1.

Very few bulls were kept in these feedlots, whereas heifers and young cows formed the largest proportion. The age distribution of cattle was compiled from the records for 1972 as an example and is given in Table 2.

Table 2. Age distribution of cattle on pasture in Store Vildmose, 1972.

	Age in years ± 3 months							
	½	1	1½	2	2½	3	unknown age	Total
Number	167	638	1228	749	128	58	193	3161
%	5.3	20.2	39.9	23.7	4.1	1.8	6.1	100

Soil analyses

Soil pH analyses were carried out by the Danish Heath Society or the North Jutland Plant Breeding Laboratories.

Climatic data

Weekly reports of rainfall, temperature, sunshine hours, and humidity from the Tylstrup Weather Station, about 10 km away, were used in the analysis.

Accumulation of recorded parameters was initiated in week 18 of each year, i.e. approx. 2 weeks before the animals were turned out.

Statistical methods

Crude incidence rates and indirectly standardized rates were calculated to show differences in the occurrence of the disease between breeds, age groups, and feedlot sections in different years and for the 12-year period overall (*Armitage* 1971).

Standardization of the rates eliminates the possible confounding effect of the factor according to which the standardization

is made (e. g. feedlot section). Otherwise a non-proportional distribution of that factor within the factor under investigation (e. g. breed) might obscure the true relationship of the latter factor to the disease.

The incidence rates were calculated on the basis of the entire pasturing period for that year and are thus presented as percentages of cattle affected per grazing season.

Cochran's test for differences between 2 adjusted rates was used to statistically compare the rates obtained by the indirect standardization method (*Cochran* 1954, *Armitage* 1971).

RESULTS

Crude incidence rates for each year of the 12-year period are shown in Table 3. Except for the incidence rates recorded in 1972 and 1981 all rates were 1 % or less. For 1972, however, the rate was as high as 4.8 % and for 1981 it was 2.4 %.

Table 3. Yearly incidence of foot rot in the sections of Store Vildmose, 1970—1981.

Year	North section			South section			Total		
	no. of cases	no. of cattle	crude rate %	no. of cases	no. of cattle	crude rate %	no. of cases	no. of cattle	crude rate %
1970	10	2751	0.4	2	621	0.3	12	3372	0.4
1971	26	2592	1.0	5	536	0.9	31	3128	1.0
1972	81	2527	3.2	70	634	11.0	151	3161	4.8
1973	14	2462	0.6	6	798	0.8	20	3260	0.6
1974	10	2387	0.4	2	806	0.2	12	3193	0.4
1975	2	2215	0.1	1	869	0.1	3	3084	0.1
1976	5	1967	0.3	8	1117	0.7	13	3084	0.4
1977	1	1796	0.1	6	1214	0.5	7	3010	0.2
1978	6	1724	0.3	9	1202	0.7	15	2926	0.5
1979	5	1758	0.3	17	1094	1.6	22	2852	0.8
1980	6	1437	0.4	14	932	1.5	20	2369	0.8
1981	25	1427	1.8	32	905	3.5	57	2332	2.4
Total	191	25,043	0.76[1]	172	10,728	1.60[2]	363	35,771	1.01

[1] Rates for "Ørne" and "Sandels" feedlots were 0.72 % and 0.88 %, respectively; the difference between the two rates is non-significant (χ^2-test).

[2] Rates for "Dam" and "Ring" feedlots were 1.81 % and 1.46 %. respectively; the difference between the two rates is non-significant (χ^2-test).

Feedlot sections

Table 3 also shows the crude incidence rates in the north and south sections of Store Vildmose. Within these 2 sections only non-significant differences existed between the respective subsections. It is noted here that there seems to be a trend for the rates to be higher in the south section than in the north section, particularly during high risk years. Using indirectly standardized incidence rates to eliminate the possible confounding effect of an uneven breed distribution between the two sections there was in fact an overall 2.1 times more foot rot in the south section than in the north section (Table 4). This difference was significant at the level of $P < 0.001$. Similarly, the table shows a 3.1 times higher incidence of foot rot in the south section than in the north section during the 1972 pasturing period. For the 1981 pasturing period, the south section had 2.2 times higher incidence of foot rot than the north section (Table 4).

Breeds

Incidence rates of foot rot in the different breeds were compared to that in the Jersey breed using indirectly standardized rates to adjust for the possible confounding effect of the 2 different sections. Table 5 shows the adjusted incidence rates in the breeds for the total 12-year period of data collection and for the high-risk years 1972 and 1981, respectively. The RDM had significantly higher incidence rates than the Jersey breed, and there were also obvious differences among the other breeds.

Age susceptibility

A breakdown of the cattle populaion by age was only obtained for the 1972 pasturing period, in which about 64 % of the cattle had an age of up to 1½ years, while 30 % of the cattle were 2—3 years; approximately 6 % had no records of their age (Table 2). Table 6 illustrates the fact that for the year 1972 there was no difference between the relative risks of the 2 age groups.

Precipitation

Accumulated precipitation for 1972, 1975 and 1981 are shown in Fig. 2 together with histograms illustrating the weekly incidences of foot rot recorded during the respective years. These

Table 4. Incidence of foot rot in the north and south sections of Store Vildmose for selected grazing periods.

Section	1970—81				1972				1981			
	No. of cases	Crude rate %	Stand.[1] rate %	Rel.[2] risk	No. of cases	Crude rate %	Stand.[1] rate %	Rel.[2] risk	No. of cases	Crude rate %	Stand.[1] rate %	Rel.[2] risk
South	172	1.60	1.60	2.1***	70	11.0	10.3	3.1***	32	3.5	3.7	2.2**
North	191	0.76	0.76	1	81	3.2	3.3	1	25	1.8	1.7	1
Total	363	1.01	—	—	151	4.8	—	—	57	2.4	—	—

[1]) Standardized according to the overall breed-specific rates for the respective period.
[2]) Relative risk is the ratio of the standardized rate for the section to the standardized rate for the north section.
**: $P < 0.01$; ***: $P < 0.001$; by Cochran's test.

Table 5. Incidence of foot rot in Store Vildmose by breed for selected grazing periods.

Breed	1970—81				1972				1981			
	No. of cases	Crude rate %	Stand.[1] rate %	Rel.[2] risk	No. of cases	Crude rate %	Stand.[1] rate %	Rel.[2] risk	No. of cases	Crude rate %	Stand.[1] rate %	Rel.[2] risk
RDM	92	1.7	1.8	4.5***	38	6.6	7.3	4.1***	13	5.6	6.3	6.3**
SDM	222	1.0	0.9	2.3**	90	4.8	4.6	2.6*	36	2.1	2.1	2.1
Crossbreeds	29	0.8	0.8	2.0*	13	4.7	4.5	2.5	5	3.3	3.5	3.5
Jersey	13	0.4	0.4	1	6	1.5	1.8	1	2	1.0	1.0	1
Unknown	7	3.6	3.1	7.8	4	15.4	8.5	4.7	1	2.2	1.6	1.6
Total	363	1.01	—	—	151	4.8	—	—	57	2.4	—	—

[1]) Standardized according to the overall section-specific rates for the respective period.
[2]) Relative risk is the ratio of the standardized rate for the breed to the standardized rate for the Jersey breed.
*: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$; by Cochran's test.

Table 6. Incidence of foot rot in Store Vildmose by age-group, 1972.

Age group	No. of cases	Crude rate %	Stand.[1]) rate %	Rel.[2]) risk
< 2 yrs	94	4.6	4.8	1.1
⩾ 2 yrs	45	4.8	4.6	1
Unknown	12	6.2	—	—
Total	151	4.8	—	—

[1]) Standardized according to the overall breed-specific rates for 1972.
[2]) Relative risk is the ratio of the standardized rate for the age-group to the standardized rate of the ⩾ 2 yrs age-group.

3 years exemplify 3 different levels of foot rot occurrence, since 1972 was a high risk year, 1975 was a low risk year, and 1981 was a medium risk year.

During the 1972 pasturing period there was an extraordinarily high rainfall in the first 8 weeks. From the 6th week (week 23) the incidence of foot rot increased rapidly. The 1975 pasturing revealed the very lowest amount of precipitation of all the years included in the survey; this year was particularly dry during the first half of the pasturing period and it also gave rise to the lowest incidence rate of foot rot (crude rate 0.1 %). In 1981 the precipitation was of a low to medium size until week 26 when it rose steeply. The foot rot cases began to appear in week 26 with the majority of cases appearing within week 30—35, i. e. several weeks later than in 1972.

Mean maximum temperature and sunshine hours

For the 2 years 1980 and 1981 detailed meteorological data (mean maximum temperature and sunshine hours per week) were available, but no apparent associations to the incidence pattern could be found.

Soil acidity

From the few records of measurements of soil pH in Store Vildmose (Table 7) it was observed that the soil in the northern section had lower pH values than the soil in the south section.

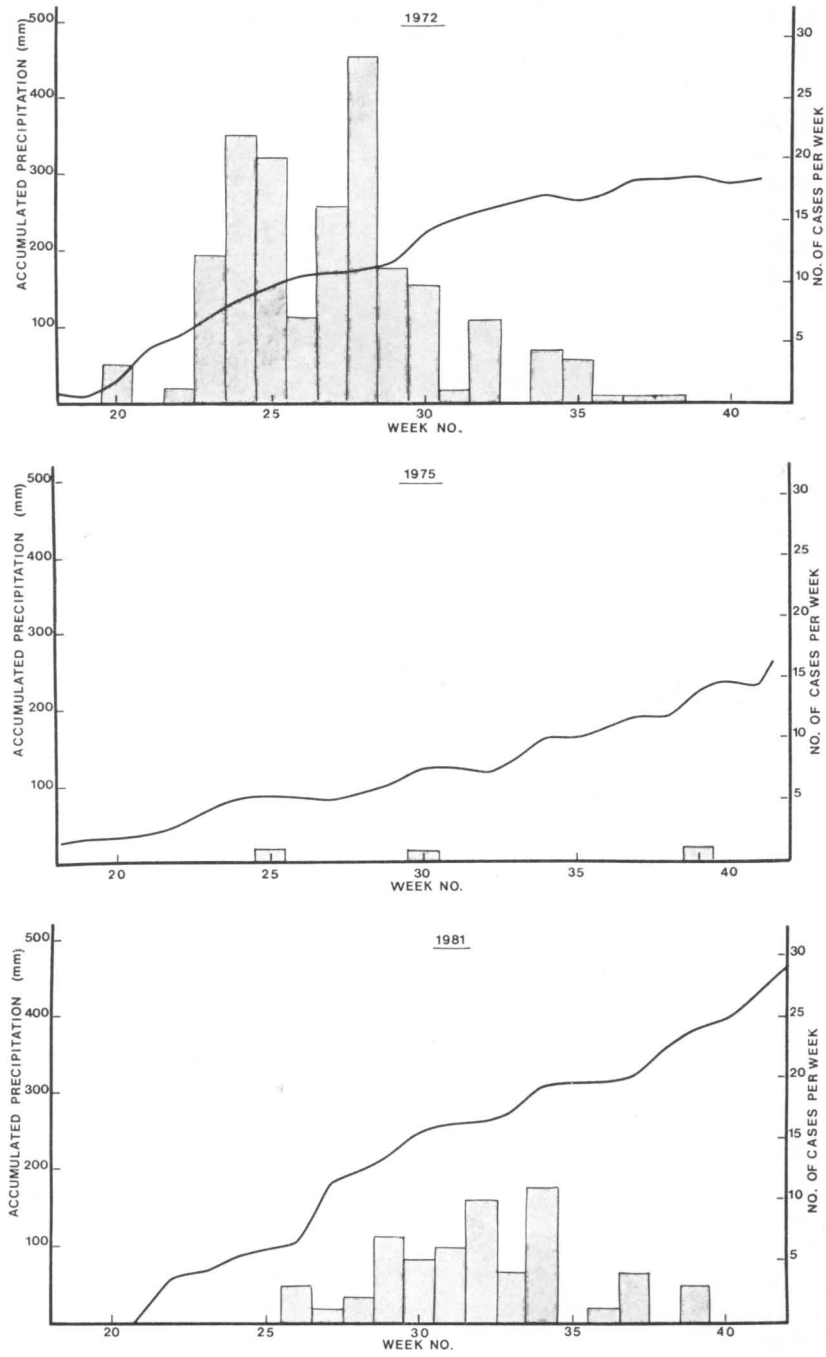

Figure 2. Curve for accumulated weekly quantity of precipitation related to number of new cases of foot rot per week in 1972, 1975, and 1981.

Table 7. Soil pH in feedlot groups in Store Vildmose, 1964—1979.

Year	North Section		South Section	
	"Ørne" feedlots	"Sandel's" feedlots	"Dam" feedlots	"Ring" feedlots
1964	4.3—4.9	—	—	5.6
1967	—	—	6.3	—
1978	—	4.7—5.2	—	—
1979	4.0—5.3	—	—	—

Management factors

The average feedlot size for each feedlot group over the 12-year period was 13.9 hectares per feedlot in the "Dam" feedlot group, while in the other 3 feedlot groups the feedlot size varied from 7.0 to 9.6 hectares per feedlot.

The average number of animals per hectare over the 12-year period was nearly the same in all feedlot groups. It varied slightly around 3.6 to 3.8 animals per hectare.

As a result of this each of the "Dam" feedlots held about 1.5 to 2 times as many animals as each feedlot in the other sections.

DISCUSSION

For foot rot to occur in cattle, an interaction of etiological agent(s), the host, and the type of management practice and other environmental factors seems to be essential (*Johnson et al.* 1969).

Fusobacterium necrophorum and Bacteroides melaninogenicus are common isolates from foot rot cases. They are, hovewer, difficult to grow and thrive best in the laboratory under strict anaerobic conditions in enrichment media. Their growth may also be retarded by the presence of other microorganisms. In the field situation, microenvironmental conditions favouring the presence of anaerobic conditions result in the multiplication of these pathogens (*Gupta et al.* 1964). If such a situation is coupled with factors conducive to maceration of the interdigital skin, then the pathogens gain access into the tissues and ultimately produce disease.

Overcrowding at watering places, gateways and muddy cowyards may predispose the interdigital skin to trauma. This increases the chance of penetration into the tissues by the pathogens,

which are in abundancy in faeces and mud in such overcrowded places (*Glider* 1960, *Gupta et al.* 1964).

In Store Vildmose, there is usually only one watering place per feedlot, and therefore the problem of overcrowding at the watering places is most serious in the "Dam" feedlots. This observation is in agreement with the fact that the "Dam" feedlot group is the most disease-prone group (cf. footnote of Table 3).

In 1972 and 1981 the risk of foot root increased approx. 4—8 weeks after a period of heavy rainfall indicating that this, possibly together with optimal soil temperatures, predisposes cattle to the disease.

Johnson et al. (1969) observed that an association seems to be present between the incidence of foot rot, increasing soil temperature and increasing amounts of precipitation. They also suggested that soil temperature may be related to the average maximum ambient temperature and sunlight hours. The optimum growth of Fusobacterium necrophorum, at least under laboratory conditions, occurs at about 37° C (*Buxton & Fraser* 1977).

The southern section had a higher risk of disease than the northern section of Store Vildmose for all pasturing periods. This may be seen in view of the fact that the southern section has no windbreaks, and therefore the soil temperature could be at the optimum level, while in the northern section the soil temperature could possibly be unfavourable for the survival of the pathogens. However, the length of the survival period of the pathogens in the soil may not be critical in the transmission of the disease, because the organisms are excreted in the faeces of healthy animals (*Aalbæk* 1982).

The higher pH values of soil in the south section are favourable for the optimal growth of the bacteria, while the low pH values recorded in the soil in the northern section are unfavourable for the growth of bacteria. This is conceivably one of the main factors causing the differences in the risk of disease between animals in the two sections.

The larger breeds were found to be more susceptible to foot rot than the Jersey breed. The adjusted rates for e. g. RDM were 1.8, 7.3 and 6.3 % for 1970—1981, 1972 and 1981 pasturing periods, respectively. The adjusted rates for the Jersey breed for 1970—1981, 1972 and 1981 pasturing periods were 0.4, 1.8 and 1.0 %, respectively. Similar breed differences have been reported by *Smedegaard* (1963) for related conditions. While many fac-

tors may have been in action during these pasturing periods, it seems likely that with adverse environmental factors, such as for 1972, the incidence of foot rot may tend to rise even in a breed known to be relatively resistant to the disease.

As long as there are factors conducive to the maceration of the interdigital skin under field conditions, the risk of foot rot exists.

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SAMMENDRAG

En epidemiologisk undersøgelse af klovbrandbylder hos græssende kreaturer.

På basis af 12 års data fra græsningsarealerne i Store Vildmose vedrørende forekomsten af klovbrandbylder kunne der påvises signifikante forskelle i incidensen imellem de forskellige fenneafsnit. Der fandtes ligeledes udtalte raceforskelle i lidelsens forekomst. Særligt fugtige græsningssæsoner viste sig at øge klovbrandbyldernes optræden. Jordbundens pH fandtes endvidere at variere imellem de fenneafsnit, der udviste forskellig sygdomsforekomst.

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