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Gastrointestinal Helminth Parasitisms of Dairy Cattle in South Dakota

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GASTROINTESTINAL HELMINTH PARASITISMS
OF DAIRY CATTLE IN SOUTH DAKOTA

by

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GASTROINTESTINAL HELMINTH PARASITISMS

OF DAIRY CATTLE IN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

During 1981-82, four studies on gastrointestinal helminth parasitisms of South Dakota dairy cattle were conducted. They were as follows:

1. Survey of parasitisms in South Dakota dairy show cattle during 1981.
2. Study of seasonal trends in parasitisms in two Brookings County, South Dakota, dairy herds during 1981-82.
3. Study of parasitisms in selected Black Hills dairy herds during 1981-82.
4. Survey of parasitisms in Dairy Herd Improvement Association (DHIA) cows in eastern South Dakota during 1982.

Although numerous surveys of gastrointestinal helminths of cattle and of their seasonal trends have been conducted in other states (Porter, 1942; Levine and Aves, 1956; Yazwinski and Gibbs, 1975; Grisi and Todd, 1978), no such projects have previously been attempted in South Dakota. This is not to say that the state has been devoid of research in the general area of internal parasites of cattle. In 1948, Kates and Runkel reported on an investigation into the life cycle of Moniezia expansa, a common tapeworm of sheep and cattle, which included collection of oribatid mites near Newell, South Dakota. During 1955-57, a study was made of the prevalence of intestinal helminths and the effect of anthelmintics on those parasitisms in 206 beef calves (Hugghins, 1957). Additionally, several projects have been conducted in nearby states (Zimmermann and Hubbard, 1961; Cox and Todd, 1962; Honess and Bergstrom, 1963; Jacobson and Worley, 1969; Leland et al., 1973).

Currently, dairying is the fourth leading commodity in cash receipts in South Dakota (USDA, 1982). During the last 20 years, dairying has greatly increased in the state, but the South Dakota average of 11,120 lb of milk per cow per year is 9.24% below the national average.

Gastrointestinal parasitisms, even at subclinical levels, have been shown to significantly decrease milk production and, consequently, profits (Todd et al., 1972; Brown and Maniscalco, 1974; Bliss and Todd, 1976; Todd et al., 1978a and 1978b). Although Hugghins (1957) established that South Dakota beef cattle are parasitized by gastrointestinal helminths, information on the nature of parasitism in dairy cattle was lacking.

Given the above facts, the present research was undertaken to ascertain the current status of gastrointestinal helminth parasitism in South Dakota dairy cattle. The objectives of the project were to determine:

For all studies:

1. The overall and generic prevalences of gastrointestinal helminth ova in the feces of dairy cattle.
2. The total and generic mean egg counts in dairy cattle.
3. The frequencies and relative frequencies of eggs analyzed from dairy cattle, as an indication of more than one genus being present in an animal (multiple helminth infections).

For Study 2 only:

Any seasonal trends in gastrointestinal helminth parasitisms in cows of the two herds, considered separately, in terms of monthly prevalences and mean egg counts.

LITERATURE REVIEW

Taxonomy and General Information

Classification of the nematode genera considered herein (Table 1) follows that of Chitwood (1969) through the Family taxon, except for Family Trichuridae, Class Adenophorea which includes the two genera *Capillaria* and *Trichuris* as in Yamaguti (1961). Subfamily designations are those presented in Yamaguti (1961). The cestode genus is classified by the system found in Wardle and McLeod (1968). Synonyms of specific members of the genera can be found in Yamaguti (1961) and Wardle and McLeod (1968).

The gastrointestinal tract of cattle (Fig. 1) serves as habitat for all parasite genera of concern (Douvres, 1957; Wardle and McLeod, 1968), and most also occur in domestic sheep and wild ruminants (Dikmans, 1939; Yamaguti, 1961; Olsen, 1974; Levine, 1980). Most gastrointestinal helminths found in the seven species of South Dakota big game mammals (Boddicker and Hugghins, 1969) have also been reported from cattle (Becklund, 1964). Additionally, *Haemonchus contortus, Ostertagia ostertagi* and three members of genus *Trichostrongylus* have rarely been reported from humans in various parts of the world (Ransom, 1911; Yamaguti, 1961: Cheng, 1973; Levine, 1980).

Types of Investigations

Generally, surveys of gastrointestinal parasites of dairy cattle are accomplished through the collection of fecal samples in order to identify and enumerate helminth ova. Another method involves examination of gastrointestinal tracts and contents obtained at abattoirs.

Table 1. Classification of the gastrointestinal helminth genera found during the research. After Yamaguti (1961), Wardle and McLeod (1968) and Chitwood (1969).

Phylum Nematoda
  Class Secernentea
    Order Rhabditida
      Suborder Rhabditina
        Superfamily Rhabdiascoidea
          Family Strongyloididae

            Strongyloides Grassi, 1879

    Order Strongylida
      Suborder Strongylina
        Superfamily Ancylostomatoidea
          Family Ancylostomatidae
            Subfamily Bunostominae

            Bunostomum Railliet, 1902

        Superfamily Strongyloidea
          Family Oesophagostomidae
            Subfamily Oesophagostominae

            Oesophagostomum Molin, 1861

      Suborder Trichostrongylina
        Superfamily Trichostrongyloidea
          Family Trichostrongylidae
            Subfamily Trichostrongylinae

            Cooperia Ransom, 1907

            Ostertagia Ransom, 1907

            Trichostrongylus Looss, 1905

            Subfamily Haemonchinae

            Haemonchus Cobb, 1898

            Subfamily Nematodirinae

            Nematodirus Ransom, 1907

    Order Ascarida
      Suborder Ascaridina
        Superfamily Ascaridoidea
          Family Toxocaridae
            Subfamily Toxocarinae

            Neoascaris Travassos, 1927 (emend. Sprent, 1957)

  Class Adenophorea
    Order Trichinellida
        Superfamily Trichinelloidea
          Family Trichuridae
            Subfamily Trichurinae

            Trichuris Roederer, 1761

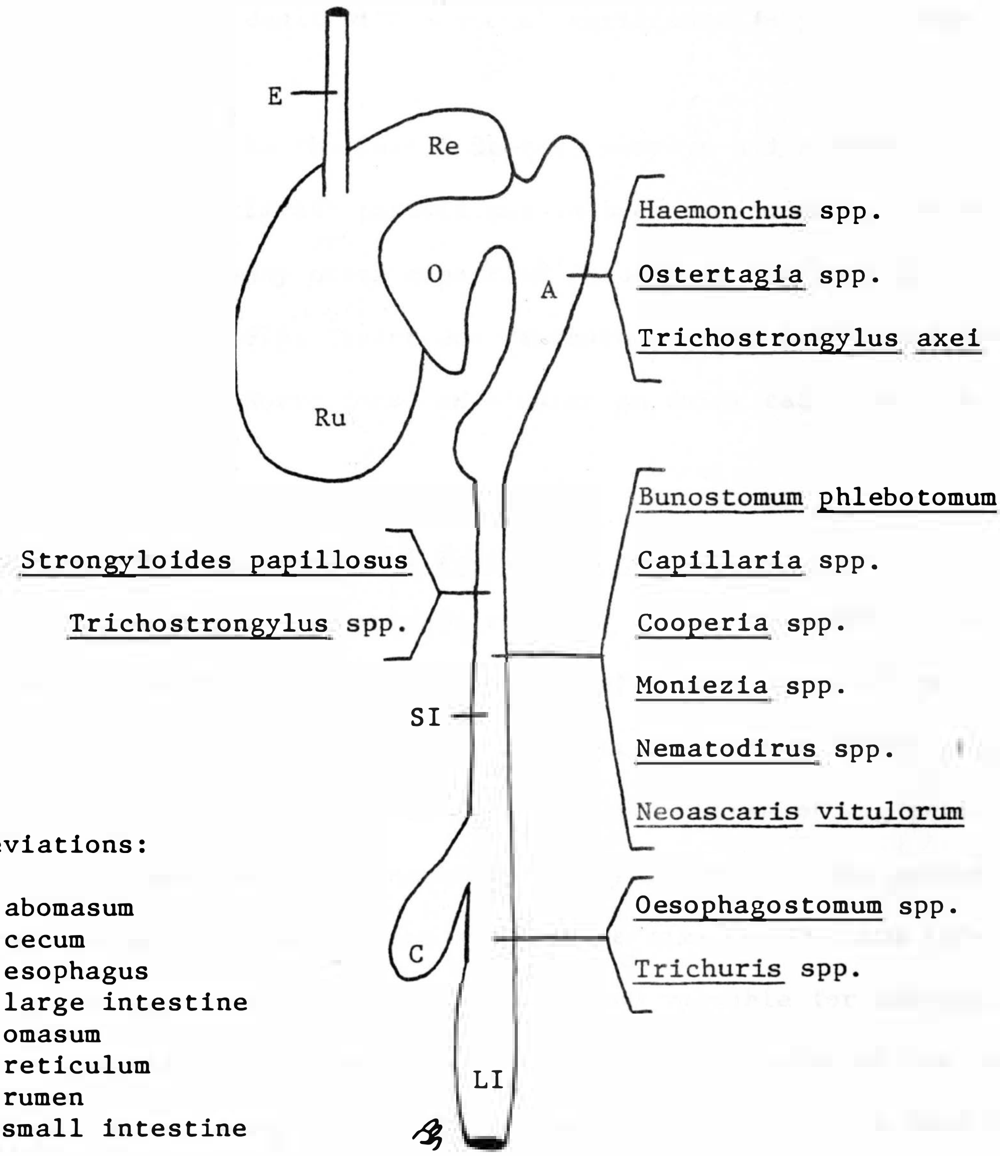
            Subfamily Capillariinae

            Capillaria Zeder, 1800

Phylum Platyhelminthes
  Class Cestoda
    Order Cyclophyllidea
          Family Anoplocephalidae
            Subfamily Anoplocephalinae

            Moniezia R. Blanchard, 1891

Fig. 1. Simplified diagram of ruminant gastrointestinal tract and usual locations of helminth genera. Modified from Frandson (1965).



Abbreviations:

A = abomasum
C = cecum
E = esophagus
LI = large intestine
O = omasum
Re = reticulum
Ru = rumen
SI = small intestine

Surveys typically report the prevalence of gastrointestinal helminth infections expressed as mean worm egg counts or numbers of worms recovered during necropsy. Usually, mention is made of variations in the above parameters in the different ages of cattle. Additionally, some projects have dealt with seasonal variations in prevalences and worm egg counts.

In addition to the United States, surveys and studies of gastrointestinal helminth parasitisms in beef and/or dairy cattle have been conducted in many other countries (Roberts et al., 1952; Brunsdon, 1964; Malczewski, 1970; Taylor and Cawthorne, 1972; Kotrla and Pavlasck, 1980). Primarily, North American studies on dairy cattle will be referred to herein.

Advantages and Significance of Fecal Worm Egg Counts

Determining the prevalence of dairy cattle helminths by fecal examination rather than by necropsy is preferred because of the cost and size of cattle (Todd et al., 1972). Eckert and Burger (1970) suggested the use of serial egg counts to ascertain the course of egg production in groups of animals. When combined with knowledge of the period of optimal larval development, the approximate times of maximum infection risk can be determined. Egg counts are also valuable for assessing pasture contamination by different animal species harboring the same trichostrongylid parasites and by various age groups of the same host species (Eckert and Burger, 1970).

The significance of fecal egg counts as a measure of the degree of infestation of cattle by gastrointestinal helminths has long been conjectured (Roberts et al., 1951; Levine and Aves, 1956). Roberts et al. (1951) stressed the diagnosis of clinical disease, whereas Levine and Aves (1956) suggested the following numbers of worm eggs per gram of feces (epg) as indicative of borderline pathogenicity: Bunostomum phlebotomum, 300; T. axei, 400; H. placei (or H. contortus), 500; Oesophagostomum radiatum, 500; Cooperia spp., 10,000. In mixed strongylinate infections, a level suggestive of borderline or subclinical infection would be 300 epg (Levine and Aves, 1956), as determined by the McMaster technique. In another study, Levine et al. (1960) found that comparable counts would have ranged from 66 to 168 epg if determined by direct centrifugal flotation (DCF).

However, in field trials in which anthelmintics were administered to subclinically infected dairy herds, egg counts as low as 10.2 mixed trichostrongylid ova/5 g of feces, as determined by the Wisconsin technique, were found to be significant in terms of the economic impact of parasitism (Todd et al., 1972; Bliss and Todd, 1974; Todd et al., 1978a). In all of these studies, worm egg counts were used effectively to diagnose active subclinical parasitisms (Todd et al., 1978b).

Factors Affecting Fecal Worm Egg Counts

Egg counts have been found to vary with several factors, including the season in which samples were collected. Grisi and Todd (1978) reported a higher mean nematode egg count in Wisconsin cows in autumn (1.9 epg) than in winter (0.5 epg). They also found that the peak in Pennsylvania cows (9.7 epg) was reached in autumn.

The number, species, age and sex of helminths present in an individual will affect the worm egg count (Leland et al., 1973).

Fecundity of adult trichostrongyles[1] varies (Dewhirst and Hansen, 1961). *Haemonchus* is considered to be the most prolific genus, averaging 5000 eggs per female per day (Olsen, 1974). *Nematodirus* compensates for low fecundity by producing eggs that are more environmentally resistant (Georgi, 1980). Gordon (1950) found the average daily output of *Trichostrongylus* in sheep to be 200 eggs per female. Andrews (1936) reported the average daily production of *Cooperia curticei* in sheep ranged from 390 to 437 eggs per female. However, *Cooperia* and *Trichostrongylus* maintain larger adult populations than the more fecund trichostrongyles (Georgi, 1980).

Egg production varies due to suppression or stimulation by various factors, resulting in egg count fluctuations (Taylor, 1935; Kelley, 1955). Decreased egg production may be attributed to crowding of the adult helminths in the host's gastrointestinal tract (Dewhirst and Hansen, 1961). Total fecundity of the helminth population of an individual appears to be limited to a certain level (Michel, 1968). Immunity of the host may be involved, in that the host's history of infection is a factor in limiting egg output (Michel, 1968). Eckert and Burger (1970) reported that the egg production of all but very small *O. ostertagi* populations was limited by host resistance to a certain level depending upon the nematodes' previous egg-laying rate.

Host age also affects worm egg counts. Yazwinski et al. (1980) found that 39.3% of 300 calves, 12.4% of 300 yearlings and only 2.1% of 600 adult cows, from which samples were obtained in Arkansas, had

[1]In Levine (1980), trichostrongyle denotes members of Superfamily Trichostrongylicae (= Trichostrongyloidea).

strongyle[2] egg counts greater than 40 epg. As host age increased, egg counts decreased due not only to better management of older, producing cattle, but also an acquired resistance to helminths.

The physiological condition of the host can affect fecal egg counts. The number of strongyloid eggs being discharged in cow feces was found to increase at parturition (Corticelli and Lai, 1960, in Hubbert et al., 1975). The consistency and amount of feces, and therefore the degree of dilution or concentration of helminth eggs, is altered by the physiological or pathological state of the host's gastrointestinal tract (Mayhew, 1940). However, Riek et al. (1958) reported that adjustments to egg counts for fecal consistency were of little value.

Fecal egg counts are also affected by the amount and kind of feed ingested by the host. The daily consumption of hay by a calf is inversely related to the number of nematode eggs counted per gram of feces (Mayhew, 1940). These results were supported by Kelley (1955), who found that calves on low-roughage and high-roughage diets had increased and decreased egg counts, respectively. The effect of roughage on egg counts was due to dilution of eggs by indigestible material (Kelley, 1955). Animals on a high-roughage diet have a fecal output seven to nine times that of those on feed concentrates (Ritzmann and Benedict, 1939, in Riek et al., 1958).

Fecal output is directly related to host age and body weight and

[2]Strongyle denotes Haemonchus, Ostertagia, Cooperia, Trichostrongylus, and Oesophagostomum in Yazwinski et al. (1980). In Levine (1980), strongyle indicates members of Family Strongylidae, Order Strongylorida (= Strongylida).

affects worm egg counts (Roberts et al., 1951 and 1952; Riek et al., 1958). According to Roberts et al. (1952), when comparisons are made between egg counts of adult cattle and younger age groups, adjustments should be made to reflect the much greater fecal production of adults. They suggested multiplying egg counts of adults by a factor of from four to eight to give the equivalent value for a 6-month-old calf. Riek et al. (1958) found that adjustments to fecal egg counts based on output were important. However, few researchers have since used such correction factors.

Considerable variations in worm egg counts can occur from hour to hour and day to day (Roberts et al., 1951). In a study on parasitisms in sheep, Spedding (1952) found substantial differences in the egg counts of 11 animals within a 24-hour period. Variation in egg counts may be the result of a rhythm in the host's intestinal activity or in the egg-laying rate of the helminth population altered by the quantity of feces in a defecation (Spedding, 1952).

The prevalence of infection and worm egg counts in beef and dairy cattle are related to herd management. In Washington, cattle with pasture access had higher prevalences of infection and mean strongyline[3] egg counts than those kept on drylots (Malczewski et al., 1975). Cattle on pasture were exposed to a higher number of infective stages than those on drylots. Yazwinski and Gibbs (1975) classified Maine dairy herds into three categories (good, fair and poor) based on the results of a herd management questionnaire. Heifers and calves

[3]Malczewski et al. (1975) did not specify what genera strongyline denotes, but it probably indicates most members of Order Strongylida.

classed as poorly managed consistently showed higher strongylorid[4] egg counts than did the other cattle. Roberts et al. (1951) noted that animals treated with anthelmintics usually show lower egg counts than those that have not been treated.

Different worm egg recovery and counting techniques vary in accuracy. Levine et al. (1960) compared the McMaster and the DCF techniques by determining egg counts of members of Suborder Strongylina in 78 cattle and 13 sheep. The McMaster technique proved to be more accurate. However, DCF has the advantage of detecting worm eggs in samples from subclinically infected animals (Levine et al., 1960). It is recommended for use when egg counts are less than 400 epg (Stoll, 1930).

Grisi and Todd (1978) evaluated the Wisconsin, Cornell-McMaster, and Fecalyzer® techniques. Each was used 10 times on a homogeneously mixed fecal sample. The Wisconsin technique was the most sensitive in detecting the low numbers of eggs characteristic of subclinical parasitisms. It was concluded that dilution methods do not reveal the actual prevalence of subclinical infections. This was supported by Gutierres et al. (1979). Slight differences in individual style and proficiency in counting eggs will affect the results (Levine et al., 1960).

Limitations of Fecal Worm Egg Counts

The number of eggs present per gram of feces should not be

[4]Strongylorid refers to *Haemonchus, Ostertagia, Cooperia, Trichostrongylus*, and *Oesophagostomum* in Yazwinski and Gibbs (1975). In Levine (1980), strongylorid denotes Order Strongylorida (= Strongylida).

interpreted as a direct indication of the intensity of infection (Kelley, 1955; Dewhirst and Hansen, 1961; Cox and Todd, 1962). According to some authors, there may be little or no correlation between egg counts and actual worm burdens or the hosts' clinical conditions (Michel, 1968; Eckert and Burger, 1970; Todd et al., 1978a). Also, there is no measure of adult male and immature helminths present (Roberts et al., 1951; Kelley, 1955). In two experimentally infected calves which had clinical symptoms of nematodiriasis, fecal examinations revealed 0.0 and 14 epg; higher egg counts, 120 and 196 epg, were found in feces from two calves without symptoms (Herlich and Porter, 1953). Only 13 epg were found in feces from a clinically infected calf which had 17,898 Nematodirus adults in its small intestine (Honess and Bergstrom, 1963). Becklund (1959) reported five egg counts of 0.0 epg from cattle which yielded 104 to 4,960 nematodes at necropsy. In a study of clinical helminthiasis in cattle, there was no correlation between the severity of anemia and the number of worm eggs present in feces (Becklund, 1962).

Given the above information, single fecal worm egg counts may have little value in diagnosis of clinical parasitism (Roberts et al., 1951; Kelley, 1955; Ross and Armour, 1960; Michel, 1968) except when used in conjunction with observations on symptoms and growth rate, and/or necropsy (Herlich and Porter, 1953). Wide variations in Haemonchus and Cooperia egg counts in feces from pathogenically infected calves demonstrate the uselessness of single egg counts in diagnosis of such cases (Ross and Armour, 1960).

Frequently helminth ova are so similar in appearance that larval differentiation is necessary to verify egg identification and facilitate interpretation of egg counts (Ross and Armour, 1960). Leland et al. (1973) noted that the value of egg counts is considerably reinforced when duplicate fecal samples are cultured to obtain distinguishable infective larvae. However, larval identification is sometimes difficult and time consuming (Shorb, 1939; Cunliffe and Crofton, 1953).

Adequate interpretation of worm egg counts is dependent upon knowledge and understanding of their limitations and advantages, and of the factors which affect them. If these are taken into consideration, egg counts can be successfully used in parasitological investigations (Kelley, 1955). If enough host animals are sampled and if the whole herd is considered to be affected, single egg counts from individuals can be an effective aid to diagnosis under field conditions (Roberts et al., 1951). If egg counts are used to determine the prevalence of infection in a herd, much of the variability is removed and the egg count becomes a reliable measure of fluctuations in worm burden from one time period to another if the ration remains constant (Kelley, 1955). However, egg counts cannot measure variations between herds managed under different systems (Kelley, 1955).

METHODS AND MATERIALS

Project Design

Study 1

Locations and dates of dairy shows were obtained from Mr. Myers Owens, South Dakota State University (SDSU) Extension Dairyman. Samples were obtained at several of the shows.

Study 2

A monthly sample collection program was originated in September, 1981, and continued through August, 1982, at two Brookings County (South Dakota) dairy farms. Local dairymen were initially contacted at the Brookings County 4-H Achievement Days, August 11-12, 1981. Subsequently, preliminary sampling was conducted at six farms. Two herds were selected; the Arne Nelson family and the Emil Misar, Jr. farms, respectively located 2 mi S, 1/4 mi W, and 2 mi E, 1 mi N of Volga, South Dakota. These herds were selected on the bases of the willingness of the owners to participate in the project, the proximity of the farms to Brookings and the presence of helminth infections in the herds, as revealed by preliminary sampling.

Study 3

A total of eight Black Hills dairy herds were included in the study. They were not selected randomly, but most were chosen with the assistance of the SDSU Extension Dairyman, on the bases of herd size and location, and the probable willingness of the owner to participate in the project.

Study 4

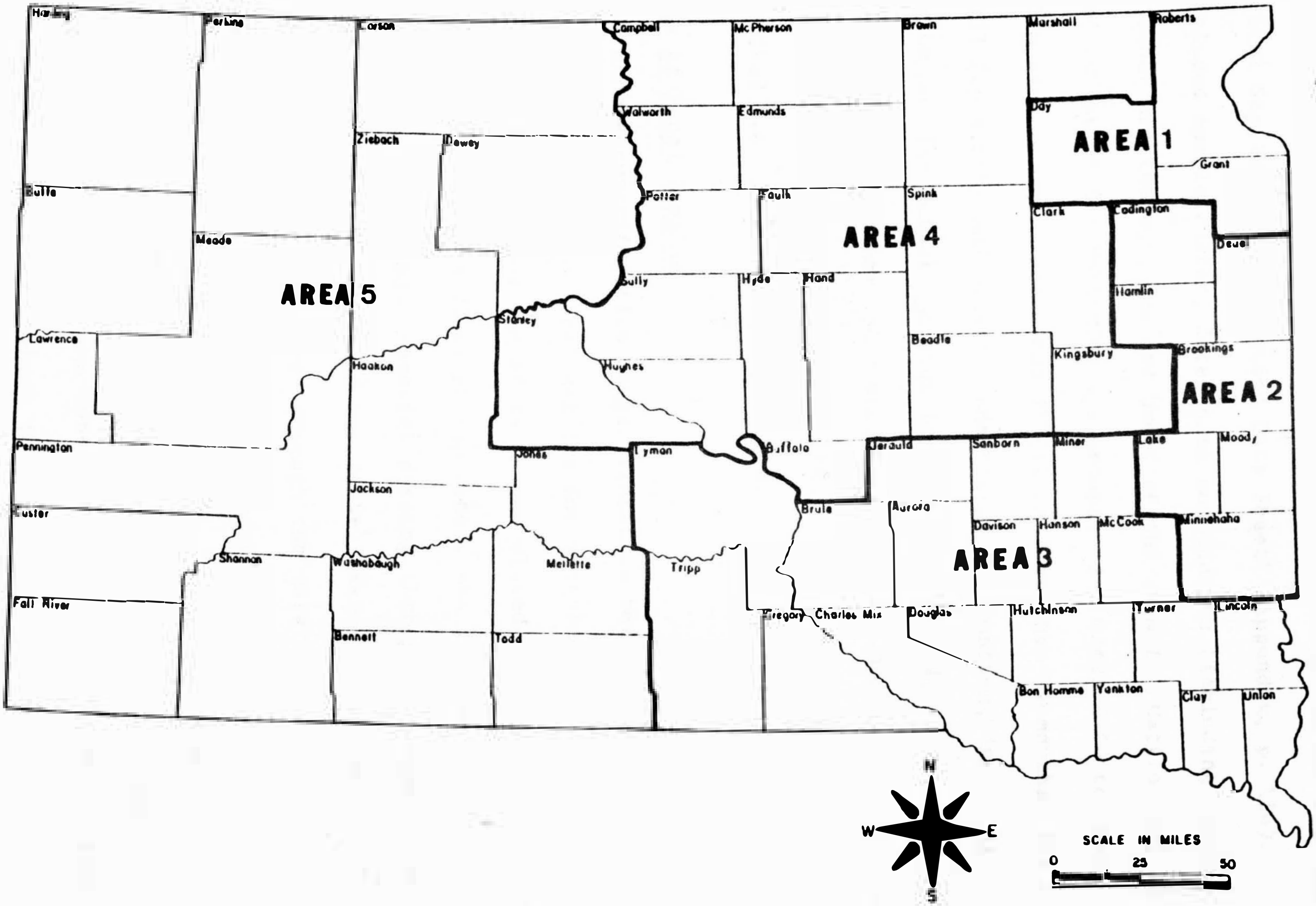
Sample collection from Dairy Herd Improvement Association (DHIA) cattle began in May, 1982, and continued for 9 weeks. The five DHIA Areas in South Dakota were officially designated to include approximately equal numbers of cows. Areas 1 through 4 comprise the eastern half of the state (Map 1) and were included in the survey. Every 3 weeks a different area was randomly selected as the survey area for that particular collection.

Random multistage cluster sampling was utilized (Chao, 1974). In each of Areas 2 through 4, three counties were randomly selected. However, all three counties in Area 1 were included in the survey. Names and addreses of all DHIA members in the selected counties were obtained from the SDSU Extension Dairyman. Three herds from each of the three counties for a given area were randomly selected. Thus, nine herds from each of the four areas, or a total of 36 herds, were included. Samples were collected from 10 lactating cows at each of the 36 farms over the 9-week period.

Collection of Fecal Samples

Fecal samples were collected randomly, immediately after the feces were voided. A small quantity (approximately 50-100 g) was retained and placed in a Nasco Whirl-Pak plastic bag. The bag was marked with an identification number and stored in a styrofoam cooler containing artificial ice. Upon returning to the laboratory, the samples were placed in a refrigerator and stored at 2°C until they could be analyzed, usually within 2 weeks.

Map 1. The South Dakota Dairy Herd Improvement Association (DHIA) Areas.



As each sample was collected, necessary information was recorded on a "Fecal Sample Field Collection Data Sheet" (Appendix, p. 114). This included sample number, date, name and address (including county) of the owner and the age, sex and breed of the animal. Cattle were assigned to one of the following age groups: Age Group I (0 to less than 12 months of age), Age Group II (12 to less than 24 months) and Age Group III (24 months and older). Additional information, including whether or not the animal had ever been on pasture and, if so, what season of year and for how long; whether the animal had ever been wormed and, if so, when and with what drug; and if the animal was currently being milked, was obtained when possible.

Analysis of Fecal Samples

A double-centrifugation, sugar flotation method (Cox and Todd, 1962) was used to prepare fecal samples for microscopic examination. For each sample, a 5 g portion of feces was placed in a beaker, diluted by thoroughly mixing with 22 ml of tap water, and then poured through a tea strainer (5 meshes/cm). Material passing through the strainer was collected in a second beaker, and the first beaker was rinsed with 8 ml of water. This liquid was poured through the material retained in the strainer. A spoon-end spatula was used to press out as much liquid as possible from the feces remaining in the strainer. The portion contained in the second beaker was then stirred quickly and immediately poured into two 15-ml centrifuge tubes. The sides of the beaker were scraped with the spatula to remove fecal remnants, which were then added to the tubes. Centrifiguation of the tubes at 1500 RPM for 10 minutes in a IEC HN-SII centrifuge followed. The supernatant was discarded, and sediment diluted with approximately 5 ml of Sheather's sugar solution (sp. gr. 1.27). This was stirred with a wooden applicator stick, and each tube was completely filled with additional sugar solution. An air-tight seal was created when a 22 mm coverglass was placed on top of each tube. The tubes were centrifuged again as above. Coverglasses were removed by lifting straight upward and were placed on a glass slide.

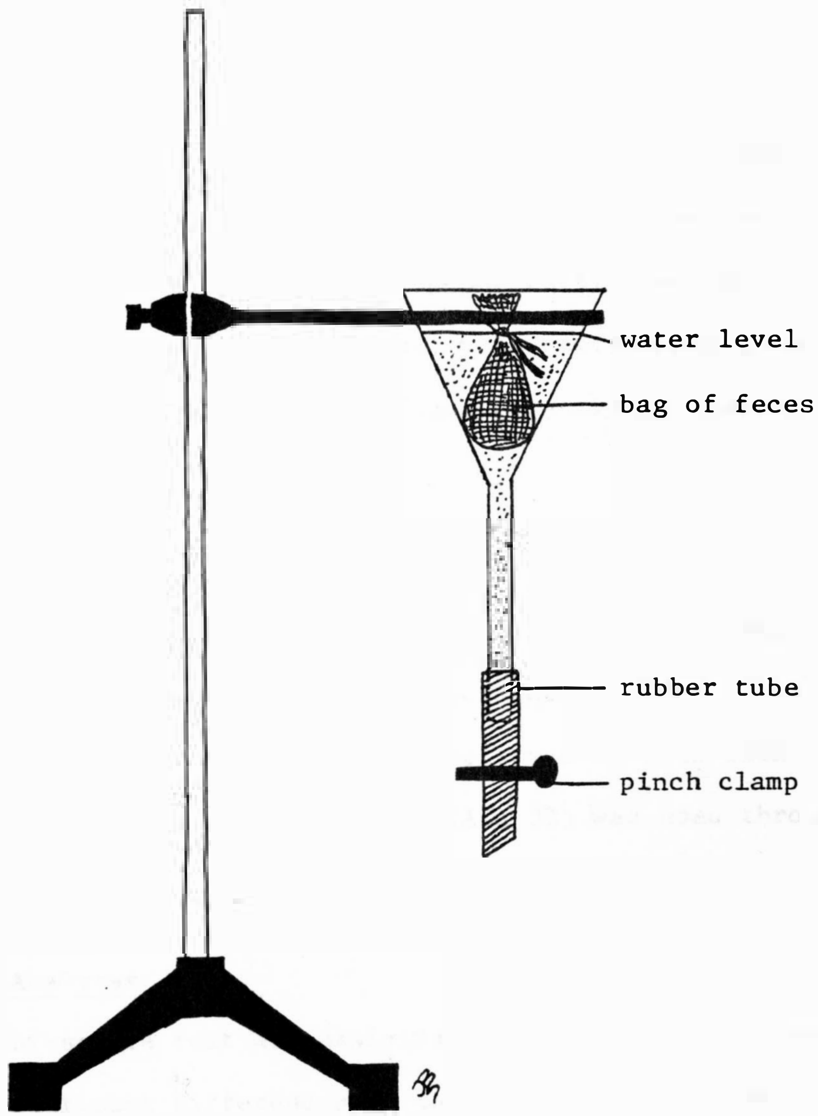
Quantitative and qualitative analyses of fecal samples were achieved through microscopic examination of the entire area of each coverglass at 150X. The number of eggs of each gastrointestinal helminth genus and the total number of worm eggs found in 5 g of feces were recorded on a "Fecal Sample Data Sheet" (Appendix, p. 115).

An ocular filar micrometer was occasionally used to measure the length and width of worm eggs. Several publications were utilized in egg identification (Shorb, 1939; Dewhirst and Hansen, 1961; Thienpont et al., 1979). Descriptions, measurements and photomicrographs of eggs of gastrointestinal helminths of cattle are given (Appendix, pp. 102-113).

Cultivation and Examination of Infective Larvae

Occasionally, feces were cultured in order to obtain infective larvae which aided in verifying egg identification. Two to three grams of moist vermiculite were mixed with 5 g of feces. The mixture was wrapped with cheesecloth, suspended in a stoppered 250-ml Erlenmeyer flask and kept at room temperature (25 to 35°C) for 2 weeks. The ball of feces was then placed in a Baermann apparatus (Fig. 2), and warm water was added (Georgi, 1980). The feces remained in water for at

Fig. 2. Baermann apparatus used in recovery of infective larvae.



least 8 hours before 30 ml of fluid was drained off into two 15-ml centrifuge tubes. Centrifugation for 5 minutes at 800 to 1000 RPM followed. Approximately 12 ml was decanted from each tube, leaving 3 ml of liquid and sediment.

Two drops of sediment material were pipetted from each tube onto a slide, and a coverglass, the edges of which were coated with petroleum jelly to prevent larval distortion, was placed on the material (Georgi, 1980). Each slide was scanned for larvae, and an ocular micrometer was used to obtain measurements. Georgi (1980) listed measurements of infective larvae of strongyles of sheep and cattle, and Borgsteede and Hendricks (1974) provided descriptions, measurements and a key for the identification of infective larvae of gastrointestinal nematodes of cattle.

Photomicrography

Photomicrography of the worm eggs was achieved through the use of a Wild M20 microscope with H-tube and Photoautomat MKa4 35 mm camera system. Phase contrast microscopy was utilized at both 150X and 300X. Kodak Panatomic-X black and white film (ASA 32) was used throughout the project.

Statistical Analyses

The chi-square test and analysis of variance (ANOVA) were used to determine significant differences in the overall prevalence of helminth ova in feces, and in total and generic mean egg counts, respectively. Chi-square analysis was used in all studies; ANOVA was used only in Studies 3 and 4.

In Study 4, two different ANOVAs were applied. ANOVA I tested for significant differences in generic and total mean egg counts between areas, counties within areas, and herds within counties. ANOVA II tested for significant differences in the above parameters between untreated and treated herds within areas, and within counties.

RESULTS AND DISCUSSION

Study 1

Fecal samples were collected from 162 cattle, representing 81 herds from 28 South Dakota counties, at seven dairy shows during 1981 (Table 2). Feces of cattle of six breeds, all three age groups and both sexes were obtained (Tables 3a and 3b). The geographic distribution of the represented herds and the total number of samples collected per county are shown in Map 2.

The fecal samples were separated into two groups. Group 1 samples were those in which ova of *Haemonchus* and *Ostertagia* were not distinguished because of the author's inexperience. Therefore, for Group 1 samples, only total worm egg counts were recorded. In Group 2, the author's increased proficiency made possible the identification of all ova to genus. Subsequently, all other worm egg counts were recorded for individual genera.

So far as is known, this is the only North American study of gastrointestinal helminths of cattle which has utilized sample collection from dairy show animals. Therefore, direct comparisons with other studies are impossible. However, examples of prelevances and egg counts from more traditional projects will be offered for the sake of discussion.

Overall, eggs of 11 nematode genera were found in 90 of 101 Group 2 fecal samples (Table 4). This is not surprising, in that Cox and Todd (1962) reported 10 of the 11 genera from Wisconsin dairy cattle, the exception being *Neoascaris vitulorum*. However, *N. vitulorum* was found

Table 2. South Dakota dairy shows included in Study 1.

Date	Location	Dairy Show	Number of Samples	Number of Herds	Number of Counties
6/16/81	Watertown	South Dakota Brown Swiss North Canton Show	19	6	4
6/17/81	Parker	South Dakota Brown Swiss South Canton Show	18	6	4
6/19/81	Watertown	South Dakota State Holstein Show	24	10	6
8/11-12/81	Brookings	Brookings County 4-H Achievement Days	27	13	1
9/4/81	Huron	South Dakota State Fair Open Class Show	14	9	8
9/4/81	Huron	South Dakota State Fair 4-H Show	36	27	16
10/9/81	Rapid City	Western Junior Open Livestock Show	24	16	9
Totals			162	81[+]	28[*]

[+]Fecal samples were collected from 81 different herds.

[*]The herds represented 28 different counties.

Table 3a. Fecal samples collected at the first three dairy shows in Study 1 (helminth eggs not identified to genera).

Dairy Show	Age Group+			Sex		Breed*					
	I	II	III	M	F	A	BS	G	H	J	MS
South Dakota Brown Swiss North Canton Show	1	9	9	1	18	0	19	0	0	0	0
South Dakota Brown Swiss South Canton Show	3	8	7	3	15	0	18	0	0	0	0
South Dakota State Holstein Show	4	8	12	1	23	0	0	0	24	0	0
Group 1 Totals	8	25	28	5	56	0	37	0	24	0	0

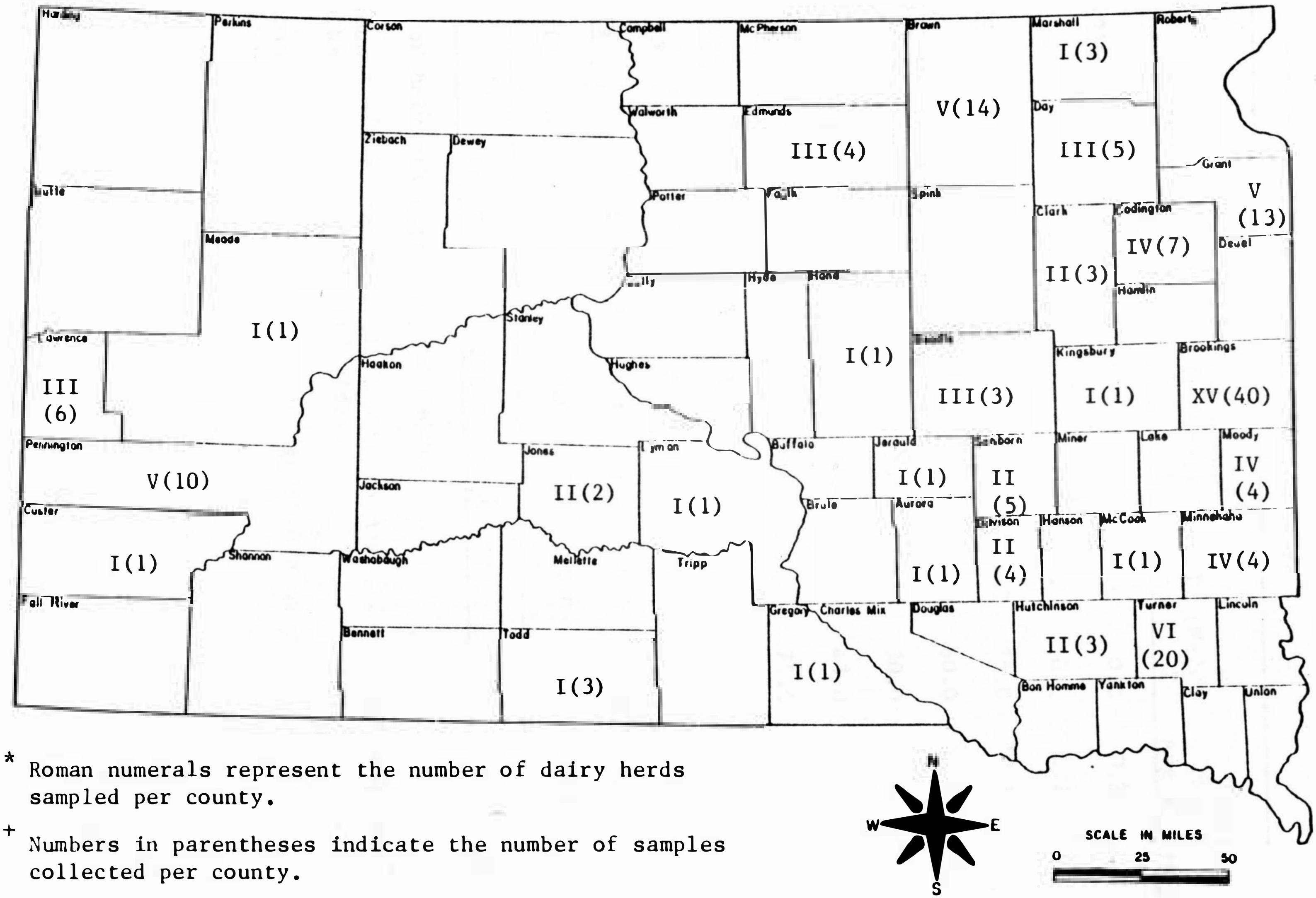
Table 3b. Fecal samples collected at the last four dairy shows in Study 1 (helminth eggs identified to genera).

Dairy Show	Age Group+			Sex		Breed*					
	I	II	III	M	F	A	BS	G	H	J	MS
Brookings County 4-H Achievement Days	16	5	6	0	27	0	4	2	21	0	0
South Dakota State Fair Open Class Show	7	4	3	1	13	0	5	0	1	5	3
South Dakota State Fair 4-H Show	14	14	8	0	36	2	2	1	29	2	0
Western Junior Open Livestock Show	11	10	3	0	24	0	2	0	19	2	1
Group 2 Totals	48	33	20	1	100	2	13	3	70	9	4
Overall Totals	56	58	48	6	156	2	50	3	94	9	4

+Age Group I = 0 to less than 12 months of age; II = 12 to less than 24 months; III = 24 months and older.

*Breed A = Ayrshire; BS = Brown Swiss; G = Guernsey; H = Holstein; J = Jersey; MS = Milking Shorthorn.

Map 2. The distribution of dairy herds* included in Study 1 and the total number of samples collected per county+.



* Roman numerals represent the number of dairy herds sampled per county.

\+ Numbers in parentheses indicate the number of samples collected per county.

Table 4. Nematode mean ($\bar{x}$) egg counts* and prevalences (%) from the last four dairy shows in Study 1.

Genus	I (N=48) $\bar{x}$	I (N=48) %	II (N=33) $\bar{x}$	II (N=33) %	III (N=20) $\bar{x}$	III (N=20) %	Total (N=101) Avg $\bar{x}$	Total (N=101) Avg %
Strongyloides	0.6	12.5	0.1	3.0	0.0	0.0	0.3	6.9
Bunostomum	0.2	10.4	0.4	12.1	0.0	0.0	0.2	8.9
Oesophagostomum	10.7	27.1	9.7	39.4	9.3	25.0	10.1	30.7
Cooperia	32.4	64.6	35.7	69.7	20.8	60.0	31.2	65.3
Ostertagia	8.2	37.5	4.5	39.4	4.3	30.0	6.2	36.6
Trichostrongylus	3.9	33.3	6.6	39.4	2.7	45.0	4.5	37.6
Haemonchus	47.2	75.0	42.3	84.8	35.6	75.0	43.3	78.2
Nematodirus	7.6	50.0	3.5	6.1	0.0	0.0	4.8	25.7
Neoascaris	#	2.1	0.0	0.0	0.0	0.0	#	1.0
Trichuris	0.4	10.4	0.1	3.0	0.0	0.0	0.2	5.9
Capillaria	0.6	6.3	0.0	0.0	0.0	0.0	0.3	3.0
Total	111.8	93.8	102.9	87.9	72.7	80.0	101.1	89.2

*Number of helminth eggs/5.0 g of feces.

+Age Group I = 0 to less than 12 months of age; II = 12 to less than 24 months; III = 24 months and older.

#Less than 0.1, but greater than 0.0 eggs/5.0 g of feces.

in one cow in Iowa (Zimmermann and Hubbard, 1961).

Haemonchus had the greatest prevalence and mean egg count in all ages of Group 2 cattle (Table 4). Cooperia was also highly prevalent in all age groups. Cox and Todd (1962) found Haemonchus eggs in 441 of 710 fecal samples from all ages of Wisconsin dairy cattle. However, the prevalence of Cooperia was only 16.1%.

Five genera were each found in less than 10% of the Group 2 samples and had average mean egg counts of 0.3 helminth ova/5 g of feces or less (Table 4). The low prevalences of Strongyloides papillosus, Trichuris sp., and Capillaria sp. reported herein are similar to those found by Jacobson and Worley (1969) in a study on parasites of Montana beef cattle. Similarly, the low prevalence of B. phlebotomum has been found before (Cox and Todd, 1962). Low egg count values for four of the five genera were reported by Yazwinski and Gibbs (1975).

No cestode ova were identified. The absence of Moniezia is conspicuous, not only when compared to the other studies of this project, but also as regards other researchers' efforts. Zimmermann and Hubbard (1961), Cox and Todd (1962) and Ciordia (1975) all reported finding Moniezia from dairy cattle. Although the eggs are distinctive, error on the part of the author in determining their presence cannot be ruled out.

The overall prevalence of nematode ova (Table 5) is similar to those of more traditional surveys. Roundworm eggs were found in 78.3% of Wisconsin dairy cattle (Cox and Todd, 1962). Ciorida (1975) found that 78 of 100 samples obtained from all ages of Georgia dairy cattle contained gastrointestinal nematode eggs.

Table 5. Summary of egg count* and prevalence data from the two groups of cattle in Study 1.

Sample Group	Age Group+	Total Egg Count $\bar{x}$	Range	%
1	I	0.7	0.0 - 8.0	12.5
	II	38.1	0.0 - 310.0	68.0
	III	30.2	0.0 - 258.0	60.7
Avg		29.6	...	57.4
2	I	111.8	0.0 - 698.0	93.8
	II	102.9	0.0 - 1053.0	87.9
	III	72.7	0.0 - 708.0	80.0
Avg		101.1	...	89.2
1 and 2	I	95.9	...	82.1
	II	75.0	...	79.3
	III	47.9	...	68.8
Avg		74.2	...	77.2

*Number of helminth eggs/5.0 g of feces.

+Age Group I = 0 to less than 12 months of age; II = 12 to less than 24 months; III = 24 months and older.

Chi-square analysis revealed a significant difference in the number of samples containing worm eggs between Groups 1 and 2 ($\chi^2 = 21.73$, 1 DF, $P < 0.01$). Also, a considerable difference in total mean egg counts was noted (Table 5). The season of year in which the feces were collected might have contributed to these differences. Group 1 samples were obtained in June, 1981, whereas Group 2 collections were from August to mid-October, 1981. Yazwinski and Gibbs (1975) found that strongylorid infections in all ages of Maine dairy cattle were most prevalent (90.1%) during September-October and least prevalent (63.7%) in March-April. However, many factors could be involved in the differences between the two groups of dairy show cattle.

There was a significant difference in the prevalence of nematode eggs between the three ages of Group 1 cattle ($\chi^2 = 7.87$, 2 DF, $P < 0.05$). The highest prevalence and total mean egg count, and the widest egg count range, were found in the yearlings (Table 5). However, no significant differences were found in Group 2 fecal samples (2 DF, $P = 0.05$). Nevertheless, total mean egg count, as well as the prevalence of eggs in feces and the number of nematode genera found, were inversely related to host age in Group 2 (Table 4). A Group 2 yearling yielded the highest total and generic egg counts, 1053 helminth ova and 722 Cooperia eggs, respectively. Ciordia (1975) reported higher prevalences, total mean egg counts, and numbers of helminth genera found in samples from calves and yearlings, than in those from cows. When all South Dakota dairy show samples were considered together, overall prevalence did not vary greatly according to host age (Table 5).

A single nematode genus was found in 13.3% of the worm egg-positive Group 2 samples. However, most yielded from two to four genera each (Table 6). Seven genera were encountered in a sample from one calf. Multiple helminth genera infections in dairy cattle are very common (Todd et al., 1978b).

Study 2

Fecal samples were collected monthly from six lactating cows of both the Misar and Nelson herds from September, 1981 through August, 1982. Occasionally, feces were obtained from the same individuals that had been sampled in previous months, although no specific attempt was made to do so. Samples were also collected from calves and yearlings when possible (Table 7). Feces were obtained from steer/bull (22 samples at each farm) and heifer (3 Misar = M; 6 Nelson = N) calves. Samples from yearling steers (1 M; 2 N) and heifers (34 M; 29 N) were also collected. All cattle included in the study were Holsteins, except for one Brown Swiss X Holstein cow of the Misar herd. Although both farms are mixed beef and dairy operations, management systems differ. Therefore, the herds will be considered separately.

The Misar Herd

Approximately 40 cows are milked, while in stanchions, with an around-the-barn pipeline system. Cows have access to pasture and the Big Sioux River throughout the grazing season (May through October). At other times of the year, the cows are confined to a partially vegetated lot and the barn. While in the barn cows receive alfalfa hay, and each stanchion stall has adequate straw bedding. Gutters are cleaned twice daily. Injectable Tramisol® (18.2% levamisole phosphate) was

Table 6. Multiple helminth infections as indicated by frequencies (F) and relative frequencies (RF) of eggs analyzed from the last four dairy shows in Study 1.

Number of Genera Found	Age Group+ I (N=48) F	RF	II (N=33) F	RF	III (N=20) F	RF	Total (N=101) F	RF
0	3	0.06	4	0.12	4	0.20	11	0.11
1	5	0.10	3	0.09	4	0.20	12	0.12
2	9	0.19	7	0.21	2	0.10	18	0.18
3	8	0.17	6	0.18	3	0.15	17	0.17
4	10	0.21	4	0.12	5	0.25	19	0.19
5	6	0.13	7	0.21	2	0.10	15	0.15
6	6	0.13	2	0.06	0	0.00	8	0.08
7	1	0.02	0	0.00	0	0.00	1	0.01
Total	48	1.01	33	0.99	20	1.00	101	1.01

+Age Group I = 0 to less than 12 months of age; II = 12 to less than 24 months; III = 24 months and older.

Table 7. Number of fecal samples collected monthly from cattle of the Emil Misar, Jr. and Arne Nelson family dairy herds.

	Misar Herd				Nelson Herd			
	Age Group+				Age Group			
Date	I	II	III	Total	I	II	III	Total
9/12/81	2	6	6	14	3	5	6	14
10/16/81	3	6	6	15	2	2	6	10
11/16/81	3	6	6	15	3	2	6	11
12/18/81	0	0	6	6	0	0	6	6
1/14/82	0	0	6	6	0	0	6	6
2/15/82	0	1	6	7	0	0	6	6
3/20/82	1	0	6	7	2	6	6	14
4/17/82	4	0	6	10	3	1	6	10
5/17/82	5	0	6	11	4	6	6	16
6/18/82	6	6	6	18	6	6	6	18
7/19/82	0	4	6	10	2	2	6	10
8/14/82	1	6	6	13	3	1	6	10
Totals	25	35	72	132	28	31	72	131

Legend same as Table 6.

administered to the animals when they were calves and again as yearlings.

Of the 11 helminth genera encountered in worm egg-positive samples, Haemonchus was the most prevalent and had the highest average mean egg count (Table 8). Cooperia, Ostertagia and Trichostrongylus were also fairly prevalent. Jacobson and Worley (1969) grouped ova of Cooperia, Trichostrongylus and Ostertagia into a "complex". Eggs of the complex were found in 67.9% of 965 Montana beef cattle fecal samples. Ostertagia and Cooperia ova were detected in 69.6% of 909 samples from Wyoming beef cattle (Honess and Bergstrom, 1963). It is interesting to note the absence of N. vitulorum from the Misar herd.

The prevalence of helminth ova in feces reported herein (Table 8) is relatively high compared to some studies (Hitchcock, 1956; Zimmermann and Hubbard, 1961). However, Yazwinski and Gibbs (1975) found the overall prevalence of strongylorid infection in all ages of 263 Maine dairy cattle sampled regularly at 2-month intervals for 1 year to be 97%.

The chi-square test failed to show a significant difference in overall prevalence between age groups (2 DF, P = 0.05), but the highest value was found in the cows (Table 8). Capillaria, Trichuris and Nematodirus were consistently absent from cow feces. Zimmermann and Hubbard (1961) found a higher prevalence (58.8%) of trichostrongyle-type[5] eggs in fecal samples from cows, than in those from calves (14.5%). All samples collected from Maine dairy cows were void of Nematodirus eggs, but they were present in younger cattle (Yazwinski and Gibbs, 1975).

[5]Trichostrongyle-type refers to eggs of most gastrointestinal parasites of Superfamilies Trichostrongyloidea and Strongyloidea.

Table 8. Helminth mean ($\bar{x}$) egg counts* and prevalences (%) from the Misar dairy herd in Study 2 (Actual means used).

	Age Group+						Total	
	I (N=25)		II (N=35)		III (N=72)		(N=132)	
Genus	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	Avg $\bar{x}$	Avg %
Strongyloides	#	4.0	0.1	8.6	#	2.8	0.1	4.5
Bunostomum	1.0	12.0	#	2.9	#	2.8	0.2	4.5
Oesophagostomum	0.2	8.0	0.4	17.1	0.8	11.1	0.6	12.1
Cooperia	26.3	68.0	14.0	57.1	6.4	63.9	12.2	62.9
Ostertagia	9.8	68.0	7.0	54.3	6.0	51.4	7.0	55.3
Trichostrongylus	4.2	40.0	1.2	17.1	1.3	40.3	1.8	34.1
Haemonchus	21.5	64.0	9.9	71.4	21.3	83.3	18.3	76.5
Nematodirus	9.0	12.0	0.4	2.9	0.0	0.0	1.8	3.0
Trichuris	1.8	24.0	#	2.9	0.0	0.0	0.4	5.3
Capillaria	0.0	0.0	0.6	2.9	0.0	0.0	0.2	0.8
Moniezia	#	4.0	0.0	0.0	0.7	5.6	0.4	3.8
Total	73.8	84.0	33.6	77.1	36.5	93.1	43.0	87.1

Legend same as Table 4.

Trichuris and Capillaria were also more prevalent in yearlings and calves.

Monthly prevalences of the four most frequently encountered genera in cow fecal samples are given in Figs. 3 and 4. Eggs of Haemonchus and Cooperia were each found in at least one of six samples per month. Ostertagia and Trichostrongylus were absent in September, 1981 and August, 1982, respectively. Total monthly prevalence of helminth ova in cow samples never fell below 66.6% (Fig. 5).

Total monthly mean egg counts are presented in Table 9. Calf samples had the highest overall mean and usually the highest age group monthly means. The two highest herd average monthly means occurred in October, 1981 and April, 1982. A calf sample in October, 1981, yielded the highest individual total egg count, 712 helminth ova. In June, 1982, one cow sample contained the highest generic egg count, 475 Haemonchus ova.

Of the positive samples, 73.9% contained from two to four helminth genera (Table 10). Eggs of a single genus were found in 13% of the samples. A maximum of seven genera was found in two samples.

Seasonal variations in the prevalences of gastrointestinal helminths and in worm egg counts have previously been reported. A total of 1,414 fecal examinations of dairy cattle were made from May through September, 1970, in southwestern Ontario (Slocombe, 1973). The greatest prevalence of gastrointestinal nematode parasitism and the highest fecal egg counts for 958 cattle kept on pasture occurred from May to early July. Yazwinski and Gibbs (1975) found that the highest strongylorid egg count (37.6 epg) in all ages of Maine dairy cattle occurred in

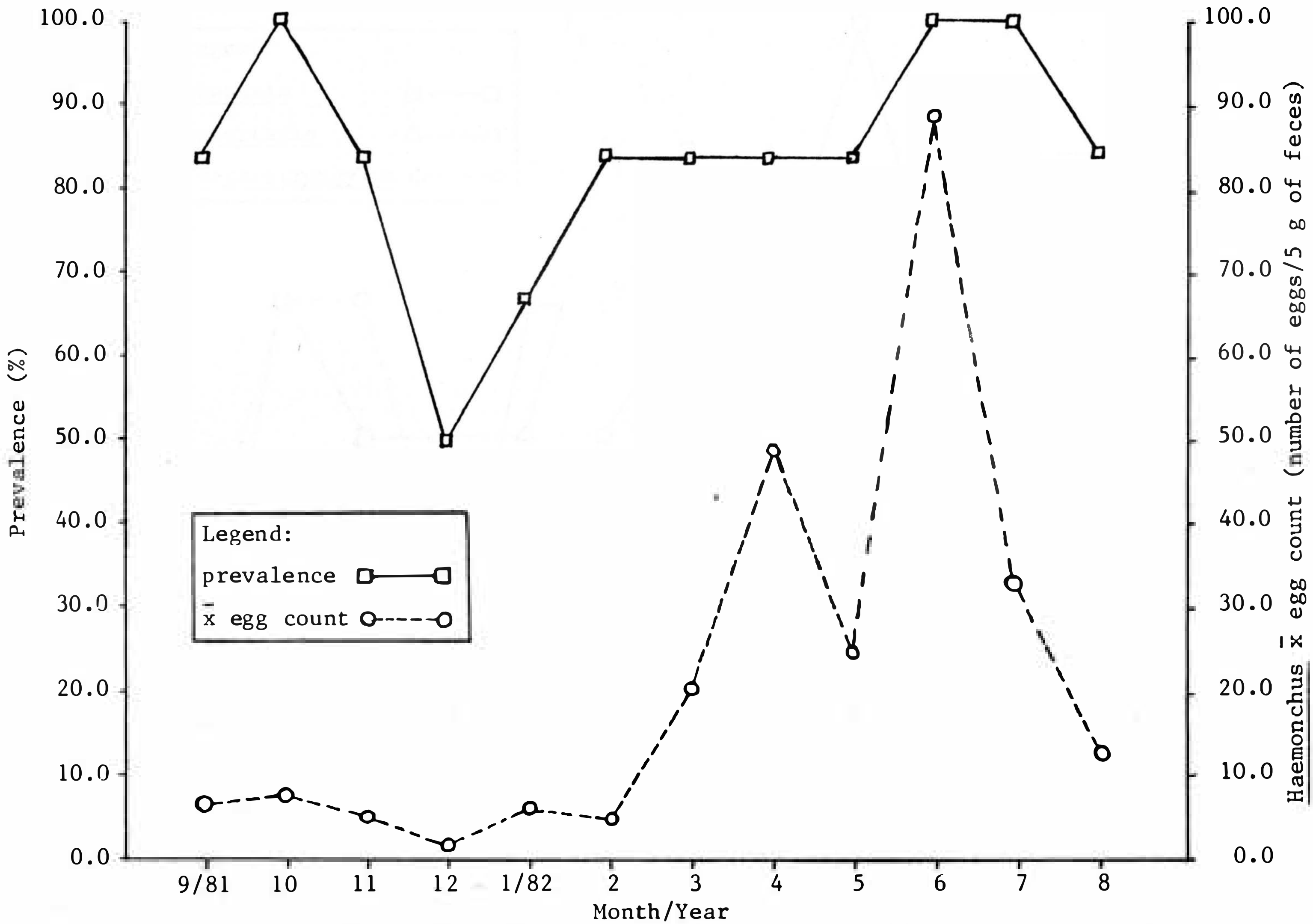


Fig. 3. Monthly prevalences and mean egg counts of <u>Haemonchus</u> in cows of the Misar herd.

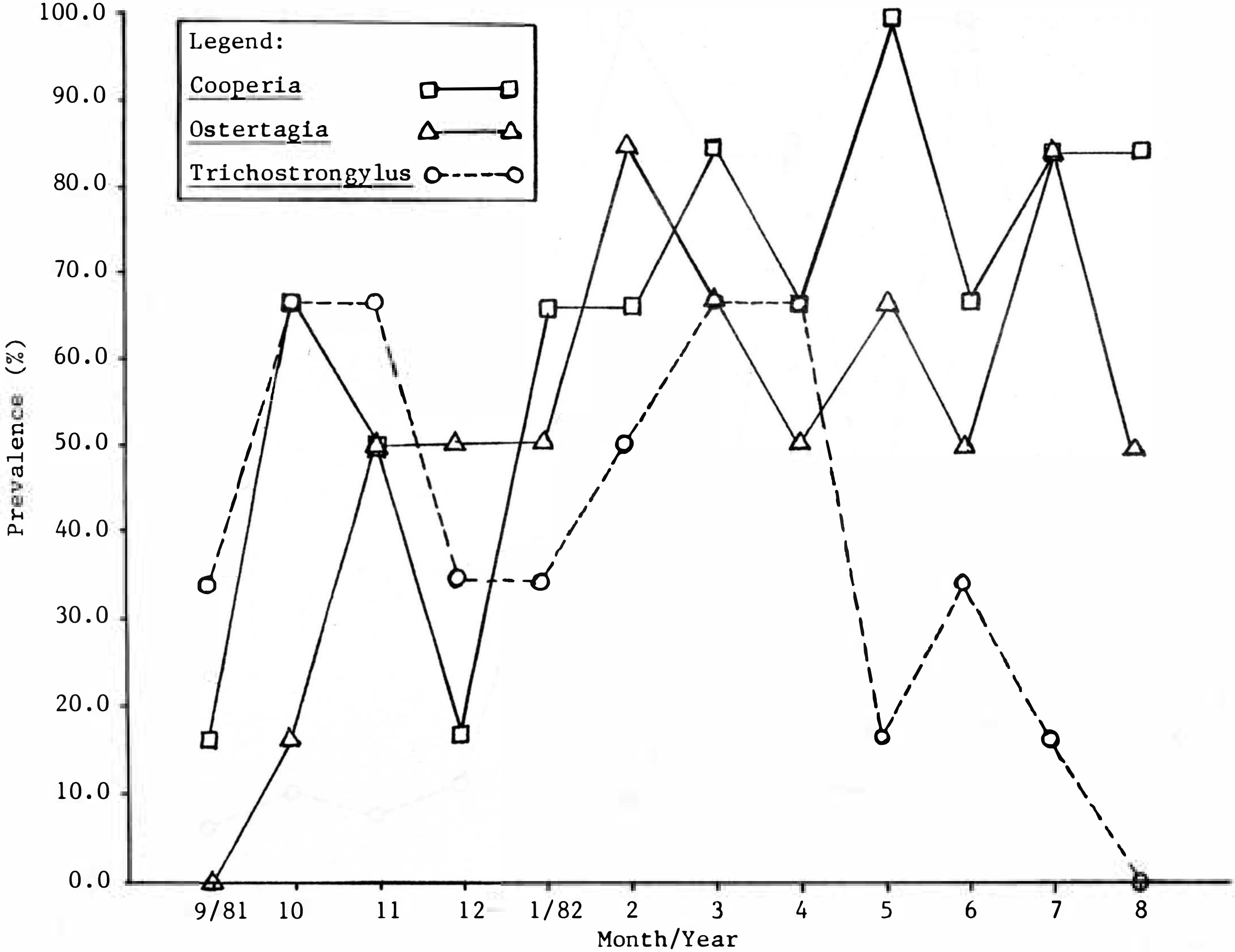


Fig. 4. Monthly prevalences of <u>Cooperia, Ostertagia,</u> and <u>Trichostrongylus</u> in cows of the Misar herd.

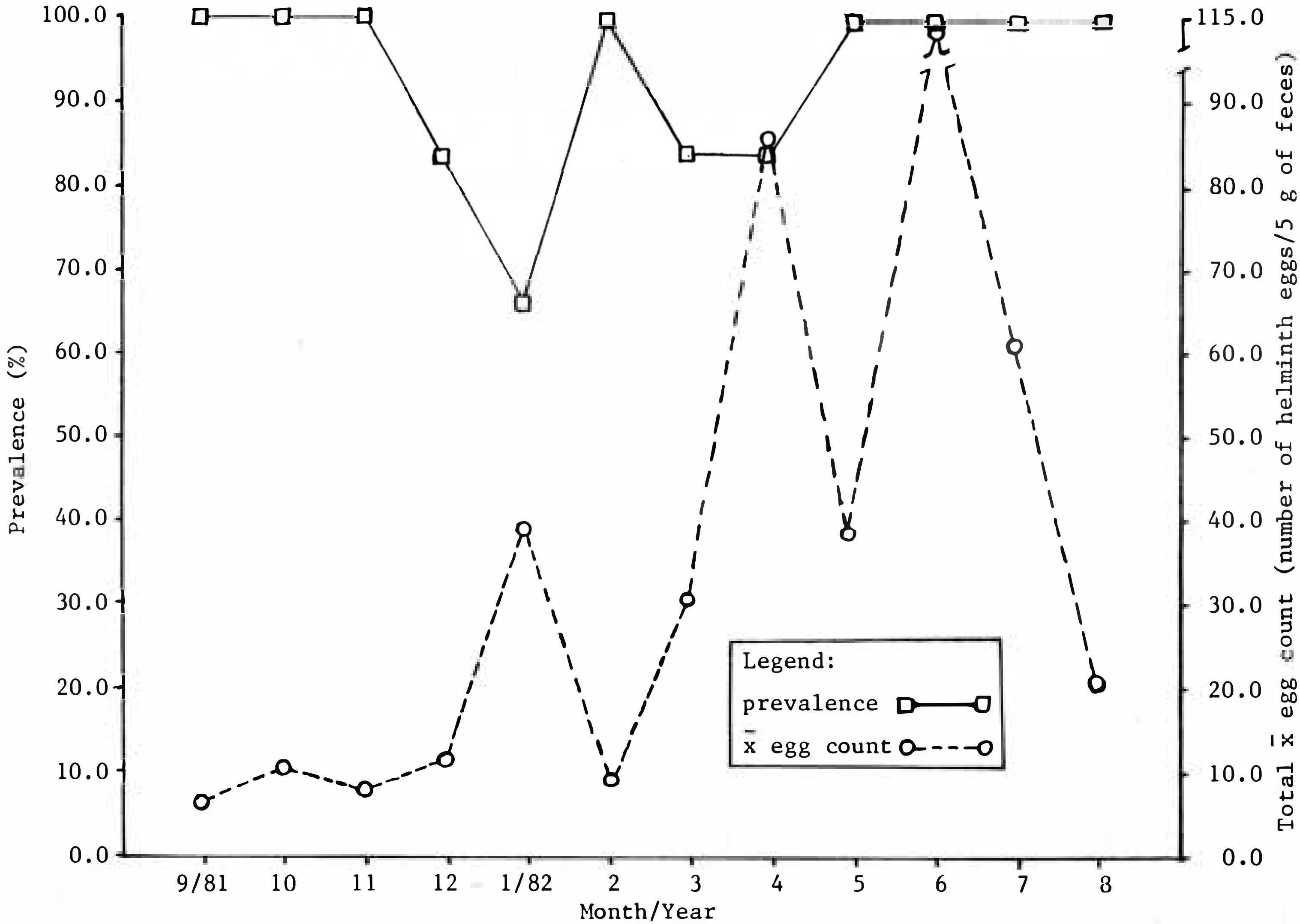


Fig. 5. Total monthly prevalences and mean egg counts in cows of the Misar herd.

Table 9. Total monthly mean ($\bar{x}$) egg counts* of dairy cattle of the Misar herd in Study 2. (Least squares means used).

Month/Year	Age Group+ I	II	III	Herd Avg Monthly $\bar{x}$
9/81	147.0	33.2	6.8	38.1
10/81	295.0	78.7	10.7	94.7
11/81	0.7	2.0	7.8	4.1
12/81	...	...	11.5	11.5
1/82	...	...	39.0	39.0
2/82	...	35.0	8.7	12.4
3/82	32.0	...	31.3	31.4
4/82	92.0	...	85.7	88.2
5/82	22.2	...	38.2	30.9
6/82	12.2	59.2	114.8	62.1
7/82	...	15.0	62.0	43.2
8/82	82.0	7.5	21.8	19.9
Total	73.9	33.7	36.5	42.8

Legend same as Table 5.

Table 10. Multiple helminth infections as indicated by frequencies (F) and relative frequencies (RF) of eggs analyzed from Misar cattle included in Study 2.

Number of Genera Found	Age Group+ I (N=25) F	RF	II (N=35) F	RF	III (N=72) F	RF	Total (N=132) F	RF
0	4	0.16	8	0.23	5	0.07	17	0.13
1	2	0.08	2	0.06	11	0.15	15	0.11
2	4	0.16	6	0.17	17	0.24	27	0.20
3	4	0.16	12	0.34	19	0.26	35	0.27
4	4	0.16	5	0.14	14	0.19	23	0.17
5	5	0.20	0	0.00	6	0.08	11	0.08
6	1	0.04	1	0.03	0	0.00	2	0.02
7	1	0.04	1	0.03	0	0.00	2	0.02
Total	25	1.00	35	1.00	72	0.99	132	1.00

Legend same as Table 6.

May-June; the lowest (8.2 epg) was found in January-February.

Environmental conditions influence the development and survival, and therefore the availability of infective stages of gastrointestinal helminths (Todd et al., 1978b). It follows that seasonal variations in temperature and moisture could have contributed to monthly differences in the prevalences of helminth ova in feces and the total mean egg counts reported herein.

The use of climatographs in visualizing the effects of temperature and moisture was introduced by Gordon (1948). He plotted mean monthly maximum temperature against average precipitation for each month and connected the resultant points to form closed curves. Lines indicative of the range of optimal climatic conditions for development and transmission of free-living stages of different ruminant nematodes were then superimposed on the closed curves. A comparison of the resultant bioclimatographs with the known prevalences of parasites in different localities was then made.

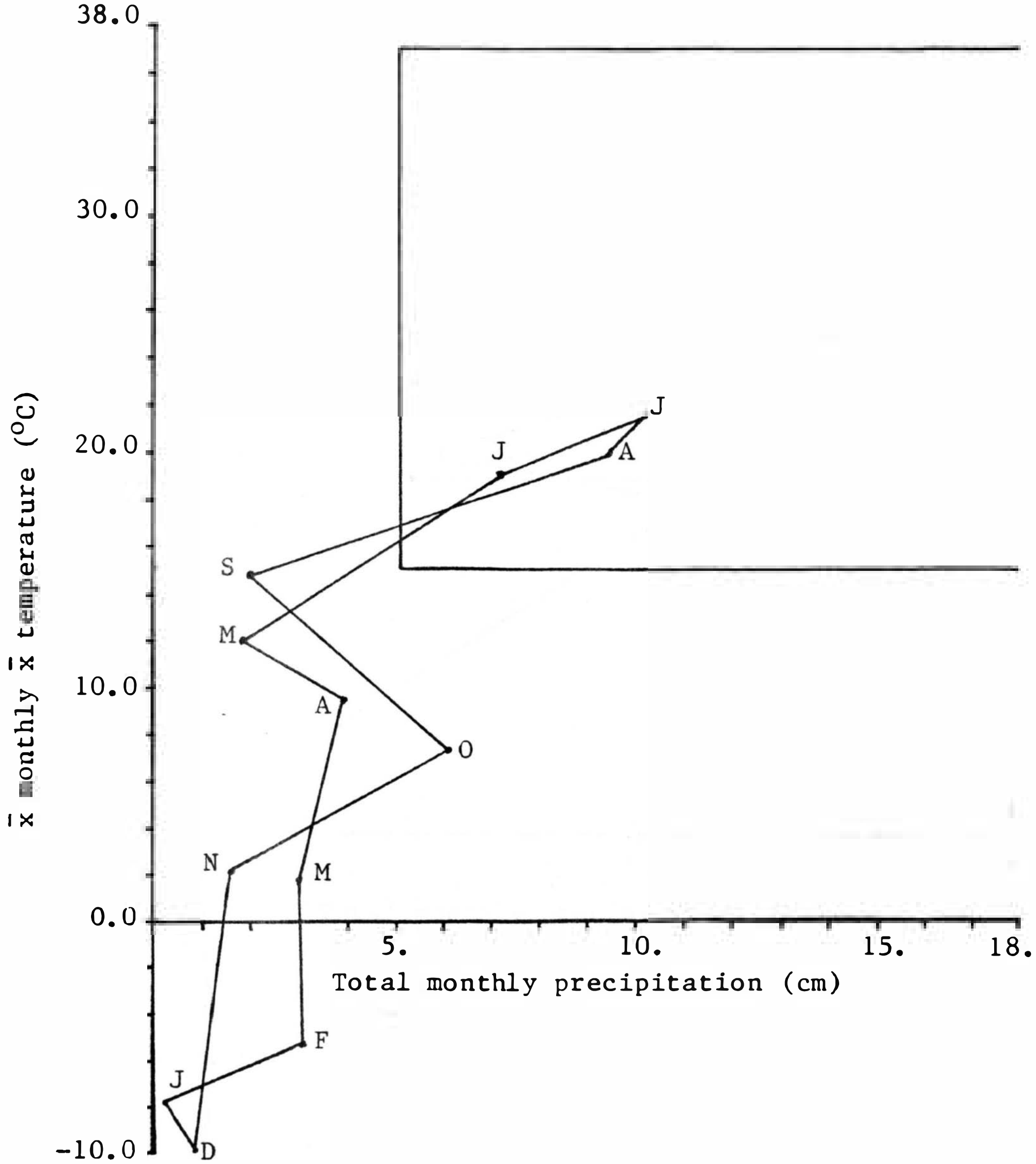
Deficiencies in the bioclimatographs exist, although they can be used to predict the general pattern of parasitism to be found in different localities (Levine, 1963). The graphs are typically based on average conditions for a period of years, and they cannot be used to predict the situation for a single year. Furthermore, potentially influential factors, other than temperature and moisture, are ignored (Levine 1959, 1963).

Nevertheless, two retrospective bioclimatographs were constructed. Total monthly precipitation and mean monthly mean temperatures for Brookings, South Dakota, from January through December, 1981 (Fig. 6) and January through August, 1982 (Fig. 7) were plotted, and the optimal conditions for pasture transmission of the most prevalent genus, Haemonchus, were superimposed. The optimal conditions used here, 5 cm or more total monthly precipitation and 15 to 37°C mean monthly mean temperature, represent average American conditions (Levine, 1963). It is interesting to note that Levine (1963) reported the optimal conditions for pasture transmission of Trichostrongylus and Ostertagia to be 5 cm or more total monthly precipitation and 6 to 20°C mean monthly mean temperature. Given this information and the climatic conditions of Brookings, South Dakota, it would seem probable that the rate of transmission, and subsequently infection, would be greater for Trichostrongylus and Ostertagia, than for Haemonchus. Apparently, this is not the case in the Misar herd. The use of Figs. 6 and 7, modifications of Gordon's 1948 bioclimatograph design, is done in an attempt to explain the monthly variations in prevalence and mean egg count of Haemonchus in samples from cows of the Misar herd (Fig. 3).

Total monthly precipitation and mean monthly mean temperatures for the 3 months prior to the first sample collection in September, 1981, were within the range of optimal conditions for Haemonchus. Possibly, this contributed to a build-up of infection, evident by a peak in prevalence in October, 1981 (Fig. 3). As climatic conditions worsened, prevalence and mean egg count declined to their lowest levels, which occurred in December, 1981.

The cows were usually kept in the barn during periods of harsh weather. However, during January and February, 1982, the milking herd was frequently confined with beef cows and calves on a snow-covered lot

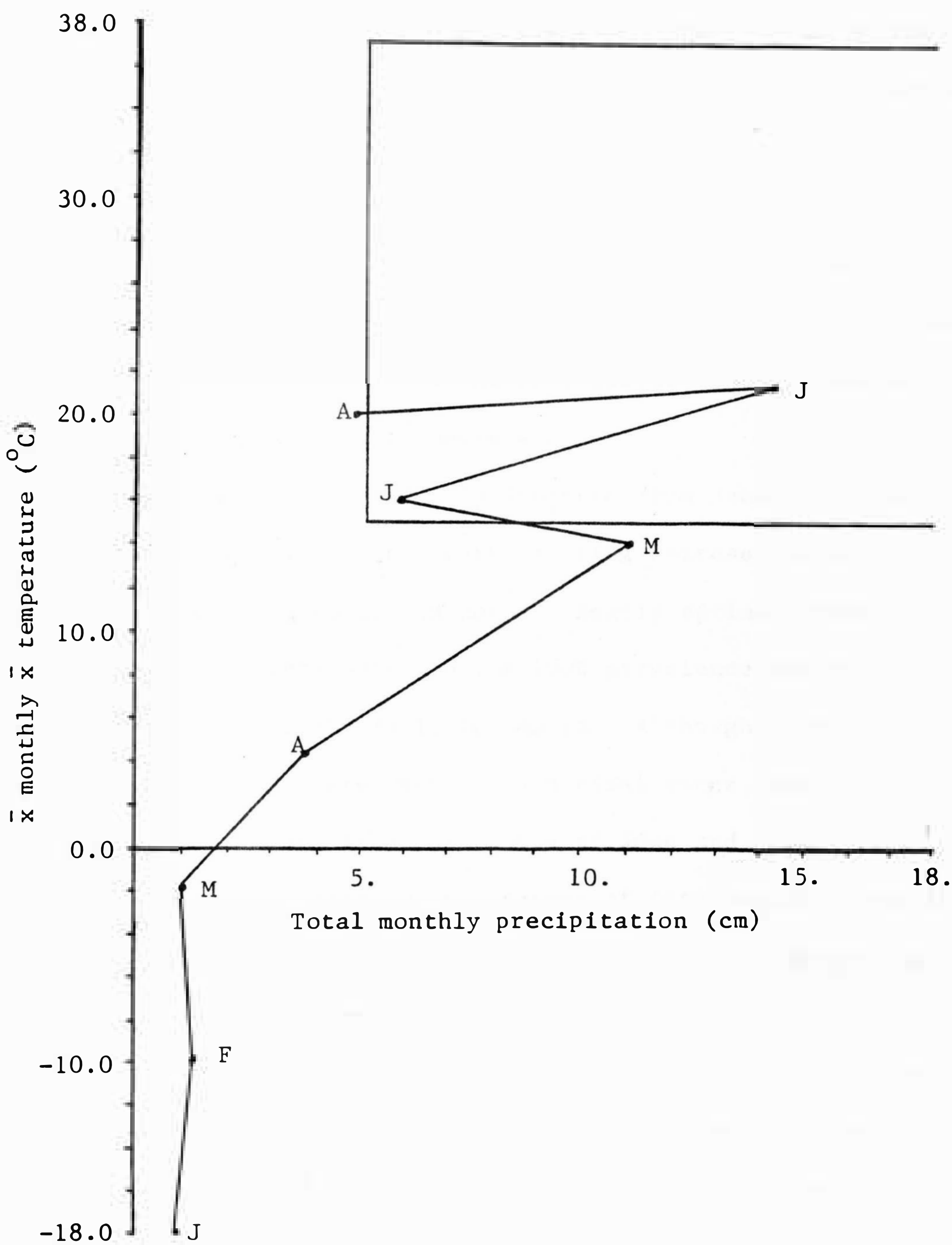
Fig. 6. Bioclimatograph of climatic conditions of Brookings, South Dakota, 1981+, in relation to optimal conditions for pasture transmission of <u>Haemonchus</u>*.



+Source: USDC, 1982a.

*Solid lines indicate average American optimum (Levine, 1963).

Fig. 7. Bioclimatograph of climatic conditions of Brookings, South Dakota, January through August, 1982[+], in relation to optimal conditions for pasture transmission of <u>Haemonchus</u>[*].



[+]Source: USDC, 1982b.

[*]Solid lines indicate average American optimum (Levine, 1963).

adjacent to the barn. Any transmission of infective larvae was most likely limited to the relatively warm barn, due to the severe climatic conditions. Carmel and Todd (1979) conducted a study at three southern Wisconsin dairy farms to ascertain the locations and relative numbers of infective nematode larvae to which dairy cows are exposed throughout the year. They found that bedding material harbored the highest number of larvae (2984.3 larvae/m^3 of material) at one farm during December. Larvae were also found on stanchion floors (346.7/m^2) and areas around water cups and mangers (87.3/m^2). After December, the concentration of larvae inside the barn steadily decreased.

Climatic conditions gradually improved from January through April, 1982, during which time a corresponding increase in both prevalence and mean egg count was noted. Nearly optimal conditions in May, 1982, probably contributed to the 100% prevalence and the peak mean egg count of Haemonchus the following month. Although climatic conditions in June and July, 1982, were within the optimal range, mean egg counts and prevalences decreased from the levels of June and July, 1982, respectively. Not surprisingly, the curves of total monthly prevalence and mean egg count (Fig. 5) roughly paralleled those of Haemonchus (Fig. 3).

The results presented above, and all interpretations thereof, must be considered cautiously because of the low number of cows sampled monthly (N=6). Moreover, the research was not conducted under controlled conditions. The effects of mixing beef and dairy cattle outside on a lot during winter are of questionable importance.

However, it is certain that fecund Haemonchus adults were present in at least three of six Holstein cows sampled each month. Other helminth genera were also present. All samples collected from cows during 8 of 12 months contained at least one worm egg. All mean egg counts might be interpreted as being indicative of subclinical infections.

The Nelson Herd

Approximately 120 cows are milked in a double-6 herringbone parlor and are confined to an adjacent free stall barn and a drylot. However, the cows had pasture access as yearlings. Cows are fed primarily a mixture of corn and hay crop silage. Individual resting areas are provided without bedding. The free stall barn has a wood slat floor with openings through which feces and urine fall. However, accumulations of fecal material are usually present around all areas of the barn floor. The cattle have never been treated with an anthelmintic.

Overall, Cooperia was the most prevalent and had the highest mean egg count of the 10 genera found (Table 11). As in the Misar herd, three of the most frequently encountered genera were Haemonchus, Ostertagia and Trichostrongylus. In Georgia, eggs of the Cooperia-Ostertagia-Trichostrongylus complex were found in 78 of 100 dairy cattle (Ciordia, 1975). Feces of 38 of the same cattle yielded ova of the Haemonchus-Oesophagostomum group. In the present study, Oesophagostomum was encountered in less than 10% of the samples. Strongyloides papillosus and Capillaria sp. were not found, but Neoascaris vitulorum was.

Sixty-eight of 131 samples contained worm eggs (Table 11). This

Table 11. Helminth mean ($\bar{x}$) egg counts* and prevalences (%) from the Nelson dairy herd in Study 2 (Actual means used).

	Age Group+						Total	
	I (N=28)		II (N=31)		III (N=72)		(N=131)	
Genus	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	Avg $\bar{x}$	Avg %
Bunostomum	0.0	0.0	0.1	3.2	0.1	1.4	0.1	1.5
Oesophagostomum	0.4	10.7	0.5	19.4	0.2	4.2	0.3	9.2
Cooperia	8.6	32.1	41.7	90.3	5.0	33.3	14.5	46.2
Ostertagia	7.3	32.1	8.4	71.0	0.6	13.9	3.9	31.3
Trichostrongylus	0.7	21.4	2.3	45.2	0.9	13.9	1.2	22.9
Haemonchus	10.4	25.0	18.1	71.0	4.3	20.8	8.9	33.6
Nematodirus	0.3	14.3	14.6	38.7	0.0	0.0	3.5	12.2
Neoascaris	0.0	0.0	0.1	3.2	0.0	0.0	#	0.8
Trichuris	#	3.6	1.0	16.1	0.0	0.0	0.3	4.6
Moniezia	0.0	0.0	27.2	6.5	0.0	0.0	6.5	1.5
Total	27.7	53.6	114.0	90.3	11.1	34.7	39.2	51.9

Legend same as Table 4.

level is similar to the 52.6% recorded for the prevalence of trichostrongyle-type ova in 593 Iowa dairy cattle of five herds, which were repetitively sampled over a 3-year period (Zimmermann and Hubbard, 1961).

The difference in overall prevalence between the three age groups was found to be highly significant ($\chi^2 = 26.87$, 2 DF, $P < 0.01$). The highest prevalence and total mean egg count were found in the yearlings (Table 11). There appeared to be a direct relationship between total mean egg count, prevalence and number of helminth genera found in samples from a particular age group. Only six genera were found in samples from cows.

Monthly prevalences of the four most frequently found genera in cow samples are given (Figs. 8 and 9). Eggs of *Cooperia* were present in at least one of six samples each month, except for January, 1982. Both *Haemonchus* and *Ostertagia* were absent from samples collected during 4 of 12 months. *Trichostrongylus* was lacking in 5 of 12 months. However, this does not necessarily indicate that these genera were entirely absent from the herd during those months. Rather, it simply means that eggs of the above genera were not found in samples obtained from individual animals on a given collection date. This might indicate the presence of a lethargic, reduced or eliminated helminth population in the representative cows. Total monthly prevalence vacillated between one of six and three of six worm egg-positive samples per month for 10 of 12 collection dates (Fig. 10).

For most months in which yearling samples were obtained, they had the highest total monthly mean egg counts for one age group (Table 12).

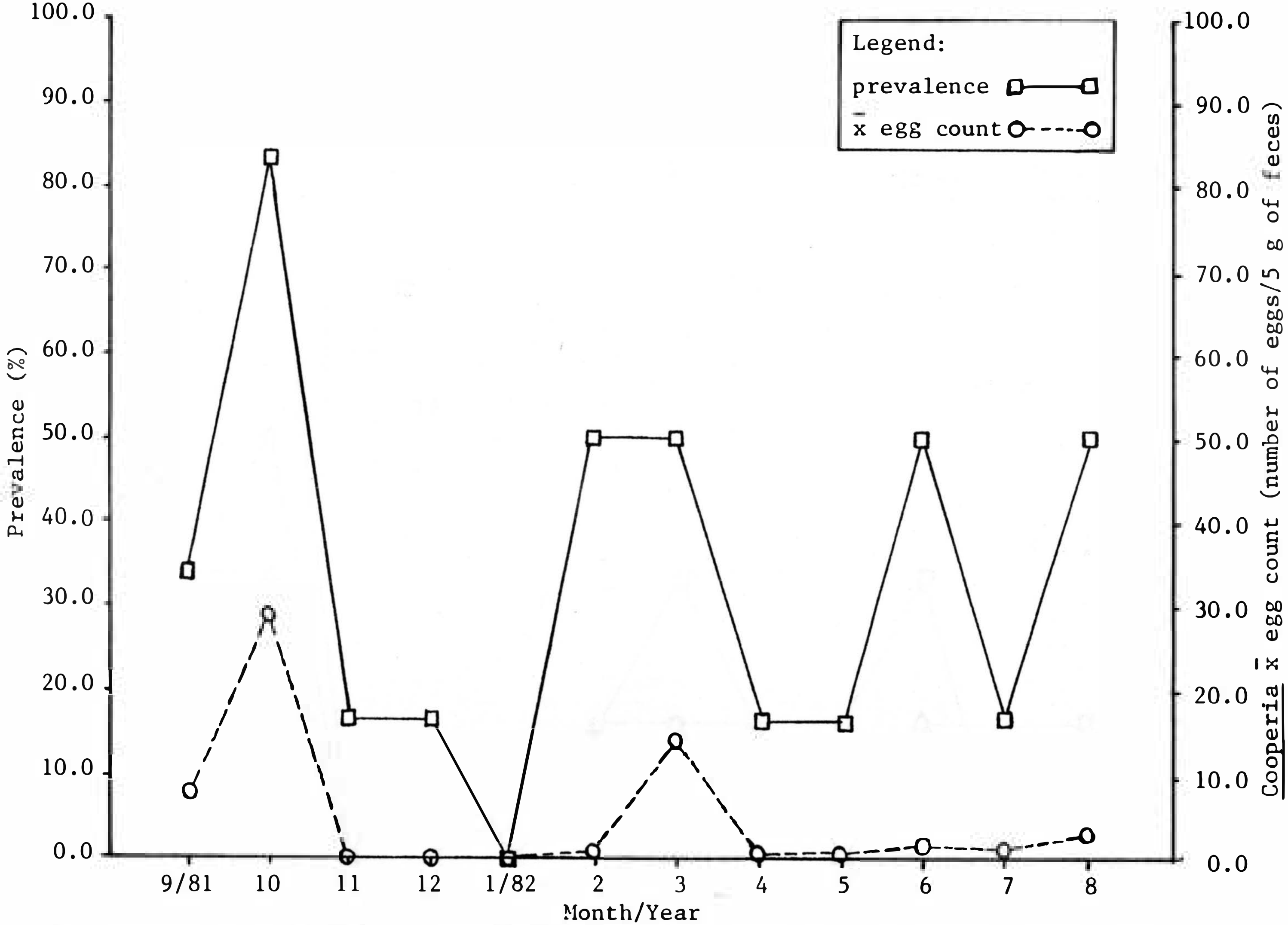


Fig. 8. Monthly prevalences and mean egg counts of Cooperia in cows of the Nelson herd.

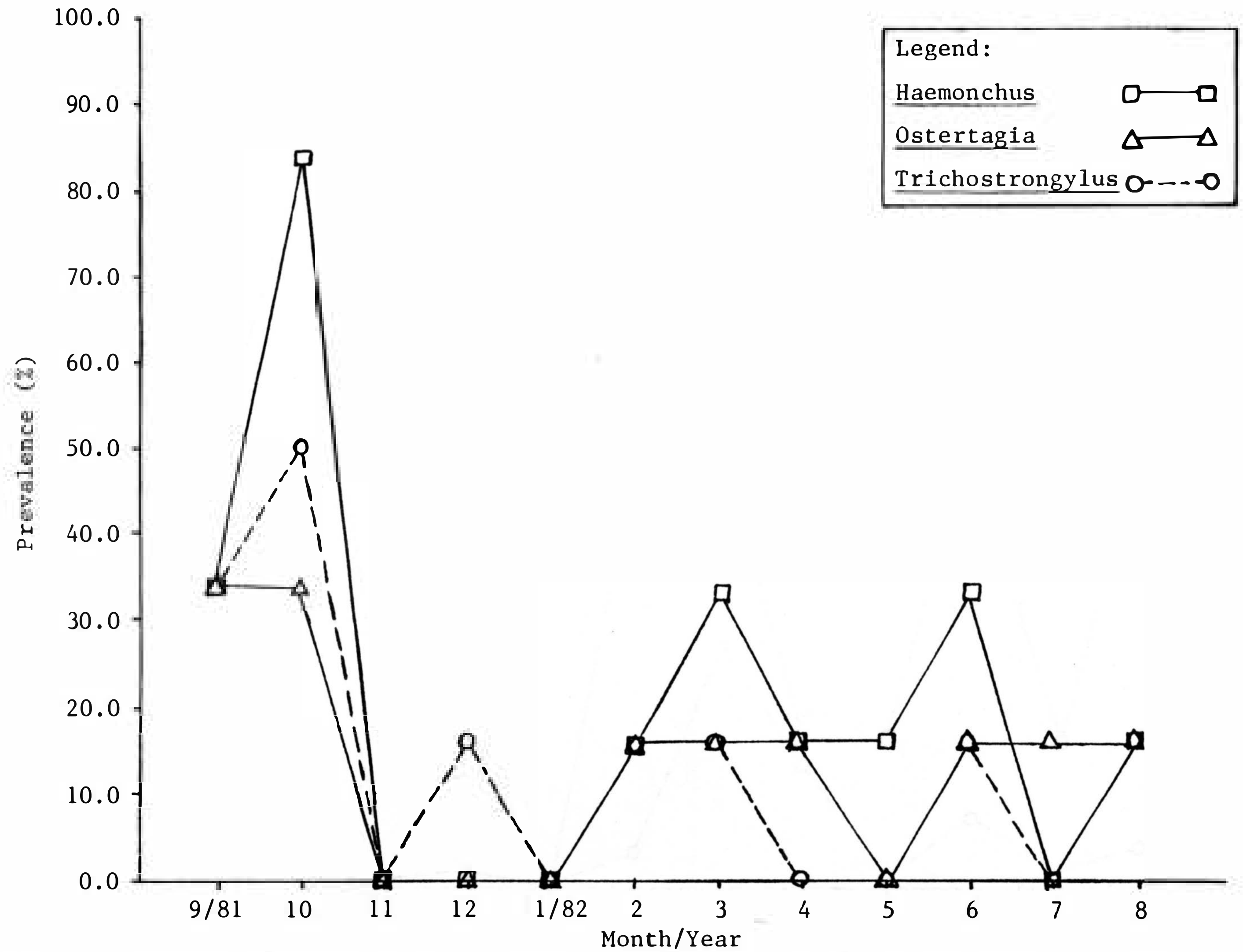


Fig. 9. Monthly prevalences of Haemonchus, Ostertagia, and Trichostrongylus in cows of the Nelson herd.

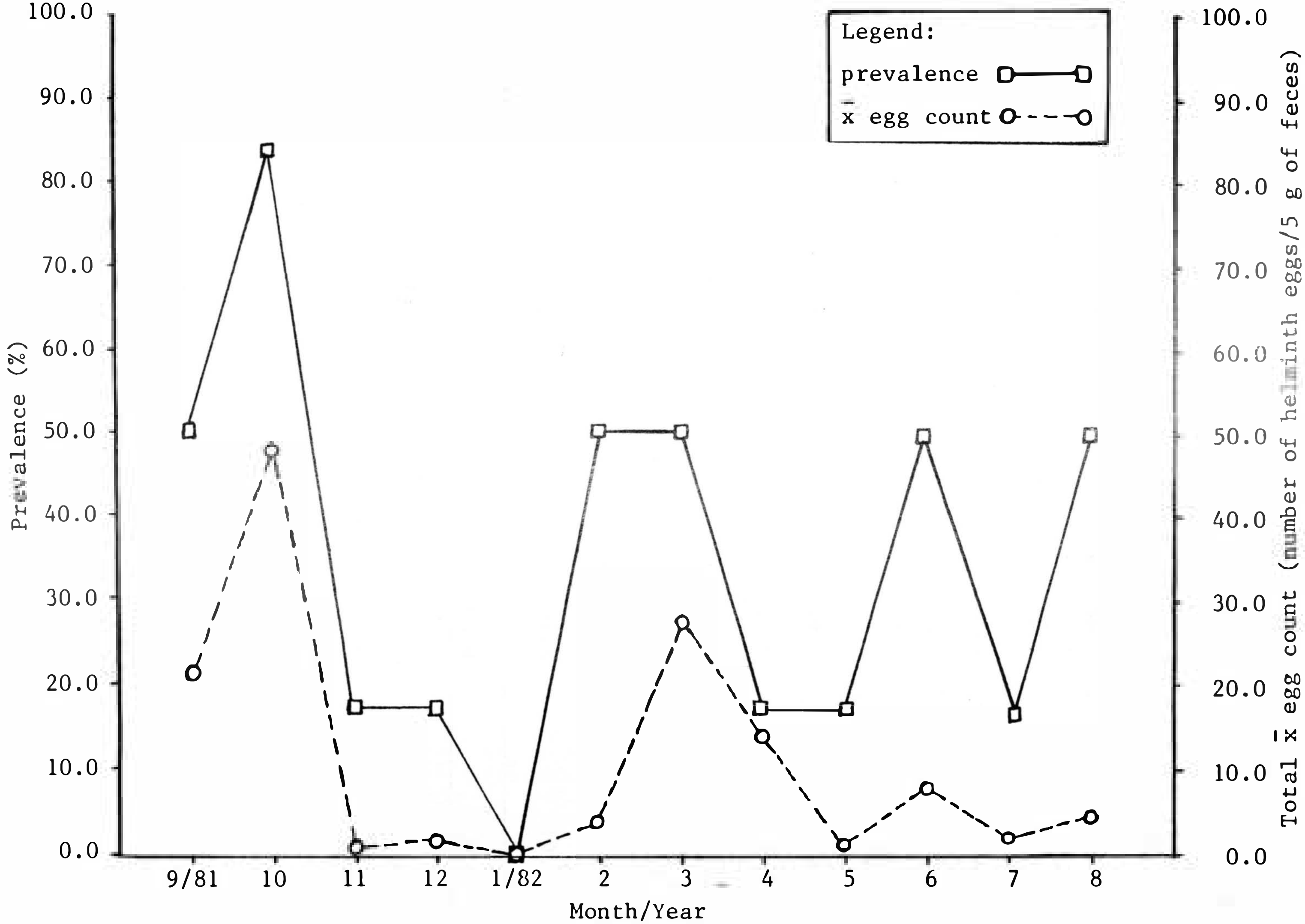


Fig. 10. Total monthly prevalences and mean egg counts in cows of the Nelson herd.

Table 12. Total monthly mean ($\bar{x}$) egg counts* of dairy cattle of the Nelson herd in Study 2. (Least squares means used).

Month/Year	Age Group+ I	II	III	Herd Avg Monthly $\bar{x}$
9/81	7.7	45.0	21.3	26.9
10/81	0.0	139.5	46.7	55.9
11/81	0.7	39.5	0.7	7.7
12/81	...	...	1.8	1.8
1/82	...	...	0.0	0.0
2/82	...	...	3.3	3.3
3/82	0.0	273.0	26.7	128.4
4/82	0.0	14.0	14.0	9.8
5/82	83.3	90.7	0.5	55.0
6/82	39.8	98.0	8.3	48.7
7/82	17.5	63.5	1.6	18.9
8/82	47.7	29.0	4.5	19.9
Total	27.7	113.7	10.9	39.0

Legend same as Table 5.

The highest herd average monthly mean occurred in March, 1982. A yearling sample collected in March, 1982, contained the highest individual total and generic egg counts, 965 worm eggs and 545 *Moniezia* ova, respectively.

Over 79% of the positive samples obtained from the Nelson herd contained more than one helminth genus (Table 13). All 28 positive yearling samples contained ova of more than one genus. The maximum number found in a sample was six.

As before, retrospective bioclimatographs were constructed to aid in interpreting the results (Figs. 11 and 12). The same climatic conditions as used in Figs. 6 and 7 were plotted, but optimal conditions for development and survival on pasture of the infective stages of *Cooperia*, rather than those of *Haemonchus*, were superimposed since the former was the most prevalent genus in cows of the Nelson herd. The optimal conditions[6] superimposed on the curves, 5 to 12 cm total monthly precipitation and 13 to 26°C mean monthly mean temperature, are from a Louisiana study (Williams and Mayhew, 1967) and are intended to serve only as a rough estimate of what the optimum might be for *Cooperia* in South Dakota.

Climatic conditions for June through August, 1981, were within the range of optimal conditions for development and survival of *Cooperia* on pasture. This might have contributed to the occurrence of peaks in prevalence and mean egg count of *Cooperia* in October, 1981 (Fig. 8). A

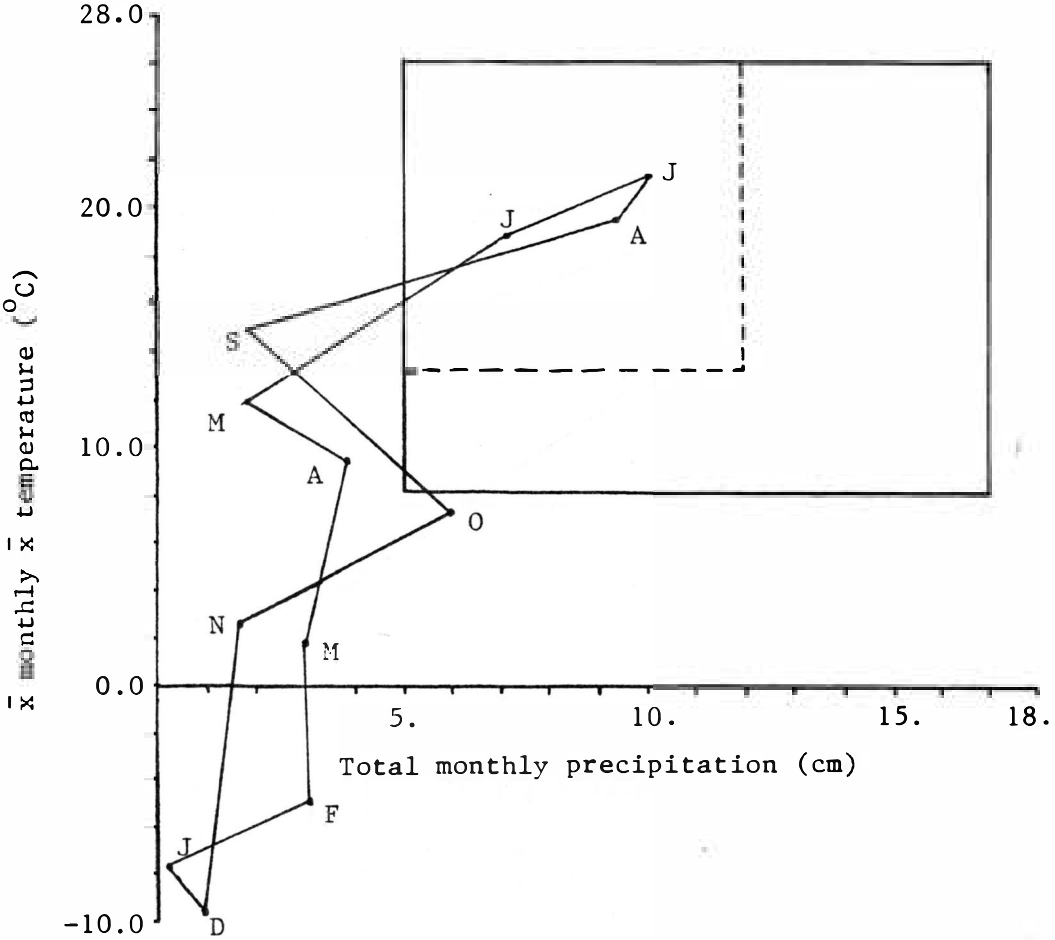
[6]The optimal conditions were for the development and survival of *C. punctata*. It is assumed that these are approximations of the optimums for other members of genus *Cooperia*.

Table 13. Multiple helminth infections as indicated by frequencies (F) and relative frequencies (RF) of eggs analyzed from Nelson cattle included in Study 2.

Number of genera found	Age Group+ I (N=28) F	RF	II (N=31) F	RF	III (N=72) F	RF	Total (N=131) F	RF
0	13	0.46	3	0.10	47	0.65	63	0.48
1	6	0.21	0	0.00	8	0.11	14	0.11
2	3	0.11	2	0.06	6	0.08	11	0.08
3	0	0.00	7	0.23	6	0.08	13	0.10
4	3	0.11	10	0.32	3	0.04	16	0.12
5	3	0.11	6	0.19	2	0.03	11	0.08
6	0	0.00	3	0.10	0	0.00	3	0.02
Total	28	1.00	31	1.00	72	0.99	131	0.99

Legend same as Table 6.

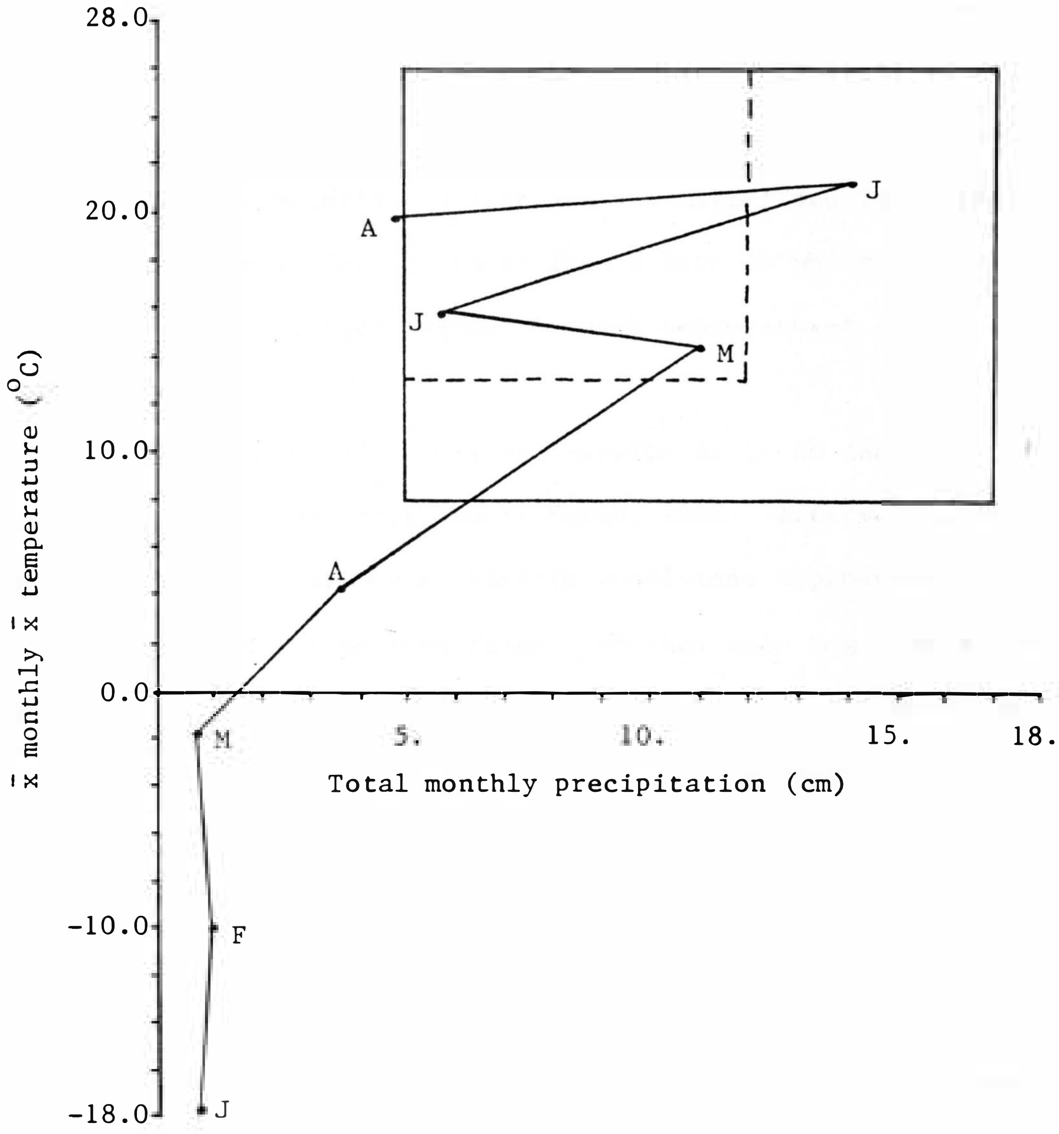
Fig. 11. Bioclimatograph of climatic conditions of Brookings, South Dakota, 1981[+], in relation to optimal conditions for pasture development and survival of *Cooperia*[*].



[+]Source: USDC, 1982a.

[*]Optimal conditions for survival are bordered by solid lines; those for development are partially bordered by dotted lines (Williams and Mayhew, 1967).

Fig. 12. Bioclimatograph of climatic conditions of Brookings, South Dakota, January through August, 1982[+], in relation to optimal conditions for pasture development and survival of *Cooperia*[*].



[+]Source: USDC, 1982b.

[*]Optimal conditions for survival are bordered by solid lines; those for development are partially bordered by dotted lines (Williams and Mayhew, 1967).

concurrent decline in climatic conditions and monthly prevalences and mean egg counts to their lowest values in January, 1982, was noted.

During periods of severe winter weather, the milking herd was confined to the unheated free stall barn. Transmission of infective stages was most likely limited to this area, since adequate sanitation procedures were followed in the milking parlor. Transmission was probably minimal due to sub-freezing temperatures in the barn and the absence of bedding material in rest areas. Carmel and Todd (1979) recovered more larvae during winter from a barn in which the temperature never fell below 7°C, than in one in which temperatures of 0°C and less were recorded.

An improvement in climate was paralleled by an increase in prevalence and mean egg count until March, 1982. Afterwards, both parameters declined, although climatic conditions approached and eventually reached the optimum range. Monthly mean egg counts remained very low and prevalences fluctuated throughout the duration of the study. The curves of monthly prevalence of *Cooperia* and of total monthly prevalence are nearly identical (Figs. 8 and 10). Also, the respective mean egg count curves follow the same pattern.

Research at the Nelson farm was conducted under more controlled conditions than at the Misar farm, in that beef and dairy cattle were not allowed to run together on the same lot. However, both research efforts must be considered as being of marginal value in demonstrating that variations in the prevalence of worm eggs in feces and in the mean egg counts were due to seasonal fluctuations in temperature and moisture alone, since variability between individuals was not statistically determined. Egg count variability within an individual was not measured, hence the inability to determine differences between individuals.

Nevertheless, there seems to be a close association between climatic conditions and the monthly prevalences and mean egg counts of Haemonchus and Cooperia in fecal samples from cows of the Misar and Nelson herds, respectively. This same correlation seems to exist for total monthly prevalences and mean egg counts of helminth genera in cow feces at both farms.

Study 3

One-hundred and forty fecal samples were obtained from Holstein cattle of eight Black Hills dairy herds. The samples were separated into two groups, based on when they were collected: Group 1 - October, 1981 (Table 14a), and Group 2 - March, 1982 (Table 14b). The separation was necessitated by the likelihood of some degree of seasonal variability in worm egg counts and prevalences of gastrointestinal helminths (Yazwinski and Gibbs, 1975; Grisi and Todd, 1978). Approximate locations of the herds and the total number of samples obtained per county are indicated in Map 3.

Haemonchus was the most prevalent of nine nematode genera encountered in the 44 worm egg-positive samples collected in October, 1981 (Table 15). But Cooperia had the highest average mean egg count. Eggs of S. papillosus, Bunostomum phlebotomum, and Oesophagostomum sp. were found in less than 10% of the samples and these species had average mean egg counts of 0.1 or less.

Table 14a. Number of samples collected from Black Hills dairy herds (Group 1).

Date	Herd Owner	Location (County)	Age Group+ I	II	III	Total
10/09/81	L. McGuigan	Lawrence	2	3	10	15
10/10/81	G. Leach	Butte	9	0	16	25
10/10/81	Foos Brothers	Butte	2	4	12	18
Group 1 Totals			13	7	38	58

Table 14b. Number of samples collected from Black Hills dairy herds (Group 2).

Date	Herd Owner	Location (County)	Age Group+ I	II	III	Total
3/10/82	L. Neugebauer	Fall River	7	7	7	21
3/10/82	S. Neugebauer	Custer	7	5	8	20
3/10/82	J. Rittberger	Custer	5	0	11	16
3/10/82	S. Jensen	Custer	1	2	8	11
3/11/82	J. Auker	Meade	2	0	12	14
Group 2 Totals			22	14	46	82
Overall Totals			35	21	84	140

Legend same as Table 6.

Map 3. The westernmost portion of South Dakota showing the locations (*) of herds included in Study 3 and the total number of samples collected per county.

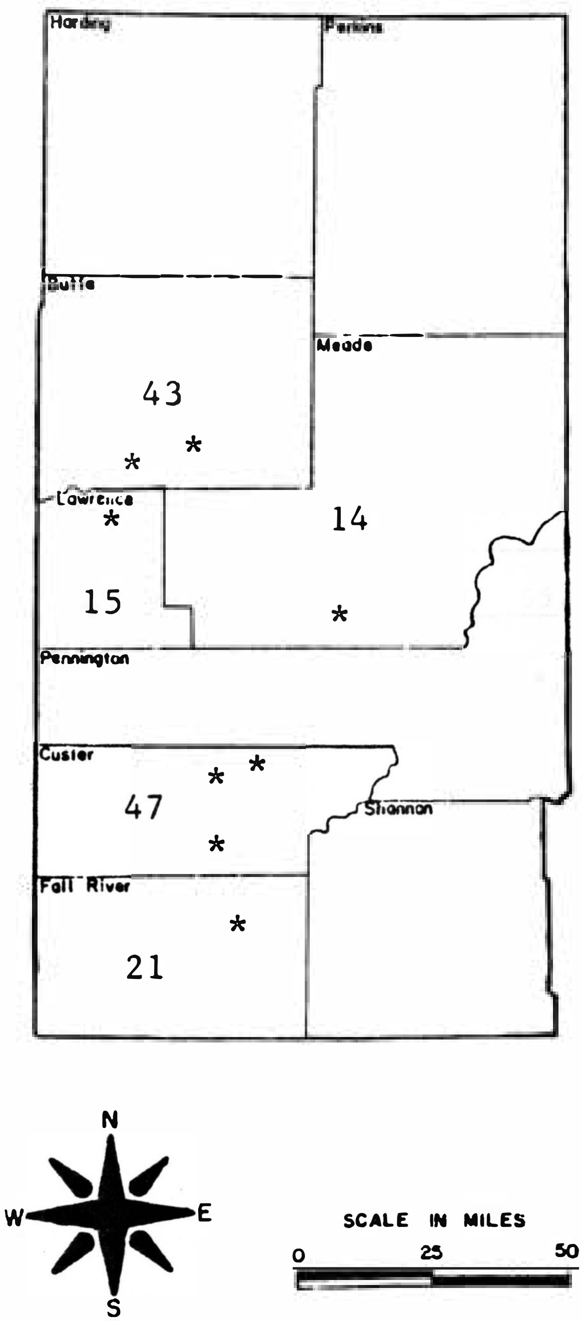


Table 15. Nematode mean ($\bar{x}$) egg counts* and prevalences (%) from Black Hills dairy cattle in Study 3, October, 1981.

	Age Group+						Total (N=58)	
	I (N=13)		II (N=7)		III (N=38)			
Genus	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	Avg $\bar{x}$	Avg %
Strongyloides	0.3	7.7	0.0	0.0	#	2.6	0.1	3.4
Bunostomum	0.0	0.0	0.0	0.0	#	5.3	#	3.4
Oesophagostomum	0.0	0.0	0.6	14.3	0.1	5.3	0.1	5.2
Cooperia	3.5	76.9	25.0	85.7	5.3	29.0	7.2	46.6
Ostertagia	0.2	15.4	2.3	42.9	1.4	29.0	1.3	27.6
Trichostrongylus	#	7.7	1.4	42.9	1.3	36.8	1.0	31.0
Haemonchus	1.9	61.5	12.7	85.7	2.8	50.0	3.8	56.9
Nematodirus	12.9	46.2	0.3	14.3	0.0	0.0	2.9	12.1
Trichuris	3.2	46.2	0.0	0.0	0.0	0.0	0.7	10.3
Total	22.0	92.3	42.3	100.0	10.9	65.8	17.1	75.9

Legend same as Table 4.

A significant difference in the overall prevalence of helminth ova in feces, according to host age, was revealed by chi-square analysis ($\chi^2 = 6.25$, 2 DF, $P < 0.05$). All yearlings were parasitized by gastrointestinal nematodes when samples were obtained. Yearlings had the highest total mean egg count, but one less genus was present than in either the cows or calves. A yearling sample contained the highest individual total and generic egg counts, 162 ova and 116 Cooperia eggs, respectively.

Nearly 66% of the positive Group 1 samples contained from two to four nematode genera each (Table 16). Eleven of 44 samples each yielded only one genus. Five genera were found in each of four samples.

Eggs of Haemonchus were more prevalent than those of the other seven helminth genera found in samples collected in March, 1982 (Table 17). Cooperia had the highest mean egg count in all three age groups. In calf samples, the Nematodirus mean egg count was also greater than that of Haemonchus. Moniezia ova were found in a cow sample.

A highly significant difference in the number of samples containing helminth eggs was found between the three ages of Group 2 cattle ($\chi^2 = 9.47$, 2 DF, $P < 0.01$). As in Group 1, all yearlings were infected with nematodes when samples were obtained. Total mean egg counts were inversely related to host age (Table 17). A calf sample yielded the highest individual total and generic egg counts, 1445 ova and 670 Nematodirus eggs, respectively. This is interesting in that Nematodirus is one of the least fecund of the ruminant nematodes (Georgi, 1980).

Of the 58 positive Group 2 samples, 11 contained eggs of only one

Table 16. Multiple nematode infections as indicated by frequencies (F) and relative frequencies (RF) of eggs analyzed from Black Hills dairy cattle in Study 3, October, 1981.

Number of genera found	Age Group+ I (N=13) F	RF	II (N=7) F	RF	III (N=38) F	RF	Total (N=58) F	RF
0	1	0.08	0	0.00	13	0.34	14	0.24
1	2	0.15	1	0.14	8	0.21	11	0.19
2	4	0.31	2	0.29	6	0.16	12	0.21
3	2	0.15	2	0.29	5	0.13	9	0.16
4	2	0.15	1	0.14	5	0.13	8	0.14
5	2	0.15	1	0.14	1	0.03	4	0.07
Total	13	0.99	7	1.00	38	1.00	58	1.01

Legend same as Table 6.

Table 17. Helminth mean ($\bar{x}$) egg counts* and prevalences (%) from Black Hills dairy cattle in Study 3, March, 1982.

Genus	Age Group+ I (N=22) $\bar{x}$	%	II (N=14) $\bar{x}$	%	III (N=46) $\bar{x}$	%	Total (N=82) Avg $\bar{x}$	Avg %
Oesophagostomum	0.0	0.0	1.9	21.4	0.0	0.0	0.3	3.7
Cooperia	57.9	50.0	42.1	85.7	3.9	37.0	24.9	48.8
Ostertagia	0.4	4.5	2.9	50.0	3.5	23.9	2.6	23.2
Trichostrongylus	0.6	4.5	1.2	21.4	0.5	17.4	0.7	14.6
Haemonchus	37.4	63.6	24.3	100.0	3.7	47.8	16.2	61.0
Nematodirus	47.8	45.5	0.2	7.1	0.0	0.0	12.9	13.4
Trichuris	2.4	40.9	0.1	14.3	0.0	0.0	0.7	13.4
Moniezia	0.0	0.0	0.0	0.0	0.4	2.2	0.2	1.2
Total	146.5	77.3	72.7	100.0	12.0	58.7	58.4	70.7

Legend same as Table 4.

helminth genus (Table 18) Over 62% of the positive samples yielded either two or three genera each. One calf sample showed eggs of six helminth genera.

No significant difference was found when the prevalences of worm eggs in fecal samples collected in October, 1981, and March 1982, were compared by the chi-square test (1 DF, P = 0.05). There was a difference in total mean egg count between the two groups, although analysis of variance did not indicate that it was significant (Tables 15 and 17).

The higher total egg count mean found in Group 2 samples possibly indicates the occurrence of a type of "spring rise" in nematode egg counts. The spring rise phenomenon has been observed in sheep in Britain, New Zealand, Australia, and the United States. It primarily involves Ostertagia, but also Trichostrongylus and Haemonchus (Levine, 1980). If a spring rise occurs, it could be due to one or more of the following: (1) maturation of immature larvae in the histotropic phase, or developmental arrest, (2) increased reproductive activity of adult nematodes, and (3) new infections which increase the number of worms present (Levine, 1980).

Dewhirst and Hansen (1963) reported a spring rise in mixed infections of yearling beef cattle. This increase was associated with a build-up of worm burden. One of the results of spring rise is the likely occurrence of a high number of infective larvae in the environment when young, susceptible animals are put on pasture for the first time.

Table 18. Multiple helminth infections as indicated by frequencies (F) and relative frequencies (RF) of eggs analyzed from Black Hills dairy cattle in Study 3, March, 1982.

Number of genera found	Age Group+ I (N=22) F	RF	II (N=14) F	RF	III (N=46) F	RF	Total (N=82) F	RF
0	5	0.23	0	0.00	19	0.41	24	0.29
1	2	0.09	0	0.00	9	0.20	11	0.13
2	8	0.36	6	0.43	6	0.13	20	0.24
3	2	0.09	4	0.29	10	0.22	16	0.20
4	4	0.18	2	0.14	2	0.04	8	0.10
5	0	0.00	2	0.14	0	0.00	2	0.04
6	1	0.05	0	0.00	0	0.00	1	0.01
Total	22	1.00	14	1.00	46	1.00	82	1.01

Legend same as Table 6.

Study 4

Fecal samples were obtained from 360 lactating Dairy Herd Improvement Association (DHIA) cows of 36 herds in eastern South Dakota from May through July, 1982. The distribution of counties included in the survey is shown in Map 4. Most (31 of 36) of the herds were Holstein. Other breeds represented were Brown Swiss (three herds), and Guernsey and Jersey (one herd each).

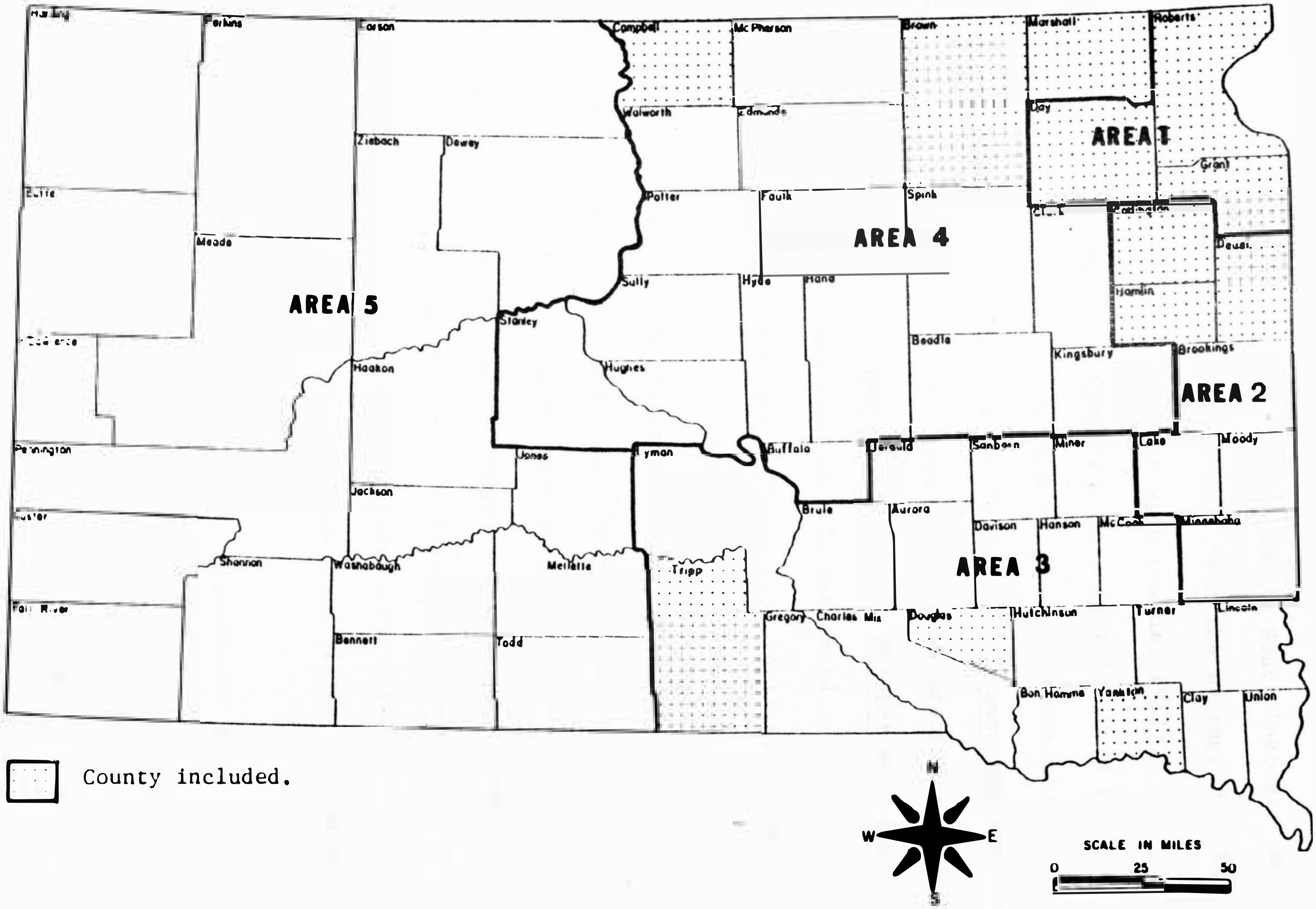
Management of the herds included in the survey varied. Twenty-two herds had been treated with an anthelmintic at least once, whereas the remaining herds had never been treated. At the time of sample collection, 29 herds had some amount of pasture access; others were confined to drylots.

DHIA testing programs are oriented towards more efficient production and increased profits. The DHIA program has been available for over 70 years, and the fundamental ideas and benefits remain unchanged. According to the SDSU Extension Dairyman, these are:

1. Identify culls that are costing the herd owner money.
2. Develop a feeding program that enables the owner to feed the cattle according to production.
3. Provide a record of the year to year progress of the herd.
4. Pinpoint herd and individual cow breeding problems.
5. Monitor other management factors such as: genetic progress, days dry, income over feed cost, and peak milk production.

In South Dakota, there were 661 herds with 37,482 cows enrolled in DHIA testing programs as of November, 1981 (Owens, 1982). Approximately 580 herds and 31,500 cows were located in the survey areas. Over 6% of the herds, and over 1% of the cows were included in the survey. As of November, 1981, cows on official testing programs had

Map 4. The South Dakota Dairy Herd Improvement Association (DHIA) Areas and the counties included in Study 4.



County included.

an average production of 13,657 lb of milk and 507 lb of fat compared to 10,497 lb of milk and 379 lb of fat for all cows in South Dakota. The income per cow on test was $395 (or 30%) more than the average for all cows in South Dakota, at $12.50/100 lb of milk (Owens, 1982).

Haemonchus, Ostertagia and Cooperia, respectively, were the most prevalent and had the highest average mean egg counts of the nine helminth genera found in the DHIA survey (Table 19). Haemonchus was the most frequently encountered genus in three of the four areas. Capillaria sp., Moniezia sp., S. papillosus, and B. phlebotomum were each found in less than 7% of the samples. In untreated animals, Haemonchus was the most prevalent genus (Table 20); in treated cows, it was Ostertagia (Table 21). However, the differences were minor.

Overall, 286 samples (79.4%) contained at least one worm egg (Table 19). This prevalence is less than the 95.4% reported for 388 DHIA cows sampled randomly at nine Vermont farms (Bliss and Todd, 1976). These relatively high prevalences are somewhat surprising, given the production-oriented DHIA programs. This information, along with other examples previously given, illustrates the widespread occurrence of gastrointestinal helminth parasitisms in even some of the best managed dairy cattle.

The chi-square test revealed a highly significant difference in overall prevalence when the four areas were compared ($\chi^2 = 18.30$, 3 DF, $P < 0.01$). However, the first analysis of variance (ANOVA I) failed to show a significant difference in total mean egg counts. The difference between prevalences in untreated cows from different areas was found to

Table 19. Helminth mean ($\bar{x}$) egg counts* and prevalences (%) from DHIA cows in Study 4.

Genus	DHIA Area I (N=90) $\bar{x}$	I (N=90) %	II (N=90) $\bar{x}$	II (N=90) %	III (N=90) $\bar{x}$	III (N=90) %	IV (N=90) $\bar{x}$	IV (N=90) %	Total (N=360) Avg $\bar{x}$	Total (N=360) Avg %
Strongyloides	0.0	0.0	#	2.2	0.0	0.0	1.1	14.4	0.3	4.2
Bunostomum	0.4	12.2	0.3	5.6	0.7	6.7	0.1	3.3	0.4	6.9
Oesophagostomum	2.7	24.4	0.4	14.4	0.4	10.0	1.6	20.0	1.3	17.2
Cooperia	12.9	58.9	11.5	63.3	22.2	48.9	17.3	47.8	16.0	54.7
Ostertagia	14.5	43.3	22.7	73.3	9.2	52.2	20.6	64.4	16.7	58.3
Trichostrongylus	3.2	40.0	1.6	30.0	1.4	24.4	0.3	14.4	1.6	27.2
Haemonchus	47.9	60.0	38.3	75.6	9.3	57.8	14.1	52.2	27.4	61.4
Capillaria	#	1.1	0.1	4.4	0.0	0.0	#	1.1	#	1.7
Moniezia	0.5	4.4	0.4	1.1	2.0	3.3	0.6	2.2	0.9	2.8
Total	82.1	70.0	75.3	94.4	45.2	75.6	55.7	77.8	64.6	79.4

*Number of helminth eggs/5.0 g of feces.

#Less than 0.1, but greater than 0.0 eggs/5.0 g of feces.

Table 20. Helminth mean ($\bar{x}$) egg counts* and prevalences (%) from untreated DHIA cows in Study 4.

	DHIA Area								Total (N=140)	
	I (N=70)		II (N=30)		III (N=20)		IV (N=20)			
Genus	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	Avg $\bar{x}$	Avg %
Strongyloides	0.0	0.0	#	3.3	0.0	0.0	1.7	30.0	0.2	5.0
Bunostomum	0.6	14.3	0.2	3.3	0.2	10.0	0.6	10.0	0.4	10.7
Oesophagostomum	2.9	25.7	0.4	23.3	0.6	20.0	4.1	35.0	2.2	25.7
Cooperia	14.1	61.4	15.7	50.0	50.4	70.0	8.2	85.0	18.8	63.6
Ostertagia	12.0	42.9	33.3	73.3	14.9	85.0	48.5	95.0	22.2	62.9
Trichostrongylus	3.6	44.3	1.7	23.3	3.4	40.0	0.8	35.0	2.8	37.9
Haemonchus	49.3	61.4	71.7	93.3	15.5	90.0	33.0	95.0	47.0	77.1
Capillaria	#	1.4	0.1	6.7	0.0	0.0	0.0	0.0	#	2.1
Moniezia	0.3	4.3	1.2	3.3	3.5	5.0	0.0	0.0	0.9	3.6
Total	82.8	70.0	124.3	100.0	88.5	95.0	96.9	100.0	94.5	84.3

Legend same as Table 19.

Table 21. Helminth mean ($\bar{x}$) egg counts* and prevalences (%) from treated DHIA cows in Study 4.

	DHIA Area								Total	
	I (N=20)		II (N=60)		III (N=70)		IV (N=70)		(N=220)	
Genus	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	Avg $\bar{x}$	Avg %
Strongyloides	0.0	0.0	#	1.7	0.0	0.0	0.9	10.0	0.3	3.6
Bunostomum	0.1	5.0	0.4	6.7	0.8	5.7	#	1.4	0.4	4.5
Oesophagostomum	2.1	20.0	0.4	10.0	0.4	7.1	0.9	15.7	0.7	11.8
Cooperia	8.6	50.0	9.4	70.0	14.2	42.9	19.9	37.1	14.2	49.1
Ostertagia	23.4	45.0	17.4	73.3	7.5	42.9	12.6	55.7	13.3	55.5
Trichostrongylus	1.9	25.0	1.6	33.3	0.8	20.0	0.2	8.6	0.9	20.5
Haemonchus	42.7	55.0	21.6	66.7	7.6	48.6	8.6	40.0	14.9	51.4
Capillaria	0.0	0.0	0.1	3.3	0.0	0.0	#	1.4	#	1.4
Moniezia	1.5	5.0	0.0	0.0	1.6	2.9	0.8	2.9	0.9	2.3
Total	80.3	70.0	50.9	91.7	32.9	70.0	43.9	71.4	45.6	76.4

Legend same as Table 19.

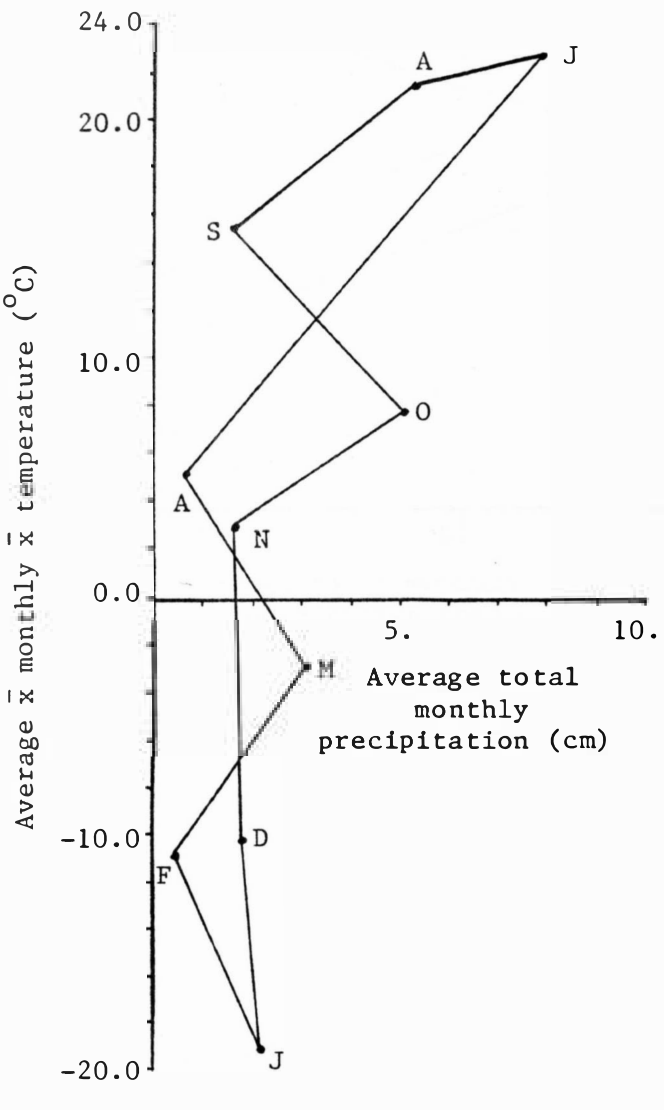
be highly significant (χ^2 = 21.84 3 DF, P < 0.01). Also, treated cows had a significant difference in the number of samples containing helminth ova (χ^2 = 10.75, 3 DF, P < 0.05).

Modified climatographs, representing average climatic conditions in each of the areas for the 12-month period prior to sample collection, were constructed in an effort to explain the differences in prevalence. Total monthly precipitation and mean monthly mean temperatures for the three counties representing each area[7] were obtained. These values were averaged and the points plotted and connected, thereby forming closed curves (Figs. 13-16). The average climatographs for the DHIA Areas show many similarities. It is unlikely that variations in total monthly precipitation and mean monthly mean temperature contributed to the differences in prevalence.

Variations in cattle management possibly contributed to the difference in the number of samples showing worm eggs when the areas were compared. However, the only management factor evaluated statistically was the use of anthelmintics. When the overall prevalences of worm eggs from untreated and treated cows were compared by chi-square analysis, no significant difference was found (1 DF, P = 0.05). However, overall prevalences in Areas 2 through 4 were greater in untreated cows than in treated stock; a comparison of Area 1 showed no difference (Tables 20 and 21). It appears that the difference in prevalence between cows of the four areas cannot be attributed to the use

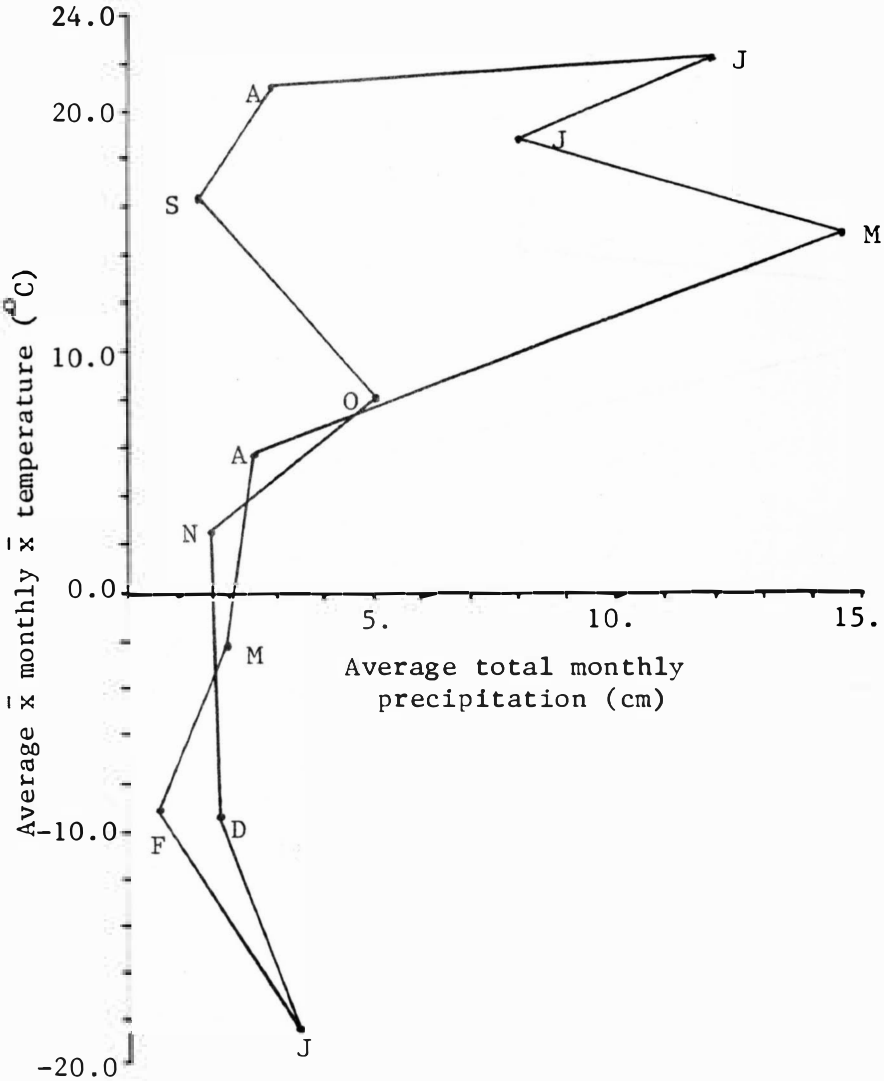
[7]In Area 3, climatic data for Menno, South Dakota (located in Hutchinson Co.) were substituted for Yankton Co., since the Yankton Co. farms were closer to the Menno weather station than to the one at Yankton.

Fig. 13. Climatograph of average climatic conditions in DHIA Area 1, August, 1981 through July, 1982*.



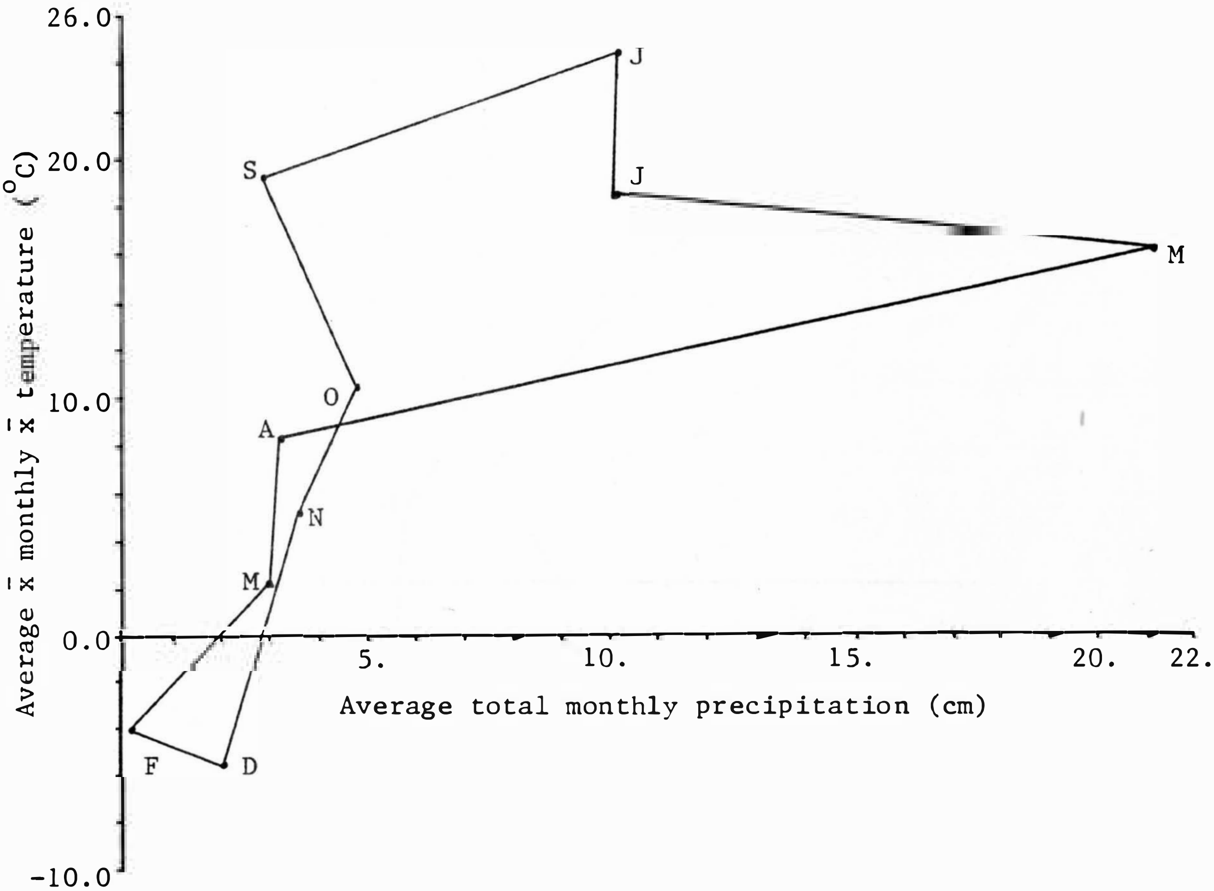
*Climatic conditions for May and June, 1982, not given (USDC, 1982a and 1982b).

Fig. 14. Climatograph of average climatic conditions in DHIA Area 2, June, 1981 through May, 1982*.



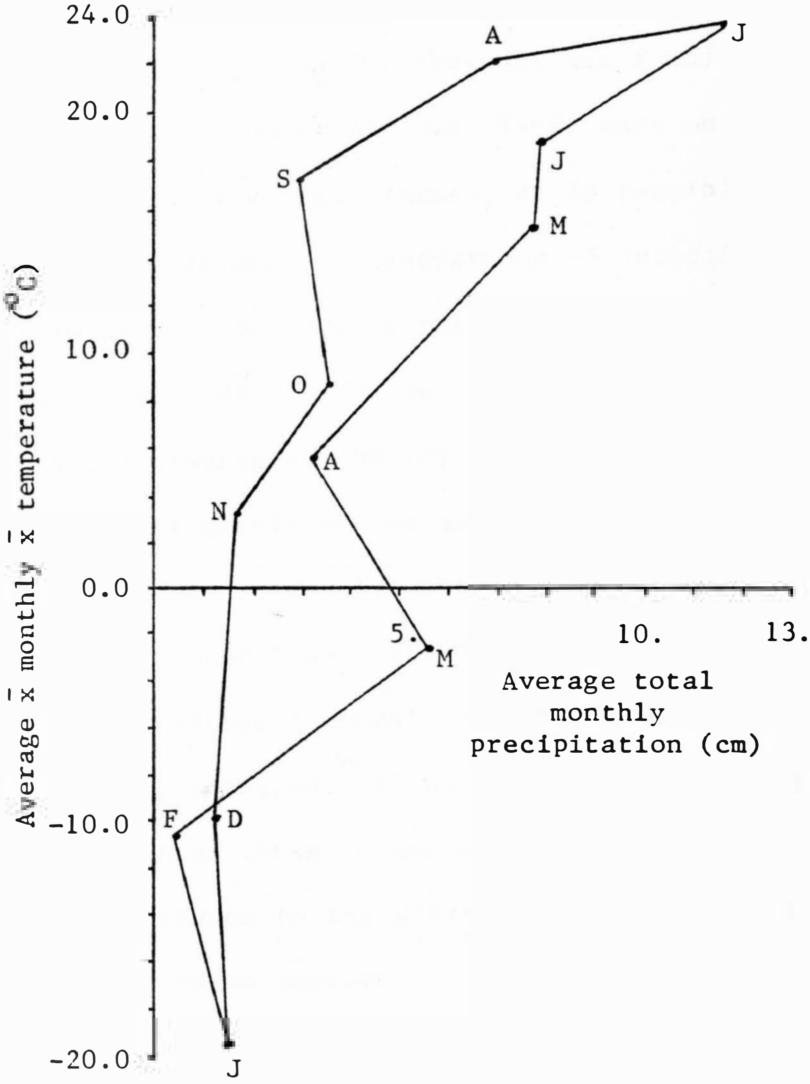
*Source: USDC, 1982a and 1982b.

Fig. 15. Climatograph of average climatic conditions in DHIA Area 3, July, 1981 through June, 1982*.



*Data incomplete for August, 1981, and January, 1982 (USDC, 1982a and 1982b).

Fig. 16. Climatograph of average climatic conditions[*] in DHIA Area 4, June, 1981 through May, 1982[*].



*Source: USDC, 1982a and 1982b.

of anthelmintics. Furthermore, there were no significant differences in total mean egg counts, between untreated and treated cows according to area.

Possibly other management factors were involved; it is not known whether the use of pasture instead of drylot had any great effect on prevalence. The highest overall prevalence was found in Area 2 (Table 19); however the lowest number of cows (N=60) were on pasture in this area, when compared to the other three. It is possible that these 60 cows were exposed to greater concentrations of infective larvae than were the higher numbers of cows in the other areas.

Rothenbacher et al. (1980) reported that variations in management contributed to differences in the prevalence of parasitism and worm egg counts found in dairy cattle of two areas in Pennsylvania. Eastern Pennsylvania cattle are primarily pasture-raised, whereas those in central and western Pennsylvania are usually barn-raised and placed on mud exercise lots. Although overall management was found to be better in the eastern area, prevalence of parasitism and worm egg counts were nearly twice as high as those in the central and western region. The difference was attributed to the greater frequency with which infective stages are transmitted on pastures as compared to drylots.

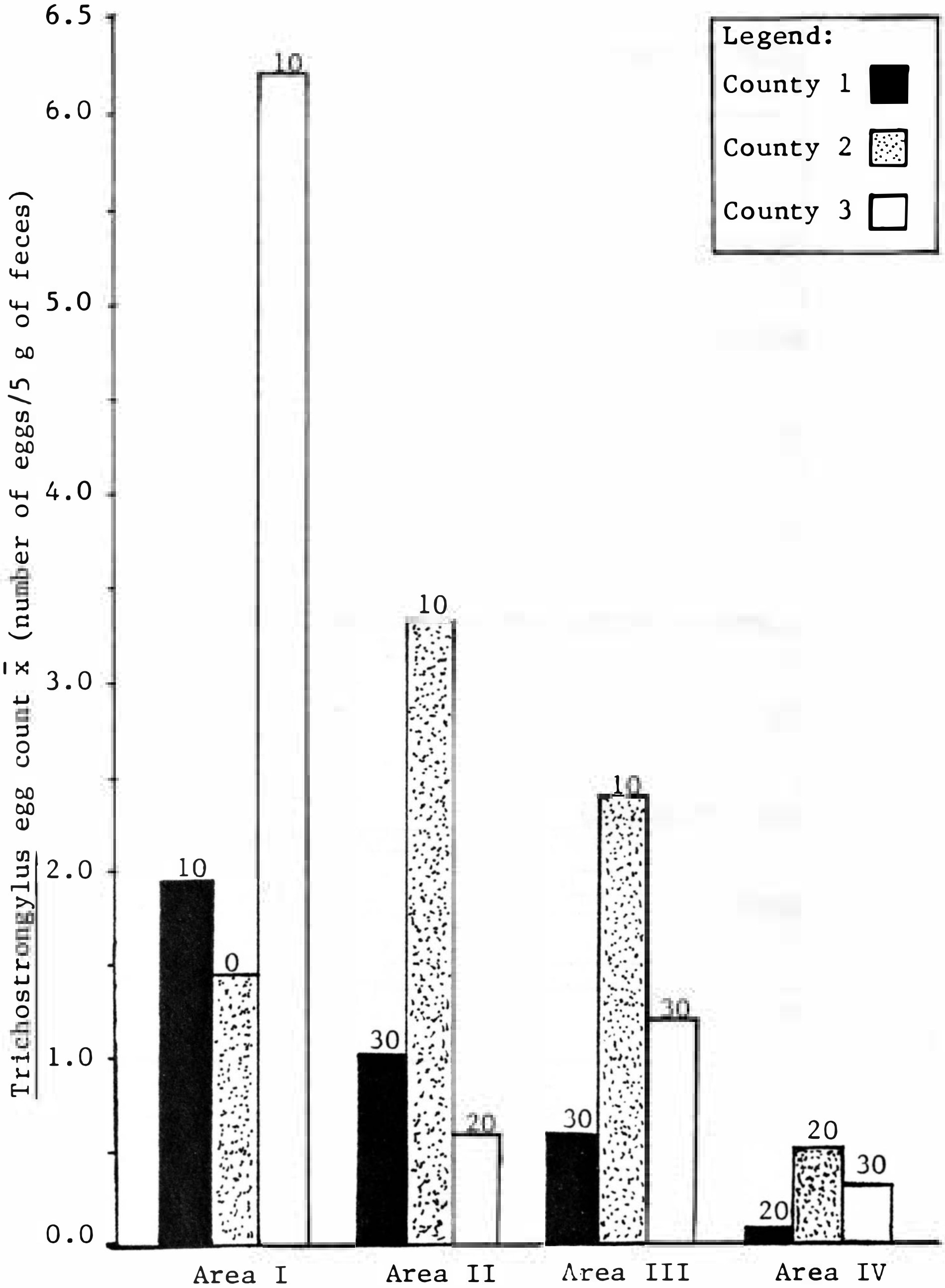
In a survey of gastrointestinal helminths in dairy cattle in two areas of Arkansas, Yazwinski et al. (1980) found that other factors contributed to a significant difference ($P < 0.05$) in strongyle mean egg counts. Climatic conditions and management practices were similar in the west-central and northwest portions of Arkansas. However, higher mean egg counts were found in the west-central area. The bases for the difference were believed to be humidity and the moisture content of vegetation, both of which were higher in west-central than in northwest Arkansas. It is not known whether these were factors in the present study.

ANOVA I showed a significant difference ($P \leq 0.05$) in S. papillosus mean egg counts between DHIA Areas. S. papillosus was found only in Areas 2 and 4 (Table 19). Capillaria was absent from samples collected in Area 3, but the difference in mean egg counts was not significant. All other genera were consistently present in the four areas, and no significant differences were found.

The difference in mean egg counts of Trichostrongylus between counties within areas was significant ($P \leq 0.05$). Its occurrence was fairly widespread, when compared to most of the other generic prevalences (Table 19). Overall, there was no correlation between the number of untreated vs. treated cows in a county and the Trichostrongylus mean egg count (Fig. 17). Climatographs for August, 1981 through July, 1982, for the three counties of Area 1, the area in which the greatest difference occurred, were constructed and evaluated. Only minor differences in climate were noted. Apparently, climatic conditions and the use of anthelmintics did not contribute to the above difference.

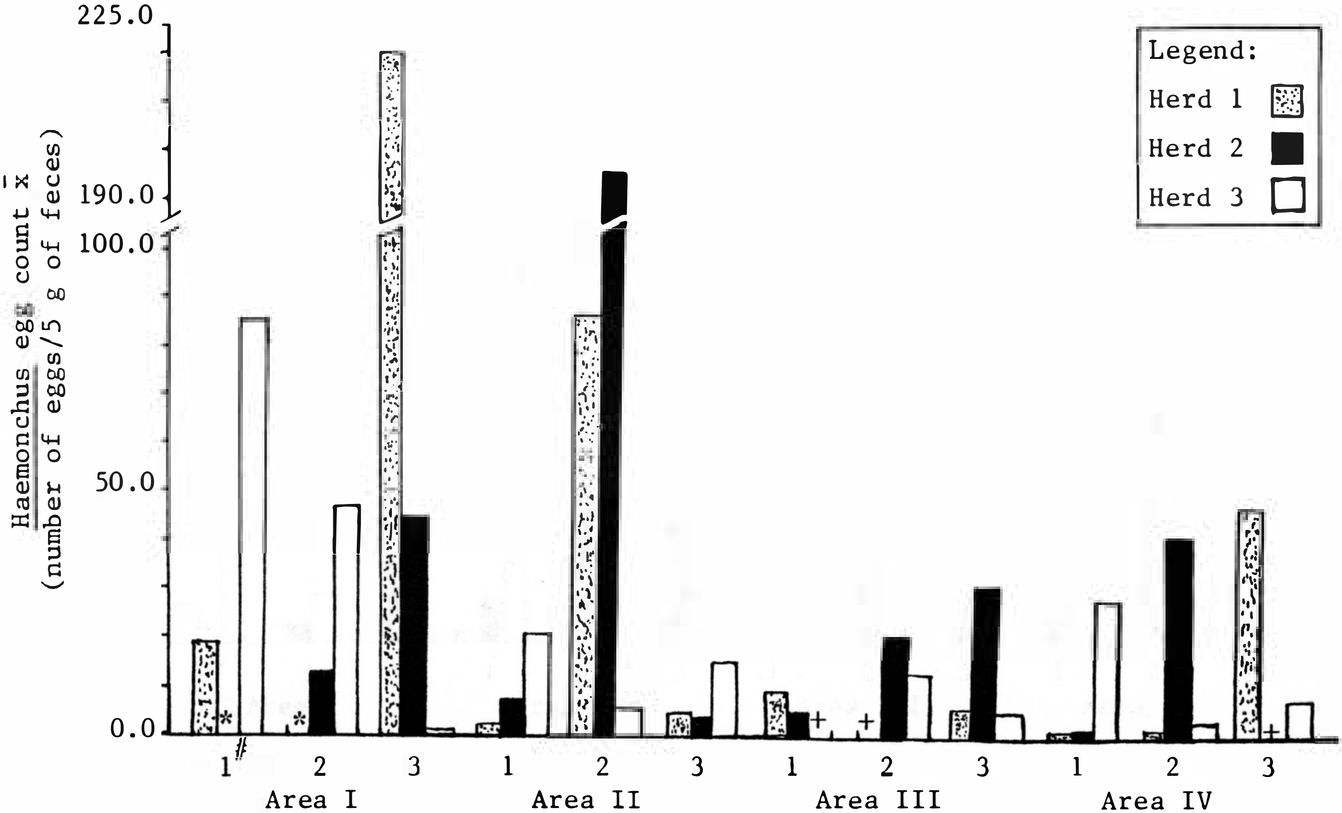
The mean egg counts of Haemonchus, Ostertagia and Trichostrongylus ($P \leq 0.01$), and Cooperia ($P \leq 0.05$) were significantly different between herds within counties. The mean egg counts of the three most prevalent genera are presented by county and area (Figs. 18-20). A highly significant difference ($P \leq 0.01$) in total mean egg

Fig. 17. Egg count means of <u>Trichostrongylus</u> by county and DHIA Area, and the number of treated cows per county*.



* Number at the top of each bar is the number of treated cows per county.

Fig. 18. Egg count means of Haemonchus by herds within counties and DHIA Areas.

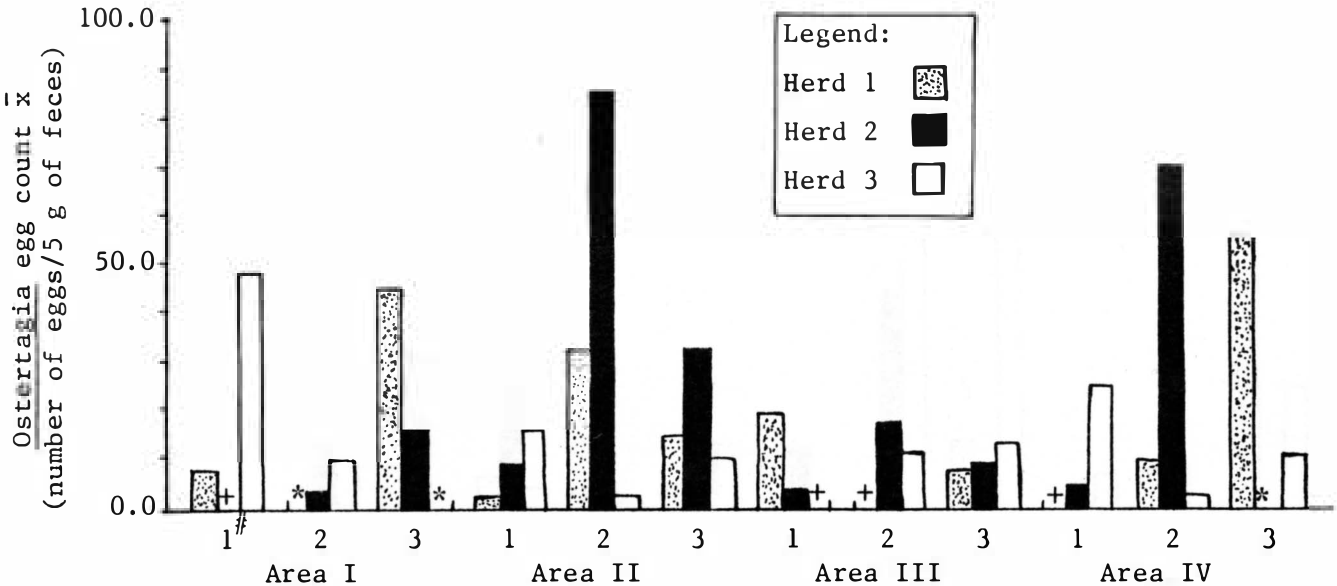


* Egg count $\bar{x}$ = 0.0

\+ Egg count $\bar{x} < 1.0$

\# Numbers below bar triplets denote counties.

Fig. 19. Egg count means of Ostertagia by herds within counties and DHIA Areas.

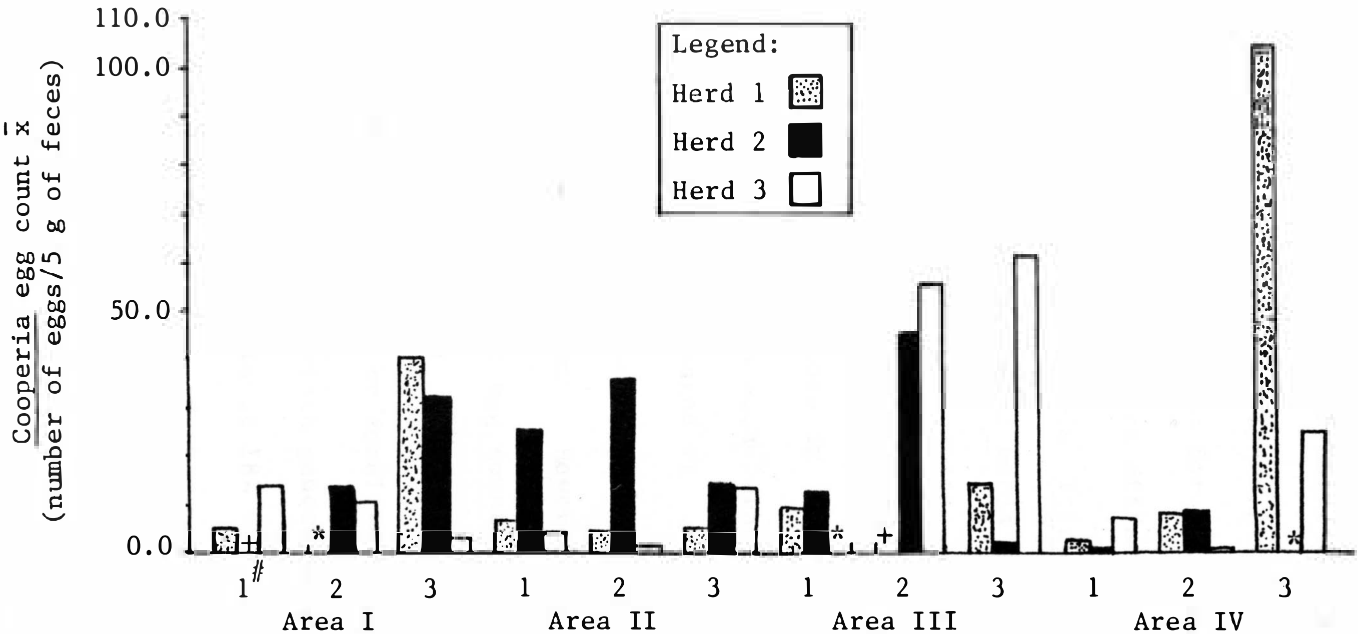


* Egg count x̄ = 0.0

\+ Egg count x̄ < 1.0

\# Numbers below bar triplets denote counties.

Fig. 20. Egg count means of Cooperia by herds within counties and DHIA Areas.



* Egg count $\bar{x}$ = 0.0

+ Egg count $\bar{x} < 1.0$

\# Numbers below bar triplets denote counties.

counts between herds within counties was noted (Fig. 21).

S. papillosus mean egg counts were found to be significantly different ($P \leq 0.01$) between treated and untreated herds within counties by ANOVA II. The average mean egg count was greater in treated than in untreated herds (Table 22). The reasons for this are unknown.

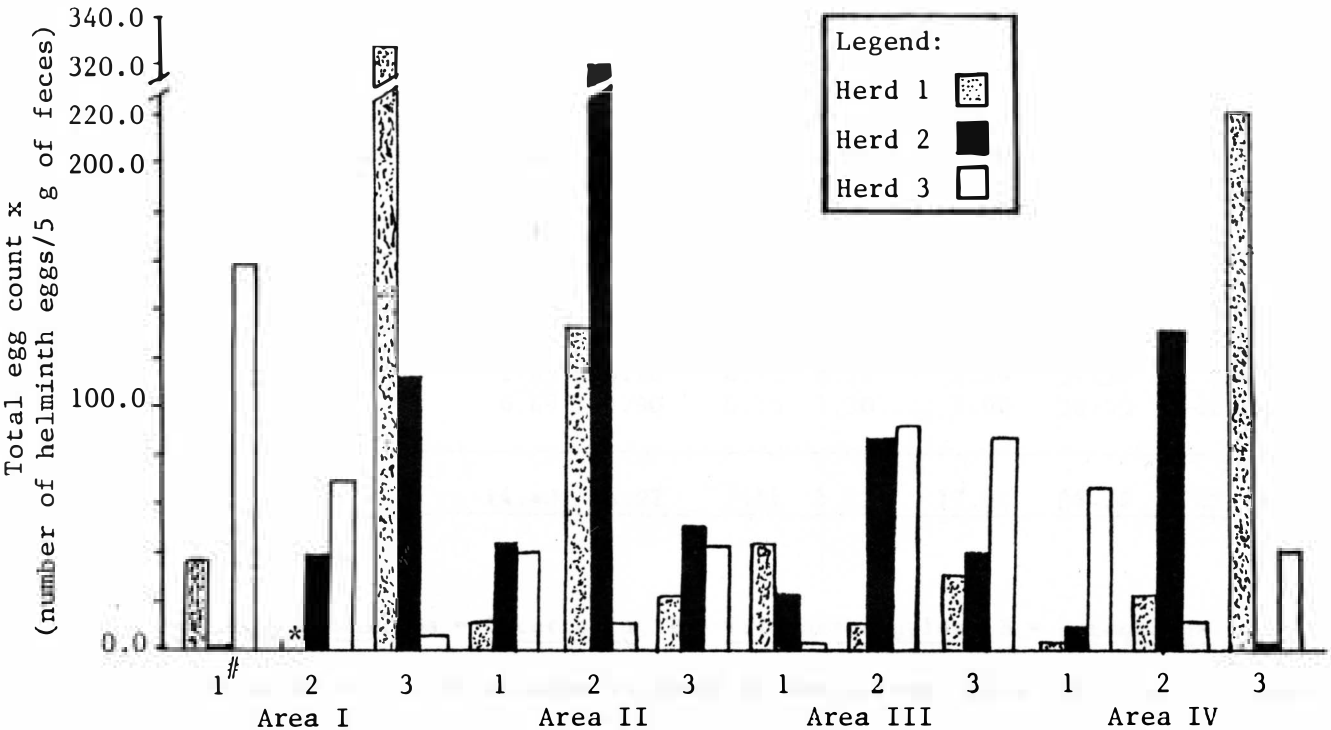
ANOVA II showed highly significant differences ($P \leq 0.01$) in mean egg counts of Oesophagostomum, Ostertagia, Trichostrongylus and Haemonchus between treated and untreated herds within counties. Total mean egg counts were also significantly different ($P \leq 0.01$). The average mean egg counts of the above genera and the average total in untreated herds were greater than those in treated animals (Table 22). It appears there was an advantage to anthelmintic treatment in terms of lower average mean egg counts in treated vs. untreated herds.

The total mean egg counts of untreated and treated herds within areas were not significantly different. However, in Areas 2 through 4 untreated cows had higher total mean egg counts than did the treated animals (Tables 20 and 21). Overall, there seems to have been some advantage to treatment as indicated by fecal worm egg counts.

Eggs of from two to four helminth genera were found in 196 of the 286 positive samples (Table 23). Almost 18% of these samples contained ova of only one genus. Five percent of the samples contained a maximum of six genera.

A sample from an untreated cow in Area 1 yielded the highest individual total and generic egg counts found in the entire project, 1810 helminth ova and 1451 Haemonchus eggs, respectively. In treated animals, the highest total egg count was 882 ova.

Fig. 21. Total egg count means by herds within counties and DHIA Areas.



* Egg count $\bar{x}$ = 0.0

\# Numbers below bar triplets denote counties.

Table 22. Mean egg counts* of the helminth genera which showed a significant difference between treated (T) and untreated (UT) herds within counties and DHIA Areas.

		Generic+ Mean Egg Counts											
DHIA		S		Oe		Os		T		H		Total $\bar{x}$	
Area	County#	T	UT	T	UT	T	UT	T	UT	T	UT	T	UT
1	1	0.00	0.00	4.30	1.40	46.70	3.55	3.70	1.05	84.50	9.80	155.90	18.20
	3	0.00	0.00	0.00	8.15	0.00	31.15	0.00	9.45	0.80	132.65	4.20	219.20
2	2	0.10	0.05	0.80	0.10	32.30	45.00	5.20	2.35	87.30	99.70	131.70	165.50
	3	0.00	0.00	0.70	1.00	22.75	10.00	0.65	0.40	5.45	15.70	38.35	42.20
3	2	0.00	0.00	0.00	0.55	0.60	14.85	0.40	3.35	0.20	15.45	9.20	88.20
4	1	0.05	3.30	0.00	0.50	2.85	25.10	0.10	0.30	1.20	27.50	5.65	64.90
	2	3.10	0.00	0.30	7.70	6.60	71.90	0.15	1.30	2.00	38.50	16.75	128.70
Avg $\bar{x}$		0.64	0.31	0.71	2.69	14.40	26.92	1.11	3.13	19.01	54.26	42.28	110.73

*Number of helminth eggs/5.0 g of feces.

+S = _Strongyloides_; Oe = _Oesophagostomum_; Os = _Ostertagia_; T = _Trichostrongylus_; H = _Haemonchus_.

#Counties not listed are those whose herds, which were included in the survey, were either all treated or untreated.

Table 23. Multiple helminth infections as indicated by frequencies (F) and relative frequencies (RF) of eggs analyzed from DHIA cows in Study 4.

	DHIA Area								Total	
Number of	I (N=90)		II (N=90)		III (N=90)		IV (N=90)		(N=360)	
Genera Found	F	RF	F	RF	F	RF	F	RF	F	RF
0	27	0.30	5	0.06	22	0.24	20	0.22	74	0.21
1	8	0.09	9	0.10	16	0.18	18	0.20	51	0.14
2	10	0.11	27	0.30	14	0.16	11	0.12	62	0.17
3	16	0.18	23	0.26	21	0.23	16	0.18	76	0.21
4	9	0.10	20	0.22	11	0.12	18	0.20	58	0.16
5	12	0.13	5	0.06	4	0.04	4	0.04	25	0.07
6	8	0.09	1	0.01	2	0.02	3	0.03	14	0.04
Total	90	1.00	90	1.01	90	0.99	90	0.99	360	1.00

A comparison of the egg count values found in this and the other studies included herein, with those proposed by Levine and Aves (1956) as being indicative of borderline pathogenicity, would be invalid since two different types of egg recovery, the Wisconsin and the McMaster techniques, were respectively employed. However, all mean egg counts can be considered subclinical.

SUMMARY AND CONCLUSIONS

Four studies were conducted during 1981-82 on gastrointestinal helminth parasitisms of South Dakota dairy cattle. The overall research objective was to determine the current status of such parasitisms. A total of 925 fecal samples were collected in several situations, primarily from Holstein cattle. Each sample was quantitatively and qualitatively analyzed for helminth ova, and photomicrographs were taken of eggs of all genera found.

In Study 1, nearly 80% of the samples obtained from dairy show cattle were positive for nematode eggs. The fact that no cestode ova were found was possibly due to error on the part of the author. The 11 nematode genera found in the project were detected in samples from the last four livestock shows (Group 2). Haemonchus and Cooperia were the most prevalent. There was a significant difference between Groups 1 and 2 in the prevalence of worm eggs in cattle feces. The season of year when samples were obtained was possibly a factor. When all samples were considered together, overall prevalence did not vary greatly with host age.

In Study 2, seasonal trends in parasitism in two Brookings County herds were investigated. Eleven helminth genera were found in 87% of samples collected from the Misar herd. Haemonchus was the most prevalent and had the highest average mean egg count. Cooperia, Ostertagia and Trichostrongylus were also relatively prevalent. Overall prevalence did not vary significantly with host age; however, the highest value was found in lactating cows. Total monthly prevalence of helminth ova in cow feces was 100% for 8 of 12 months. Calf samples yielded the highest total mean egg count and, usually, the highest monthly means.

Seasonal climatic variations possibly contributed to monthly differences in prevalence and total mean egg counts in cows of the Misar herd. Bioclimatographs indicated that climatic conditions from June through August, 1981, were optimal for pasture transmission of *Haemonchus* in Brookings, South Dakota. Prevalence and mean egg count of *Haemonchus* seemed to correspond with climatic conditions. Peaks in the two parameters occurred in June, 1982. Total monthly prevalence and mean egg count roughly paralleled those of *Haemonchus*. The results and conclusions must be considered cautiously, given the limitations of the research.

Over half of the samples obtained from the Nelson herd contained worm eggs. Of the 10 genera found, *Cooperia* had the highest mean egg count and was the most prevalent. *Haemonchus*, *Ostertagia* and *Trichostrongylus* were also frequently encountered. There was a highly significant difference in overall prevalence between the three ages of cattle. Yearlings showed the highest prevalence, total mean egg count and, usually, the highest total monthly mean egg counts.

Climatic conditions for June through August, 1981, were within the optimal range for development and survival of *Cooperia*. Monthly prevalence and mean egg count of *Cooperia* peaked in October, 1981. The two parameters seemed to correspond to climatic conditions throughout most of the 12-month period. Total monthly prevalence was nearly identical to that of *Cooperia*. Respective mean egg counts were similar.

Conditions at the Nelson farm were more consistent than at the Misar farm. However, variability between individual cows of both herds was not measured; therefore it cannot be concluded that the observed variations in prevalences and mean egg counts were due solely to seasonal climatic fluctuations.

In Study 3, nearly 76% of the samples collected from Black Hills dairy cattle in October, 1981 (Group 1) contained eggs of nine nematode genera. No cestode ova were found. Overall prevalence was significantly different, according to host age. The highest total mean egg count was found in yearling samples. Helminth ova of eight genera were found in over 70% of samples obtained in March, 1982 (Group 2). There was a highly significant difference in prevalence between the three ages of cattle. Host age was inversely related to total mean egg count.

In both groups, Haemonchus was the most prevalent genus, while Cooperia had the highest average mean egg count. All yearling samples contained helminth ova. There was no significant difference in either prevalence or total mean egg count between the two groups. However, a considerably higher total mean egg count was noted in Group 2. This may possibly be attributable to a type of spring rise phenomenon.

In Study 4, approximately 80% of the samples obtained during the DHIA survey were worm egg-positive. Overall prevalence varied significantly, according to area but total mean egg counts did not. There was no significant difference in overall prevalence between untreated and treated cows. There were few climatic differences between the four areas. It appeared that anthelmintic administration and climate were not contributing factors to the differences in prevalence between the four areas. It is unknown if the use of pasture vs. drylot was a factor in this study. The three most prevalent genera, *Haemonchus, Ostertagia* and *Cooperia,* respectively, had the highest mean egg counts of the nine helminth genera found.

The significant difference in *S. papillosus* mean egg counts between DHIA Areas was due to its isolated occurence in herds of only two areas. The significant differences in *Trichostrongylus* mean egg counts between counties within areas was apparently not due either to climate or to the use of anthelmintics.

Significant differences in generic and total mean egg counts between all herds, and between untreated and treated herds, within counties and DHIA Areas were reported. The average mean egg count of *S. papillosus* was greater in treated animals than that in untreated cows. However, the average mean egg counts of *Oesophagostomum, Ostertagia, Trichostrongylus* and *Haemonchus* and the average total mean were greater in untreated cows than those in treated animals. There appeared to be an advantage to treatment in terms of lower average mean egg counts in treated vs. untreated herds.

The four studies established the widespread prevalence of subclinical gastrointestinal helminth parasitisms in selected groups of South Dakota dairy cattle, including some of the best managed herds in the state. A total of 12 helminth genera were found. Of these, *Haemonchus* was the most prevalent. Most samples contained from two to four genera each. A maximum of seven genera was found in one sample.

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APPENDIX

DESCRIPTIONS, MEASUREMENTS AND PHOTOMICROGRAPHS OF EGGS OF GASTROINTESTINAL HELMINTHS OF CATTLE

The ova of some helminth genera are easily identifiable; others are not. The eggs of Oesophagostomum, Cooperia, Ostertagia, Trichostrongylus, and Haemonchus are, at times, difficult to distinguish because of their respective similarities. However, ova of Strongyloides, Bunostomum, Nematodirus, Neoascaris, Trichuris, Capillaria, and Moniezia are distinctive.

Of the genera found in this project, Strongyloides, Bunostomum, and Neoascaris are each represented by a single species in cattle (Shorb, 1939). The other nine genera encountered are each represented by two or more species. Descriptions of the eggs of each genus or species as found in fresh feces are given below, and measurements are found in Table 1.

Photomicrographs of helminth ova are provided (Figs. 1-10). Frequently, organisms other than worm eggs were found during fecal examinations. Mite eggs (Fig. 11) and coccidia oocysts (Fig. 12) are similar to helminth ova in appearance, but can readily be distinguished.

Strongyloides papillosus (Fig. 1)

The eggs are thin-walled, non-operculated and each contains a fully developed first-stage larva (Shorb, 1939). The eggs have similar, wide, slightly flattened poles and similar, barrel-shaped side-walls (Thienpont et al., 1979).

Bunostomum phlebotomum (Fig. 2)

The thick-walled eggs are more rectangular than those of the other nematode genera found in this project (Shorb, 1939; Krug and Mayhew, 1949). The eggs have nearly parallel sides, blunt ends and four to eight darkly stained blastomeres (Dewhirst and Hansen, 1961; Thienpont et al., 1979).

Oesophagostomum (Fig. 3)

The nearly similar side-walls of the egg are markedly barrel-shaped and the poles wide and round (Thienpont et al., 1979). The eggs have four to sixteen blastomeres and relatively thick shells (Shorb, 1939; Dewhirst and Hansen, 1961).

Cooperia (Fig. 4)

Characteristics of a typical egg include a thin, chitinous, smooth-surfaced shell, nearly similar small poles and flattened, parallel sides (Dewhirst and Hansen, 1961; Thienpont et al., 1979). The eggs usually contain 16 to 32 cells.

Ostertagia (Fig. 5)

The eggs have symmetrical, not very wide poles, slightly barrel-shaped sides, and a smooth shell (Thienpont et al., 1979). A large number of blastomeres nearly fill the entire egg (Dewhirst and Hansen, 1961).

Trichostrongylus (Fig. 6)

The eggs are irregularly shaped, with dissimilar, not very wide poles, one of which is more rounded than the other, and one flattened side-wall (Shorb, 1940; Thienpont et al., 1979). Typically, 16 to 32 cells are found in each egg (Dewhirst and Hansen, 1961).

Haemonchus (Fig. 6)

One side of the oval-shaped egg is more curved than the other and the poles are unequally convex (Veglia, 1915). The eggs contain four blastomeres (Veglia, 1915), but later are nearly filled with many, barely distinguishable cells (Thienpont et al., 1979).

Nematodirus (Fig. 7)

These are the largest nematode eggs found in cattle feces. Each egg contains two to eight large, darkly stained blastomeres (Dewhirst and Hansen, 1961; Thienpont et al., 1979).

Neoascaris vitulorum (Fig. 8)

The nearly spherical egg contains a single cell. The eggshell is thick, albuminous and uniformly mammilated on the surface (Shorb, 1939; Thienpont et al., 1979).

Trichuris (Fig. 7)

The eggs are lemon-shaped, amber in color and have bipolar opercula (Dewhirst and Hansen, 1961; Thienpont et al., 1979). Granular, unsegmented contents are enclosed within the thick shell.

Capillaria (Fig. 9)

These eggs also have bipolar plugs and unsegmented, granular contents (Shorb, 1939). They differ from those of Trichuris by being smaller and having nearly parallel sides (Thienpont et al., 1979).

Moniezia (Figs. 4 and 10).

The irregularly rounded to more or less tri- or quadrangularly shaped eggs have thick, grey shells (Thienpont et al., 1979). Each egg contains a hexacanth embryo surrounded by a membrane, the pyriform apparatus (Morgan and Hawkins, 1949). Eggs of *M. benedeni* are usually more cuboidal than those of *M. expansa.*

Table 1. Measurements of eggs of some gastrointestinal helminths of cattle.

Genus or Species	Length (μ) Range	Length (μ) Avg	Width (μ) Range	Width (μ) Avg	Reference
Strongyloides papillosus	56- 64		34- 42		Basir, 1950
	47- 65		25- 26		Thienpont et al., 1979
Bunostomum phlebotomum	88-104	96.5	47- 56	50.3	Shorb, 1939
	52-106		48- 60		Schwartz, 1924
Oesophagostomum spp.					
O. radiatum	75- 98	85.8	46- 54	49.2	Shorb, 1939
O. venulosum[*]	85-105	92.7	47- 59	52.2	Shorb, 1939
Cooperia spp.					
C. bisonis	91- 99		41- 49		Levine, 1980
C. curticei[+]	68- 82		34- 42		Levine, 1980
C. oncophora	74- 95	85.7	36- 44	39.4	Shorb, 1939
C. pectinata	67- 80	72.7	31- 38	34.5	Shorb, 1939
C. punctata	69- 83	76.6	29- 34	32.2	Shorb, 1939
Ostertagia spp.					
O. lyrata	75- 85		34- 42		Rose, 1960
O. ostertagi	74- 90	78.5	38- 44	40.1	Shorb, 1939
Trichostrongylus spp.					
T. axei	70-108	86.0	30- 48	40.0	Thienpont et al., 1979
T. colubriformis[+]	79-101	87.5	39- 47	43.9	Shorb, 1939
T. vitrinus	85-125	101.0	37- 55	47.0	Cunliffe and Crofton, 1953
Haemonchus spp.					
H. contortus	72- 92	81.7	39- 47	43.8	Shorb, 1939
H. similis	64- 82	70.8	39- 49	44.5	Shorb, 1939

Table 1, cont.

Genus or Species	Length (μ) Range	Avg	Width (μ) Range	Avg	Reference
Nematodirus spp.					
N. helvetianus	160-230		85-115		May, 1920
	184-233	212.0	84-110	96.7	Shorb, 1939
N. spathiger	150-220		80-110		May, 1920
	175-260	200.0	106-110	108.0	Thienpont et al., 1979
Neoascaris vitulorum	69- 93	80.0	62- 77	67.8	Shorb, 1939
	75- 95		60- 75		Soulsby, 1968
Trichuris spp.					
T. discolor	60- 73		25- 35		Levine, 1980
T. ovis	70- 80	75.0	30- 42	35.0	Levine, 1980
Capillaria spp.					
C. bovis	41- 54	47.6	21- 25	22.3	Shorb, 1939
C. brevipes		50.0		25.0	Levine, 1980
Moniezia spp.					
M. benedeni		60.0		60.0	Ivens et al., 1978
	80- 90		80- 90		Thienpont et al., 1979
M. expansa	56- 70		56- 70		Ivens, et al., 1978
	50- 60		50- 60		Thienpont et al., 1979

*Host was a goat.

+Host was a sheep.

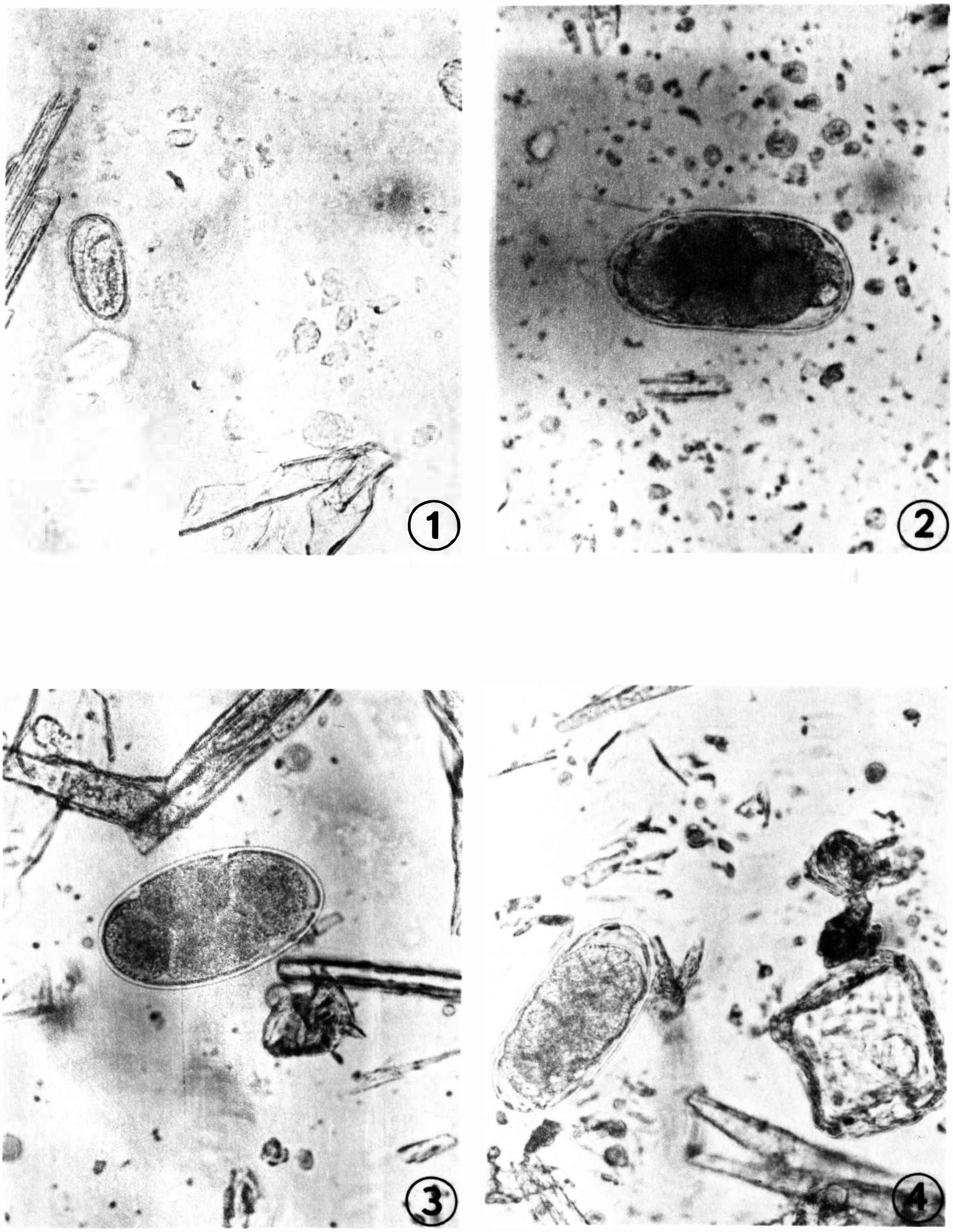
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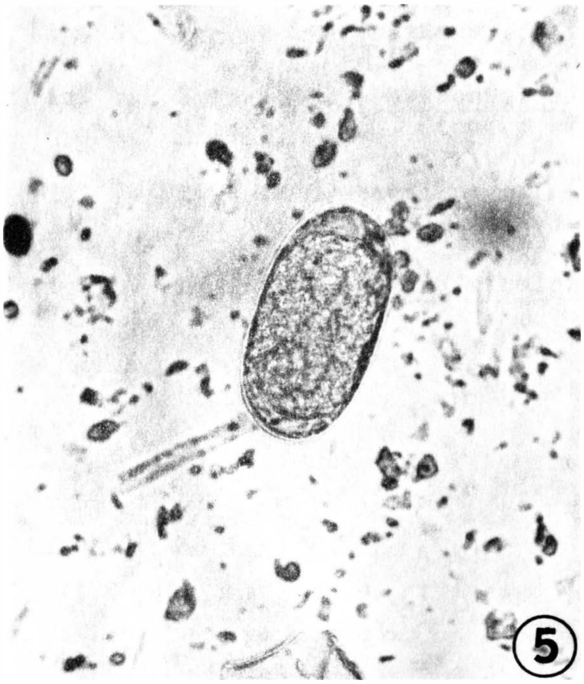
Fig. 1. Egg of Strongyloides papillosus, 46.4 x 23.2 μ (980X).

Fig. 2. Egg of Bunostomum phlebotomum, 98.6 x 50.0 μ (940X).

Fig. 3. Egg of Oesophagostomum sp., 87.4 x 51.0 μ (1000X).

Fig. 4. Eggs of Cooperia sp. (left), 92.4 x 41.8 μ, and Moniezia sp. (right), 71.4 x 61.0 μ (950X).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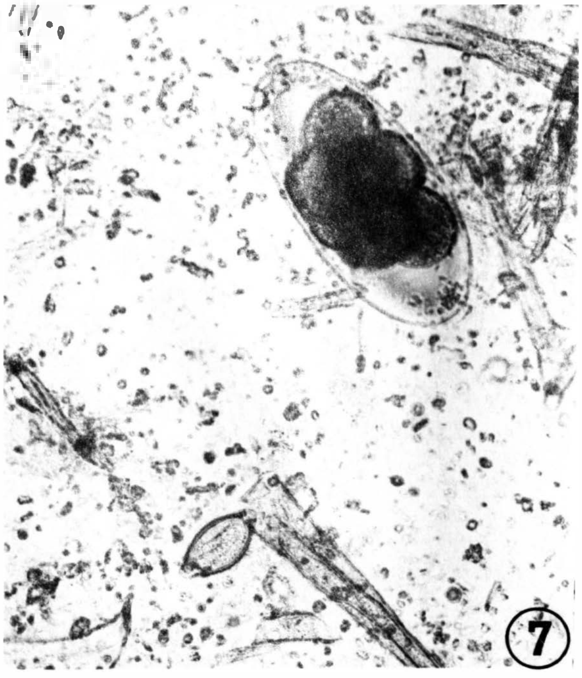
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Fig. 5. Egg of <u>Ostertagia</u> sp., 91.3 x 44.2 μ (975X).

Fig. 6. Eggs of <u>Trichostrongylus</u> sp. (upper), 133.8 x 47.8 μ, and <u>Haemonchus</u> sp. (lower), 77.4 x 47.1 μ (950X).

Fig. 7. Eggs of <u>Nematodirus</u> sp. (upper), 210.2 x 95.3 μ, and <u>Trichuris</u> sp. (lower), 64.2 x 34.3 μ (460X).

Fig. 8. Egg of <u>Neoascaris vitulorum</u>, 79.2 x 78.9 μ (930X).


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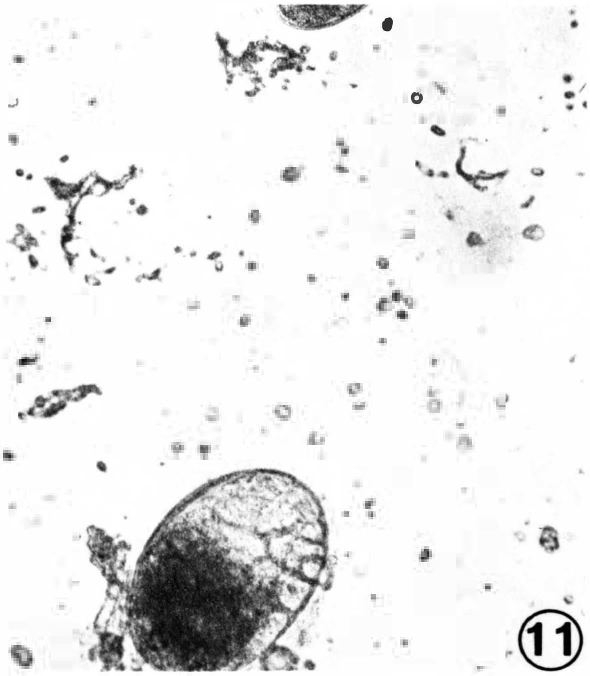
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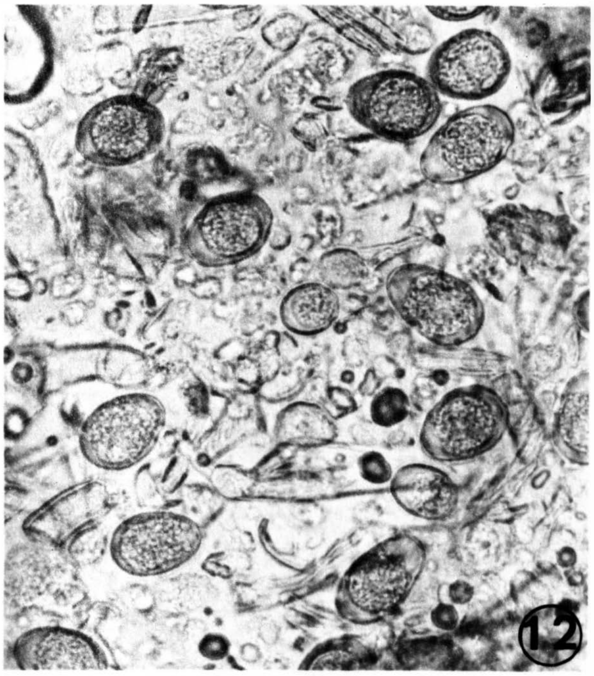
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Fig. 9. Egg of *Capillaria* sp., 51.0 x 23.9 μ (1020X).

Fig. 10. Eggs of *Moniezia* sp. (left) 63.9 x 62.1 μ and (right) 62.4 x 56.7 μ (900X).

Fig. 11. Mite egg (900X).

Fig. 12. *Eimeria* spp. oocysts (975X).

FECAL SAMPLE FIELD COLLECTION DATA SHEET

Sample No. ________ County ______________________________ Date __________

Name of Owner ________________________________ Age of animal ____________

Address ____________________________________ Sex of animal ____________

Ever on pasture? No ___ Yes ___; season of year & how long ______________

Ever wormed? No ___ Yes ___; when & with what drug ____________________

Milking? No ___ Yes ___; Other comments: ______________________________

____

Sample No. ________ County ______________________________ Date __________

Name of Owner ________________________________ Age of animal ____________

Address ____________________________________ Sex of animal ____________

Ever on pasture? No ___ Yes ___; season of year & how long ______________

Ever wormed? No ___ Yes ___; when & with what drug ____________________

Milking? No ___ Yes ___; Other comments: ______________________________

____

Sample No. ________ County ______________________________ Date __________

Name of Owner ________________________________ Age of animal ____________

Address ____________________________________ Sex of animal ____________

Ever on pasture? No ___ Yes ___; season of year & how long ______________

Ever wormed? No ___ Yes ___; when & with what drug ____________________

Milking? No ___ Yes ___; Other comments: ______________________________

____

Sample No. ________ County ______________________________ Date __________

Name of Owner ________________________________ Age of animal ____________

Address ____________________________________ Sex of animal ____________

Ever on pasture? No ___ Yes ___; season of year & how long ______________

Ever wormed? No ___ Yes ___; when & with what drug ____________________

Milking? No ___ Yes ___; Other comments: ______________________________

____

____

FECAL SAMPLE DATA SHEET

Sample No. __________ Date collected __________ County ____________________

Owner ____ Age of animal ____________

Address ______________________________________ Sex of animal ____________

Ever wormed? No ___ Yes ___; when & with what drug ____________________

Milking? No ___ Yes ___. Other comments: ______________________________

____

Date analyzed __________

Parasite	Number of eggs/oocysts	
	/2.5 g feces	/5.0 g feces
Haemonchus		
Ostertagia		
Oesophagostomum		
Trichostrongylus		
Cooperia		
Nematodirus		
Bunostomum		
Trichuris		
Capillaria		
Other		
Total number of worm eggs		
Coccidia		

Additional comments: ____

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