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The epidemiology of nematode infections in ewes and lambs on irrigated pastures was investigated during one reproductive cycle in a commercial operation in Central Oregon. Primary objectives were to determine the sources of parasitism, the effect on lamb weight gains, and the effectiveness of control procedures in minimizing the detrimental effects of parasitism. Methodology included fecal nematode egg counts, animal necropsies and the use of tracer lambs. The relationships between blood trace mineral levels, parasitism and suboptimal weight gain in lambs and calves were also examined.

High pasture burdens of infective larvae were found in spring and early summer from overwintering larvae and in late summer from autoinfestation by ewes and lambs. Lamb weight gain from March until mid-July was 0.48 lb/head/day. From mid-July until September when the study terminated, lamb weight gain declined (-0.03 to 0.28 lb/head/day). Parasite burdens were low to moderate early in the grazing period, but increased markedly during the mid-July to September period, despite monthly deworming of the flock. It

appeared that parasite burdens, high summer temperatures and the lack of shade, and possibly low cobalt and selenium levels were responsible for the late summer decline in weight gain.

Evaluation of control measures indicated that intensive deworming prior to parturition eliminated arrested or inhibited larvae in the ewes. The periparturient relaxation of resistance, however, permitted development of infective larvae acquired from the pre- and post-lambing pastures. Maturation of these larvae caused a marked rise in post-parturient egg per gram counts of the ewes with subsequent relatively high rates of pasture contamination. Monthly deworming of the flock was moderately effective in reducing parasite burdens and pasture contamination. Alternate grazing of pastures by cattle and sheep, and *ad lib*. feeding of phenothiazine in salt were not effective as control measures.

An Epidemiologic Study of the Seasonal Incidence of Nematode Parasites in Sheep on Irrigated Pastures in Central Oregon

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INTRODUCTION

Expanding human populations have required increased meat production, but have caused decreased availability of land for grazing animals. Economical production of red meat is a major concern of the livestock industry and consumers in the United States (US). To meet these needs, livestock producers must manage their animals intensively, obtaining greater yields per acre and production of animals at the lowest possible cost.

The US sheep industry has faced economic deterrents to optimal production in recent years, including rising grain prices, costs of labor, land valuation, and the 1972 executive order which banned the use of toxicants and consequently eliminated effective predator control on rangelands. Range flocks once comprised the predominant type of sheep husbandry in the western states. Oregon alone maintained 2-1/4 million sheep in 1920 on rangelands (Anonymous 1976). Range flocks in Oregon declined to 410,000 in 1976 (Anonymous 1976). Under fenced pasture management, lambs are fattened on available pasture forage and marketed directly from the pastures, thereby eliminating the necessity and expense of feeding concentrates.

Performance of grazing lambs, as measured by average daily gain (ADG), is an index to economical production. The key factors which impair optimum performance include: genetics, nutritional value of available forages, mineral deficiencies, crowded feeding conditions, diseases, stress induced by heat or handling and parasitism (Ensminger 1962).

Gastrointestinal parasitism is a major detrimental factor in weight gain performance of grazing animals. The annual parasite induced loss in US sheep production was estimated as nearly 40 million dollars in 1956 and 24.8 million dollars in 1965 (Nordquist and Pals 1956; USDA 1965).

The economic status of the sheep industry in the US ranks far below cattle and swine in terms of total farm value (Ensminger 1962). The value of the sheep sold in Oregon in 1974 was $10,192,000 (Anonymous 1976). Conversely, the sheep industry in a number of foreign countries (e.g. Argentina, Australia, Great Britain, and New Zealand) is of major agricultural and economic importance. In these countries, much emphasis is placed on wool and meat production, whereas meat production is the primary consideration in the US. In Australia, Great Britain and New Zealand ranchers have relied extensively for many years on pastoral husbandry and fenced pastures for sheep production. Consequently, much attention has been focused on practical management practices on intensively used pastures. By comparison, the current knowledge in the US in this area is limited.

In Oregon a multiplicity of climatic conditions influence livestock husbandry. The National Oceanic and Atmospheric Administration

(NOAA)(1975) recognizes nine distinct climatic regions in the state. The climate in Western Oregon is comparable to the climate in Great Britain in that both areas possess high rainfall and moderate temperatures. The northern Cascades, the coastal area and the Willamette Valley are the regions of highest annual precipitation averaging 82.80, 78.94 and 52.39 inches respectively, with most rainfall occurring from October through March. Temperatures in Western Oregon are mild, averaging 52.6 F annually. The normal summer (June, July, August) average maximum temperature is 76.4 F. The average minimum temperature in the winter (December, January, February) is 34.4 F in Western Oregon in the Willamette Valley, with infrequent freezing temperatures (NOAA 1975). It is possible that some results from Great Britain and other areas could be applied to areas in Western Oregon (Levine and Clark 1961; Donald 1968; James and Johnstone 1967; Reid and Armour 1972). However, the lack of detailed climatological data in most papers make such comparisons difficult or impossible. Nevertheless, clinical evidence indicates climate in Western Oregon is favorable for most of the economically important protozoan and metazoan parasites of sheep.

Central and Eastern Oregon differ markedly from Western Oregon in climate, hence each region presents its own array of livestock management and husbandry problems. The complexity of livestock production is exemplified in Central Oregon. Intensive natural ranching is prevented by the low annual rainfall (less than 10 inches annually) which limits forage growth and abundance. This situation is remedied by the use of irrigation water from collection reservoirs in the Cascade Mountains. Extensive overhead irrigation in Central Oregon permits grain and livestock production in the area. The volcanic soil has a spectrum of mineral deficiencies which precluded large scale livestock production until they were recognized and corrected by supplementation. This removed a significant deterrent to intensive livestock production in the area (Church et al. 1971). Despite correction of obvious major problems, a summer decline in weight gain performance still occurs. The reason for lowered summer weight gains is obscure, but some ranchers feel that the low gains result from gastrointestinal parasitism.

Intensive investigations have not been conducted on gastrointestinal parasitism in sheep in Central Oregon. Although plot studies can be conducted, they do not accurately reflect farm conditions (Michel 1974). It is necessary to investigate the epidemiology and acquire information that will permit tailoring of nematode parasite control measures for each individual farm (Gordon 1973). To do this, the investigator must appraise farm conditions by means of an "epidemiological excursion", and the farmer must use similar techniques to continuously appraise his operations and take whatever remedial action is necessary (Michel 1974).

This investigation was conducted to determine the extent of gastrointestinal parasitism and its influence on weight gain performance in lambs on an intensively managed ranch in Central Oregon, which utilized irrigated pastures. A tentative management program was developed and implemented to assist in parasite control. Parasite burdens of the sheep were monitored throughout one grazing season to evaluate the effectiveness of the control program and to determine when and where parasites were acquired. Climatologic data were collected to determine when development of infective larvae and transmission could occur. Based on the study results, additional recommendations were formulated to assist in controlling sheep gastrointestinal parasites in Central Oregon.

LITERATURE REVIEW

The epidemiology of gastrointestinal parasitism in grazing animals involves the investigation of the causes and control of helminth diseases. It includes all the elements contributing to the occurrence or non-occurrence of the disease in a population (Guralnik 1972). A thorough understanding of those factors which influence helminth disease will permit the intelligent application of practical control measures (Michel 1969). Many aspects of gastrointestinal parasitism in sheep have been extensively studied and reported in the literature.

This review is not all encompassing, but will be limited to those aspects of parasitism in sheep relevant to this study. The salient aspects of gastrointestinal parasitism in sheep include (1) the nature of natural infections, (2) the clinical signs and effects of gastrointestinal parasitism, (3) life cycles and environmental factors influencing parasitism, (4) epidemiological investigations, (5) trace-mineral involvement and (6) control measures.

It has long been recognized that gastrointestinal nematode parasites constitute a problem in most sheep-raising areas of the world. Parasite free flocks in all probability do not exist (Spedding 1956a; Lucker and Foster 1957; Soulsby 1965; Levine 1968). Reasons for this world-wide problem are that parasites are extremely prolific and successful, and control is extremely difficult (Spedding 1956b; Donald 1968; Bradley 1972).

Two types of nematode parasitism have been described by Whitlock (1955). The first, parasitiasis, is balance between parasite and host characterized by small burdens with absence of significant lesions or clinical signs. This form of parasitism approaches a commensal relationship. It occurs typically in older animals, which serve as reservoirs,and provides a continuum for maintainance of the parasite species. The second, parasitosis, is an imbalance between the parasite and the host, characterized by heavier burdens with associated clinical signs and lesions. With nematode parasitism, parasite numbers, pathogenicity of species and or strains and host resistance are the major factors determining the relationship. Parasitosis may be either primary, e.g. due entirely to the parasite, or secondary, in which the host is weakened by some other factor. The pathogenesis of nematode infections will be discussed by first presenting results from experimental infections followed by epidemiological studies.

Under natural conditions, parasite burdens are composed of mixed populations of nematode species. Therefore, the effects of the parasite on the host, whether subclinical or clincial, depend on the net effect of the entire parasite populations (Soulsby 1965). Experimental work has been conducted on the pathology of infections with various nematode species individually, but limited information has been published regarding the pathogenicity of mixed infections. Results of monospecific parasite studies nevertheless serve to elucidate the pathologic capabilities of nematode parasites commonly found in Oregon sheep.

Whitlock (1955) contended that *Haemonchus contortus* was the only ovine parasite capable of causing primary disease. Sommerville (1954), Gibson (1954a) and Seghetti and Senger (1958) however, demonstrated primary disease caused by *Ostertagia circumcincta*, *Trichostrongylus axei* and *Nematodirus helvetianus*. The clinical signs of primary gastroenteritis due to *H. contortus* have been widely documented. The predominant sign is anemia, with frequently concurrent hydremia and edema. Other less constant signs include progressive loss of weight, weakness, rough hair coat, anorexia and intermittent constipation. Chronic hemonchosis can develop as a sequel to clinical disease (Whitlock 1955). Mortality in an infected flock is frequently high.

In gastrointestinal helminthiasis caused by other species or by mixed infections, primary or secondary parasitic disease is manifested by such clinical signs as decline in growth rate, anorexia, diarrhea, vomiting, edema, fever and nervous disorders (Symons 1969). Although mortality does occur, it is relatively infrequent. Morbidity rather than mortality is the more common and severe cause of production losses. The average annual loss from internal parasites during 1951 to 1960 in sheep and goats combined was nearly $17.2 million from morbidity and $7.6 million from mortality (USDA 1965).

Poor rate of growth in lambs, and even weight loss, is one of the most widely described effects of parasitism. This is caused by a complex of pathophysiologic alterations, including impaired digestion, anorexia and competition by the parasites for food. Gibson (1954a, 1955) found that lambs administered moderate numbers (100,000 larvae) of *T. axei* gained 30 lb per head less than comparable but worm-free control lambs over a period of 1 year. A similar result was obtained in lambs experimentally infected with *T. axei* at lower infection levels (48,000 to 115,000 larvae) by Spedding (1953); worm-free controls gained an average of 16 lb per lamb per year more than the infected animals. Spedding (1955) in a later paper concluded that even at subclinical levels, the loss was considerable and a marked deterrent to economical production of meat. In pasture experiments simulating natural conditions, the live-weight gain of worm-free control lambs was significantly ($p=0.05$) greater than in subclinically infected lambs. Loss of productivity was on the order of 15%. After a decline in live-weight gain, it was found that lambs did not regain the lost weight although they may reattain their normal rate of gain (Spedding 1954c).

Some of the disturbances contributing to poor weight gains include significant depression in the digestibility coefficients of dry matter and crude protein. Parasitized lambs absorbed 10% less food and had an 8% depression of appetite compared to worm-free lambs (Spedding 1954b). These factors are probably the chief reasons why worms depress the live-weight gain of the host. Earlier studies by Franklin, Gordon and Macgregor (1946) using dosages of 200,000 *Trichostrongylus colubriformis* larvae in lambs gave results which agreed with the above findings. However, results obtained by Andrews, Kauffman and Davis (1944) differed with respect to the digestibility reduction. They found an increased metabolic rate in infected animals, indicating that the animals' ability to utilize feed economically was reduced by infection with *T. colubriformis*. Additionally, removal of parasites by anthelmintics improved feed efficiency and feed consumption (Knapp, McArther, and Eller 1965), which confirmed that anorexia and reduced feed efficiency are caused by gastrointestinal parasitism. In lambs experimentally infected with 80,000 or more *Nematodirus spathiger* larvae, death occurred in lambs under three months of age. In older animals, the only clinical sign was a transient diarrhea (Seghetti and Senger 1958). Moderate parasite infections in naturally infected pregnant ewe lambs, as determined by fecal egg counts, resulted in considerably lighter lambs at weaning than lambs from comparable worm-free ewes (Spedding, Brown and Wilson 1958).

The life cycles of members of the *Trichostrongylidae* are direct and essentially similar, with only minor species variations (Soulsby 1965). The eggs are discharged in the feces in an early stage of segmentation. The number of strongyle eggs in the feces in a flock is greatly variable, dependent on the genera present, the size of the parasite burden, diet of the sheep, illness and immune mechanisms (Mayhew 1940; Kelley 1953; Soulsby 1965). In addition, the output of eggs from an infected animal exhibits marked variation throughout the day (Spedding 1952).

Rates of embryonation, hatching and larval development have been studied extensively. The speed of these developmental processes is directly related to temperature, moisture and oxygen supply. Eggs of *Ostertagia* spp. and *Trichostrongylus* spp. are relatively resistant to cold and will develop and hatch at temperatures below 5 C (41 F) (Furman 1944a). Survival is as long as 20 days at -6 C (21.2 F). Above 0 C (32 F), the developmental rate is inversely related to temperature (Furman 1944a, 1944b). Eight weeks were required for hatching at 7 C (44.6 F and four weeks were required at 14 C (57.2 F) (Silverman and Campbell 1959). Continuous hatching and larval production may occur for up to 50 days at 14.4 C (58 F) from a single group of fecal pellets (Silverman and Campbell 1959).

Development of first stage larvae to the infective stage requires considerable time. In Great Britain upward of two weeks was required for *H. contortus* larvae to reach the infective stage during the summer, and considerably longer at other times of the year (Silverman and Campbell 1959). Under optimal conditions, two to three weeks are required for maximum production of third stage larvae of *H. contortus* after the feces have been shed. Even more time is required for development after hatching of other species.

The persistance of infection on pasture is dependent on environmental factors. Unembryonated eggs and infective larvae are most resistant to environmental extremes (Kates 1965).

Numerous studies have been conducted on the survival of infective larvae under different climatic conditions. Infective larvae of *O. circumcincta* are extremely resistant to cold temperature; with survival up to 271 days at temperatures near 0 C (32 F) (Furman 1944a). *O. circumcincta* larvae have been shown to overwinter on pastures in Canada,Maryland, Montana, and Virginia (Swales 1940b; Threlkeld 1946; Seghetti 1948; Kates 1950). Above 0 C, mortality increases with temperature. The genus *Trichostrongylus* is similar to *O. circumcincta* in that infective larvae are resistant to cold temperature, with survival up to 20 weeks in cold weather (Taylor 1938; Crofton 1948). Low numbers of infective larvae will survive the winter on pasture (Taylor 1938; Swales 1940; Hawkins, Cole and Kline 1944; Seghetti 1948; Kates 1950). *Cooperia* spp., *Bunostomum trigonocephalum* and *Oesophagostomum* spp. do not normally survive the winter on pasture (Kates 1950; Soulsby 1965).

The movement and behavior of infective larvae on herbage have been investigated to determine the effect of environmental conditions. Migration of infective larvae of the genera *Chabertia*, *Haemonchus*, *Ostertagia* and *Trichostrongylus* onto grass is favored by mild light and moisture (Rees 1950; Levine 1963, 1968). Temperature and humidity also influence the vertical migration of infective larvae (Kauzal 1941), with larval movement onto forage under favorable conditions and to the soil during unfavorable conditions.

Considerable work has been done in different parts of the world on the epidemiology of helminth parasitism in sheep. This subject has been reviewed extensively (Gordon 1948, 1953, 1958a; Soulsby 1965; Levine 1968; Ollerenshaw and Smith 1969; Michel 1969, 1974, 1976; Bradley 1972). Epidemiological investigations have been conducted in Canada (Fallis 1938; Swales 1940a, 1940b; Cameron 1956; Ayalew and Gibbs 1973), Great Britain (Taylor 1935; Hawkins and DeFreitas 1947; Cushnie and White 1948; Morgan, Parnell and Rayski 1951; Crofton 1955; Connan 1958; Cornwell, Jones and Potts 1971; Gibson and Everett 1967, 1971a, 1971b, 1973a, 1973b; Thomas and Boag 1972, 1973; Boag and Thomas 1973), Australia (Forsyth 1953; Gordon 1948, 1950, 1958; Parnell 1963; Dunsmore 1965; James and Johnstone 1967), Scotland (Reid and Armour 1972), Tasmania (Gordon 1953), and New Zealand (Brunsdon 1963). In the United States, similar work has been conducted in Michigan (Hawkins, Cole and Kline 1944), Georgia (Ciordia and Neville 1969), Illinois (Levine 1959, 1963), Maryland (Kates 1950; Levine 1963), and New York (LeJambre and Whitlock 1968; LeJambre and Ractliffe 1971). The species of nematodes present in various regions and their relative abundance depend on the climate and micrometeorologic conditions. The character of the soil, terrain type, nature and amount of vegetation, and the species and number of wild ruminants grazing on the same land as the sheep also affect species and number (Gordon 1958; Levine 1963, 1968). These factors are considered in this study.

Since the seasons and climatic conditions vary greatly in different areas, seasonal prevalence and severity of parasitism differ from one location to another. Species of parasites which overwinter on pasture in Australia do not necessarily survive with the same frequency in New Zealand, England or the US. In general, *H. contortus* predominates in warmer climates since it is unable to overwinter in cold regions, except as inhibited larvae. *Trichostrongylus* spp. and *Ostertagia* spp. are more adaptable to cooler climates, and *Nematodirus* spp. survive in cold climates (Levine 1963, 1968).

In Oregon, the principal parasites found in sheep are *O. circumcincta* and *Trichostrongylus* spp. Others found include *B. trigonocephalum*, *Chabertia ovina*, *Dictyocaulus filaria*, *H. contortus*, *Moniezia* sp., *Nematodirus abnormalis*, *N. helvetianus*, *N. spathiger*, *Strongyloides papillosus* and *Trichuris ovis* (Shaw and Muth 1946; Kistner, T. P. 1972-1975, unpublished data).

Epidemiologic studies have established that various factors greatly influence the method whereby infection is perpetuated from one grazing season to another. *H. contortus* overwinters in adult sheep as inhibited larvae (Michel 1974), resuming development the following spring. In colder areas, this parasite is only able to complete a single generation each year, whereas in warmer areas, two or more generations may be possible (Heath and Michel 1969; Boag and Thomas 1971; Ayalew and Gibbs 1973). *Nematodirus battus* and *N. filicollis* overwinter as eggs on pasture. Alternate chilling and warming are necessary for embryonation and hatching. These species therefore produce only one generation per year. With

N. helvetianus and N. spathiger, development and hatching occur year round (Herlich 1954; Soulsby 1965). Cooperia spp. develop and survive most favorably in warm moist weather; survival is adversely affected in cool dry weather. Cooperia does not survive over the winter on pasture but also undergo inhibition (Kates 1950; Soulsby 1965, Michel 1974).

During the grazing season, the frequency and relative numbers of parasites present in a given sheep population change in a relatively predictable pattern. This may be explained by differences in environmental conditions to which the non-parasitic stages are exposed (Gordon 1948; Thomas and Boag 1971), generation interval and relative fecundity of each species (Crofton 1957), host resistance and spontaneous elimination of some species (Brunsdon 1970), and differing rates of development of the free-lving stages (Gibson and Everett 1971a).

Certain of the trichostrongyles are able to interrupt their development in the host and survive for extended periods of time in an arrested or inhibited state. This inhibition phenomenon is a form of hypobiosis; development ceases at an early stage. Resumption of development may be spontaneous or in response to signals received from the host (Michel 1974). Larvae of O. circumcincta undergo a histotrophic phase, completing the third ecdysis in the mucosal crypts and remain as early fourth stage larvae for three months or longer (Sommerville 1953, 1954; Dunsmore 1960; James and Johnstone 1967; Michel 1974). Larvae of Cooperia, Nematodirus and Trichostrongylus have also been shown to undergo inhibition in sheep (Sommerville 1960; Donald et al. 1964; Denham 1969; Michel 1974). Inhibited development is contingent upon seasonal temperatures, exposure to high numbers of infective larvae, parturtion, host resistance, deworming and nutrition (James and Johnstone 1967; Michel 1974). Development or maturation of inhibited larvae and subsequent egg production contribute significantly to the epidemiologic pattern of infection in lambs.

The onset and severity of parasitic disease in any grazing season can be influenced by factors extrinsic to the host-parasite relationship (Soulsby 1965). Zimmermann (1965) showed an increase in parasitism caused by more concentrated pasture utilization. The amount of infective material on a pasture has been shown to increase by the square of the animal density (number of grazing animals)(Taylor 1930, 1938). The susceptibility of the annual lamb crop contributes directly to parasite burdens in lambs and subsequently on the pasture, since female worms in susceptible animals are more fecund.

The practice of grazing young animals with older animals exposes the young to damaging levels of infection, since the older animals may carry but be unaffected by moderate burdens. Parasites in older animals however, can heavily contaminate pastures and make them an unsatisfactory environment for young animals.

Abrupt increase in fecal nematode egg counts in the spring or following parturition is commonly known as the spring rise, the post-parturient rise, the periparturient relaxation of resistance, or the lactation rise (Michel 1976). This phenomenon was initially observed by investigators in Australia, Great Britain, New Zealand, Scotland and the United States, and led to the belief that change in diet and newly acquired worms were the cause (Taylor 1935; Hawkins and DeFreitas 1947; Morgan, Parnell and Rayski 1951; Gordon 1948, 1952; Parnell, Dunn and Mackintosh 1954; Paver, Parnell and Morgan 1955; Spedding and Brown 1956; Crofton 1958; Field, Brambell and Campbell 1960; Condy 1961: Brunsdon 1964b, 1967; Dunsmore 1965; Connan 1968a, 1968b). Another theory was that the increase in egg production was due to hormonal changes associated with lactation and parturition (Spedding and Brown 1956; Crofton 1958; Brunsdon 1964a, 1966a, 1966b, 1966c, 1967; Dunsmore 1965). It was also thought that the "rise" came from arrested larvae which had resumed development. The phenomenon is now considered to result from relaxation of resistance by the host at parturition with increased fecundity in existing worms, unimpeded development of newly acquired infective larvae and resumed development of arrested larvae (Soulsby 1966; Southcott, George and Lewis 1972; Michel 1974). This relaxation of resistance in ewes allows increased numbers of worm eggs with subsequent increased source of infection for young lambs (Morgan and Sloan 1947; Crofton 1958; Brunsdon 1964a). Where pastures burdens are low, the periparturient rise is the source of virtually all the larvae picked up by young lambs, and the major cause of parasitic gastroenteritis in these lambs (Heath and

Michel 1969; Boag and Thomas 1971).

The detrimental effects of parasitism are directly related to the nutritional status of lambs (Weir et al. 1948). Whitlock (1949), in series of nutrition experiments with natural infections of Trichostrongylus spp. and Cooperia spp., demonstrated that diet profoundly influenced the numbers of worms which became established and the clinical effects. The parasites exerted no significant effects on conformation or weight gain in the well-fed group, whereas poorly fed parasitized lambs had obvious distortions of physique and depressed weight gain. Lambs on a relatively poor ration were more severely affected by H. contortus and Oesophagostomum columbianum than lambs on good rations (Lawrence et al. 1951). Brunsdon (1964) found that lambs on a low-plane diet were less resistant to re-infection with H. contortus, Ostertagia spp., Trichostrongylus spp. and Cooperia spp., than lambs which had been maintained on a higher nutritional plane. Whitlock (1951) found that gastrointestinal parasites and early weaning combined to produce severe stunting effects in growing lambs. Spedding (1955, 1956a) suggested that this was due to a lowered nutrition level caused by the withdrawal of milk.

The role of trace minerals in the nutrition of grazing animals is poorly understood. Addition of selenium to the diets of weaned and unweaned lambs produced highly significant live-weight gains (P=0.05), both in flocks with a high incidence of white muscle disease, and in absence of this disease (McLean, Thompson and Claxton 1959a, 1959b). Accelerated growth rate has been obtained in unthrifty weaned lambs supplemented with selenium (Drake, Grant and Hartley 1960; Jolly 1960; Skerman 1962). The maximum effective period for selenium administered by injection at a dosage of 0.055 mg/kg of body weight appeared to be 14 days. The kidneys and injection site did not have increased selenium content after injection (Van Vleet 1975).

Other mineral deficiencies have been shown to influence the effects of parasite infections in grazing animals. In experimental _H. contortus_ infections, lambs on a high protein diet receiving mineralized salt and bone-meal carried higher worm burdens than unsupplemented lambs on the same diet (Weir et al. 1948). In a study with cobalt by Keener, Percival and Morrow (1948), lambs fed normal amounts of cobalt had greater worm burdens than cobalt deficient lambs but gained more weight than the deficient lambs. It was reported that the feeding of cobalt and steamed bone-meal increased resistance to _H. contortus_ infections (Richard et al. 1954). Threlkeld, Price and Linkous (1956) concluded that the ability of _H. contortus_ to establish themselves with the host animal appeared to be dependent on the presence of adequate dietary cobalt.

Stress factors such as shipping, handling, overheating and concurrent disease may predispose lambs to the detrimental effects of gastrointestinal parasites (Ensminger 1962). Additionally, high summer temperatures can cause heat stress in sheep, thereby resulting in poor weight gains in the lambs.

A variety of control measures have been developed to reduce pasture contamination. These depend upon integrating the local factors that affect parasitism. Total eradication of gastrointestinal parasites is considered to be practically impossible at this time (Michel 1976). Therefore, practical control measures require integration of good management procedures and anthelmintics. This combination should minimize the potential of clinical parasitism (Gordon 1973).

Pasture rotation and grazing management as methods of controlling infection with gastrointestinal parasites have been studied for many years. The theory behind this method is that alternation of grazing interspersed with pasture resting periods would reduce the parasite population of a pasture by exposing the eggs and larvae to adverse environmental conditions (Ciordia et al. 1964). Selection of a pasture rotation system for the control of nematodes is primarily a problem involving parasite larval ecology (Donald 1969). Factors affecting the problem include climatic conditions, intensity of pasture utilization, the time required for the larvae to reach the infective stage and larval survival time on pasture (Levine and Clark 1961).

Control of parasitism in lambs by systems of grazing management may or may not be effective. Ciordia and coworkers (1962) demonstrated that the degree of parasitism is directly related to the intensity of grazing; more parasitic nematodes occur in animals on heavily grazed pastures than in those on moderately or lightly grazed pastures. Additionally, the stocking rate of animals on pasture is directly related to the intensity of parasitism (Ciordia et al. 1971). Spedding (1954c) was able to experimentally prevent gastrointestinal parasitism in lambs by moving them every two days onto clean pasture. By contrast, in rotation experiments conducted by Levine and Clark (1955) in which lots were grazed for one week and rested for five weeks, fecal egg counts of the rotated lambs reached peaks of 8844 eggs per gram (EPG) of feces, compared with peaks of 9900 EPG in the constantly grazed control lambs. In a pasture rotation program where lambs were moved twice a week and then returned to the original pasture after six weeks, the mean egg count of the rotated lambs reached a peak of 2086 EPG while that of the constantly grazed controls was 2950 EPG (Levine et al. 1956). In a similar experiment, mean egg counts of the rotated lambs reached a peak of 4471 EPG and that of the constantly grazed controls was 800 EPG (Bradley and Levine 1957). However, pasture utilization was much better on the rotated pastures than on the control one. In a rotation program in Illinois where pastures were grazed for one week and rested for five weeks, lambs acquired heavy burdens of *H. contortus* (Levine and Clark 1961). In Georgia, a rotational grazing experiment in which calves grazed each pasture for two weeks did not reduce the parasite population (Ciordia et al. 1964). In Iowa, rotation of lambs at one week intervals through two 6-pasture cycles was moderately effective in suppressing parasitism, but rotation at two-week intervals through two 4-lot cycles proved ineffective (Zimmerman 1965).

It is evident that it is not economically practical to attempt rotational pasture management. Maximum utilization of the pasture cannot be achieved if effective parasite control is to be maintained (Levine and Clark 1961, Ciordia et al 1964). The practice of deworming lambs at weaning coupled with a move to clean pasture, or moving to clean pasture without deworming has proved effective in reducing parasite burdens in England (Thomas and Boag 1973).

Much controversy still exists regarding the value of rotational grazing for the control of gastrointestinal parasites and for production. Michel (1969) stated that use of resistant animals or another species of animal to graze alternately with the flock may result in reduction of infective larvae for sheep. He subsequently stated however that any system of practical rotation can have no effect on the control of parasite nematodes (Michel 1976). Gordon (1973) in a review, cited investigators who reported high degrees of sheep parasite control by alternately grazing sheep and cattle on the same pastures. This alternate grazing is presumably effective because sufficient strain differences exist so that alternate grazing largely destroys parasite larvae through creating unfavorable conditions for survival in the heterologous host. This practice is currently advocated in Australia (Gordon 1973).

The use of anthelmintics can be divided into strategic and tactical treatments (Gordon 1958b). Strategic treatments are related to the seasonal trend of worm burdens, with deworming schedules tailored to local conditions (Gordon 1948b, 1950). Tactical treatments are used upon recognition of conditions favoring an imminent increase in worm burdens. Tactical treatments are based on weather, stocking density, plane of nutrition, and other factors (Gordon 1950). Both treatment regimes must be flexible and their effects constantly monitored to assure beneficial results.

A variety of anthelmintics have been developed and used in the treatment of gastrointestinal parasitism. Books and review articles on this subject include Morgan and Hawkins (1949), Gordon (1962), Hebden (1962), Lapage (1962), Drudge et al. (1964), Soulsby (1965) and Levine (1968). Anthelmintics considered in this review will be limited to phenothiazine[a], thiabendazole[b], tetramisole[c] and haloxon[d]. The sequence in which these drugs are presented represents the history of treatment in the past four decades.

Phenothiazine (thiodiphenylamine) has been used for many years in treating parasitized sheep (Harwood 1953). The recommended dosage is 12.5 g for lambs under 60 lb, 25 to 30 g for lambs over 60 lb, and 45 g for sheep over 125 lb (Levine 1968; Georgi 1969).

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[a] phenothiazine - numerous supply sources.

[b] thiabendazole - Thibenzole^R, Merck & Company, Inc., Rahway, New Jersey.

[c] tetramisole - Tramisole^R, American Cyanamid Company, Princeton, New Jersey.

[d] haloxon - Loxon^R, William Cooper and Nephews, Inc., Chicago, Illinois

This drug is highly effective against adult H. contortus and Oesophagostomum spp., less effective against adult Cooperia spp. Ostertagia spp. and Trichostrongylus spp. and ineffective against Nematodirus spp. The size of the oral cavity of the parasite is the major determinant of susceptibility; H. contortus and Oesophagostomum have large oral cavities. Phenothiazine is only effective against adult worms; larvae and lungworms are unaffected. Treatment must be repeated at two week intervals to kill adults which develop after the first treatment. Contempory use of phenothiazine is primarily limited to feeding low-level phenothiazine daily in salt to interrupt transmission by preventing egg production and larval survival (Drudge et al. 1959). Low levels (2g/day) will sterilize the eggs and/or kill larvae developing in the manure (Drudge et al. 1964). A mixture of 1 lb phenothiazine in 9 - 10 lb loose salt is fed continuously ad libitum.

Thiabendazole (2-(4'-thiazolyl)benzimidazole) was marketed in 1958 and represented the first broad spectrum anthelmintic and the first major advance in a quarter century after discovery of phenothiazine. This drug has been extensively tested and compared with other drugs. The oral therapeutic dosage for sheep is 50 to 55 mg/kg body weight (Cairns, 1969; Gordon 1961, 1964; Hebden 1961; Baker and Douglas 1962; Bell, Galvin and Turk 1962; Dunsmore 1962; Drudge and Szanto 1963; Herlich 1963; Kiesel et al. 1963; Leiper and Crowley 1963; Miller and Argo 1963; Kates and Thompson 1967). A major advantage is that it is relatively non-toxic. In experimental work, Lyons, Drudge and Knapp (1967) found that a single dose of 50 mg/kg of thiabendazole was 94 to 100% effective against adult C. oncophora, H. contortus, N. spathiger and Nematodirus sp., O. circumcincta and Ostertagia spp., T. axei and T. colubriformis; 100% effective against immature H. contortus, 87% effective against immature Nematodirus, but ineffective against Trichuris ovis. Southcott (1963) also had high efficacies against immature and adult H. contortus, Ostertagia spp., T. colubriformis, and adult O. columbianum. Thiabendazole, however, is ineffective against lungworms at these dosages. Connan (1973) found 100 mg/kg effective against Dictyocaulus filaria.

Tetramisole (2,3,5,6-tetrahydro-6-phenyl-imidazo [2,1 b] thiazole; Ripercol-l-levamisole), an imidazo thiazole compound was introduced in 1966 (Thienpont et al. 1966). This drug was found to be highly effective at an oral dosage of 15 mg/kg body weight against all stages of all gastrointestinal nematodes of sheep and goats except Trichuris (Walley 1966). A dosage of 5 mg/kg would remove all the adults. High efficacy at 8 mg/kg has been reported by other investigators (Pankhurst and Sutton 1966; Ross 1966; Fitzsimmons 1966; Forsythe 1966).

Haloxon (0,0 di-(2-chlorethyl) 0-(3-chloro-4-methylcoumarin-7-yl) phosphate) at 50-70 mg/kg is also used frequently in sheep (Brown et al. 1962; Armour, Brown and Sloan 1962; Harbour 1963; Ross 1963; Armour 1964; Nunns, Rawes and Shearer 1964b; Malone 1964). This drug is highly effective against the abomasal and small intestinal parasites Cooperia spp., H. contortus, Ostertagia spp., and Strongyloides spp., less effective against Bunostomum spp. and Trichostrongylus spp., irregular in effect on Nematodirus and has little effect on the large intestinal parasites Chabertia spp. and Oesophagostomum spp. and on lungworms.

The use of anthelmintics has been demonstrated to increase production. Brunsdon (1966) found that treating lambs every two weeks with thiabendazole increased their total weight gains 27 lb over untreated animals in ten months. Gardiner and Butler (1964) were able to improve growth by treating lambs at weaning and after the "break of the season" with thiabendazole or phenothiazine-coroxon (Coopex[e]). In studies using tetramisole, good weight gains were achieved at 15 mg/kg although this dosage level approached toxic levels (Forsythe 1966).

Development of anthelmintic resistant parasite strains presents a problem in treatment and control. Phenothiazine resistant H. contortus strains first appeared in Kentucky in the the late 1950's (Druge, Leland and Wyant 1957; Drudge et al 1959). These strains were moderately resistant to normal therapeutic levels. A highly resistant strain was found on an Illinois farm where phenothiazine had been used extensively for 19 years (Levine and Garrigus 1962). Another resistant strain developed in Maryland (Enzie et al. 1960). Resistance subsequently was found to thiabendazole in another strain of H. contortus (Drudge et al. 1964).

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[e] Coopex^R - Coroxon: 0,0-diethyl 0-(3)chloro-4-methyl coumarin-7yl) phosphate.

The alternation of anthelmintics is a practice advocated to prevent buildup of resistant nematode strains (Drudge et al. 1964).

The use of anthelmintics in combination with trace mineral supplements has been shown to increase weight gain performance in lambs. Shumard et al. (1956), fed lambs additions of trace mineralized salt, dicalcium phosphate, phenothiazine and combinations of these, and showed that a phenothiazine/trace mineral/dicalcium phosphate combination was superior to any of these alone. In comparative experiments, highest weight gains were obtained when a selenium supplement and thiabendazole were used concurrently in lambs (Scales, Lewis and Ludecke 1968). Skerman (1962) also produced a significant growth response in unthrifty lambs using an anthelmintic and selenium supplements.

MATERIALS AND METHODS

Experimental Design (Overview)

This investigation was designed to examine the epidemiological aspects of gastrointestinal parasitism in sheep. This study was conducted on a working ranch under practical field conditions in Central Oregon. The study was initiated by a request from the owner who felt that poor performance in spring lambs resulted from gastrointestinal parasitism.

The experimental design included formulation of a management program for control of gastrointestinal parasites in grazing lambs based on modifications of previous management practices, evaluation of the effectiveness of that program and reevaluation if parasitism persisted as a major performance-inhibiting factor, and bionomics of the parasite populations in both ewes and lambs. In the bionomics evaluation the following questions were investigated. (1) Did over-wintering larvae or inhibition of larvae in the abomasums of ewes and the associated post-parturient relaxation of resistance produce pasture contamination of sufficient magnitude to cause weight losses in the lambs in the early grazing period? (2) Did early infection of the lambs lead to autoinfestation of the pastures, build-up of parasite burdens during the grazing season and poor weight gain performance in the lambs during the latter part of the grazing season?

The levels of infective larvae on the pastures were monitored with tracer lambs. Climatological factors were recorded for possible correlation with larval development. Additionally five lambs and three calves were slaughtered and examined for gastrointestinal parasites late in the grazing season when weight gain performance declined. Since the study ranch was located in a mineral deficient area, analyses of blood samples from lambs and calves were made to assess the mineral status in the animals.

Study Area

The study ranch, owned by Mr. Phil Farrell and Son, is a commercial sheep operation, located nine miles northeast of Madras, Oregon in Jefferson County. The site is near the northwest edge of Central Oregon's high plateau area at latitude 44.30 °N and longitude 121.08 °W. The elevation in this region ranges from 2,100 to 2,400 feet mean sea level (msl), and averages 2,230 feet msl at the study site. The dry climate has definite seasonal characteristics (Holbrook 1971; Appendix I). Annual rainfall averages 10 inches with precipitation greatest in winter (January and February) and a second maximum in June. Overhead pasture irrigation is extensively used throughout the region, and is made possible by water from man made reservoirs which collect the eastern runoff from the Cascade Mountains during the spring thaw. Temperatures range from below freezing in the winter to 100 F and above in the summer.

The ranch had 450 acres under irrigation; 234 acres were used for row crops and 116 acres were in six permanent pastures. Pasture usage consisted of hay harvest and a rotational grazing system involving cattle and sheep. The six individually fenced pastures ranged in size from 10 to 57 acres (Fig. 1). Pasture numbers and predominant forages present are described in Table I.

Soil and forage samples from the pastures were analyzed annually by the Oregon Extension Service for mineral content and fertilization recommendations. The pastures were fertilized each October following these recommendations insofar as was possible.

Previous Management Practices

The study ranch maintained a flock of 375 ewes of mixed breeds and a herd of 100 beef cattle. During February prior to lambing, the ewes were sheared and held on pasture 2 which had been heavily grazed by sheep the previous year. The ewes were lambed in lambing pens. Ninety per cent of the lambing occurred within the first three weeks in March. Following parturition, the ewes and newborn lambs were moved into the lambing shed for several days before being placed on pasture. Pasture 1, the first pasture on which the ewes and lambs were placed, was irrigated alfalfa which was usually grazed the preceding October by adult sheep. The flock was alternately maintained with cattle on a rotational program throughout the grazing season. Each pasture was grazed for ten days each, first by sheep and then by cattle. Before animals were returned to a pasture, hay crops were cut and removed or seed

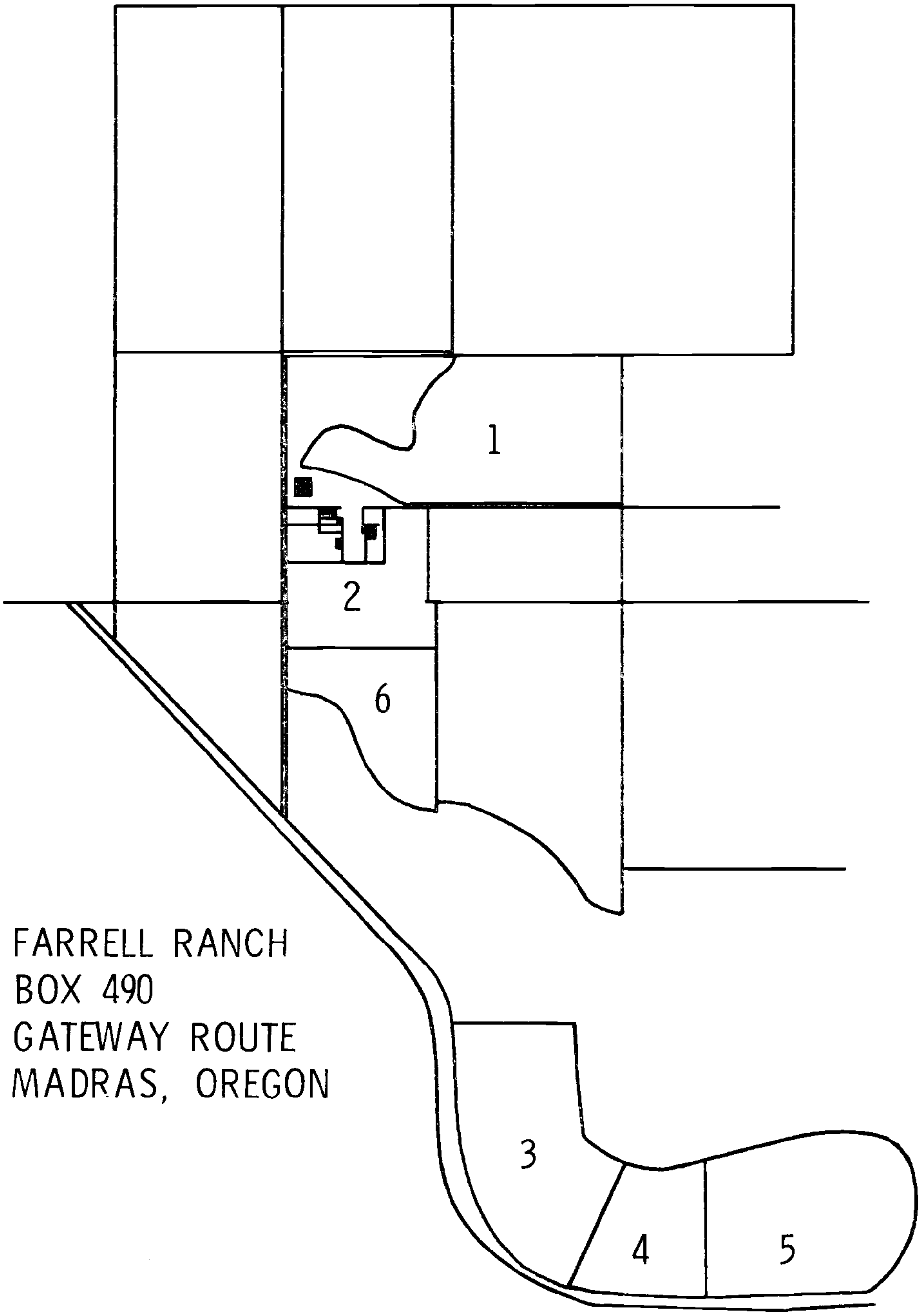

Figure 1. Map of the Farrell Ranch, Madras, Oregon with designated study pastures.

Table I. Pasture designation, size and forages on the Farrell Ranch, Madras, Oregon 1975.

Pasture Number	Size (Acres)	Predominant Forages
1	57	alfalfa (*Medicago sativa*) predominantly, and bulbous blue grass (*Poa compressa*).
2	17	altafescue (*Festuca elation*) predominantly, orchard grass (*Dactylis glomerata*), and alfalfa (*Medicago sativa*).
3	23	fawn fescue (*Festuca* sp.) predominantly, alfalfa (*Medicago sativa*), orchard grass (*Dactylis glomerata*), and altafescue (*Festuca elatior*).
4	11	altafescue (*Festuca elatior*) predominantly, and ladino clover (*Trifolium repens*).
5	14	orchard grass (*Dactylis glomerata*) and altafescue (*Festuca elatior*).
6	18	altafescue (*Festuca elatior*) predominantly, ladino clover (*Trifolium repens*) and orchard grass (*Dactylis glomerata*).

was combined. Irrigation was resumed several days prior to the reintroduction of animals.

The flock was periodically dewormed by the rancher (Table II). The ewes were dewormed two weeks before breeding in the fall, and again in late February just prior to lambing. Both the lambs and ewes were dewormed once each in June, July, and August (Table II). Sodium selenite was added to the deworming drench for the ewes and lambs at deworming. Sheep and cattle were constantly supplied with approximately 50 lb per week of a trace-mineralized salt (Appendix II). Phenothiazine (thiodiphenylamine) and dicalcium phosphate were added to the salt for the sheep.

Modifications per Protocol (Animal)

The rotational grazing program used prior to this study appeared to return sheep to a pasture when maximum numbers of infective larvae were available. Therefore, instead of cattle immediately following the sheep onto a pasture, the rotational schedule was modified to allow a 10 to 15 day pasture rest period before placement of cattle on the pasture. Precise dates of pasture rotation were based on available feed in each pasture and consequently did not adhere to a rigid time schedule (Table III). Slow growth of pasture forages in late spring necessitated removal of the sheep from the ranch for one month to a sagebrush pasture which had not been grazed previously by sheep.

Table II. Deworming schedules for 1974 and 1975 on the Farrell Ranch, Madras, Oregon.

Year	Date	Anthelmintic	Se[a]	Animals Treated
1974	22 Feb.	Tramisol		Pregnant Ewes
	1 June	Thiabendazole		Ewes and Lambs
	24 June	Tramisol		Scoury Lambs
	29 June	Tramisol		Ewes and Lambs
	15 July	Thiabendazole II		Ewes and Lambs
	1 Aug.	Loxon		Ewes and Lambs
	15 Aug.	Tramisol		Ewes and Lambs
	22-23 Sept.	Tramisol	Yes	Pregnant Ewes
1975	17-20 Feb.	Tramisol	Yes	Pregnant Ewes (Se in drinking water)
	31 March	Tramisol	Yes	Ewes and Lambs (Se drench with anthelmintic)
	17 May	Tramisol	Yes	Ewes and Lambs (Se drench with anthelmintic)
	16 June	Thiabendazole	No	Ewes and Lambs
	3 July	Tramisol	Yes	Ewes and Lambs (Se drench with anthelmintic)
	15 Aug.	Tramisol	Yes	Ewes and Lambs (Se drench with anthelmintic)

[a] Sodium selenite (2.2 gm/gal of drench). Dosage: 1 oz/lamb; 1.5 oz/ewe).

Table III. Pasture rotation schedule on Farrell Ranch, Madras, Oregon 1975.

Date	Pasture Number	Days on Pasture
3/9	1	39
4/17	Off Ranch[a]	29
5/17	3 and 4	17
6/2	5	14
6/16	6	15
7/1	2	21
7/22	3	12
8/4	5	11
8/15	6	17
9/1	2	Undetermined

[a] Sheep were placed on a neighbor's pasture away from the Farrell ranch.

A deworming schedule involving successive dosing with tetramisole, haloxon and thiabendazole was formulated to minimize the potential of drug resistance. However, haloxon was not used during the study period. Deworming of the ewes and lambs began in March and was continued monthly throughout the grazing season (Table II). The sheep were allowed continuous access to phenothiazine salt. The salt mixture used during the study is given in Appendix II (p. 103). Each gallon of deworming drench was supplemented with 2.2 g sodium selenite. The drench was administered at the rate of 1 oz per lamb and 1.5 oz per ewe.

Parasite Monitoring of Ranch Animals

Parasite burdens within the flock were monitored during the months of February through September to assess the nature of the parasite burden in the flock and the effect of these burdens on weight gain performance. Methods used included fecal nematode egg counts of a randomly selected group of 20 resident ewes and 20 of their lambs. One-half of the lambs were dewormed monthly and the remaining lambs were not.

Quantitative fecal nematode egg counts were conducted on ewes and lambs at monthly intervals from February to August, 1975 using the modified McMaster technique (Whitlock 1948). The counts served as an index of the potential contribution of the ewes to pasture contamination. At lambing, 20 ewes and their lambs were randomly selected from the flock and identified. The ewes were monitored for fecal egg output, dewormed and comingled with the flock throughout the grazing period.

The identified lambs were divided into ten control and ten sample lambs, to serve as an index of changes in the parasite burdens and to determine performance of the flock lambs. The ten controls did not receive anthelmintic treatment. The remainder received monthly anthelmintic treatments with the flock. Rectal fecal samples of both control and sample lambs were collected monthly. Nematode egg counts were performed using the McMaster technique. Both groups of lambs were weighed monthly and the average daily gain (ADG) was calculated.

FECAL NEMATODE EGG EXAMINATIONS

A modified McMaster procedure (Whitlock 1948) was used for quantitative estimation of fecal egg output. Five grams of a rectally-collected fecal sample were thoroughly mixed with a sodium nitrate solution (specific gravity 1.40) to a total volume of 75 ml. A McMaster counting chamber[f] was filled with the mixture. Ova. excluding those of <u>Strongyloides</u> spp. and <u>Trichuris</u> spp. were counted from both grids on the counting chamber, summed, and multiplied by 50 to give the egg count expressed as eggs per gram (EPG) of feces.

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[f] Haver-Lockhart, Northwest Veterinary Supply Company, P.O. Box 389, Oregon City, Oregon.

When the parasite burdens produced too few ova to be detected by the modified McMaster's technique (fewer than 50 EPG of feces), a semi-quantitative method was used to estimate the eggs per gram of feces. Two to five grams of a rectally-collected fecal sample were mixed thoroughly with approximately 25 ml of sodium nitrate solution (specific gravity 1.40). The mixture was strained through two layers of cheesecloth into a beaker. A small vial was filled with the strained material until a positive meniscus was formed. A clean slide was placed on top of the vial so that it contacted the fluid. After ten minutes, the slide was removed, inverted, coverslipped, and microscopically examined at 100X for nematode eggs. The eggs were counted and divided by the weight of the fecal sample to give the number of eggs per gram of feces.

NECROPSY AND PARASITOLOGICAL EXAMINATIONS

To determine the number and species of gastrointestinal parasites present at various times during the grazing season, sheep which died were necropsied and examined for gastrointestinal parasites. Late in the season, five lambs and three calves were randomly selected and examined parasitologically to compare the extent of parasite cross-infection between cattle and sheep.

The animals used in this project were killed with an overdose of barbiturates and exsanguinated. The procedure for necropsy and parasitologic examinations have been previously described (Kistner and Wyse 1975).

The gastrointestinal tracts were removed from each carcass and separated into abomasum, small intestine and large intestine plus cecum. Each organ was opened longitudinally, scraped and washed. Contents and washings of each organ were preserved in 5% formalin. Abomasums were subsequently digested in acid-pepsin for recovery of immature nematodes (Herlich 1956). The digested material was washed with water over a 150-mesh Tyler Analytical sieve[g]; the material collected on the screen was added to the contents. After three days fixation, the abomasal and small intestinal materials were washed individually through a 150-mesh sieve. The material collected on the sieve was placed in a beaker and tap water added to a total volume of two liters. A magnet was added and the sample suspended by magnetic stirring. During agitation, three 50-ml aliquots were removed and placed in separate beakers. Iodine was added to each aliquot to facilitate worm recovery (Whitlock 1948b). Worms from the first aliquot were removed and collected in vials containing 5% formalin. If 50 or more worms were collected from this aliquot, the worms in each of the remaining two aliquots were just enumerated. Otherwise, collection was continued.

The worms in each vial were poured into a petri dish and mixed. The first 25 nematodes were removed, placed on clean microscope slides, cleared in lacto-phenol and examined under a compound microscope. The developmental stage of each worm was identified. Males were speciated and females and larvae were identified to the generic

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[g] Tyler analytical sieve - W. S. Tyler, Inc., Mentor, Ohio, USA 44060

level.

The cecal and large intestinal contents were washed through a 20-mesh sieve placed above a 150 mesh sieve. Adult worms were removed from the top sieve, enumerated and identified by genus. The material collected on the 150-mesh sieve was diluted to two liters, mixed, and three 50 ml aliquots were removed and examined for immature nematodes. From the above data, the parasite fauna of each animal, the total burden per organ, and the number of each species was determined.

Tracer Lambs

Twenty-four lambs were used as tracers to monitor larval numbers resulting from overwintering and autoinfection as the sheep moved from pasture to pasture. It was anticipated that these data would assist in determining critical periods of high larval availability so that appropriate control measures could be formulated. These lambs were reared parasite-free in facilities of the School of Veterinary Medicine, Oregon State University in Corvallis, Oregon. Eighteen of these lambs were progeny from 20 summer-bred Dorset ewes. Five ewes were placed in each of four, steam-cleaned, indoor, concrete-floored pens containing wood shavings for bedding. Pens were thoroughly cleaned and swept three times weekly. The ewes were dewormed with 8 mg/kg injectible tetramisole twice prior to lambing. The ewes and lambs were subsequently dewormed monthly with the same compound until the lambs were weaned. The ewes were then removed. The other six lambs were the progeny of additional ewes; these lambs were separated from their mothers after having received colostrum, and were reared in a separate pen on milk replacer; other husbandry factors were the same as described above.

Lamb management included ear-tagging, tail docking, castration, vaccination with Clostridium perfringens toxoid types C and D, and spraying for sheep keds (Melophagus ovinus). Shortly after weaning, all lambs were moved to a large concrete pen in the Veterinary Medicine Animal Isolation Laboratory, Oregon State University, where they were isolated from sources of helminth parasitism.

Groups of two tracer lambs were placed on pasture at the Farrell ranch from March through September to graze for ten days each time the ranch flock was moved to a new pasture. Following the ten day grazing period, the tracer lambs were transported to Corvallis and placed in steam-cleaned, concrete-floored isolation pens for 14 days and then killed for parasitologic examination.

Mineral Determinations

To determine whether trace mineral deficiencies existed in the ranch animals which may have influenced the degree of parasitism and weight gain, analyses were conducted on plasma, serum and whole blood samples from 35 lambs and 20 calves in mid-August. Analyses were performed by personnel of the Agricultural Chemistry Department, Oregon State University, under the guidance of Dr. Paul H. Weswig and Dr. Philip D. Whanger. Analyses included determinations for calcium, copper, iron, magnesium, phosphorous, selenium and zinc.

Meteorologic Instrumentation and Procedures

Ambient temperature in degrees Farenheit and percent humidity were measured from March to September 1975 on the Farrell ranch to establish a climatologic baseline against which the development and survival of the free-living stages of parasitic nematodes could be studied. A hydrothermograph, calibrated by a meteorologist at the U. S. Weather Bureau Station in Corvallis prior to usage, was placed approximately three feet above the ground and 15 feet from any wall in a three-sided farm shed. Temperatures and humidities were measured to the nearest degree and percent, respectively.

RESULTS

Modifications per Protocol (Animal)

The sheep consumed approximately 50 lb of the phenothiazine salt weekly. The consumption rate (if the lambs were disregarded) indicated that the ewes were obtaining an average of 768 mg of phenothiazine per day. Calculation of the consumption of phenothiazine by both ewes and lambs (assuming equal consumption) gave an average daily intake of 317 mg phenothiazine.

Parasite Monitoring of Ranch Animals

FECAL NEMATODE EGG COUNT MONITORING

The mean EPG counts for the sample ewes and the sample and control lambs during the grazing season are presented in Table IV. Figure 2 relates the egg counts to the deworming times and sequence of pasture rotation. The EPG counts of the ewes rose from a mean of 11 EPG in February to 220 EPG in mid-May. Lambs were not sampled during this period. A decline to 7 EPG in the ewes occurred in June. The EPG counts of both lamb groups also declined from May to June. The mean EPG counts of the ewes rose again from 7 EPG in June to 141 EPG in August. The dewormed sample lambs' mean EPG count continued to decline from 167 EPG in June to 56 EPG in September. However, the mean EPG count of the control lambs rose from 88 EPG in June to 238 EPG in September. The EPG count of the ewes declined only after the May deworming, rising after all

Table IV. Mean nematode fecal egg counts from sample ewes and sample spring lambs on the Farrell Ranch, Madras, Oregon, 1975

	Ewes		Dewormed Lambs		Control Lambs	
Date	Sample size	Eggs per gram feces (EPG)	Sample size	Eggs per gram feces (EPG)	Sample Size	Eggs per gram feces (EPG)
2/21	31	11	*	*	*	*
3/12	30	95	*	*	*	*
3/31	20	105	*	*	*	*
5/17	20	220	9	200	9	167
6/16	21	7	18	167	8	88
7/3	20	15	20	106	8	294
8/15	21	141	15	193	7	193
9/11	*	*	17	56	8	238

*Fecal samples not collected.

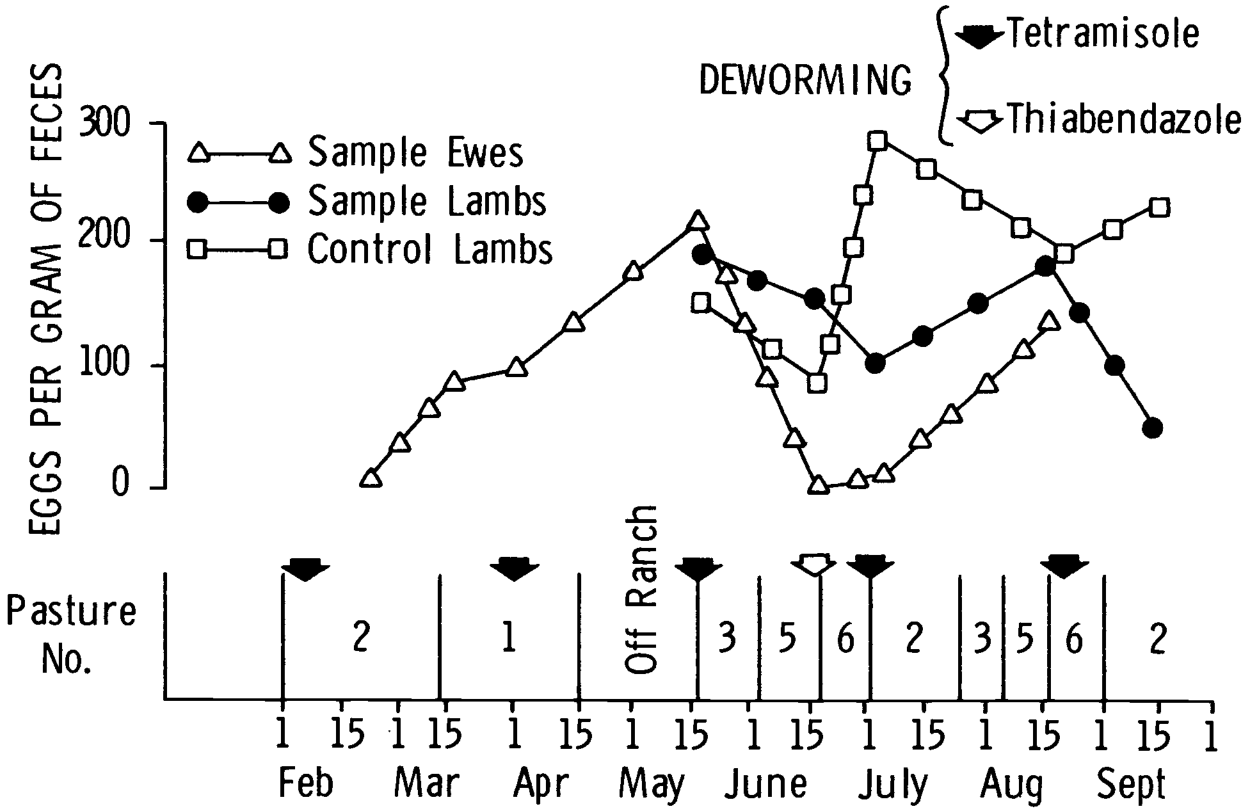

Figure 2. Deworming times, pasture rotations, and mean nematode fecal egg counts for sample ewes, sample lambs and control lambs on the Farrell Ranch, Madras, Oregon 1975.

other dewormings. The EPG counts of the sample lambs declined after all but the June and July dewormings.

WEIGHT GAIN PERFORMANCE

Monthly weight gain data of the lambs are presented in Table V and Figure 3. Comparable gains were made by both groups of lambs through June. In July, a greater rate of gain was made by the untreated lambs, whereas the rate of gain of the sample lambs remained constant. The rate of gain of both groups decreased during July through September. The average daily gain (ADG) of the sample lambs stabilized at +0.28 lb/day compared to +0.19 lb/day for the untreated controls. During September, the ADG of the treated lambs remained at +0.28 lb whereas the control lambs exhibited an ADG of -0.03 lb.

QUANTITATIVE PARASITOLOGIC EXAMINATIONS

Seven ewes and eight lambs were necropsied and examined for parasites from February to mid-September. Parasite burdens from these animals are presented in Table VI. The parasites recovered included Ostertagia circumcincta, Ostertagia (Teledorsagia) davtiana, Ostertagia trifurcata, Trichostrongylus axei, Cooperia oncophora, Cooperia mcmasteri, Nematodirus spathiger, Nematodirus abnormalis, Oesophagostomum venulosum and Trichuris spp.

In the ewes examined, Ostertagia spp. comprised 90% of the total burden. The mean total parasite burdens of the ewes increased by eleven-fold (1096%) from early February to late March and the

Table V. Weight gain of sample (dewormed) and control (not dewormed) lambs on the Farrell Ranch, Madras, Oregon 1975.

	Control lambs (No deworming)					Sample lambs (deworming)				
Date	No. Lambs	Total Weight (lb)	Average Weight (lb)	Average Gain (lb)	ADG (lb)	No. Lambs	Total Weight (lb)	Average Weight (lb)	Average Gain (lb)	ADG (lb)
5/17/75	10	599	59.9			23	1258	54.7		
6/16/75	9	674	74.9	15.0	0.50	22	1523	69.2	14.5	0.48
7/3/75	9	769	85.4	10.5	0.62	25	1934	77.3	8.1	0.48
8/15/75	10	935	93.5	8.1	0.19	18	1604	89.1	11.8	0.28
9/11/75	9	836	92.8	-0.7	-0.03	21	2027	96.5	7.4	0.28

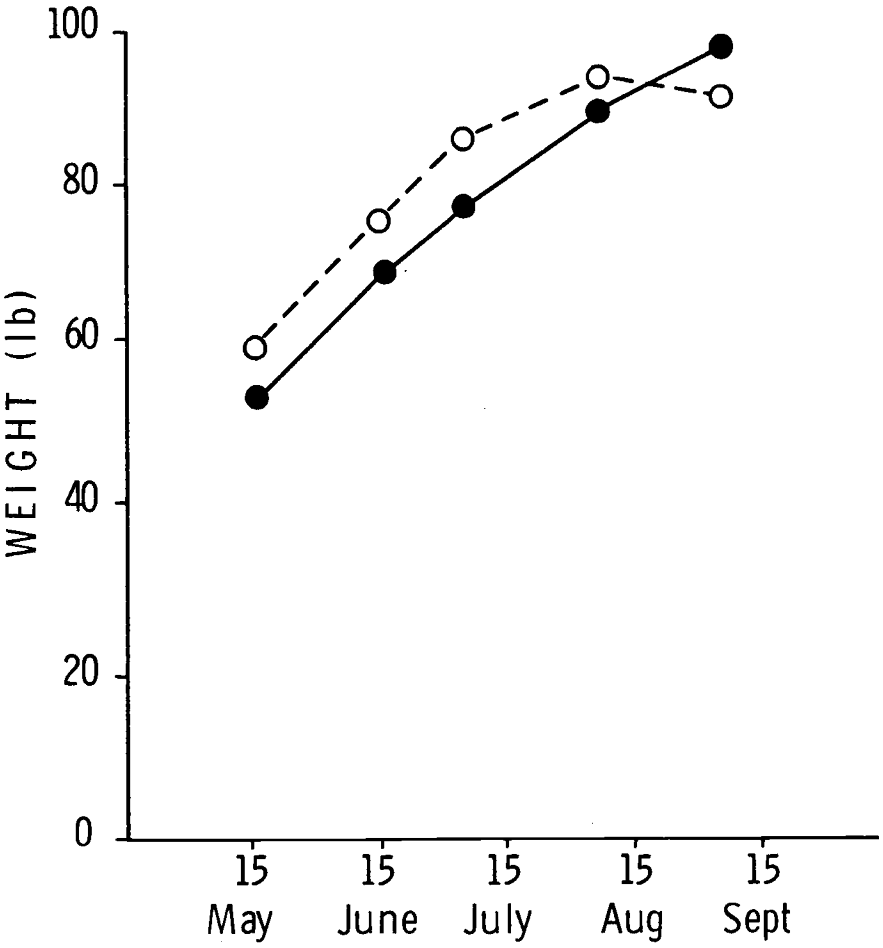

Figure 3. Mean weights of the sample (—) and control (--) lambs on the Farrell Ranch, Madras, Oregon 1975.

Table VI. Gastrointestinal helminth parasite burdens of lambs and ewes from the Farrell Ranch, Madras, Oregon, 1975.

				Abomasal Parasites			Small Intestinal Parasites			Cecal and Large Intestinal Parasites		
	Date	Animal Number	Total Parasite Burden	Total Abomasal Burden	*Ostertagia* spp.[a]	*Trichostrongylus axei*	Total Small Intestinal Burden	*Cooperia* spp.[b]	*Nematodirus spathiger*	Total Cecal and Large Intestinal Burden	*Oesophagostomum venulosum*	*Trichuris* spp.
Ewes	2/7	VDL 553 (1)	421	420	390	30	0[c]	0	0	1	1	0
	2/7	VDL 553 (2)	587	585	529	56	0	0	0	2	2	0
	2/7	VDL 553 (3)	110	90	90	0	20	20	0	0	0	0
		Mean	373	365	336	29	7	7	0	1	1	0
	3/26	104	6896	6200	6200	0	0	0	696[d]	0	0	0
	3/26	159	3464	3318	3318	0	0	0	146[d]	0	0	0
	3/26	351	1904	1800	1800	0	0	0	104[d]	0	0	0
		Mean	4088	3773	3773	0	0	0	315[d]	0	0	0
	4/1	VDL 1099	*	9480	9100	380	*	*	*	*	*	*
Lambs	5/6	VDL 525 (1)	*	711	711	0	*	*	*	*	*	*
	5/6	VDL 525 (2)	*	553	553	0	*	*	*	*	*	*
		Mean		632	632	0						
	7/4	LI	786	624	624	0	160	82	78	2	0	2
	9/11	1	5348	600	600	0	4740	3981	759	8	0	8
	9/11	2	3209	1000	1000	0	2200	1496	704	9	0	9
	9/11	3	6109	1540	1540	0	4560	3648	912	9	0	9
	9/11	4	11596	1420	1420	0	10140	7300	2840	36	0	36
	9/11	5	5311	960	960	0	4340	3298	1042	11	0	11
		Mean	6315	1104	1104	0	5196	3945	1251	15	0	15

*Undetermined.

[a] Includes *Ostertagia circumcincta* (88-100%) and *O.* (*Teledorsagia*) *davtiana* (4-12%).

[b] Includes *Cooperia oncophora* (73-90%) and *C. mcmasteri* (10-27%).

[c] One *Moniezia* sp. was found.

[d] *Nematodirus abnormalis*.

mean abomasal burden increased ten-fold (1037%) during this period. The abomasal burden again increased nearly three-fold (250%) from late March to early April.

In the lambs examined, Ostertagia spp. comprised 17 to 79% of the total parasite burdens. The mean total parasite burden increased by 803% from early July to mid-September, whereas the mean burdens in the abomasums increased only by 175% from early May to mid-September. From early July to mid-September, the mean abomasal burdens consisted of 100% Ostertagia spp. This percentage, compared to total burden, decreased from 79% to 17% while the mean small intestinal burdens (composed of 51 to 76% Cooperia spp. and 24 to 49% Nematodirus spathiger) increased from 20% to 82% of the mean total parasite burden.

Three calves were necropsied and examined for parasites in late August (Table VII). The mean total parasite burden in these calves was 14,904 worms. Parasites recovered included 40.8% Ostertagia ostertagi, 3.0% O. circumcincta, 2.3% T. axei, 50.5% C. oncophora, 3.4% Nematodirus helvetianus, 0.005% O. venulosum and 0.065% Trichuris sp.

Tracer Lambs

Two of 24 tracer lambs (8%) were killed by coyotes on pasture 5. The carcasses were not available for parasite examinations. The dates of introduction to each pasture, group number and parasite burdens of the tracer lambs are presented in Table VIII.

Table VII. Gastrointestinal helminth parasite burdens of calves from the Farrell Ranch, Madras, Oregon, August, 1975.

			Abomasal Parasites				Small Intestinal Parasites			Cecal and Large Intestinal Parasites	
Animal Number	Total GI Parasite Burden	Total Abomasal Burden	*Ostertagia ostertagi*	*Ostertagia circumcincta*	*Trichostrongylus axei*	Total Small Intestinal Burden	*Cooperia oncophora*	*Nematodirus helvetianus*	Total Cecal and Large Intestinal Burden	*Oesophagostomum venulosum*	*Trichuris* sp.
F24	14434	6172	5678	0	494	8252	8252	0	10	2	8
F25	15655	7776	6156	1351	269	7872	7872	0	7	0	7
B&W	14622	6667	6389	0	278	7941	6438	1503	14	0	14
Mean	14904	6872	6074	450	347	8022	7521	501	10	1	10

Table VIII. Gastrointestinal helminth parasite burdens of tracer lambs on pastures on the Farrell Ranch, Madras, Oregon, 1975

				Abomasal Parasites			Small Intestinal Parasites			Cecal and Large Intestinal Parasites		
Date on pasture	Pasture number	Animal and group number	Total Parasite Burden	Total Abomasal Burden	*Ostertagia* spp.[a]	Total Small Intestine Burden	*Capillaria* sp.	*Cooperia oncophora*	*Nematodirus* spp.[b]	*Strongyloides* sp.	Total Cecal and Large Intestinal Burden	*Oesophagostomum* sp.	*Trichuris* spp.
3/1/75	1	951 (Ia)	340	320	320	20	0	0	0	20	0	0	0
3/1/75	1	954 (Ia)	456	428	428	28	0	0	14	14	0	0	0
		Mean	398	374	374	24	0	0	7	17	0	0	0
3/1/75	2	952 (Ib)	948	800	800	148	0	0	148	0	0	0	0
3/1/75	2	953 (Ib)	740	660	660	80	0	14	66	0	0	0	0
		Mean	844	730	730	114	0	7	107	0	0	0	0
3/31/75	1	955 (II)	1028	1028	1028	0	0	0	0	0	0	0	0
3/31/75	1	956 (II)	480	480	480	0	0	0	0	0	0	0	0
		Mean	754	754	754	0	0	0	0	0	0	0	0
5/17/75	3	959 (III)	1080	372	372	708	0	0	680	28	0	0	0
5/17/75	3	960 (III)	908	108	108	800	0	192	608	0	0	0	0
		Mean	994	240	240	754	0	96	644	14	0	0	0
6/2/75	5	963 (IV)	65	13	13	52	0	39	13	0	0	0	0
6/2/75	5	* (IV)											
		Mean	65	13	13	52	0	39	13	0	0	0	0
6/16/75	6	965 (V)	574	320	320	252	0	92	160	0	2	0	2
6/16/75	6	966 (V)	460	320	320	120	0	66	54	0	20	20	0
		Mean	517	320	320	186	0	79	107	0	11	10	1
7/1/75	2	961 (VI)	1672	1580	1580	92	0	15	62	15	0	0	0
7/1/75	2	977 (VI)	868	760	760	108	0	0	108	0	0	0	0
		Mean	1270	1170	1170	100	0	8	85	8	0	0	0
7/22/75	3	970 (VII)	402	172	172	228	13	201	14	0	2	0	2
7/22/75	3	971 (VII)	253	120	120	132	0	119	13	0	1	0	1
		Mean	328	146	146	180	7	160	14	0	2	0	2

Table VIII. (continued)

8/4/75	5	973 (VIII)	241	1	1	240	0	173	53	14	0	0	0
8/4/75	5	976 (VIII)	*										
		Mean	241	1	1	240	0	173	53	14	0	0	0
8/15/75	6	974 (IX)	4521	880	880	3640	0	2622	728	290	1	0	1
	6	975 (IX)	2132	492	492	1640	0	918	262	460	0	0	0
		Mean	3327	686	686	2640	0	1770	495	375	1	0	1
9/1/75	2	254 (X)	80	90	80	0	0	0	0	0	0	0	0
9/1/75	2	1009 (X)	100	60	60	40	0	0	40	0	0	0	0
		Mean	90	70	70	20	0	0	20	0	0	0	0
9/11/75	2	251 (XI)	130	50	50	80	0	0	80	0	0	0	0
9/11/75	2	972 (XI)	105	55	55	50	0	0	55	0	0	0	0
		Mean	118	53	53	65	0	0	65	0	0	0	0

[a] Includes _O_. _circumcincta_ (50-100%; 88.0% average), _O_. _trifurcata_ (0-22.2%; 2.7% average), and _O_. (_Teledorsagia_) _davtiana_ (0-33.3%; 9.3% average).

[b] Includes _N_. _spathiger_ (50-100%; 90.8% average), and _N_. _abnormalis_ (0-50%; 9.2% average).

*Tracer lamb was killed by coyotes.

Mean parasite burdens of the tracer lamb groups ranged from 65 to 3327. Parasites recovered included 0.4 to 100% *Ostertagia* spp., 0 to 2% *Capillaria* spp., 0 to 60% *C. oncophora*, 0 to 65% *Nematodirus* spp., 0 to 11% *Strongyloides* sp., 0 to 2% *Oesophagostomum* sp. and 0 to 0.6% *Trichuris* sp.

Mean parasite burdens for each tracer group on pasture throughout the grazing season are illustrated in Figure 4. Low parasite burdens of predominantly *Ostertagia* spp. were found from March through June. The burdens were higher in the July and August pasture rotations with exception of pastures 3 and 5. *Cooperia* became the predominant small intestinal parasite in July and August replacing *Nematodirus* spp. Parasite burdens of tracers on pasture 2 in September were very low.

Mineral Determinations

Results from the mineral analyses conducted on sheep and calves on the study ranch are summarized in Table IX.

Meteorologic Data

Temperature and humidity data are recorded in Table X and illustrated in Figure 5. The mean daily temperature rose from 39 F in April to 74 F in July, followed by a decline to 61 F in August and September. The highest maximum weekly means were recorded in July at 90 F. Although humidity exhibited a daily fluction, the mean percent humidity declined from 63% in early April to 39% in mid-September.

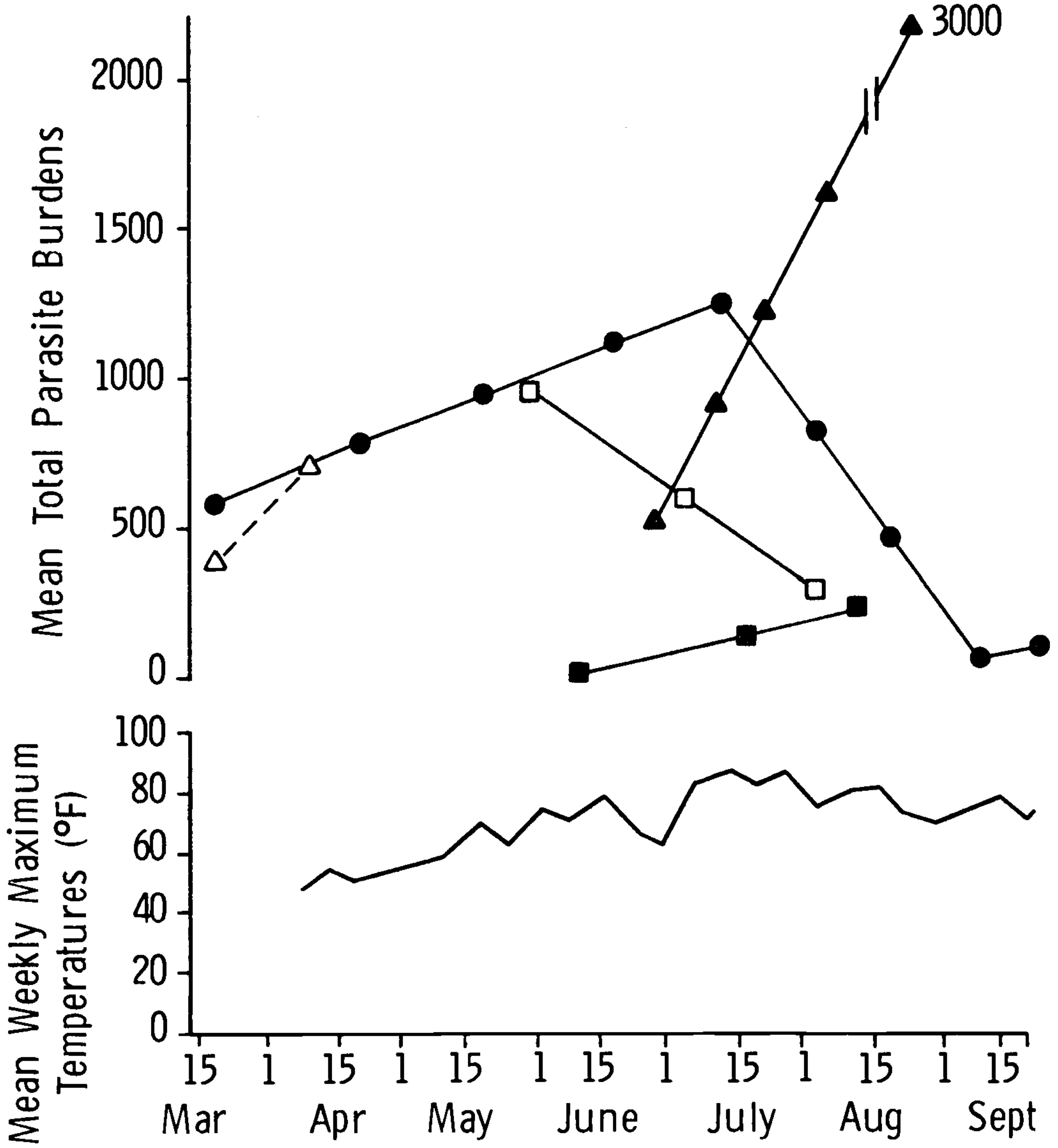

Figure 4. Mean parasite burdens of the tracer lambs on pastures at the Farrell Ranch, Madras, Oregon 1975. (△---△ pasture 1; ●——● pasture 2; □——□ pasture 3; ■——■ pasture 5; ▲——▲ pasture 6)

Table IX. Mean trace mineral determinations (±1 standard deviation) in blood portions of lambs and calves on the Farrell Ranch, Madras, Oregon 1975.

		Lambs		Calves
	Date	7/13	8/15	8/15
	Sample Size	15	20	20
Blood portion	Mineral	(ppm)	(ppm)[a]	(ppm)[a]
Plasma	Ca	*	70 ± 4	68 ± 3.5
	Cu	0.611 ± 0.128[b]	0.95 ± 0.17[b]	0.93 ± 0.10[b]
	Fe	2.095 ± 0.368	*	*
	Mg	*	22 ± 2	23 ± 2.35
	Se	0.02[c]	0.03 ± 0.01[c]	0.01
	Zn	0.596 ± 0.106	*	*
Whole Blood	Zn	*	3.2 ± 0.3	2.8 ± 0.4[d]
	Fe	*	358 ± 30[e]	401 ± 22[e]
Serum	P	*	6.55 ± 0.84	7.12 ± 0.49

[a] Phosphorous levels are in mg/100 ml.

[b] Supplemental Cu was fed.

[c] Supplemental Se was fed (sheep only).

[d] Supplemental Zn was fed (cattle only).

[e] Supplemental Fe was fed (cattle only).

* Undetermined.

Table X. Average weekly maximum, minimum, and mean temperatures and humidities for Farrell Ranch, 1975.

Weekly	Temperature (°F)			Humidity (%)		
Interval	Maximum	Minimum	Mean	Maximum	Minimum	Mean
3/31/-4/6	48	28	39	93	32	63
4/7-4/13	56	31	44	89	20	55
4/14-4/20	53	34	44	93	26	60
4/21-4/27	55	36	46	89	27	58
4/28-5/4	57	34	46	73	24	51
5/5-5/11	62	37	50	96	29	64
5/12-5/18	71	44	58	85	25	56
5/19-5/25	62	38	50	86	27	57
5/26-6/1	78	48	63	81	21	52
6/2-6/8	71	48	60	96	30	63
6/9-6/15	80	50	66	76	19	48
6/16-6/22	70	45	58	95	29	62
6/23-6/29	64	44	54	96	28	62
6/30-7/6	84	55	69	82	20	51
7/7-7/13	90	62	76	87	23	55
7/14-7/20	83	51	68	91	21	56
7/21-7/27	90	57	74	71	19	45
7/28-8/3	78	50	65	92	28	61
8/4-8/10	82	50	66	89	24	56
8/11-8/17	83	53	68	82	22	52
8/18-8/24	76	50	64	91	27	59
8/25-8/31	71	49	60	88	25	57
9/1-9/7	77	45	62	81	17	50
9/8-9/14	81	52	66	60	22	41
9/15-9/21	74	46	61	75	22	49
9/22-9/23	76	45	61	68	19	39

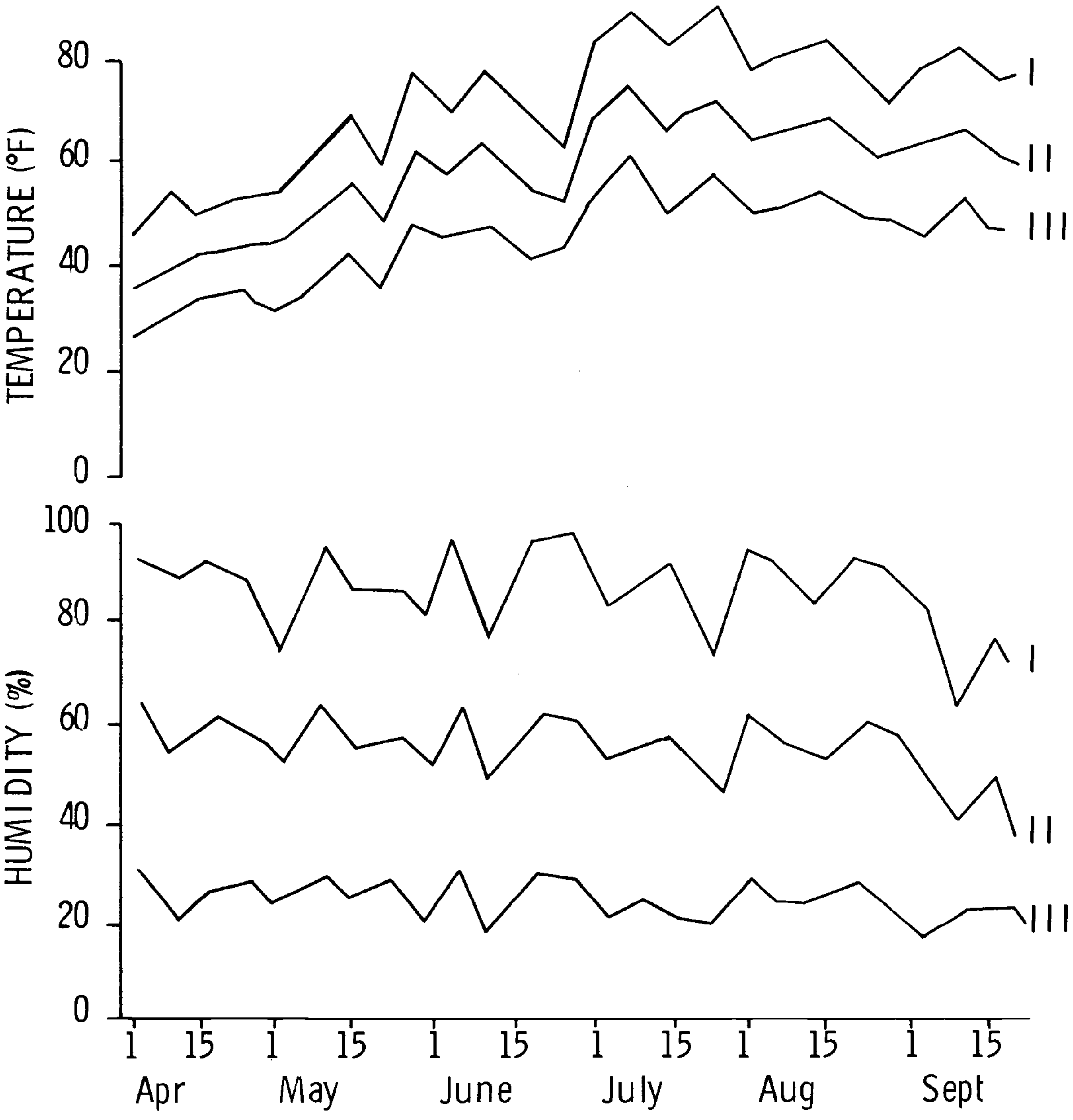

Figure 5. Mean weekly maximum (I), minimum (III), and mean (II) temperatures and humidities for the Farrell Ranch, Madras, Oregon 1975.

DISCUSSION

Modifications per protocol (Animal)

The consumption levels of phenothiazine in the flock were below the levels necessary to achieve marked suppression of ovulation and larval development (Levine 1968). The effectiveness of this control measure during the study period was probably negligible. For this procedure to be effective, phenothiazine consumption should be increased to the prescribed therapeutic dosages (1-2 g/head/day).

Parasite Monitoring of Ranch Animals

FECAL NEMATODE EGG COUNT MONITORING

The fecal nematode egg counts of the ewes and lambs during this investigation suggested that parasite burdens within the study flock were low to moderate. The fluctuation pattern of the nematode egg output of the ewes indicated that the times of maximum pasture contamination by the ewes were in May and August. A rise in fecal nematode egg counts of the ewes from March through May was observed despite deworming the flock in the fall prior to breeding and again two weeks prior to lambing. This rise corresponded to the spring rise or periparturient rise in fecal nematode egg counts reported by many investigators (Michel 1974, 1976). Implications were discussed in detail in the literature review (p. 16-18).

Deworming the ewes shortly before or after lambing as a means to suppress the periparturient rise has been advocated by several investigators (Leiper 1951; Nunns, Rawes and Shearer 1965; Brunsdon 1966a; Gibson and Everett 1967, 1972; Reid 1973; Reid and Armour 1975). In this investigation, however, the periparturient rise in nematode egg counts of the ewes was not eliminated.

The increase in egg output of the study flock following parturition appeared to be less than that reported in many areas. The peak egg counts in this study occurred within the 6-8 week period surrounding parturition, which agreed with the work of Crofton (1954). It appeared that this periparturient rise was due to the rapid reinfection of the ewes following anthelmintic treatment. This has been reported by several other investigators (Connan 1968b; O'Sullivan and Donald 1970; Arundel and Ford 1969; Arundel 1971; Thomas and Boag 1973). These authors suggest that the periparturient rise is due to a temporary relaxation of immunological resistance, and that it would be reasonable to expect this to be reflected in the maturation of inhibited larvae, increased fecundity of existing parasites, and susceptibility to new infection. Thomas and Boag (1973) and Arundel (1971) concluded that although anthelmintic treatment may nullify the effects of larval maturation and increased fecundity, it will not prevent the rapid re-establishment of the worm burden by new infections.

The epidemiological importance of the spring/periparturient rise phenomenon is that it heavily contaminates pastures, thereby constituting a significant source of infection for the young lambs grazing with their dams (Levine 1968; Boag and Thomas 1971). Frequent post parturient deworming of ewes would contribute greatly to parasite control. In Central Oregon sheep lambing in March, the periparturient rise appears to take place around the last week of April and the first week of May.

The fecal nematode egg counts of the sample lambs in May indicated that the flock lambs had acquired moderate numbers of parasites during their first nine weeks on pasture. These burdens fluctuated throughout the grazing season with the dewormings and pasture rotations. The untreated control lambs had higher EPG counts and exhibited less fluctuation, indicating that their parasite burdens remained higher and more constant during the grazing period.

WEIGHT GAIN PERFORMANCE

Comparison of the ADG of the control and the dewormed lambs shows that the lambs which were not dewormed had a lower rate of gain than the lambs which were dewormed. This is best exemplified in the late summer data (Table V). The early summer rate of gain of 0.48 to 0.50 lb/day was good in both groups of lambs for grazing animals. However, by August, the ADG of both groups declined. This trend continued into September at which time the control lambs lost weight and the sample lambs gained at a minimal rate. The poorer performance of the control lambs may be attributed to the effects of gastrointestinal parasites or to low selenium and possibly other mineral levels, since the dewormed/supplemented lambs had better weight gain performance. These results support the well-documented fact that gastrointestinal parasitism may depress performance of growing animals (Spedding 1953, 1955; Gibson 1954a, 1955; Soulsby 1965; Georgi 1969; Levine 1968). However, depression of performance in both groups of lambs suggested that other factors were involved. The flock lambs were weaned in mid-August. It is possible that weaning may have weakened their resistance to other infections (Whitlock 1949, 1951). Nutritional deficiency is unlikely since the lambs were on high quality improved pasture from fertilization and irrigation. Additional mineral deficiencies may have been involved in the depressed late-summer performance, although the lambs regularly had access free-choice to trace mineral salt. A small percentage of the lambs exhibited diarrhea and "poor doing" during June, and an outbreak of soremouth occurred in the flock in May and June. It is also possible that heat stress may have been involved in lowering weight gain performance during July and August, since hot weather is a well known depressant in sheep (Ensminger 1962). These stresses may have contributed to the poor performance of the flock during the hottest part of the summer.

QUANTITATIVE PARASITOLOGIC EXAMINATIONS

Parasitologic examinations of flock ewes and lambs generally revealed low to moderate worm burdens, which represented subclinical infections (Soulsby 1965; Levine 1968; Georgi 1969). The low parasite burdens in ewes examined during February confirmed the egg count data, that is, ewes harbored few parasites. The fall and pre-parturition deworming of the ewes were intended to eliminate these larvae. The results of this treatment regime were in agreement with results obtained by Gibson and Everett (1967).

The higher parasite burdens recovered from the ewes two and three weeks following parturition demonstrated that they had rapidly become infected and that this newly acquired infection was the cause of the periparturient increase in fecal nematode egg counts. This infection indicated that considerable numbers of infective larvae were available in pastures 1 and 2. These pastures were heavily used the preceding year for sheep, undoubtedly were heavily contaminated, and had high spring overwintered infective larval populations.

The low EPG counts in May and July in lambs indicated low parasite burdens; these data were confirmed by low numbers of parasites recovered from lambs necropsied at the same times. These burdens did not appear to be adversely affecting the lambs. The late summer higher parasite burdens correlated with the rise in EPG in September. The levels found in September, evaluated against reported data (Soulsby 1965; Levine 1968; Georgi 1969), are considered to represent sub-clinical infections but may have been of sufficient magnitude to depress weight gains. Subclinical parasite burdens in lambs have been shown to depress weight gain and feed efficiency (Spedding 1954, 1955).

From the postmortem examinations, *Ostertagia* spp. and *Trichostrongylus* spp. were found to represent the predominant parasites during the early part of the grazing season (February-May), and were apparently primarily involved in overwintering on the pasture and the subsequent contributors to the peripartrient rise. Previous investigators have demonstrated that these genera are resistant to cold weather and commonly overwinter on pasture as infective larvae (see literature review). *Nematodirus* and *Cooperia* spp. overwintered in low numbers in the ewes. These were the predominant nematodes recovered in September; the free-living stages of these genera have optimal developmental temperature ranges higher than those for *Ostertagia* and *Trichostrongylus* spp. (see literature review).

Comparing the parasite fauna of the calves (Table VII) and sheep (Table VI), both species harbored moderate numbersof *O. circumcincta* and *C. oncophora*, and lesser numbers of *T. axei*, *O. venulosum* and *Trichuris* sp. Cross infections apparently occurred with *C. oncophora* and *O. circumcincta*; both species are of epidemiological importance. Additionally, some of the larval *Ostertagia* recovered in the sheep may have been *O. ostertagi* which are pathogenic in sheep (Herlich 1975). *O. ostertagi*, however, develop only to the adolescent stage; adults are not found and larval speciation is impossible.

Investigators dealing with alternate grazing of pastures by heterologous hosts have mixed opinions as to the value of this procedure (Michel 1969; Gordon 1973). In this investigation, control of parasitism was not achieved by this method.

Tracer Lambs

Results from the tracer lamb examinations demonstrated that the number of infective larvae available on the pastures varied during the grazing season. The seasonal succession of the parasites acquired was similar to the trends found for flock lambs and ewes. The parasite burdens recovered from tracer groups Ia, Ib, III, IV and V indicated presence of overwintering nematodes on pastures 1, 2, 3, 5, and 6 respectively. As in the flock ewes and lambs, the predominant overwintering parasites were *Ostertagia* spp.

High levels of infection on pastures 2 and 6 in July resulted from autoinfection of pastures by the ewes and lambs. Pastures 2 and 6 probably became highly contaminated during the first grazing in March and June respectively. When the sheep returned to the pasture, large numbers of infective larvae were available to the tracer lambs and the remainder of the flock. This is in contrast to decreased numbers of infective larvae available when the sheep returned to pastures 2 and 3 in July and September. Temperatures during the late summer appeared to be too high for good survival of the trichostrongyle larvae (Gordon 1948; Levine 1963). Larval availability on pasture 5 remained low throughout the grazing season. This pasture was drier and rockier than the others and desiccation may have been responsible for the lower numbers of infective larvae.

Mineral Determinations

Although insufficient work has been conducted in sheep to fully delineate the relationship of trace mineral deficiencies in gastrointestinal parasitism, studies indicate that some correlations exist depending on the parasites involved (see literature review, p. 18-19). However, until additional work is conducted to unequivocably establish these relationships, it is impossible to evaluate the relationship between these two factors. Normal mineral blood values used here are those reported by Underwood (1966, 1971) in sheep and other ruminants. Normal selenium blood levels in grazing ruminants has been established at 0.05 ppm; our findings in the flock sheep were variable, but below normal. The non-supplemented control lambs exhibited poorer performance than the supplemented lambs. This suggests that the poorer performance may be attributed to the effects of low selenium levels or combined parasitism/selenium deficiency. On the study ranch, only the sheep received supplemental selenium, yet the sheep underwent a summer decline in weight gain performance. The cattle had low selenium blood levels according to Underwood (1971), but weight gain of the cattle was not monitored. It was therefore impossible to determine if cattle were affected by a summer decline. Poor performance may have been augumented by low cobalt levels in forage from the Madras area. The encephalomalacia problem on this ranch strongly suggests a cobalt deficiency (T. P. Kistner, 1977, pers. comm.). These data are inconclusive; however, it can be speculated that low selenium and cobalt levels adversely affected performance in the flock.

Meteorologic Determinations

The humidity data recorded on the study ranch during the 1975 grazing season did not reflect the soil moisture content because the recording instrument was not placed at ground level and was not subject to irrigation (Levine 1963). Considerable difference exists between ambient temperature and humidity and that which occurs at ground level in the microclimate.

The nearly constant use of irrigation on the pastures should have created sufficiently moist conditions for the maturation and survival of infective trichostrongyles of sheep. Gordon (1948) considered that the limit for optimal pasture development of *Ostertagia* and *Trichostrongylus* was 5 cm (2 inches) or more total precipitation per month. However, soil moisture content varies according to the soil type, water runoff, balance between precipitation and evapotranspiration (Levine 1968) and soil type and density (Anderson, Levine and Boatman 1970).

When irrigation was withheld from pasture during hay harvest, it is probable that sufficient desiccation occurred to kill some infective larvae. The interval from cessation of irrigation until reirrigation of the fields was as short as one week and as long as two weeks (Phil Farrell 1976, pers. comm.). During mid-summer, temperatures were high enough to cause rapid drying when irrigation was withheld. The recorded ambient air temperatures indicated that during much of the grazing season, conditions were close to ideal for the maturation and development of the trichostrongyles of sheep (Gordon 1948; Levine 1959, 1963). As indicated in the literature review (p. 13) considerable disagreement exist as to the value of recorded ambient temperatures in comparison to micrometeorological values obtained at the surface and beneath the soil. However, the validity of micromeasurements in the larval habitat is questionable according to Michel (1976). Budgetary limitation precluded equipment necessary for micro-measurements of temperature and humidity.

During May and June, temperatures were within the optimum range (55 to 73 F) for maturation and development of Ostertagia spp. and Trichostrongylus spp. (Gordon 1948; Levine 1959). Additional specifics on developmental temperatures and times are in the literature review (p. 11-12). During July and August, the mean monthly temperatures were above the optimal range for these nematodes, but were close to ideal for Cooperia and Nematodirus spp. The effect of these temperatures aided in producing the high numbers of infective larvae of these genera in the late summer.

SUMMARY AND CONCLUSIONS

Results of this investigation indicated that a parasite problem in sheep exists in Central Oregon on intenstively managed ranches. This problem stems from rearing relatively large numbers of sheep on limited acreage and from the overwinter survival of _Ostertagia_ spp. and _Trichostrongylus_ spp. on pastures.

Early spring infection results from animal placement on pastures carrying overwintered _Ostertagia_ spp. and _Trichostrongylus_ spp. eggs and larvae. The ewes undergo a periparturient increase in fecal egg counts during six to eight weeks surrounding parturition. This increase was derived from infective larvae on the pre-lambing and post-lambing pens.

Lambs are initially exposed to infection when placed on pastures carrying overwintering larvae, but the level of exposure decreased through June as overwintering larvae died. High numbers of infective larvae were available to lambs on regrazed pastures during mid-summer (July). These larvae developed from eggs passed by the ewes during the periparturient rise and from eggs passed by the lambs. Pasture larval numbers declined in late August-September, probably because larval survival decreased during the hot weather in July.

The parasite control measures used in this study were not entirely effective. Putting cattle for ten days on the pastures after sheep have been moved appears to have had little if any effect on the parasite burdens of the lambs. The cattle were apparently placed on the pastures before larval maturation to the infective stage, and therefore did not consume maximum numbers of infective ovine parasites. Cross-infections with *O. ostertagi* *O. circumcincta*, *N. helvetianus* and *C. oncophora* may have occurred.

Anthelmintic treatment of the ewes in the fall and prior to lambing appears to be effective in eliminating hypobiotic larvae. Rapid reinfection of the ewes was only partially stemmed by postparturient deworming. The remainder of the deworming schedule reduced the parasite burdens of the ewes and lambs.

The feeding of phenothiazine salt could be markedly beneficial in suppressing levels of pasture contamination. Since each sheep received an average dose of only 317 mg/day, however, this dosage appeared insufficient for optimum control.

The relationship between weight gain performance, supplemental use of selenium and the feeding of a trace mineralized salt on parasite burdens within the flock is indeterminable. The blood levels of the minerals, with the possible exception of selenium appear to be within normal limits. Selenium levels may have been low in the lambs and were definitely low in the calves. The relationship of these factors to parasitism is poorly understood. It is believed that effort should be made to bring the levels of selenium up to normal values by supplementation, while monitoring parasite burdens. In this manner the relationship, if any, may be defined.

RECOMMENDATIONS FOR FUTURE PARASITE CONTROL

The following recommendations are suggested for nematode parasite control in sheep under ranch conditions in Central Oregon.

1. Prior to breeding deworm the flock in the fall with normal dosage levels of an anthelmintic.
2. Deworm the ewes immediately prior to leaving the lambing sheds for pasture using Thiabendazole at 100 mg/lb body weight.
3. Deworm the ewes with normal therapeutic levels of anthelmintic 2 to 3 week intervals after going onto spring pasture until mid-May. This will minimize the pasture contamination by the ewes until they regain their immunity.
4. Deworm lambs prior to movement to each new pasture during the initial grazing cycle, alternating anthelmintics.
5. Terminate phenothiazine, or increase consumption to 2 g/day/sheep. This may be accomplished by the addition of molasses or linseed meal.
6. Provide shade for sheep in the hot months to reduce heat stress.

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APPENDICES

I--Climatological Summary for Madras, Oregon

The following climatological summary of Madras, Oregon has been reproduced from Holbrook, 1971; U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Climatography of the United States, No. 20-25.

> "Madras lies near the northwest edge of Central Oregon's high plateau area. The immediate agricultural bench lands vary in elevation from 2,100-2,400 feet msl and drain generally westward for 6 miles to the Deschutes River. Foothills of the Cascade Range become forested just a few miles west of the Deschutes canyon and rise to elevations of 5,000 and 6,000 at the crest ridge about 33 miles west of the city. Many prominent buttes and ridges are visible in the area while several snowcapped peaks reach above 10,000 feet. The rolling plateau area extends southward into California and Nevada and eastward into Idaho, broken only by hills or chains of relatively low mountains. The plateau north is cut by canyons of the Deschutes and its tributaries and other drainage streams flowing into the Columbia.
>
> Madras is only 150 miles east of the Pacific Ocean, but the predominately marine air masses that cross this area are greatly modified during their inland passage. Much of the precipitable moisture is condensed out of the air movement over the Coastal and Cascade ranges which extend the full north-south length of Oregon. Occasional outbreaks of polar continental air in winter will push west of the Rocky Mountains and move southward across this region, giving the more extreme low temperatures.
>
> The mild, dry climate of Madras provides definite seasonal characteristics with gradual changes usually noted between them. The light precipitation is greatest in winter when it occurs on half the days and 30% of the moisture falls as light snow. Cold winter days are eased by sunshine occurring 25-35% of the time. The spring rains decrease sharply by mid-June when sunshine 65% of the time increases to 85% by late summer. Crops are eased through the warm dry summers by extensive use of ditch and sprinkler irrigation. Mid-summer showers are likely on 1 day out of 14 and wet days increase to 1 day out of 7 again by late fall.
>
> Madras like most other areas of Oregon has a winter rainfall climate but experiences a secondary maximum in June. Annual moisture in Jefferson County varies from near 90 inches at the crest of the Cascade Range to 10 inches in the Madras area and

back up to 15 inches at the east border. Madras receives 35% of its annual total in winter, 22% in spring, 17% in summer, and 26% in fall. Individual years have ranged from 4.70 inches in 1930 to 15.24 inches during 1949. Thunderstorms occur mostly from April through October on 12-15 days a year. These may last for a few hours and produce some of the area's most intense rainfall. For a ten-year return period, one could expect a maximum 3-hour total of 1.1 inches or a 24-hour total of 2.1 inches. A 100 year return period shows a 3-hour total of 1.7 inches and a 24-hour total of 3.0 inches. Snowfall accounts for 15% of the annual moisture and occurs each winter. The winters average 13 days of snowcover and the average depth on those days is slightly less than 4 inches. Greatest depth ever recorded was 15 inches; however, in 75% of the seasons it never exceeded 8 inches and in 50% it was not more than 6 inches.

Moderate to warm days and cool nights characterize year-around temperatures at Madras. Daily extremes are eased by a 24-hour range of temperature which averages 20 degrees in January and varies up to a 42-degree range in July and August. Annual temperature extremes show that only 1 year out of 5 will be cooler than - 20° or warmer than 106°. Summer readings of 100° and above occur in 3 years out of 4 and average 3 such days per year. Cold extremes show that 3 years out of 4 will cool below 0° while the 4 mildest winters during the past 50 years have not been colder than 10-13° Light freezing summer minimum that occur in only 1 year out of 3 will drop temperatures to near 32° for only a very short time but cause little or no drop damage. The 100-110 growing days reported by the Jefferson County Extension Office relates well with the 108-day growing season for Madras as based on the average date of last 28° or lower in spring and that the first occurrence in fall.

Climatological interpolations provide these additional details for the Madras area. Clear days number 125 per year while 90 days are partly cloudy and 150 days are cloudy. Early morning relative humidity averages 70-80% year-around while mid-afternoon values vary from 25-35% in summer to 50-65% in winter. Wind directions are predominately from the south in winter and the north in summer. Wind speeds are at a minimum between 3 and 7 a.m. with averages of 3-6 mph. These increase reaching a peak of 10-12 mph between 3 and 5 p.m. during most of the year except about three hours earlier in winter. Fastest 1-minute average winds of 56 mph have been observed in this area with gusts reported up to 78 mph. Infrequent hail will occasionally cause damage across very small areas. Only one small tornado has been observed in the area since 1887, and that was a brief touchdown without damage or injury on the Indian Reservation 20 miles northwest of Madras on May 11, 1970.

The sunny climate and fertile lands of the Madras area favor a wide variety of economic and recreational activities. Despite the low average annual rainfall and relatively cool nights, extensive agriculture is carried on in this area.

Cold streams fed by heavy snowpacks in the Cascade Mountains provide water for the irrigation of more than 60,000 acres of highly productive farm land. Through the central part of the county lies the North Unit Irrigation District where seed, potatoes, hay, and mint are produced. The 12,500 acres of mint in the county is one of the largest known county acreages in the United States. The Madras area grain yields are also highest in Oregon. The eastern part of the county has wheat farming and grazing lands for cattle. The livestock feeding industry handles 30-35,000 heads of cattle annually. The western part is timber lands and the Warm Springs Indian Reservation is located in the northwestern part of the county.

II--Compositions of Mineralized Salts

Table 1-2

Table 1. Composition of mineralized cattle salt used on Farrell Ranch, 1974-1975[a,b].

Morton T-M Salt trace mineralized, medicated organic iodine new supplement	Greater than or equal to (%)	Less than or equal to (%)
NaCl	95.0	98.0
Zn	0.350	
Mn	0.280	
Fe	0.175	
I	0.141	
Cu	0.035	
Co	0.007	

[a] Cattle consumed about 50 lb/week.

[b] For sheep, Ca_2PO_3 and Phenothiazine was added in 1974.

Table 2. Composition of mineralized Phenothiazine salt used for sheep on Farrell Ranch, 1975[a].

Mn	$\geq$	0.680%		
Cu	$\geq$	0.0100%		
Co	$\geq$	0.0024%		
I	$\geq$	0.0120%		
Phenothiazine	=	8.88%		
NaCl	$\geq$	87.80%	$\leq$	88.80%

[a] Sheep consumption was about 50 lb/week.