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Title: CHEMICAL ANALYSIS OF THREE FORAGE PLANTS COLLECTED FROM PASTURES SUSPECTED OF INCITING ACUTE BOVINE PULMONARY EMPHYSEMA

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A two-year study was made of pastures suspected of inciting acute bovine pulmonary emphysema (ABPE) in east-central Oregon. Objectives of this study were (1) to determine the vegetation composition of these pastures, (2) to determine seasonal trends of tryptophan, crude protein, and nitrogen/sulfur ratios in selected pasture plants, (3) to determine daily utilization immediately after cattle were introduced to these pastures, (4) to relate cattle foraging habits to development of symptoms of ABPE, and (5) to determine common herd characteristics and management practices on ranches frequently affected by ABPE.

Frequency data collected from plant communities on inciting pastures on the Lemcke and Palmer ranches showed a large number of species on these meadows. Kentucky bluegrass, Nebraska sedge, and

common rush were common to mesic portions of all pastures studied. These three species were collected over the 1973 growing season and analyzed for tryptophan, crude protein and the nitrogen/sulfur ratio.

Tryptophan content decreased from May 24 to September 4, with the largest change occurring over the first half of the season. It was determined that a 1000 lb cow eating the forage with the highest tryptophan level would have to ingest 43.8 kg (dry weight) of material to assimilate an equivalent amount of a single dose of tryptophan administered in laboratory induction of ABPE. This amount of forage could only be ingested over a period of several days.

Crude protein content of Nebraska sedge, common rush, and Kentucky bluegrass declined from the first sampling to the last and decreased most rapidly early in the season. Crude protein of all plants was adequate for lactating range cattle through the soft dough stages of plants sampled. Crude protein content of Kentucky bluegrass in latter stages of seed development were not adequate to maintain lactating range cows.

Nitrogen/sulfur ratios of Nebraska sedge, common rush, and Kentucky bluegrass varied more than tryptophan or crude protein within sampling periods. A decrease in nitrogen/sulfur ratios was noted over the season, the most rapid decline occurring during the last part. Sulfur content of all samples was adequate to maintain lactating range cows. No conclusions were drawn concerning the involvement of the nitrogen/sulfur ratio in ABPE.

Utilization measurements taken on mesic portions of the Lemcke and Palmer pastures showed Kentucky bluegrass, common rush, and Nebraska sedge utilized on the Lemcke ranch and birdsfoot trefoil, Kentucky bluegrass, bluebunch wheatgrass, smooth brome, and Nebraska sedge selected by cattle on the Palmer ranch. Observations of grazing habits of cattle on the Lemcke and Palmer pastures in 1972 and 1973 failed to correlate grazing patterns with development of symptoms of ABPE.

Questionnaires were completed for six ranch operations that had recent histories of ABPE. Factors common to all six areas were (1) occurrence of the disease between early July and mid-October, (2) appearance of symptoms after a change from relatively dry, sparse to relatively succulent, abundant forage, (3) a natural water source, (4) apparent high susceptibility of mature, lactating Herefords, (5) unpredictable morbidity, and (6) high probability of recurrence of symptoms after ABPE had been diagnosed in a herd.

Determination of cattle diets on ABPE-inciting pastures and chemical analysis of additional plant species is suggested for future work. Investigation of summer forage on frequently victimized ranches and continued compilation of case history information is also needed.

Chemical Analysis of Three Forage Plants Collected from Pastures Suspected of Inciting Acute Bovine Pulmonary Emphysema

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INTRODUCTION

Acute bovine pulmonary emphysema (ABPE) is a serious disease in cattle, occurring in several areas in Oregon with increasing severity. Its etiology is unknown, but the symptoms can be produced in the laboratory by several methods (Carlson *et al.*, 1968).

The occurrence of ABPE varies in time and place. However, its peak season runs from mid-July through September. Typically, symptoms appear two to ten days after cattle are moved from dry upland range to lush lowland meadows. Morbidity and mortality rates vary but may increase if cattle are placed under stress during the first two weeks on the new pasture.

ABPE seems a selective disease, striking lactating cows in larger proportion than steers, young cattle or dry cows. This fact accentuates the seriousness of the ailment, as brood cows are not only expensive, but constitute a major part of the genetic and reproductive base of the herd. The reason for this selective characteristic has been assumed to be that lactating cows consume more forage than dry cows or young stock. Bulls have been reported to have contracted the disease and possibly are as susceptible as wet cows, but are not as numerous and are victimized less frequently.

LITERATURE REVIEW

Introduction

In the first symposium held specifically to consider ABPE, Maki (1963) presented a review of the literature concerning this disease. This review covered papers dated as early as 1830, when bovine pulmonary emphysema was first reported in dairy cattle on the island of Cotenin. Later, the disease was noted in Belgium, Germany, France, Holland, India, Spain, Tasmania, Italy, Great Britain, and the United States.

Clinical Pathology

ABPE is characterized by a large, identifiable lesion covering the entire lung. The affected animal is afebrile and normally has a full rumen at the onset of the symptoms. Observable signs include severe expiratory dyspnea, increased salivation, and audible, open-mouth breathing with a marked expiratory grunt. Respiration is shallow, rapid, and the animal often stands with head extended. Pulse increases and the victim will not normally lie down, due to its difficulty in breathing. In some cases affected animals develop a cough and/or occasional nosebleed. If recovery does not ensue, the later stages of the disease are accompanied by cyanosis and hypoxia. Fatalities result from heart failure (Moulton *et al.*, 1961; Railsback, 1945; Schofield, 1948). Animals that recover from ABPE suffer permanent lung damage and susceptibility is increased by former contraction of the disease (Moulton *et al.*, 1961).

Proposed Etiology

Many scientists have proposed one or more possible causes for ABPE. Maki (1963) mentioned several of the most tenable prospective causes of the disease. He stated that the problem has been compounded by the widespread nature of ABPE and the varied circumstances under which it occurs. Bovine asthma, marsh pneumonia, fog fever, grunts, husk, forage poisoning, high altitude disease, summer snuffles, and swamp fever were names used to describe disorders with symptoms similar or identical to those of ABPE (Maki, 1963; McIntyre, 1963; Klussendorf, 1954). Also, some forms of pneumonia and parasitic respiratory disorders have produced like effects.

Fog fever, a syndrome noted in Great Britain, was described by Barker (1948, in MacKenzie, 1965). Symptoms were similar to those of ABPE and were precipitated by moving the cattle onto hay aftermath. Etiology of fog fever has not been established because similar symptoms have been seen in cattle eating moldy feed, being exposed to dust or smog, or hosting lungworms (MacKenzie, 1965). Barker (1948), in MacKenzie, 1965) implicated grass protein shock as an inciting factor in pasture cases and MacKenzie (1965) ruled out lungworms as a primary cause by reasoning that in the western United States calves of affected cows did not contract the disease, though they (the calves) were more susceptible to lung parasites.

Pirie et al. (1971) documented a study of the fog fever syndrome. "Farmer's lung," an asthma-like disease, was investigated and found to be caused by precipitins of a fungal spore or dust present in moldy hay. Studies indicated that such spores could cause symptoms of pulmonary emphysema in cattle under enclosed conditions on dry hay.

Verminous pneumonia, caused by lungworm larvae and worsened by consequential bacterial or viral infections, produced interstitial pulmonary emphysema in work done by Rubin (1965).

McIntyre (1963) described emphysema as a final stage of husk, or parasitic bronchitis, and stated that bovine lung structure was particularly susceptible to the occurrence of the emphysema lesion. He also noted that in the patent and post-patent stages of lungworm (Dictyocaulas viviparus) infestations extensive emphysema, dyspnea and anoxia could occur.

In the ABPE symposium held at Laramie, Wyoming, Griner (1963) detailed his work at Colorado State University on the toxins of Clostridium perfringens. Goodman (1956) had speculated previously that Clostridium welchii was implicated and found that type D antitoxin of C. perfingens effectively combatted C. welchii. Type BCD antitoxin of C. perfringens appeared to give some protection against pulmonary emphysema in work done by Maki and Tucker (1962).

The involvement of eructated toxic rumen gases was investigated by Moulton *et al.* (1963). One suspect compound was nitrogen dioxide, responsible for "silo-fillers'" disease in humans. Three groups of cattle were studied: unaffected animals on dry range, sick cattle on lush pasture, and those of the latter category that had died from ABPE. Rumen gases from each of these groups were analyzed.

It was found that range cattle had low rumen fermentation rates as compared with cattle on lush forage. Range cattle were also characterized by a high ammonia content in the rumen. Some sick animals had high rumen concentrations of ammonia, indicating that these rumens had not yet adjusted to lush forage prior to onset of symptoms.

Methane content was essentially the same for all three groups, and no other gases were found to vary consistently between groups. It was concluded that no significant difference in the major rumen gases existed between healthy, sick, or emphysema-killed animals.

Certain family lines have shown particular susceptibility to ABPE, according to Mackey (1952). He used antihistamines to counteract the suspected allergic reaction. Moulton *et al.* (1961) used the above allergy hypothesis to explain the preponderance of emphysema in older animals, the latent period between pasture change and symptoms, and the seasonal occurrence of the disease. Attempts to locate the allergen failed.

The pasture switch prerequisite to ABPE under range conditions has been studied by several investigators. Muscle lesions and a resultant stiffness were noted by Monlux (1953) in Texas cattle. Stomach disorders were also present after a change from poor to luxuriant forage or grain.

Schofield (1948) suspected rape, kale, and turnip tops as causative agents, but admitted that emphysema symptoms developing in cattle on these forages might be attributed to other factors, possibly the succulence of the diet.

Experimental feeding of sedge (*Carex aquatilis*), bullrush (*Scirpus americanus* var. *polyphyllus*), prickly lettuce (*Lactuca scariola*), and alfalfa-smooth brome (*Medicago sativa*-*Bromus inermis*) mix failed to incriminate a single species. Pulmonary emphysema did occur, but appeared to be related to forage succulence (Maki and Tucker, 1962).

Purple mint (*Perilla frutescens*) was suspected of abetting ABPE in work done by Peterson (1965). His investigations were made primarily in Oklahoma on acid, mineral-deficient soils. Plant species of offending pastures were recorded and purple mint was finally named as the inciting agent. An introduced annual, the plant had become a troublesome weed in this area and in some cases reportedly made up 90 percent of the ground vegetation. Turning cattle out to pastures containing this weed produced disastrous results in eight cases documented by Peterson (1965). Seeds of purple mint were found in the digestive tracts of dead cattle.

Nutritional background of cattle exposed to the mint appeared to be an important factor in determining relative palatability and consequent danger. Cattle brought in from high-quality, plentiful forage were less likely to eat purple mint and to contract emphysema.

The Tryptophan Hypothesis

Forage aspects of the complex ABPE problem have been given little attention; yet forage work relates to the most tenable of current etiological hypotheses. One of the most promising of these hypotheses was presented by Carlson *et al.* (1968) and by Carlson *et al.* (1972). This hypothesis concerns the possible involvement of tryptophan and suggests an opportunity for fruitful study of the role of forages in development of symptoms of ABPE.

In experimental work, tryptophan administered orally to cattle caused emphysema symptoms (Carlson *et al.*, 1968). Tryptophan was detected in the blood plasma and was shown to peak four to eight hours after dosing. Variations in time of peak concentration or in amount of detectable tryptophan in the plasma did not relate to the severity of the disease. Treated similarly, sheep also displayed a rise in plasma tryptophan, but did not contract pulmonary emphysema.

Later work (Carlson *et al.*, 1972) confirmed that only oral doses of DL-tryptophan produced the emphysema lesion, even though both oral and intravenous administrations registered in the plasma. This led to the speculation that a product of digestion was involved. Trials with both D and L isomers proved the L form was the causative agent. Indolacetic acid also produced emphysema when given orally.

Trials were run to determine rumen products of D-tryptophan, L-tryptophan, and indolacetic acid in the bovine. Both L-tryptophan and indoleacetic acid were converted to 3-methylindole (3-MI). Some indoleacetic acid was also formed from L-tryptophan. D-tryptophan produced none of these compounds. Goats given 0.30 g oral 3-MI/kg body weight died from pulmonary edema between 36 and 54 hours after dosage. Goats, like sheep, were not affected by oral administration of tryptophan, suggesting rumen products of cattle differ from those of sheep and goats (Carlson *et al.*, 1972).

Further work showed that the goats developed clinical signs of pulmonary emphysema within four hours, and died between 5 and 11 hours post-administration if one feeding was skipped just prior to oral 3-MI dosage. Oral dosing of cattle demonstrated that 0.20 g 3-MI/kg body weight caused symptoms and death in less time than did 0.10 g 3-MI/kg body weight (Carlson *et al.*, 1972).

Unlike L-tryptophan, 3-MI was capable of producing emphysema in cows if given intravenously. Clinical symptoms of ABPE developed 6 to 12 hours after intravenous administration of 0.06 g 3-MI/kg body weight, and one cow died within 56 hours. Also, oral doses of 3-MI were shown to cause symptoms more quickly and at lower molar equivalents than oral L-tryptophan. A dose of 0.10 to 0.20 g oral 3-MI/kg body weight incited ABPE. Using L-tryptophan, 0.57 to 0.70 g oral 3-MI/kg body weight was necessary to obtain similar results (Carlson _et al._, 1972).

The type of lung damage noted in emphysema-stricken cattle could be linked to 3-MI, as this and related substances are lipophilic and can rupture membranes. Also, 3-MI has been shown to hemolyze erythrocytes and cause disintegration of certain rumen protozoa (Carlson _et al._, 1972).

Involvement of the Nitrogen/Sulfur Ratio

The sulfur requirement of plants is closely related to the amount of sulfur in plant protein. Amounts of sulfur amino acids (which make up 90 percent of the organic sulfur in plants) vary only with changes in relative amounts of different plant proteins containing varying quantities of sulfur. The latter changes are principally due to environmental factors and are usually not significant. Successful manufacture of each protein hinges on availability of correct amounts of constituent amino acids. Sulfur-containing amino acids must be in proper proportion to those lacking sulfur (Thompson _et al._, 1970).

Plant nitrogen/sulfur ratios have been shown to vary from 4:1 to 55:1 (Stewart and Porter, 1969, in Moir, 1970). Grass leaves averaged 14:1 and legume leaves 17:1 in work done by Dijkshoorn and van Wijk (1967, in Moir, 1970). Nitrogen/sulfur ratios were narrowed by application of both nitrogen and sulfur in studies by Walker and Williams (1963).

Ulrich et al. (1967, in Hylton et al., 1968) showed that location of most sulfur in the plant varied but if any accumulation took place it was in the lower portion of the stem. Total available sulfur was evenly distributed for growth. Low sulfur in plants caused accumulation of nitrates, amides, and amino acids (Moir, 1970).

Sulfur has been shown to be an essential element for normal ruminant metabolism. Low sulfur limits non-protein nitrogen utilization and can alter the protein balance and energy balance in the animal. Moir (1970) has shown that optimum nitrogen balance is achieved with a dietary nitrogen/sulfur ratio of 10:1. With inadequate sulfur, total rumen protein production, as well as cellulose digestion, is lowered (Moir, 1970).

Whanger and Matrone (1965, in Moir, 1970) have demonstrated that lack of sulfur (or a wide nitrogen/sulfur ratio) results in altered rumen fermentation rates, products and types of microorganisms. Pope et al. (1968, in Moir, 1970) reported that low sulfur may depress feed intake and cause retention of selenium by the animal. Narrow nitrogen/sulfur ratios resulted in depressed selenium uptake and retention.

Seasonal Trends of Crude Protein in Forage

Crude protein content of meadow forage has not to date been implicated in the etiology of ABPE. However, determination of seasonal trends in plant protein content is important to livestock producers.

Chemical composition of range grasses varied with season, mainly because of changes in leaf-to-stem ratios, in work done by Cook and Harris (1968). Stems increased in weight at a faster rate than did leaves as growth occurred, resulting in a net decrease in plant crude protein content. However, there was a trend in both stems and leaves to decrease in protein over time (Cook and Harris, 1968). Crude protein content of wheatgrass (*Agropyron* spp.), brome (*Bromus* spp.), wildrye (*Elymus* spp.), fescue (*Festuca* spp.), and bluegrass (*Poa* spp.) decreased steadily from early leaf to mature stages of phenological development according to Robertson and Torell (1958).

Protein requirements for cattle under range conditions were presented by Cook and Harris (1968). It was recommended that cows in the first eight weeks of lactation be provided with forage of at least 5.4 percent digestible protein. Cows in the last 12 weeks of lactation were found to require 4.5 percent and gestating animals 4.4 percent digestible protein in the diet (Cook and Harris, 1968).

OBJECTIVES

A. To determine vegetation composition on ABPE-inciting meadows.

B. To determine seasonal variations of tryptophan, crude protein, and nitrogen/sulfur ratios in selected plants from ABPE-inciting meadows.

C. To determine utilization on ABPE-inciting meadows immediately following introduction of cattle to these meadows.

D. To relate cattle grazing diets and foraging habits to development of symptoms of ABPE.

E. To determine common herd characteristics and management practices on ranches with chronic histories of ABPE.

DESIGNATION OF STUDY AREAS

Geographical areas of investigation were privately-owned beef cattle ranches in east-central Oregon and U.S. Forest Service grazing allotments on the Malheur National Forest (Figure 1). In 1972, interviews were held with six ranchers who had sustained recent ABPE losses. Cooperating ranchers were Denny Ashby (Boston Ranches) and Vern Palmer of the Paulina area, Bob Lemcke and Joe Oliver on ranches near Seneca, Laurie Wyllie of Mt. Vernon, and Bill Mascall of Dayville. In addition, examination was made of a portion of the Abe Rickman Ranch (on the John Day River South Fork) which incited several cases of ABPE in October, 1972.

The Lemcke, Oliver, and Palmer ranches were selected for further study in 1973. Another ranch owned by Oris Crisp of Arlington, was included in the investigation when several cases of ABPE were diagnosed on his operation in August, 1973.

Grazing units containing natural "wet meadows" or irrigated pasture were used for fall grazing on the study ranches. These units are termed "inciting pastures." Summer range units, from which cattle are moved onto inciting areas, are called "stress pastures." "Turnout," as used in this paper, refers to the time cattle are moved from stress to inciting pastures. Detailed descriptions of the inciting pastures on the Lemcke, Oliver, and Palmer ranches are presented in Appendix A.

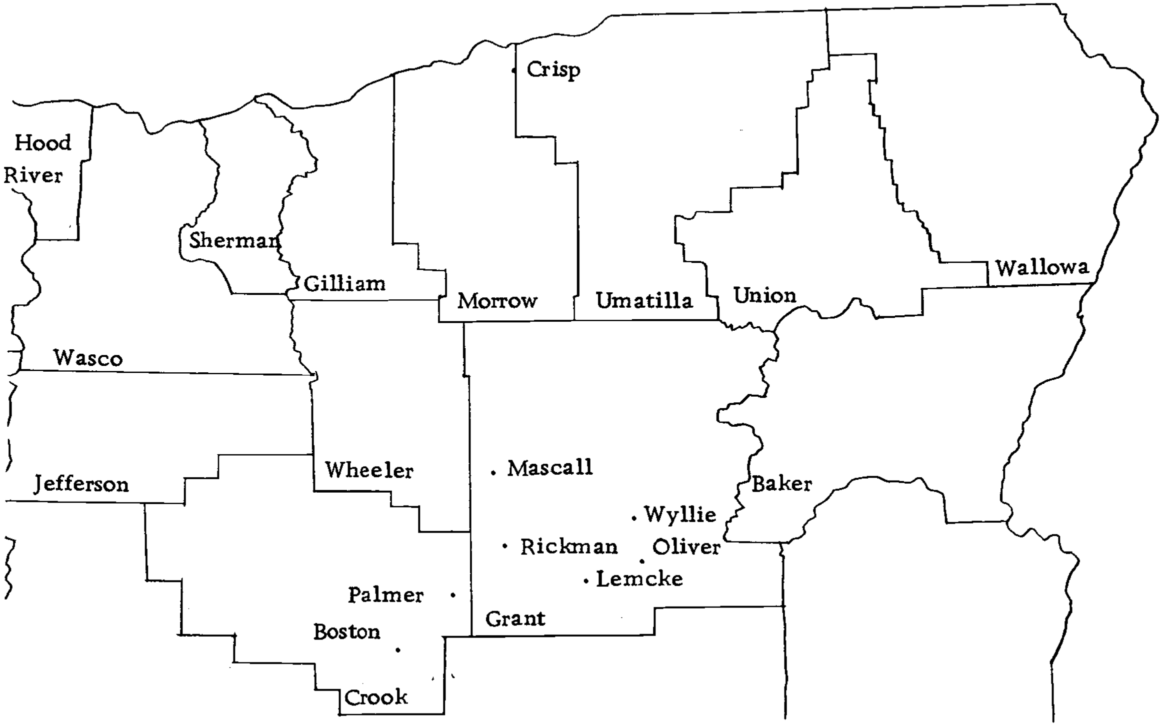

Figure 1. Approximate locations of ranches cooperating with acute bovine pulmonary emphysema study, 1972 and 1973.

ABPE in eastern Oregon seems to occur on a relatively small proportion of wet meadows. Pastures containing these inciting meadows were the only ones studied. However, often no differences in vegetation were noted between inciting pastures and those nearby which had never been implicated in causing pulmonary emphysema.

METHODOLOGY

Plant List and Frequency Determination

In June of 1972 a comprehensive plant species list was compiled for six inciting pastures. Collection and identification of unknown species continued throughout the 1972 field season.

Plant communities were delineated in inciting pastures of the Lemcke and Palmer ranches and frequency measurements taken using the pace transect (Brown, 1954). A square steel frame, 12 inches on a side (plot size 3), was dropped at the toe of the left foot ten times per transect at five-step intervals. The interior of the sampling frame was quartered into six-inch squares (plot size 2). One of these, in turn, was quartered into three-inch squares (plot size 1). A preselected "size 1" was read first at every location, followed by a specific "size 2" and finally the "size 3" frame. Three different plot sizes were used in order that one might be selected which approached an ideal size for sampling the vegetation at hand. The virtual absence of 100% frequency indicated that all three sizes were too small but that plot size 3 provided the best indication of frequency for all species present. Tabulated frequency data were taken only from plot size 3.

The number of transects taken per community depended upon the size and variability of each community. Five transects were taken in the *Juncus*-*Trifolium*-*Aster* community and two in the *Achillea*-*Aster* community of the Lemcke Silvies pasture. On the Palmer Number 2 Meadow, two transects were taken in the *Poa* community, three in the *Elymus*-*Brassica* community, three in the *Achillea*-*Elymus* community, and four in the *Elymus*-*Achillea*-*Chrysothamnus* community.

Plant Collection for Chemical Analyses

Three forage species -- Kentucky bluegrass (*Poa pratensis*), common rush (*Juncus effusus*), and Nebraska sedge (*Carex nebraskensis*) -- were chosen for determination of tryptophan, crude protein, and nitrogen/sulfur levels during the 1973 growing season. These species were noted in 1972 as being common to all three inciting pastures and were grazed heavily by cattle immediately after turnout.

Plant samples were taken weekly during the period May 24 through August 7, then biweekly through September 4. Phenological stage of development was noted at each sampling date and recorded as follows: (1) preboot, (2) boot, (3) heading out, (4) soft dough, (5) hard dough, and (6) mature seed. All areas had been heavily frosted by the last sampling date. Plant collection was effected by cutting the culms at approximately one and a half inches above ground level with a sharp knife. The harvested material was then cut in lengths of approximately six inches and placed in small paper sacks. Two 80-quart ice chests filled with dry ice were used as field storage vessels. Samples were placed in them immediately following collection to preserve plant tryptophan, a constituent under investigation.

At the end of each sampling trip, collected samples were freeze-dried for 36 hours, ground through a 40-mesh screen on a portable electric grinder, and sealed in airtight jars. All samples were stored at room temperature until subjected to chemical analyses.

To facilitate statistical analyses, the six phenological stages were later grouped into three growth stages. Stage I included the preboot and boot; stage II the heading out to soft dough period, and stage III the hard dough and mature seed. All comparisons and statistical analyses of plant chemical data were based on these three growth stages.

Tryptophan Determination

Forage samples collected on 9 of the 14 sampling dates were analyzed for total tryptophan. Due to cost, analysis was done on samples collected from every other sampling period. Tryptophan analysis was conducted by the Biochemistry Department at Oregon State University, using techniques adapted from those presented in Knox *et al.* (1970).

Crude Protein Determination

Portions of all forage samples analyzed for tryptophan were also analyzed for nitrogen. Nitrogen content was determined in the Rangeland Resources Laboratory at Oregon State University using the micro-Kjeldahl procedure with some modifications (Aminco reprint No. 104, 1959).

In the analysis, 0.1 g of sample material was added to a 30 ml micro-Kjeldahl flask with one boiling chip, 3 ml of concentrated H_2SO_4, and 1/4 teaspoon prepared catalyst. The filled flasks were placed on a heated digestion rack for approximately one hour. When digestion was completed, the flasks were allowed to cool; then 20 ml distilled H_2O was added to the solution.

The distillation phase consisted of placing each digest-filled flask in a distillation apparatus heated by conducting steam from an attached boiling water source. The ammonium sulfate formed during digestion released ammonia gas during distillation after 10 ml 40 percent NaOH and five percent $Na_2S_2O_3$ were added to the samples. The gas was captured in a condensation tube and received in four percent boric acid solution containing a few drops of bromcresol green-methyl red indicator. The condensation tube was left immersed in the boric acid for three minutes of distillation. After this, the flask containing the boric acid was lowered so the condensation tube could drain. The NH_3 caught in the boric acid was then titrated to first pink color with standard 0.02 N HCl.

Each sample was run in duplicate until values obtained did not vary more than ten percent between duplicates. Total nitrogen was determined by the following formula:

$$\%N = \frac{100 \times \text{net ml titrant used} \times \text{normality of titrant} \times \text{molecular weight N}}{\text{mg sample} \times \% \text{ dry matter sample}}$$

Percent crude protein was computed by multiplying the percent nitrogen by 6.25.

Nitrogen/Sulfur Ratio Determination

Sulfur content of the nine selected plant sample lots was determined by the Extension Soils Laboratory at Oregon State University. This analysis was conducted so plant nitrogen/sulfur ratios could be determined. Method of determination followed closely that set forth by Roberts *et al.* (1971). The only exception to this procedure is as follows and replaces the extraction portion of the process.

Perchloric digest: One gram of well-mixed plant material was placed, with 15 glass beads, in a 125 ml erlenmeyer flask. The prepared flasks were then heated slowly and 12 ml of nitric acid were added per flask. After foaming subsided the flasks were allowed to cool. Then 6 ml 70 percent perchloric acid were introduced to each flask and the batch was reheated. After the reaction mixture became colorless, the digestion was continued for five additional minutes. The flasks were removed from heat and allowed to cool for 30 seconds. Then 20 ml distilled water were added and the solution swirled to dissolve any precipitate. Filtering through Whatman no. 50 filter paper followed. The filtrate was caught in 100 ml flasks, the filter papers washed thoroughly and the flasks diluted to volume with redistilled water.

Dry Weight Factor Determination

Percent dry matter of the field plants collected for chemical analyses could not be determined since freeze-drying of the whole plant had been done immediately after collection. To obtain percent dry matter of the ground material, two grams of each sample were placed in a 100°C oven for at least eight hours. This portion of the sample was then reweighed and the latter weight expressed as a percentage of the first. This percentage was used to convert results of all analyses to dry weight basis.

As with the Kjeldahl treatment, these were done in duplicate. However, no tolerance limit was set for duplication in dry weight determination.

Statistical Analysis

Data obtained from chemical analyses were subjected to analyses of variance using a completely randomized design. Duncan's multiple range test was administered to the results of the analyses of variance (Steel and Torrie, 1960). This work was conducted to determine if statistically significant differences existed between chemical constituents in plants collected at different phenological stages or on different pastures.

Forage Plant Utilization

Daily utilization measurements were taken on two inciting pastures for several days following turnout. Ten plots in each meadow were chosen to represent the most succulent vegetation. Particular attention was paid to selecting communities with high concentrations of Kentucky bluegrass, common rush, and Nebraska sedge.

Plant height prior to grazing was the standard for determining utilization. Plant measurements were effected on the perimeter of a circle (radius three feet) scribed around a steel post placed in each of the ten selected plots. Average stubble height was determined by dividing the sum of the heights in inches of all species rooted on the perimeter by the number of measurements taken.

Measurements were taken in each plot daily for nine days after turnout on the Palmer ranch and five days on the Lemcke ranch. Cattle on the Lemcke pasture displayed symptoms of ABPE five days after turnout and were removed. Mr. Oliver did not move his cattle as originally planned and no utilization measurements were taken on his pasture.

Percent utilization was computed by comparing each daily average measurement with the pre-turnout (ungrazed) measurement for each plot. Each daily figure was subtracted from the original height and difference converted to percent, which represented percent plant height removed over a given time period. Invisible grazing (regrowth, trampling, ingestion of entire plant, seed drop) was recognized, but was not included in these measurements. Cattle rubbing or lying against the posts did not appear to be a significant problem.

Grazing Observations

After each turnout on the Lemcke and Palmer ranches, observations were made of apparent forage preferences of cattle, heavily utilized grazing areas, and general animal behavior. Observations were generally made daily for a ten-day period immediately following turnout. The purpose of these observations was to correlate foraging habits with the development of symptoms of ABPE.

Questionnaires

Questionnaires, prepared early in 1972, were completed with the assistance of each cooperating rancher. The purpose of these questionnaires was to define common circumstances and/or conditions under which ABPE developed.

RESULTS AND DISCUSSION

Plant List and Frequency Determination

The comprehensive plant species list of July 1972 (Appendix B) was compiled from vegetation in the inciting pastures of the Boston, Lemcke, Mascall, Oliver, Palmer, and Wyllie ranches. Its purpose was to identify forage plants present on inciting meadows and to serve as a reference list for future studies of ABPE. No poisonous plant species was common to all inciting pastures.

Frequency data for portions of the Lemcke and Palmer meadows provided a description of species composition of the major plant communities in these two meadows in July 1972. The data also aided in identifying forage species common to the Lemcke and Palmer meadows shortly before turnout.

The *Achillea*-*Aster* community of the Lemcke Silvies Pasture was primarily composed of yarrow (*Achillea lanulosa*) and aster (*Aster* spp.). Kentucky bluegrass, slender cinquefoil (*Potentilla gracilis* var. *glabrata*), and common dandelion (*Taraxacum officinale*) were also prevalent. Mesic growing conditions were indicated by the species composition of this community which also contained sedges and rushes (Table 1).

The *Juncus*-*Trifolium*-*Aster* community of the Lemcke Silvies Pasture was composed mainly of rush, clover (*Trifolium* spp.), and

Table 1. Frequency percentages for plant species present in two plant communities of the Lemcke Silvies Pasture, July, 1972.

	Achillea-Aster community	*Juncus-Trifolium Aster* community
Grasses		
Agrostis alba		6
Deschampsia caespitosa	5	28
Phleum pratense	10	
Poa pratensis	75	24
Forbs		
Achillea lanulosa	80	
Aster spp.	80	66
Astragalus spp.	20	
Epilobium angustifolium		8
Equisetum spp.		2
Fragaria cuneifolia	40	2
Mimulus guttatus		2
Potentilla gracilis var. *glabrata*	60	4
Taraxacum officinale	60	54
Trifolium spp.		66
Urtica spp.	5	
Grasslikes		
Carex spp.	25	58
Juncus spp.	10	76

aster. Sedge and common dandelion were also frequently encountered. The high frequency of sedge and rush indicated relatively high water availability in this community (Table 1).

Both the communities sampled for frequency in the Lemcke Silvies Pasture contained primarily plants that favored mesic or wet conditions. The presence of sedge, rush, tufted hairgrass, common dandelion, and common strawberry (*Fragaria cuneifolia*) indicated that moisture was relatively plentiful. Occurrence of introduced species such as Kentucky bluegrass and common dandelion indicated disturbance in both communities.

The *Poa* community of the Palmer Number 2 Meadow was well represented by Kentucky bluegrass, with a 100 percent frequency reading. Giant wildrye (*Elymus cinereus*), aster, common dandelion, and curly dock (*Rumex crispus*) were also well distributed throughout the community. Species present indicated that this was a relatively xeric community (Table 2).

The *Elymus-Brassica* community of the Palmer Number 2 Meadow did not contain any species with frequency ratings over 50 percent. Giant wildrye and birdrape (*Brassica campestris*) were the two major species. Aster, perennial flax (*Linum perenne*), Kentucky bluegrass, and mountain brome (*Bromus marginatus*) were relatively well distributed. No hydrophyllic species were present in this community (Table 2).

Table 2. Frequency percentages for plant species present in four plant communities of the Palmer Number 2 Meadow, July, 1972.

	Poa Community	Elymus-Brassica Community	Achillea-Elymus Community	Elymus-Achillea Chrysothamnus Community
Shrubs				
Artemisia tridentata		3		5
Chrysothamnus viscidiflorus			3	40
Grasses				
Agropyron desertorum		10		
Agropyron intermedium			10	
Agrostis alba				14
Bromus marginatus		17	3	
Bromus tectorum		7	7	14
Deschampsia caespitosa				5
Distichlis stricta			10	11
Elymus cinereus	55	43	51	57
Hordeum jubatum	5			
Phleum pratense	10			
Poa pratensis	100	27	47	29
Poa secunda	5		27	23
Forbs				
Achillea lanulosa	10	10	84	43
Aster spp.	55	24	23	25
Astragalus spp.	5			
Brassica campestris		40		
Crepis spp.	10		3	6
Equisetum spp.			10	
Fragaria cuneifolia	15			
Linum perenne		20	17	11
Potentilla gracilis var. glabrata	45	3		
Rumex crispus		3		
Taraxacum officinale	55		13	
Urtica spp.		10	7	
Grasslikes				
Carex spp.			36	13
Juncus spp.				9

The Achillea-Elymus community of the Palmer Numer 2 Meadow had a well distributed population of yarrow. Giant wildrye and Kentucky bluegrass were moderately prevalent, followed by sedge, Sandberg bluegrass (Poa secunda), aster, and perennial flax. The frequency of sedge and the presence of horsetail (Equisetum spp.) indicated relatively high water availability in parts of this community (Table 2).

The Elymus-Achillea-Chrysothamnus community of the Palmer Number 2 Meadow was composed primarily of giant wildrye, yarrow and tall green rabbitbrush (Chrysothamnus viscidflorus). Aster, Kentucky bluegrass, and Sandberg bluegrass were relatively well distributed. Sedge and rush were both present at moderate frequencies (Table 2).

Communities sampled for frequency on the Palmer Numer 2 Meadow were composed in large part of introduced species. The presence of nettle (Urtica spp.) in two and cheatgrass (Bromus tectorum) in three of the four communities indicated some disturbance had occurred which allowed invasion of these species. Sedge occurred in only two of the four communities, rush and tufted hairgrass in only one, suggesting that water availability was not as high as on the Lemcke Silvies Pasture where these hydrophyllic species were relatively plentiful. Communities in the Palmer Number 2 Meadow also had lower total proportions of "wet meadow" plants than the Lemcke

Silvies Pasture. Instead, drought-tolerant species such as alkali saltgrass (_Distichlis stricta_), Sandberg bluegrass, cheatgrass brome, giant wildrye, and hawksbeard (_Crepis_ spp.) were frequently encountered. Total numbers of species encountered per community were similar on both the Lemcke and Palmer pastures. Sedge, rush, and Kentucky bluegrass were common to both pastures.

Tryptophan Determination

The tryptophan content of plants sampled decreased from May 24 to September 4 (Appendix C). Tryptophan content of the selected forages varied from a high of 5.92 μg/mg for Kentucky bluegrass on the Oliver ranch May 24 to a low of 0.71 μg/mg for Kentucky bluegrass on the Oliver ranch July 3 (Figure 4).

Figures 2 through 4 displayed the individual trends of each plant species on each ranch with regard to tryptophan content. It was evident from these figures that Kentucky bluegrass (Figure 4) sustained a sharper decrease in tryptophan over the season than did Nebraska sedge or common rush (Figures 2 and 3).

In phenological stage I, tryptophan content of Nebraska sedge ranged from 4.19 μg/mg on the Oliver ranch to 2.56 μg/mg on the Palmer ranch. Values for tryptophan in Nebraska sedge in phenological stage II were lower, ranging from 3.19 μg/mg on the Lemcke ranch to 1.70 μg/mg on the Oliver ranch. Nebraska sedge in

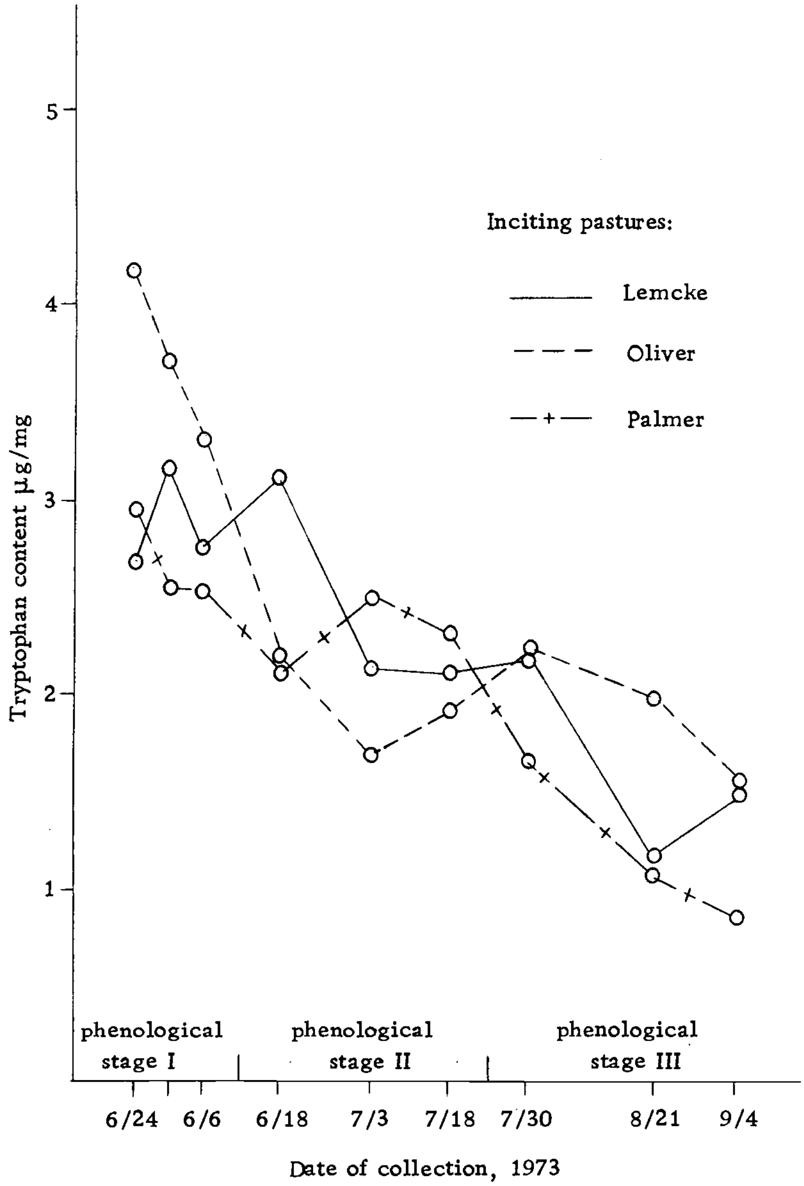

Figure 2. Tryptophan content of Nebraska sedge, sampled over the 1973 growing season on three study ranches.

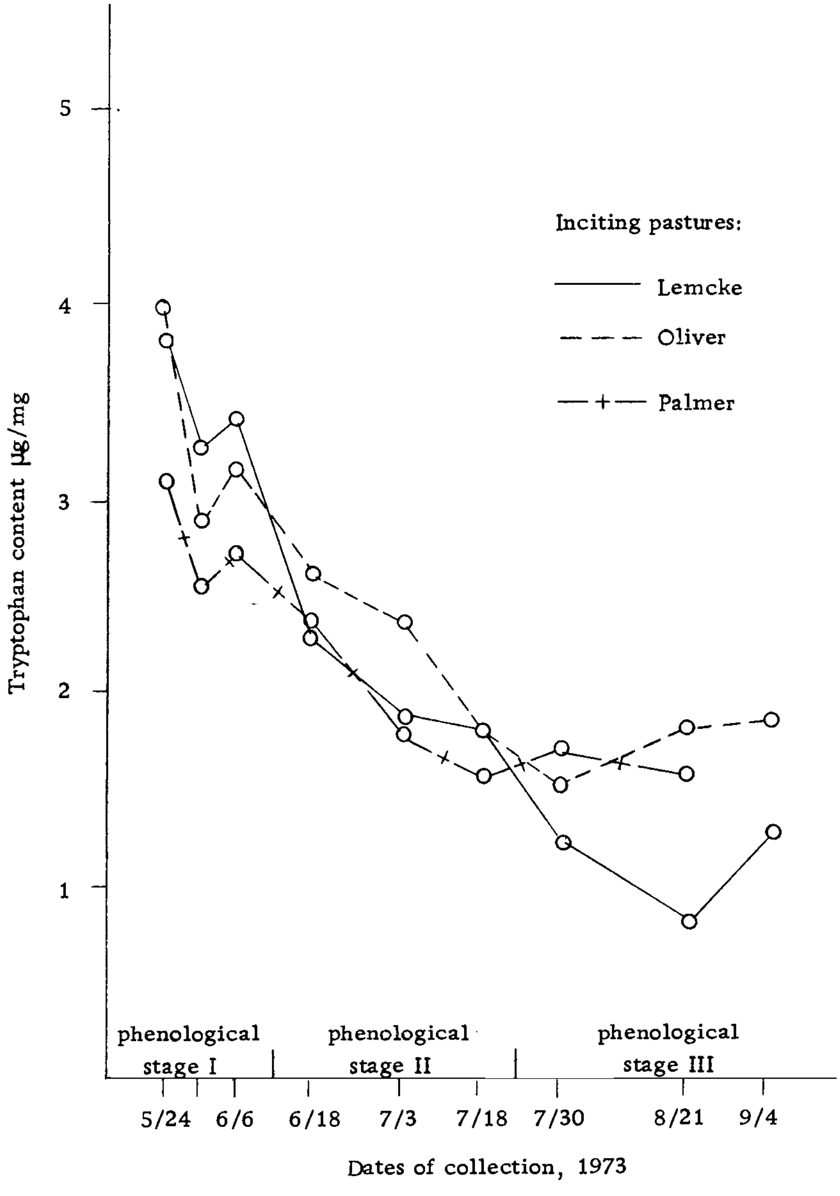

Figure 3. Tryptophan content of common rush, sampled over the 1973 growing season on three study ranches.

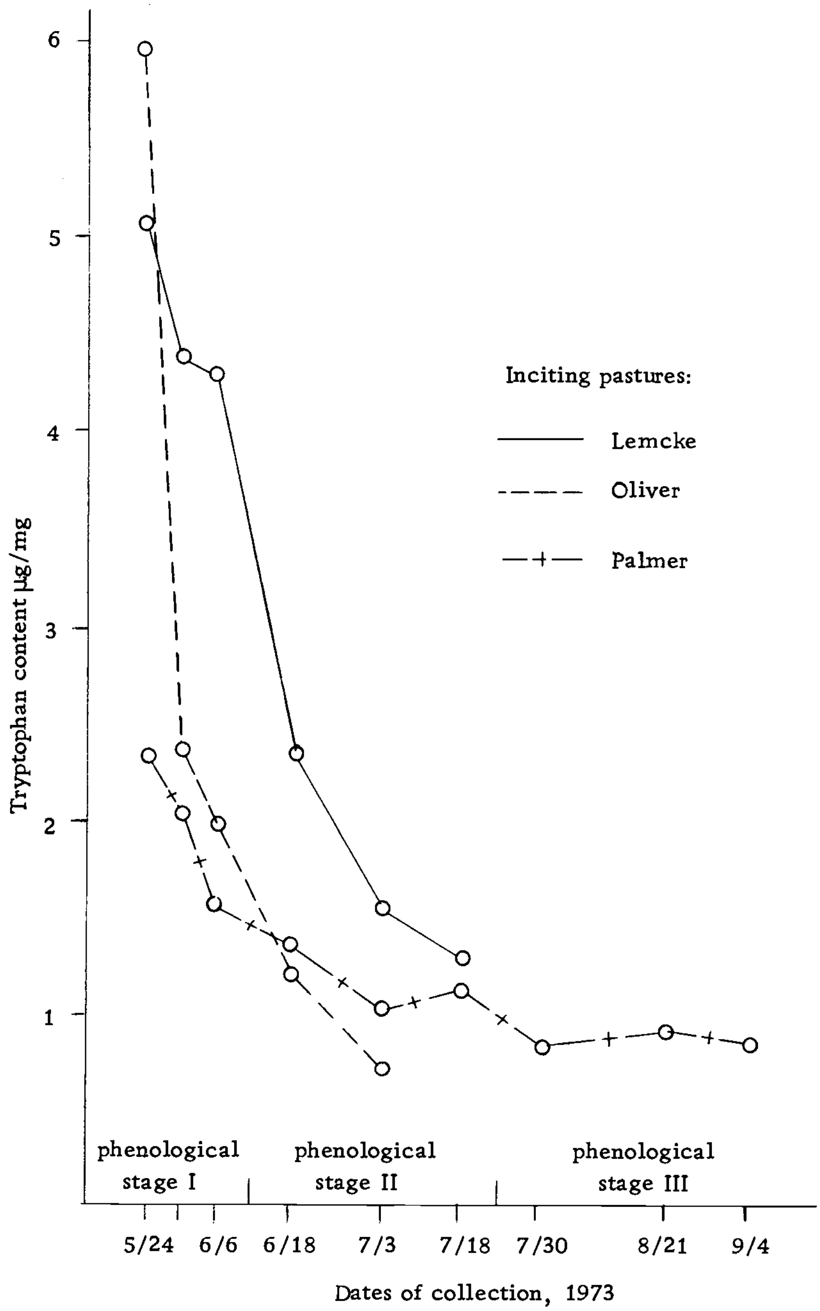

Figure 4. Tryptophan content of Kentucky bluegrass, sampled over the 1973 growing season on three study ranches.

phenological stage III had tryptophan readings of from 2.27 μg/mg on the Oliver ranch to 0.93 μg/mg on the Palmer ranch (Figure 2).

Tryptophan content of common rush varied from 3.98 μg/mg on the Oliver ranch to 2.53 μg/mg on the Palmer ranch during phenological stage I. Tryptophan in common rush elicited readings of from 2.66 μg/mg on the Oliver ranch to 1.62 μg/mg on the Palmer ranch in phenological stage II. Values for common rush tryptophan in phenological stage III ranged from 1.87 μg/mg on the Oliver ranch to 0.84 μg/mg on the Lemcke ranch (Figure 3).

Tryptophan in Kentucky bluegrass in phenological stage I varied from 5.92 μg/mg on the Oliver ranch to 1.59 μg/mg on the Palmer ranch. In phenological stage II, Kentucky bluegrass tryptophan ranged from 2.42 μg/mg on the Lemcke ranch to 0.71 μg/mg on the Oliver ranch. Values for tryptophan in Kentucky bluegrass during phenological stage III were relatively uniform on the Palmer ranch, ranging from 0.82 μg/mg to 0.97 μg/mg. The Lemcke and Oliver ranches were not sampled during phenological stage III (Figure 4).

The most significant difference in tryptophan content over the growing season occurred between phenological stages I and II (Table 3). Tryptophan values for Nebraska sedge on the Lemcke and Palmer ranches and Kentucky bluegrass on the Oliver meadow did not differ significantly between stages I and II. Only common rush on the Lemcke ranch and Nebraska sedge on the Palmer meadow differed

Table 3. Results of analysis of variance of tryptophan content (μg/mg) between three stages of phenological development of three plant species collected from three ranches over the 1973 growing season.[1]

		Phenological Stage		
		I	II	III
Lemcke Ranch				
Species:	Nebraska sedge	2.86^{a}	$2.49^{a,b}$	1.67^{b}
	common rush	3.48^{a}	2.03^{b}	1.14^{c}
	Kentucky bluegrass	4.65^{a}	1.78^{b}	
Oliver Ranch				
Species:	Nebraska sedge	3.75^{a}	1.98^{b}	1.98^{b}
	common rush	3.33^{a}	2.30^{b}	1.75^{b}
	Kentucky bluegrass	3.45^{a}	2.56^{a}	
Palmer Ranch				
Species:	Nebraska sedge	2.68^{a}	2.36^{a}	1.25^{b}
	common rush	2.78^{a}	1.95^{b}	1.69^{b}
	Kentucky bluegrass	2.02^{a}	1.18^{b}	0.89^{b}

[1]Numbers indicate μg/mg of total tryptophan; those with identical superscripts are not statistically different at the 95% level. Horizontal comparison only is valid.

significantly in tryptophan content between stages II and III. The greatest decline in tryptophan for the sampled species occurred early in the season (Table 3).

Tryptophan levels for Nebraska sedge on the Oliver ranch were statistically different from those on the Lemcke and Palmer ranches in phenological stage I (Table 4). Common rush in phenological stage III on the Lemcke ranch yielded statistically different tryptophan readings compared to the Oliver and Palmer meadows. The small number of statistically significant differences between plants on different ranches for tryptophan over the growing season suggested that all species sampled were subjected to similar growing conditions in 1973. Site differences between the three pastures appeared to be small (Table 4).

Weather service data for Seneca, Oregon, showed an average precipitation for June and July of 2.35 inches (U.S. Dept. of Commerce, 1972). In 1973, precipitation for these two months was only 0.04 inch (U.S. Dept. of Commerce, 1973). The 1973 drought may have caused vegetation in these pastures to accelerate phenological development as compared to more favorable growing seasons. In summers with higher rainfall, levels of tryptophan could be assumed to remain at relatively high levels for a longer period of time.

Carlson *et al.* (1972) found that symptoms of pulmonary emphysema in cattle could be produced through oral dosage of 0.57 g

Table 4. Results of analysis of variance of tryptophan content (µg/mg) between three plant collection sites of three plant species in three stages of phenological development over the 1973 growing season.

		Site		
		Lemcke	Oliver	Palmer
Phenological Stage I				
Species:	Nebraska sedge	2.86[a]	3.75[b]	2.68[a]
	common rush	3.48[a]	3.33[a]	2.78[a]
	Kentucky bluegrass	4.65[a]	3.45[a]	2.02[a]
Phenological Stage II				
Species:	Nebraska sedge	2.49[a]	1.98[a]	2.36[a]
	common rush	2.03[a]	2.30[a]	1.95[a]
	Kentucky bluegrass	1.78[a]	2.56[a]	1.18[a]
Phenological Stage III				
Species:	Nebraska sedge	1.67[a]	1.98[a]	1.25[a]
	common rush	1.14[a]	1.75[b]	1.69[b]
	Kentucky bluegrass	No data		

[1]Numbers indicate µg/mg of total tryptophan; those with identical superscripts are not statistically different at the 95% level. Horizontal comparison only is valid.

tryptophan/kg body weight. Calculations were made to determine minimum dry weight intake of the forage sample containing the most tryptophan to duplicate oral dosage of 0.57 g tryptophan/kg body weight. A 454 kg (1000 lb) animal was chosen as a standard and Kentucky bluegrass on the Oliver ranch May 24 entered as having the highest sampled tryptophan content at 5.92 μg/mg. It was shown that the above animal would have to consume 43.8 kg (dry weight) of bluegrass during the time of highest sampled tryptophan content to ingest an equivalent of 0.57 μg/mg body weight oral-dosed tryptophan. This is more material than would normally be ingested over a short time period. It has not yet been demonstrated whether prolonged treatments of moderate dosing with oral tryptophan will incite ABPE. Since lung damage associated with the disease is apparently irreversible, and since symptoms do not always surface in cases where mild lung damage occurs, it appears that if tryptophan is the causative agent, cumulative assimilation of tryptophan from meadow forage at levels lower than 0.57 mg/kg may be able to incite pulmonary emphysema.

It is possible that an animal taken from one diet and placed on another, higher in tryptophan and available in greater quantity, may be subjected to digestive disturbance. Inciting pastures are normally younger phenologically than stress pastures, and younger plants have a considerably higher tryptophan content than older ones. In addition, the lush, ungrazed inciting forage is more easily obtained in large quantity over a shorter period of grazing time than is stress forage in midsummer.

Crude Protein Determination

Crude protein values for Nebraska sedge, common rush, and Kentucky bluegrass over the 1973 growing season were presented in Appendix C. Crude protein content varied from a high of 26.94 percent for Kentucky bluegrass on the Oliver ranch May 24 (Figure 7) to a low of 5.53 percent for Nebraska sedge on the Palmer ranch September 4 (Figure 5). All species showed a net decrease in crude protein content over the season.

The shapes of the crude protein curves in Figures 5, 6 and 7 were similar to those depicting trends in tryptophan content (Figures 2, 3 and 4). Kentucky bluegrass on the Lemcke and Oliver ranches displayed the highest initial crude protein values. However, the crude protein content of Kentucky bluegrass on these ranches also had the sharpest seasonal drop of the three sampled species (Figure 7).

Crude protein of Nebraska sedge in phenological stage I ranged from 18.70 percent on the Oliver ranch to 12.68 percent on the Palmer ranch. Nebraska sedge crude protein in phenological stage II varied from 13.87 percent on the Palmer ranch to 9.25 percent on the Oliver ranch. During phenological stage III crude protein values for

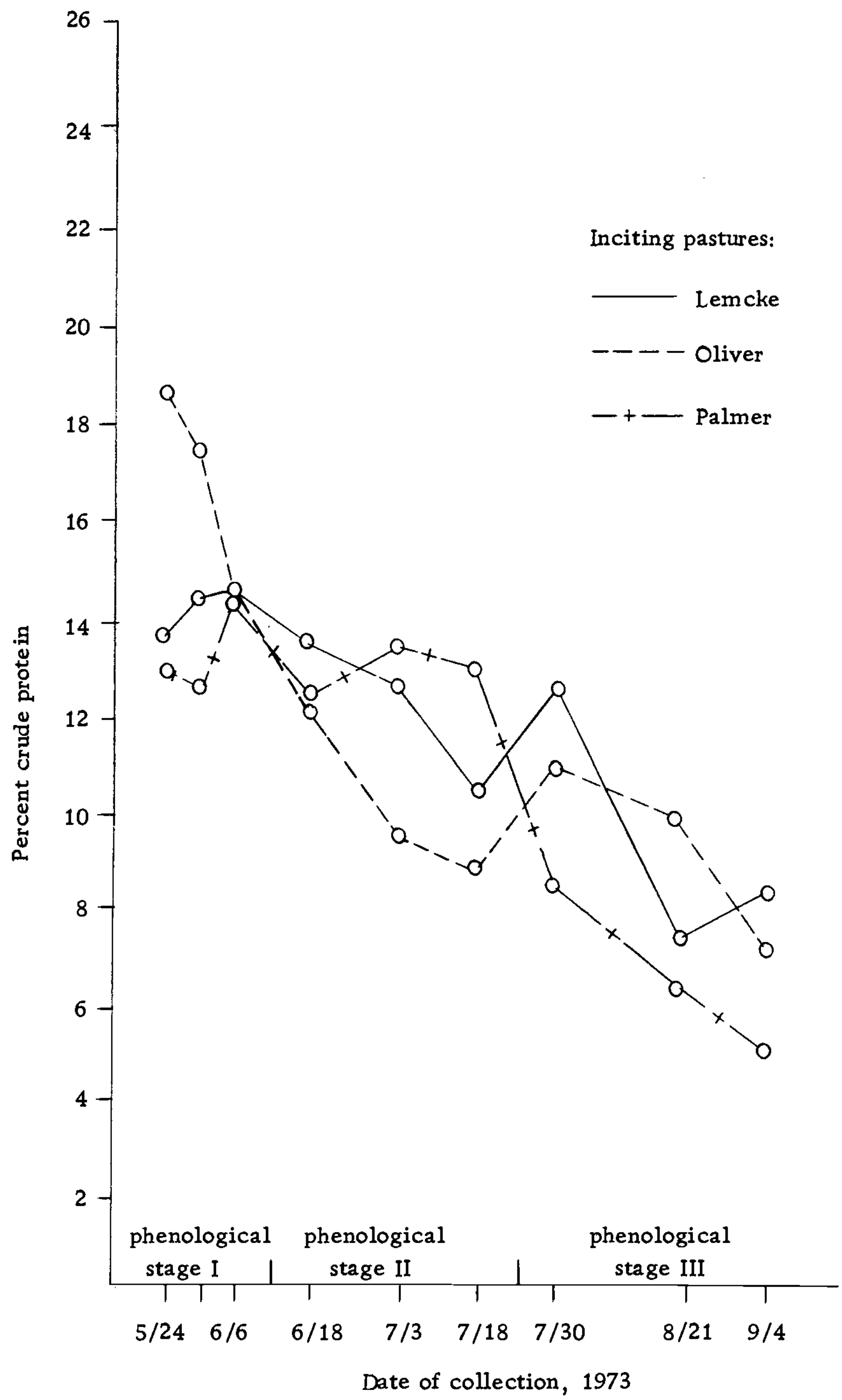

Figure 5. Crude protein content of Nebraska sedge, sampled over the 1973 growing season on three study ranches.

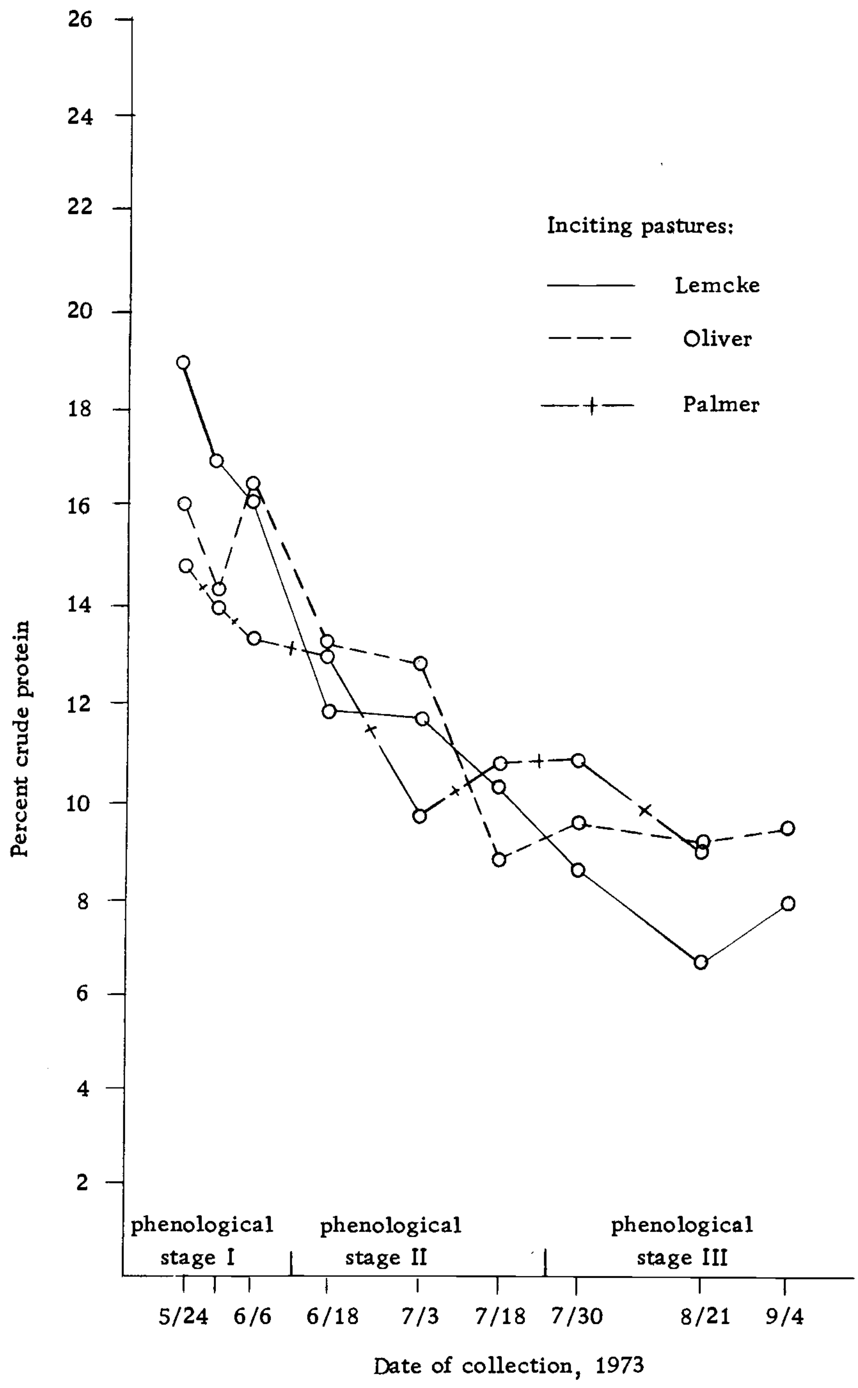

Figure 6. Crude protein content of common rush, sampled over the 1973 growing season on three study ranches.

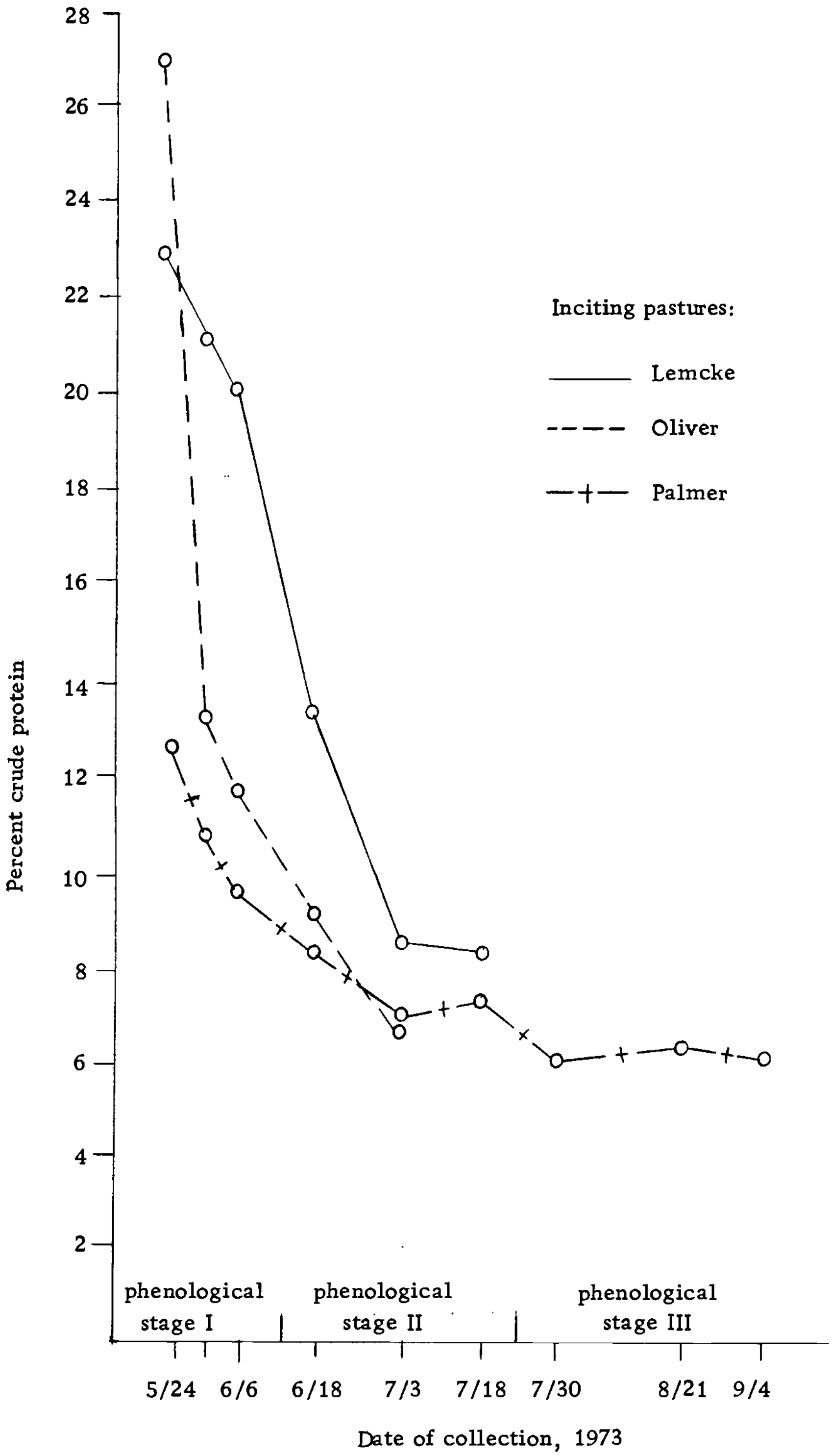

Figure 7. Crude protein content of Kentucky bluegrass, sampled over the 1973 growing season on three study ranches.

Nebraska sedge ranged from 12.82 percent on the Lemcke ranch to 5.53 percent on the Palmer ranch (Figure 5).

Crude protein of common rush varied from 19.10 percent on the Lemcke ranch to 13.58 percent on the Palmer ranch during phenological stage I. In phenological stage II, crude protein values for common rush ranged from 13.71 percent on the Oliver ranch to 9.20 percent, also on the Oliver ranch. Crude protein of common rush during phenological stage III ranged from 10.97 percent on the Palmer ranch to 7.19 percent on the Lemcke ranch (Figure 6).

Kentucky bluegrass crude protein values varied from 26.94 percent on the Oliver ranch to 9.89 percent on the Palmer ranch in phenological stage I. During phenological stage II, values for crude protein in Kentucky bluegrass ranged from 13.78 percent on the Lemcke ranch to 6.80 percent on the Oliver ranch. Samples taken only from the Palmer ranch in phenological stage III showed variation from 6.53 to 6.05 percent for crude protein content of Kentucky bluegrass (Figure 7).

Statistical differences in crude protein values due to plant phenology were displayed primarily between phenological stages I and II (Table 5). Only common rush on the Lemcke pasture and Nebraska sedge on the Palmer pasture displayed significant disparity between phenological stages II and III. Five of the nine sets of crude protein values analyzed differed significantly between stages I and II (Table 5).

Table 5. Results of analysis of variance of crude protein content (percent) between three stages of phenological development of three plant species collected from three ranches over the 1973 growing season.[1]

		Phenological Stage		
		I	II	III
Lemcke Ranch				
Species:	Nebraska sedge	14.28[a]	12.37[a,b]	9.72[b]
	common rush	17.52[a]	11.53[b]	8.03[c]
	Kentucky bluegrass	21.45[a]	10.33[b]	
Oliver Ranch				
Species:	Nebraska sedge	17.06[a]	10.42[b]	9.63[b]
	common rush	15.64[a]	12.04[b]	9.76[b]
	Kentucky bluegrass	17.51[a]	8.06[a]	
Palmer Ranch				
Species:	Nebraska sedge	13.39[a]	13.12[a]	7.09[b]
	common rush	14.07[a]	11.34[a,b]	10.15[b]
	Kentucky bluegrass	11.15[a]	7.71[b]	6.26[b]

[1] Numbers indicate percent crude protein; those with identical superscripts are not statistically different at the 95% level. Horizontal comparison only is valid.

Analysis of variance of crude protein content of the sampled species revealed the following significant differences attributable to site (Table 6). Crude protein values for common rush on the Palmer ranch were statistically different from those of the Lemcke ranch in all three phenological stages. Crude protein of Nebraska sedge on the Lemcke and Palmer ranches differed from that of the Oliver pasture in phenological stage I. Crude protein of Nebraska sedge and common rush in phenological stage II differed significantly between the Oliver and Palmer ranches. Crude protein of Kentucky bluegrass in phenological stage I and common rush in stage II differed between the Lemcke and Palmer pastures.

Crude protein content of Nebraska sedge, common rush, and Kentucky bluegrass in phenological stages I and II met the requirements presented by Cook and Harris (1968) for range cattle in gestation or late lactation, assuming forage protein digestibility of 60 percent. In phenological stage III, crude protein values for Nebraska sedge and Kentucky bluegrass on the Palmer ranch were not high enough to provide cattle with a minimum 4. 5 percent digestible protein in the diet. Common rush on all ranches and Nebraska sedge on the Lemcke and Oliver ranches were adequate in digestible protein during phenological stage III. Extrapolation of the trends of crude protein in Kentucky bluegrass on the Lemcke and Oliver ranches to phenological stage III indicated that digestible protein content might be inadequate

Table 6. Results of analysis of variance of crude protein content (percent) between three plant collection sites of three plant species in three stages of phenological development over the 1973 growing season.[1]

		Site		
		Lemcke	Oliver	Palmer
Phenological Stage I				
Species:	Nebraska sedge	14.28^{a}	17.06^{b}	13.39^{a}
	common rush	17.52^{a}	$15.64^{a,b}$	14.07^{b}
	Kentucky bluegrass	21.45^{a}	$17.51^{a,b}$	11.15^{b}
Phenological Stage II				
Species:	Nebraska sedge	$12.37^{a,b}$	10.42^{a}	13.12^{b}
	common rush	11.53^{a}	12.04^{a}	11.34^{b}
	Kentucky bluegrass	10.33^{a}	8.06^{a}	7.71^{a}
Phenological Stage III				
Species:	Nebraska sedge	9.72^{a}	9.63^{a}	7.09^{a}
	common rush	8.03^{a}	9.76^{b}	10.15^{b}
	Kentucky bluegrass	No data		

[1]Numbers indicate percent crude protein; those with identical superscripts are not statistically different at the 95% level. Horizontal comparison only is valid.

inadequate to maintain gestating or lactating animals late in the summer.

Nitrogen/Sulfur Ratio Determination

Nitrogen/sulfur ratios for Nebraska sedge, common rush, and Kentucky bluegrass on the Lemcke, Oliver, and Palmer pastures varied throughout the season but exhibited a net decline from May 24 to September 4 (Appendix C). Nitrogen/sulfur ratios ranged from a high of 20.52 for the May 24 sampling of Kentucky bluegrass on the Oliver ranch to a low of 3.05 for common rush on the Lemcke meadow September 4 (Figures 8, 9 and 10).

Nitrogen/sulfur ratios for Nebraska sedge in phenological stage I ranged from 15.93 on the Lemcke ranch to 9.13 on the Oliver ranch. In phenological stage II, nitrogen/sulfur ratios for Nebraska sedge varied from 16.85 on the Lemcke ranch to 5.13 on the Oliver ranch. Nitrogen/sulfur ratios for Nebraska sedge in phenological stage III ranged from 12.81 to 3.32, both on the Lemcke ranch (Figure 8).

Nitrogen/sulfur ratios for common rush varied from 14.47 on the Palmer ranch to 8.03 on the Lemcke ranch in phenological stage I. In phenological stage II, nitrogen/sulfur ratios for common rush ranged from 14.93 on the Palmer ranch to 5.66 on the Oliver ranch. Common rush nitrogen/sulfur ratios in phenological stage III ranged from 9.29 on the Oliver ranch to 3.05 on the Lemcke ranch (Figure 9).

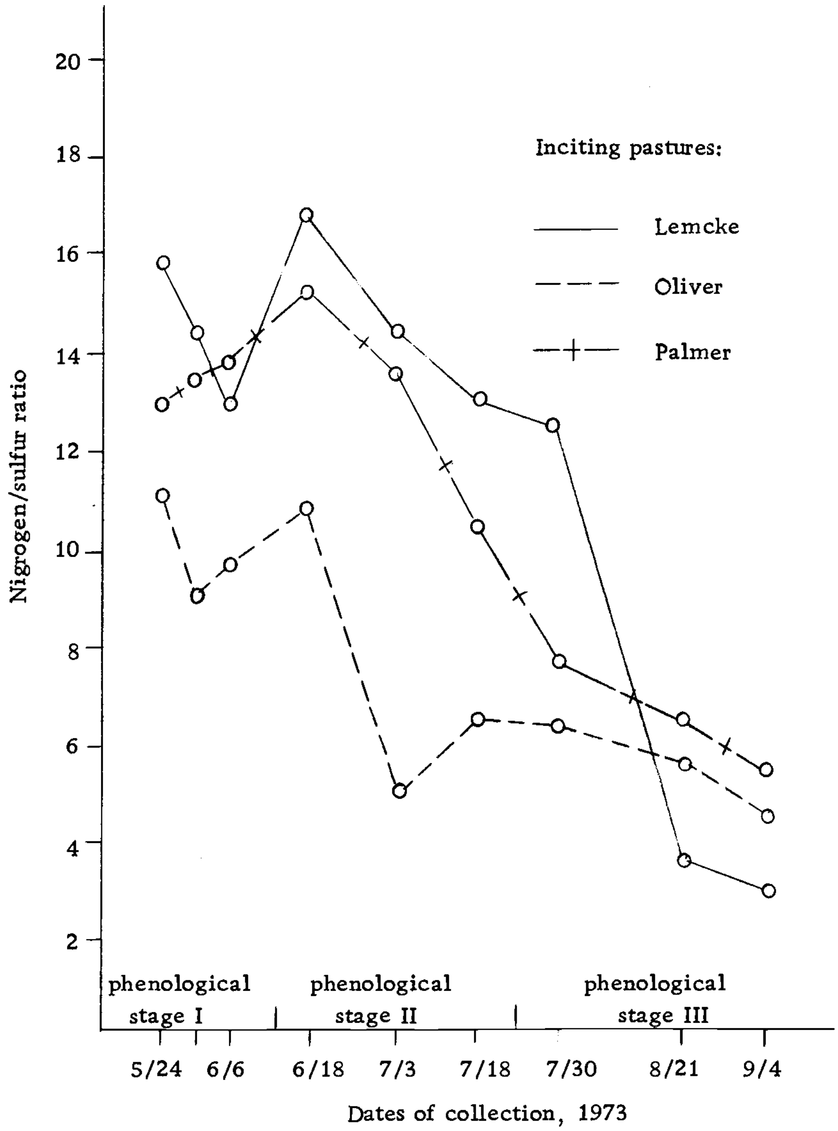

Figure 8. Nitrogen/sulfur ratios of Nebraska sedge, sampled over the 1973 growing season on three study ranches.

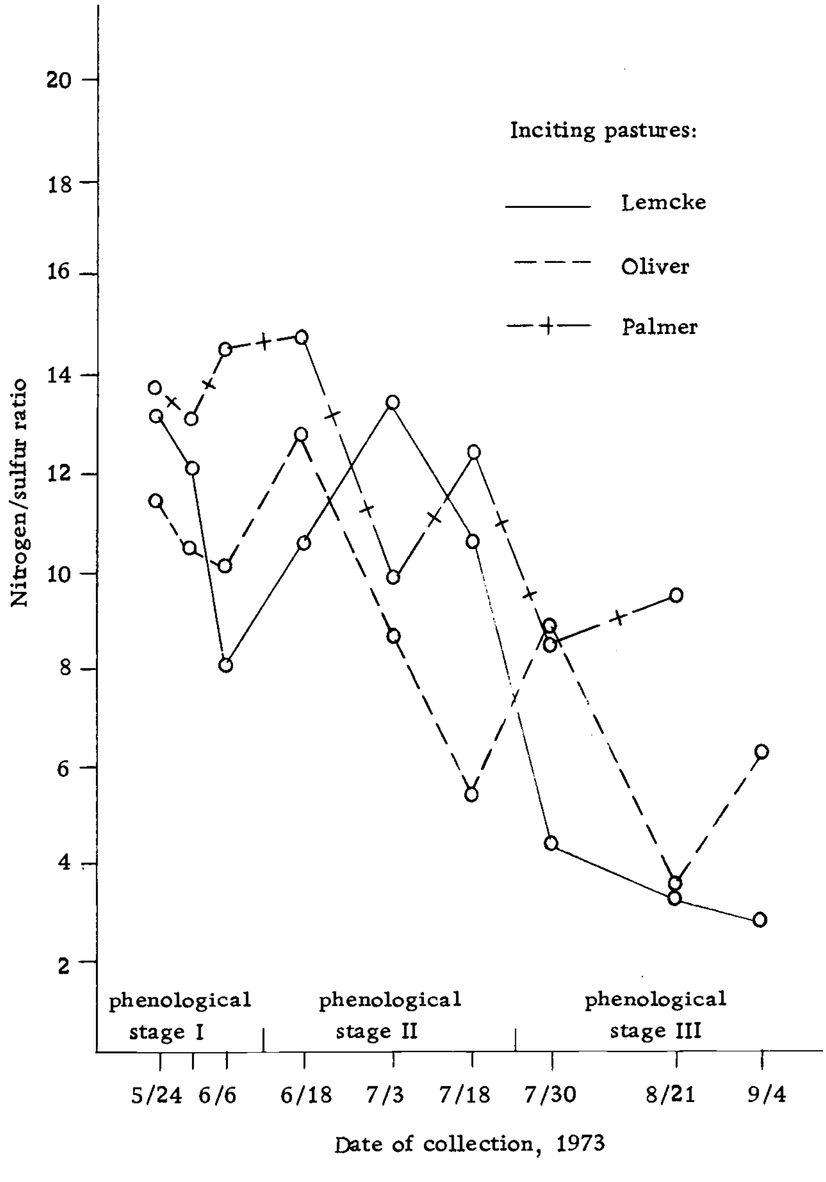

Figure 9. Nitrogen/sulfur ratios of common rush, sampled over the 1973 growing season on three study ranches.

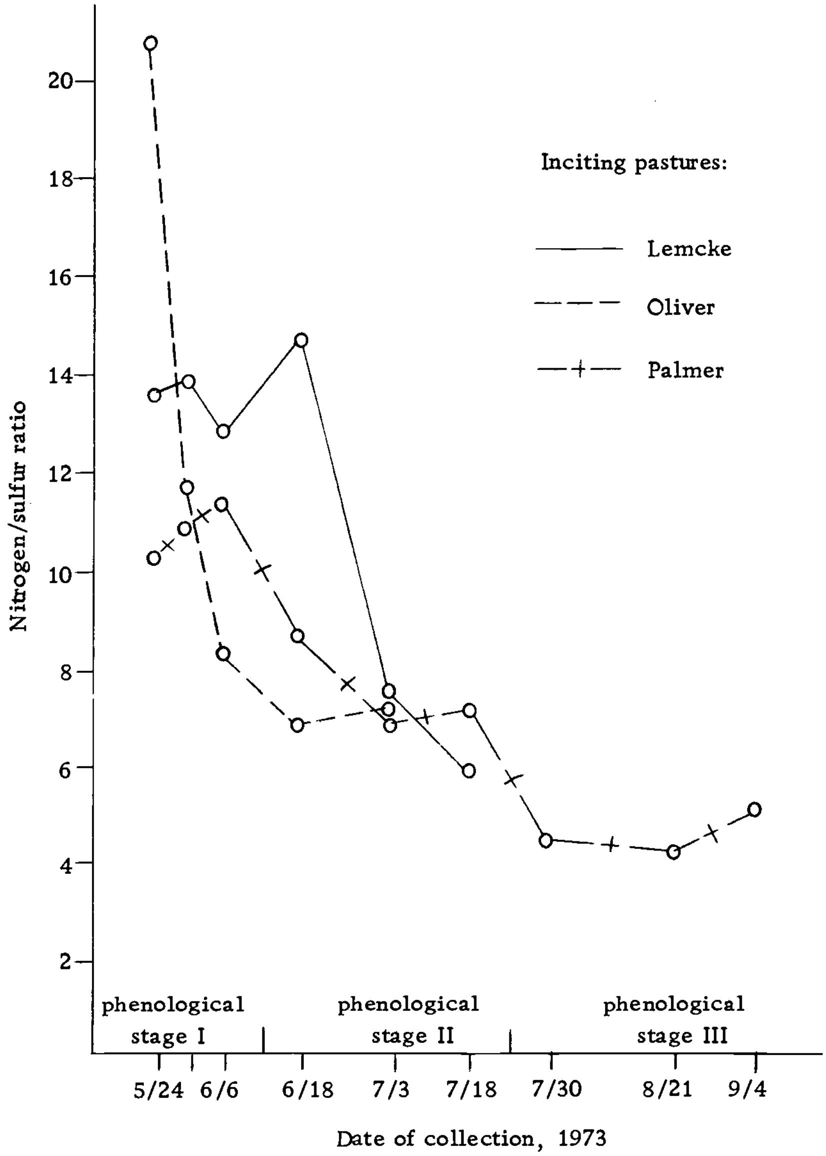

Figure 10. Nitrogen/sulfur ratios of Kentucky bluegrass, sampled over the 1973 growing season on three study ranches.

Kentucky bluegrass nitrogen/sulfur ratios varied from 20.52 on the Oliver ranch to 8.30 also on the Oliver ranch during phenological stage I. In phenological stage II, nitrogen/sulfur ratios for Kentucky bluegrass ranged from 14.73 on the Lemcke ranch to 5.87 also on the Lemcke ranch. In phenological stage III, nitrogen/sulfur ratios for Kentucky bluegrass on the Palmer ranch ranged from 4.95 to 4.16. The Lemcke and Oliver ranches were not sampled (Figure 10).

Statistical analysis of differences in nitrogen/sulfur ratios between three phenological stages indicated the largest difference in nitrogen/sulfur ratios existed between stages II and III (Table 7). Nitrogen/sulfur ratios of Nebraska sedge on the Oliver ranch, common rush on the Oliver ranch, and common rush on the Palmer ranch did not differ significantly between phenological stages II and III. In only one instance, that of nitrogen/sulfur of Kentucky bluegrass on the Palmer meadow, were stages I and II statistically different. These findings indicated that most phenologically-induced differences in nitrogen/sulfur ratios in the study plants occurred between phenological stages II and III, differing from those of tryptophan and crude protein content, in which cases the greatest decline generally occurred between phenological stages I and II. Relatively large variations within each phenological stage (between samplings) were present in the nitrogen/sulfur data. A larger number of samples should have been analyzed so that values obtained could have been substantiated.

Table 7. Results of analysis of variance of nitrogen/sulfur ratios between three stages of phenological development of three plant species collected from three ranches over the 1973 growing season.[1]

		Phenological Stage		
		I	II	III
Lemcke Ranch				
Species:	Nebraska sedge	14.41[a]	14.86[a]	6.65[b]
	common rush	11.14[a]	11.67[a]	3.72[b]
	Kentucky bluegrass	13.36[a]	9.32[a]	
Oliver Ranch				
Species:	Nebraska sedge	10.01[a]	7.43[a, b]	5.69[b]
	common rush	10.75[a]	9.11[a]	6.51[a]
	Kentucky bluegrass	13.45[a]	6.65[a]	
Palmer Ranch				
Species:	Nebraska sedge	13.39[a]	13.20[a]	6.74[b]
	common rush	13.81[a]	12.48[a, b]	9.34[b]
	Kentucky bluegrass	10.77[a]	7.29[b]	4.44[c]

[1]Numbers indicate nitrogen/sulfur ratios in decimal form; those with identical superscripts are not statistically different at the 95% level. Horizontal comparison only is valid.

Analysis of variance showed three cases where nitrogen/sulfur ratios varied significantly between sites (Table 8). Nitrogen/sulfur ratios of Nebraska sedge in stages I and II on the Oliver ranch differed from corresponding values obtained on the Lemcke and Palmer meadows. Nitrogen/sulfur ratios for common rush in phenological stage III differed between the Lemcke and Palmer pastures (Table 8).

Sulfur content of all plant samples analyzed (Appendix C) exceeded requirements suggested by the National Research Council for beef cattle (National Research Council, 1970). No correlation was drawn between sulfur content of plants and development of symptoms of ABPE. The nitrogen/sulfur ratios for Nebraska sedge, common rush, and Kentucky bluegrass displayed high variability within each respective phenological stage, even though a definite decrease was noted in nitrogen/sulfur ratios over the season. This variability, and the limited available literature on the subject, precluded positive correlation between ABPE and plant nitrogen/sulfur levels. The data presented in Appendix C are valuable as future reference, should sulfur or the nitrogen/sulfur ratio be linked to development of symptoms of pulmonary emphysema.

Forage Plant Utilization

Utilization measurements on the Lemcke meadow in 1973 indicated plots containing Kentucky bluegrass sustained the heaviest

Table 8. Results of analysis of variance of nitrogen/sulfur ratios between three plant collection sites of three plant species in three stages of phenological development over the 1973 growing season.[1]

		Site		
		Lemcke	Oliver	Palmer
Phenological Stage I				
Species:	Nebraska sedge	14.41[a]	10.01[b]	13.39[a]
	common rush	11.14[a]	10.75[a]	13.80[a]
	Kentucky bluegrass	13.36[a]	13.45[a]	10.77[a]
Phenological Stage II				
Species:	Nebraska sedge	14.85[a]	7.42[b]	13.20[a]
	common rush	11.67[a]	9.11[a]	12.48[a]
	Kentucky bluegrass	9.32[a]	6.65[a]	7.29[a]
Phenological Stage III				
Species:	Nebraska sedge	6.65[a]	5.69[a]	6.74[a]
	common rush	3.72[a]	6.51[a, b]	9.34[b]
	Kentucky bluegrass	No data		

[1]Numbers indicate nitrogen/sulfur ratios in decimal form; those with identical superscripts are not statistically different at the 95% level. Horizontal comparison only is valid.

utilization over the five days following turnout (Table 9). Grazing of associated species appeared equal to that of Kentucky bluegrass in bluegrass-dominated plots. Utilization of all five plots containing bluegrass exceeded 65 percent by the fifth day. By comparison, only one plot dominated by sedge was utilized over 60 percent during the same period of time (Table 9).

All plots were utilized by the third day after turnout (Table 9). Up to 32 percent use per day was noted on all species the first two or three grazing days. As 55 to 65 percent of the bluegrass was removed, daily grazing reduced a smaller proportion of plant height. No difference in grazed height was noted between days four and five on three of the five bluegrass plots. Only 40 to 50 percent use was effected on sedge and rush before grazing rate slowed notably. This indicated Kentucky bluegrass was of higher palatability than sedge or rush under these conditions and/or that more of the entire bluegrass plant was acceptable to the cattle during the above time period than was sedge or rush.

The Palmer meadow, a more diverse pasture, elicited different use patterns (Table 10). Three plots -- timothy (*Phleum pratense*)-Kentucky bluegrass, Nebraska sedge, and common rush -- were neglected by the cattle during the nine-day grazing period. Heaviest use was made of birdsfoot trefoil (*Lotus corniculatus*), which was 75 percent grazed by day four. The Kentucky bluegrass-bluebunch

Table 9. Percentage utilization, based on plant height removed, from ten selected plots in the Lemcke Silvies pasture, for five days following turnout, July, 1973.

Community	Days after turnout[2]				
	1	2	3	4	5
Juncus-Trifolium-Aster					
common rush[1]	11	26	58	58	58
Nebraska sedge	0	0	24	41	47
Nebraska sedge	0	0	29	50	50
Nebraska sedge	0	17	33	42	42
Nebraska sedge, common rush	9	27	36	64	64
Achillea-Aster					
Kentucky bluegrass	20	53	60	67	67
Kentucky bluegrass, Nebraska sedge, common rush	22	33	44	56	67
Kentucky bluegrass, Nebraska sedge	22	44	56	67	67
Kentucky bluegrass, Nebraska sedge	31	62	62	69	69
tufted hairgrass, Kentucky bluegrass, common rush	19	37	45	63	69

[1]plant species measured

[2]Symptoms of ABPE were noted the fifth day after turnout and cattle were moved to another pasture.

Table 10. Percentage utilization, based on plant height removed, from ten selected stands in the Palmer Number 2 Meadow, for nine days following turnout, August, 1973.

Community (plot)	Days after Turnout 1	2	3	4	5	6	7	8	9
Medicago-Bromus[2]									
Nebraska sedge, smooth brome[1]	20	20	20	40	40	40	40	40	40
Nebraska sedge, Kentucky bluegrass	0	0	8	17	25	25	25	33	33
Poa									
timothy, Kentucky bluegrass	0	0	0	0	0	0	0	0	0
Kentucky bluegrass, timothy	0	12	12	31	31	31	31	31	31
Carex[2]									
Nebraska sedge	0	0	20	20	20	20	20	20	20
Nebraska sedge	0	0	0	0	0	0	0	0	0
Nebraska sedge, Kentucky bluegrass	0	7	7	13	13	13	13	13	13
Lotus[2]									
Birdsfoot trefoil	0	50	50	75	75	75	75	75	75
Elymus-Brassica									
Kentucky bluegrass, bluebunch wheatgrass	0	0	0	31	31	37	44	44	56
Elymus-Achillea-Chrysothamnus									
common rush	0	0	0	0	0	0	0	0	0

[1]Plant species measured.
[2]Not sampled for frequency in 1972.

wheatgrass (Agropyron spicatum) plot sustained the next-heaviest grazing and by day nine was 56 percent utilized. Three heterogeneous plots elicited between 30 and 40 percent utilization by day nine. They were composed primarily of Nebraska sedge, Kentucky bluegrass, timothy, and smooth brome (Table 10).

Only one of the ten utilization plots on the Palmer meadow was grazed the first day (Table 10). Overall use during the first nine days was lighter than on the Lemcke meadow (Table 13). No plots except birdsfoot trefoil appeared to be actively sought by cattle. Kentucky bluegrass was generally well utilized except once where it occurred in a mixture dominated by timothy (Table 10). In this instance, it was not grazed. Bluebunch wheatgrass in combination with Kentucky bluegrass sustained relatively heavy utilization. Only one common rush plot was measured and it sustained no utilization. Sedge was lightly used in most cases (Table 10).

Grazing was not as intensive on the Palmer pasture as on the Lemcke pasture and data obtained from forage utilization plots on the Palmer pasture were not as consistent as from plots on the Lemcke pasture (Tables 9 and 10). Palmer's cattle were more widely distributed in the pasture and utilized a larger area than Lemcke's herd.

Cattle diets could not be determined from utilization measurements. However, utilization of Nebraska sedge, common rush, and Kentucky bluegrass indicated they were important constituents of the diet. On both the Lemcke and Palmer pastures, Kentucky bluegrass was most heavily grazed compared to other species measured. This finding implied that amounts of chemical constituents ingested by the herd in general paralleled the levels of those constituents in Kentucky bluegrass. It has been noted that 43.8 kg (dry weight) of Kentucky bluegrass at its highest tryptophan level would have to be eaten to supply as much tryptophan to a 1000 pound cow as a laboratory dose of 0.57 g/kg body weight administered orally. By Lemcke's July 3, 1973, turnout, tryptophan in Kentucky bluegrass had dropped to less than 50 percent of its highest (May 24) level, indicating the above animal would have to ingest more than twice the calculated 43.8 kg to obtain lethal dose of tryptophan. This amount could only be accumulated from Kentucky bluegrass over an extended grazing period. Tryptophan levels of Nebraska sedge and common rush near midsummer were similar to those of Kentucky bluegrass (Appendix C). Turnouts effected after July 3 subjected the cattle to even lower concentrations of tryptophan in Nebraska sedge, common rush, and Kentucky bluegrass.

Crude protein and sulfur data for the sampled plants on the Lemcke and Palmer ranches near the time of their respective turnouts did not suggest any deficiencies in levels of these constituents. Nitrogen/sulfur ratios were not consistent enough during this time to foster any conclusion as to their adequacy in ruminant diets.

The portion of cattle diets comprised of the study plants was not thought to provide toxic amounts of tryptophan or inadequate amounts of nitrogen or sulfur immediately following turnout on the Lemcke and Palmer inciting pastures.

Grazing Observations

Grazing observations were made in 1972 of the Lemcke and Palmer herds to determine foraging habits on inciting pastures. Immediately after the Lemcke turnout, August 18, cattle foraged on the more xeric parts of the Silvies pasture, concentrating on communities containing intermediate wheatgrass (*Agropyron intermedium*), Kentucky bluegrass, Sandberg bluegrass, and timothy. By the second day following turnout, areas supporting Nebraska sedge and common rush were favored. A mature, lactating Hereford was found dead the fifth day after turnout. An autopsy performed by a veterinarian indicated ABPE as the cause of death (Figures 11 and 12). The remainder of the herd was moved off the Silvies pasture immediately. Two more animals were displaying ABPE symptoms at the time but neither died.

Grazing on Palmer's Number 2 Meadow appeared to be selective following an August 14, 1972, turnout. Birdsfoot trefoil sustained initial use. Cattle then grazed regrowth of a recently harvested hay meadow consisting primarily of Kentucky bluegrass, smooth brome, timothy, and alfalfa. The four communities containing giant wildrye

Figure 11. Autopsy of Lemcke's cow, August 1972, revealed about 15 percent normal lung tissue remaining, according to DVM Stevenson.

Figure 12. Hyaline membrane, abnormal dark color of lung tissue of Lemcke's cow, August 1972, indicated bovine pulmonary emphysema.

were not frequented by the cattle except for bedding purposes. White sweetclover (Melilotus alba) was selected in these areas. No cattle were observed to behave "abnormally." The bulls congregated the second day following turnout and stayed apart from the herd. The eighth day after turnout a mature lactating Hereford displayed symptoms of ABPE. Symptoms continued until the twelfth day when recovery was completed (Figure 13).

On October 3, 1972, a visit was made to Abe Rickman's "Rockpile Ranch" on the South Fork of the John Day River. Three Hereford cows had died only a few hours previous. In addition three more were sick, one seriously (Figure 14). DVM Guy Reynolds diagnosed the sick cows as having definite cases of pulmonary emphysema. The herd had been moved from dry hill pastures to relatively lush river-bottom forage ten days prior to the first animal's display of symptoms. Inspection of the grazed area revealed sedges growing along the banks of the John Day River had been lightly utilized. Time did not permit a thorough reconnaissance of the area. However, alfalfa, clover, and/or lush stands of grasses were absent.

In 1973, the Lemcke and Palmer herds were observed following the respective turnouts, July 3 and August 13. Inciting pasture forage on the Lemcke ranch did not appear as succulent as in 1972, due to lower-than-average precipitation prior to turnout. Lemcke's cattle seemed to select communities dominated by Kentucky bluegrass,

Figure 13. Sick cow on Palmer Number 2 Meadow, August, 1972, displayed head-extended stance and flared nostrils, both symptomatic of acute bovine pulmonary emphysema.

Figure 14. Sick cow on Rickman Ranch, October, 1972, showed typical pulmonary emphysema symptoms before death. Abnormal head position, excessive salivation, dilated nostrils were visible signs of the disease.

intermediate wheatgrass, and Nebraska sedge initially. However, among the relatively palatable wet meadow species occurring in dense aggregation the cattle did not appear to actively select material. On the fifth day following turnout, symptoms of ABPE were noted in two mature lactating Herefords. The cattle were moved to another pasture and no further symptoms developed.

Grazing patterns exhibited by the Palmer cattle on Number 2 Meadow in 1973 were similar to those observed in 1972. Birdsfoot trefoil, alfalfa, Kentucky bluegrass, smooth brome, and timothy appeared to be favored. A "conditioning" scheme was employed to circumvent occurrence of ABPE. For five days following turnout the cattle were allowed to graze in the inciting meadow only part of each day. The remainder of the time they were kept in dry lot and supplemented with hay. No symptoms of ABPE were noted in the Palmer herd in 1973. Degree of grazing selectivity displayed by the cattle appeared to decrease under the conditioning scheme.

On August 17, it was learned that pulmonary emphysema had been diagnosed on the Oris Crisp ranch near Arlington, Oregon. A visit disclosed that two mature lactating Herefords had died the day before and a third animal had succumbed a few hours previous when an attempt was made to move the herd off the inciting pasture. Another cow was displaying symptoms of ABPE. A veterinarian had autopsied the first victim and had diagnosed the cause of death as ABPE.

The Crisp cattle had been grazing on irrigated alfalfa-orchard grass (Dactylis glomerata) pasture for six days. They had been brought in from a sparse, degenerated stand of alfalfa. The heaviest use in the inciting pasture was on bassia (Bassia hyssopifolia), a bushy weed prevalent along the irrigation ditch. The alfalfa-orchardgrass forage showed little utilization. This was the first occurrence of ABPE on the Crisp ranch. Summer forage in 1973 had been in unusually short supply and had led to an undesirably high stocking rate on the summer range. Turnout had therefore been accomplished earlier than usual.

Grazing habits of cattle on all study ranches following turnout were similar. Leaves of most grazed species appeared to be taken before stems or flower parts. Utilization progressed uniformly on preferred species. The upper portions of most plants were eaten before the lower plant parts. Degree of selectivity appeared to increase with time spent on the inciting pasture. Differences in plant species selected between ranches were noted and accounted for by the presence of different associated species, different stocking rates, different plant phenological stages, different stress pasture vegetation, and different management.

Poisonous plants were present in small amounts in nearly all pastures. Poisonous species included milkvetch loco (Astragalus spp.), tailcup lupine (Lupinus caudatus), tall larkspur (Cicuta *douglasii*), and foothill deathcamas (*Zigadenus paniculatus*). For the most part, cattle left these plants untouched. The only noted exception was milkvetch loco, which was sporadically grazed on the Lemcke ranch. Degree of utilization on this species was difficult to ascertain because its low growth form and the apparent uniform succulence of plant parts fostered consumption of most above-ground material. However, only a small number of these plants were eaten. No single poisonous species was observed to be present on every pasture.

Questionnaires

Ranch questionnaires (Appendix D) provided a basis for comparison of herd compositions, management practices, and pasture characteristics preceding development of pulmonary emphysema symptoms in frequently-affected herds. The following similarities were noted.

1. Turnout occurred between early July and mid-October.
2. The resulting change of diet was always from relatively dry, sparse to relatively succulent and abundant forage.
3. Inciting pastures had a natural water source.
4. Mature, lactating Herefords were the principal victims.
5. Annual morbidity was unpredictable.
6. Once a herd had been victimized by ABPE, later appearance of symptoms in that herd was probable.

Questionnaires sent to veterinary practitioners and county agents in eastern Oregon did not elicit significant response. Although a majority of the questionnaires were answered, information was uncertain and general in nature. However, the questionnaires did indicate that ABPE is widely distributed over eastern Oregon. Since death can occur rapidly after onset of symptoms, sick animals are often not detected. Therefore, it can be assumed that some animals are lost to pulmonary emphysema but never reported. Also, symptoms of ABPE are similar to those of grass tetany and the two maladies may be confused in some areas. For these reasons it is hypothesized that the diagnosed extent of ABPE in Oregon is currently an underestimate of its actual importance.

SUMMARY AND CONCLUSIONS

Eastern Oregon pastures suspected of inciting pulmonary emphysema in cattle were studied in 1972 and 1973. Plant frequency data were collected from two pastures and grazing observations were made immediately after cattle were released to the inciting pastures. Three plant species noted to be favored by cattle and prevalent in inciting pastures were sampled at regular intervals during the 1973 growing season from three pastures. These samples were analyzed for tryptophan, crude protein, and the nitrogen/sulfur ratio. Utilization measurements were taken of selected forages on two of the sampled pastures following turnout. Questionnaires concerning ranch histories of ABPE were completed for six cooperating ranches.

Frequency data collected on inciting pastures indicated differences in species composition between the two pastures sampled. Observations of other inciting areas supported this finding. No single poisonous plant species was found in all meadows studied.

The tryptophan content of Nebraska sedge, common rush, and Kentucky bluegrass was shown to decrease from May 24 to September 4, 1973, on three selected inciting pastures. The greatest decrease for all three ranches was in the first part of the season, between phenological stages I and II. Sampling conducted the same date on different ranches yielded similar values for tryptophan content of the sampled species.

Calculations of forage intake necessary to duplicate laboratory doses of tryptophan used to incite ABPE showed that 43.8 kg (dry weight) of the forage with highest tryptophan content (Kentucky bluegrass on May 24) was equal to an oral dose of 0.57 g/kg body weight administered to a 454 kg (1000 lb) animal. This amount of forage is more than would normally be ingested in a short time period. However, there is a possibility that lung damage caused by tryptophan can be incurred through repeated ingestion of relatively small doses of the amino acid.

Crude protein content of Nebraska sedge, common rush, and Kentucky bluegrass also declined over the growing season in the sampled pastures. The greatest drop in crude protein due to plant phenology occurred between phenological stages I and II. A more gradual decline was noted between stages II and III. There were few statistically significant differences between crude protein contents of samples collected on different pastures the same day.

Crude protein contents of all samples tested in phenological stages I and II were adequate to maintain cattle in gestation or late lactation under range conditions, according to nutritive requirements presented by Cook and Harris (1968). However, in phenological stage III, values obtained for crude protein of Kentucky bluegrass on the Palmer ranch were not adequate for maintenance of gestating animals.

Nitrogen/sulfur ratios for Nebraska sedge, common rush, and Kentucky bluegrass decreased from May 24 to September 4 on the three study pastures. Unlike the tryptophan and crude protein trends, that of plant nitrogen/sulfur ratios showed the sharpest decline between phenological stages II and III, relatively late in the summer. Variations between nitrogen/sulfur ratios from plants collected in the same phenological stage suggested that a larger number of samples should have been taken. Sulfur content of sampled plants was adequate for lactating range cows. However, no conclusions were drawn concerning a relationship between sulfur or the nitrogen/sulfur ratios and ABPE.

Utilization measurements taken on ABPE-inciting pastures on the Lemcke and Palmer ranches in 1973 showed meadow vegetation on Lemcke's Silvies Pasture more heavily grazed than that on Palmer's Number 2 Meadow, in general. Three plots on the latter pasture sustained no detectable grazing during the nine-day period immediately following turnout. Less than 35 percent total utilization on the majority of the remaining plots suggested that more and larger sampling units should have been used. Utilization measurements indicated Kentucky bluegrass was a preferred forage on the Lemcke ranch. Nebraska sedge and common rush were taken as readily as Kentucky bluegrass on plots where the three species were mixed. Relatively pure stands of Nebraska sedge were not utilized until

Kentucky bluegrass plots had become partially depleted. Utilization of common rush alone was moderate.

Post-turnout grazing observations taken on the Lemcke and Palmer ranches in 1972 and 1973 failed to relate animal grazing habits with development of symptoms of ABPE. Cattle did not utilize any poisonous species except milkvetch loco, which was occasionally grazed on the Lemcke meadow in 1972. Foraging habits of cattle on all study pastures were noted to be similar. Leaves were taken before stems or flowering parts and upper portions of leaves on several preferred plants were grazed evenly before lower plant parts were utilized. Selectivity appeared to increase with time after turnout due to rumen fill and/or discovery by cattle of the most palatable species and communities. Differences were noted between species selected for on different ranches. Explanations were differences in associated species, stocking rates, plant phenological stages, stress pasture vegetation, and herd management.

Questionnaires completed for ranches with past histories of bovine pulmonary emphysema showed several herd characteristics and management practices common to all six ranches. Annual turnout dates were between early July and mid-October. Symptoms of ABPE were always noted following a change from relatively dry, sparse to relatively succulent, abundant forage. All inciting pastures had natural watercourses. Mature lactating Herefords were principal victims. Although annual morbidity was unpredictable, the probability of ABPE occurring in a herd seemed to be enhanced by former appearance of the disease in that herd.

More work is needed to relate range forage and livestock management to development of symptoms of bovine pulmonary emphysema. Information is needed on composition of cattle diets immediately after turnout. Stress pasture vegetation should be thoroughly studied and selected plants analyzed for tryptophan. Compilation of additional case histories is needed to determine common pertinent factors on frequently affected ranches.

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APPENDICES

APPENDIX A. STUDY PASTURE DESCRIPTIONS

Lemcke Inciting Pasture Description

Name: Silvies Pasture (Figures A1, A2)

Ownership: Robert Lemcke, Seneca, Oregon

Location: T16S, R29E, S5; 11 miles west of Seneca on USFS Rd. 1611

Size: 600 acres

Size of "wet meadow" area: 125 acres

Physiography:

Elevation--5,000 feet

Contour--rolling

General aspect--southwest

Slope--5 to 10% (estimate)

Soil type--untested

Drainage:

Name--Silvies River

Where in relation to pasture--north side

Direction--Northeast

Summer size--5 feet wide, 1 foot deep (approximate)

Characteristics--clean; gravel bed

Vegetation:

Frequency measurements were taken on two mesic communities in this pasture (Table 1).

Figure A1. Nebraska sedge community (center) in a moist pocket of the Lemcke Silvies Pasture was photographed July, 1973.

Figure A2. Nebraska sedge, common rush, and meadow foxtail dominated this portion of the Lemcke Silvies Pasture, July, 1972.

Oliver Inciting Pasture Description

Name: Mare Pasture (Figures A3, A4)

Ownership: Joseph C. Oliver, John Day, Oregon

Location: T16S, R32E, S17; 4 miles east of Hwy. 395, 3 miles north of Seneca

Size: 600 acres

Size of "wet meadow" area: 4 acres (Shoestring Glade)

Physiography:

Elevation--4,800 feet

Contour--rolling

General aspect--west

Slope--0 to 5% (estimate)

Soil type--Silvies silt loam, Marsden silt loam

Drainage:

Name--tributary into Bear Creek

Where in relation to pasture--west side

Direction--south

Summer size--small, may dry up completely

Characteristics--dirt bed

Vegetation:

The vegetation on the mesic portions of this pasture was not analyzed quantitatively but appeared to be made up of two major plant communities.

Figure A3. Upper portions of sedge and rush plants are indicated by brown coloration in photo center. These species marked the drainage of the Oliver Mare pasture, July, 1972.

Figure A4. Nebraska sedge occupied only the areas subtended by or immediately adjacent to the creek bed in the Oliver Mare pasture, July, 1972.

The *Carex*-*Juncus* community occurred only in or within 20 yards of the Mare Pasture drainage. The principal species were Nebraska sedge and common rush. When the creek bed dried up in midsummer, meadow foxtail (*Alopecuris pratensis*) appeared, increasing as the season progressed.

The *Juncus*-*Deschampsia* community occupied a more xeric area than the *Carex*-*Juncus* community. Principle species were common rush, tufted hairgrass, Kentucky bluegrass, Nebraska sedge, slender cinquefoil, and common dandelion. This community bordered, but did not include, the drainage.

Palmer Inciting Pasture Description

Name: Number 2 Meadow (Figures A5, A6)

Ownership: Vern Palmer, Paulina, Oregon

Location: T16S, R24E, S29 and 32; 13 miles east of Paulina on Rager Road

Size: 160 acres

Size of "wet meadow" area: 160 acres

Physiography:

Elevation--4,000 feet

Contour--flat

General aspect--west

Slope--0 to 5% (estimate)

Soil type--untested

Drainage:

Name--Beaver Creek

Where in relation to pasture--middle

Direction--north

Summer size--small, dredged, may dry up completely

Characteristics--dirt bed

Vegetation:

Frequency measurements were taken on four mesic communities in this pasture (Table 2).

Figure A5. Willows in photo center indicated Beaver Creek in Palmer's Number 2 Meadow, August, 1972. Giant wildrye was present in foreground and bunchgrass summer range in rear.

Figure A6. Recently mowed portion of the Palmer Number 2 Meadow provided cattle with palatable forage, August, 1972. Giant wildrye bordered the cutting on the left.

APPENDIX B. COMPREHENSIVE PLANT SPECIES LIST OF ACUTE BOVINE PULMONARY EMPHYSEMA-INCITING PASTURES ON SIX STUDY RANCHES, 1972[1]

Family and Scientific Name	Common Name
Amaranthaceae	
Amaranthus retroflexus	redroot amaranth
Caprifoliaceae	
Symphoricarpos albus	common snowberry
Caryophyllaceae	
Stellaria media	chickweed
Chenopodiceae	
Bassia hyssopifolia	bassia
Salsola kali var. *tenuifolia*	Russian-thistle
Compositae	
Achillea lanulosa	yarrow
Ambrosia artemisifolia	ragweed
Antennaria spp.	pussytoes
Arctium minus	burdock
Artemisia tridentata	big sagebrush
Aster spp.	aster
Bellis perennis	daisy
Centaurea spp.	centaurea
Chrysothamnus nauseosus	tall gray rabbitbrush

[1]Plant identification from Hitchcock and Cronquist (1973). Common names mainly from Garrison *et al.* (1967).

Family and Scientific Name	Common Name
Compositae (Continued)	
Chrysothamnus viscidiflorus	tall green rabbitbrush
Cirsium arvense	Canada thistle
Cirsium vulgare	bull thistle
Crepis spp.	hawksbeard
Erigeron philadelphicus	Philadelphia fleabane
Gnaphalium spp.	cudweed
Solidago spp.	goldenrod
Taraxacum officinale	common dandelion
Convolvulaceae	
Convolvulus spp.	morninglory
Crassulaceae	
Sedum debile	stonecrop
Cruciferae	
Brassica campestris	bird rape
Cupressaceae	
Juniperus occidentalis	western juniper
Cyperaceae	
Carex spp.	sedge
Carex geyeri	elk sedge
Carex nebraskensis	Nebraska sedge
Carex rossii	Ross sedge

Family and Scientific Name	Common Name
Equisetaceae	
Equisetum spp.	horsetail
Geraniaceae	
Geranium richardsonii	Richardson geranium
Graminae	
Agropyron desertorum	crested wheatgrass
Agropyron inerme	beardless bluebunch wheat-grass
Agropyron intermedium	intermediate wheatgrass
Agropyron repens	quackgrass
Agropyron smithii	bluestem wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Agrostis spp.	bentgrass
Agrostis alba	redtop
Alopecuris pratensis	meadow foxtail
Arrhenatherum elatius	tall oatgrass
Avena fatua	wild oat
Bromus brizaeformis	rattle brome
Bromus carinatus	California brome
Bromus inermis	smooth brome
Bromus marginatus	mountain brome
Bromus tectorum	cheatgrass brome

Family and Scientific Name	Common Name
Graminae (Continued)	
Calamagrostis rubescens	pinegrass
Dactylis glomerata	orchardgrass
Deschampsia caespitosa	tufted hairgrass
Distichlis stricta	alkali saltgrass
Elymus cinereus	giant wildrye
Elymus glaucus	blue wildrye
Festuca idahoensis	Idaho fescue
Glyceria elata	tall mannagrass
Hordeum jubatum	foxtail barley
Koelaria cristata	prairie Junegrass
Lolium perenne	perennial ryegrass
Phalaris arundinacea	reed canarygrass
Phleum pratense	timothy
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Poa secunda	Sandberg bluegrass
Sitanion hystrix	bottlebrush squirreltail
Stipa comata	needleandthread
Juncaceae	
Juncus spp.	rush
Juncus effusus	common rush

Family and Scientific Name	Common Name
Labiatae	
Monardella spp.	monardella
Scutellaria spp.	scullcap
Leguminosae	
Astragalus spp.	milkvetch loco
Lotus corniculatus	birdsfoot trefoil
Lupinus caudatus	tailcup lupine
Medicago sativa	alfalfa
Melilotus alba	white sweetclover
Trifolium spp.	clover
Liliaceae	
Brodiae spp.	brodia
Camasia quamash	common camas
Zigadenus paniculatus	foothill deathcamas
Linaceae	
Linum spp.	flax
Linum perenne	perennial flax
Malvaceae	
Sidalcea oregana	Oregon checkermallow
Onagraceae	
Epilobium angustifolium	fireweed

Family and Scientific Name	Common Name
Pinaceae	
Pinus ponderosa	ponderosa pine
Pseudotsuga menzesii	Douglas-fir
Plantaginaceae	
Plantago spp.	plantain
Polygonaceae	
Eriogonum spp.	buckwheat
Rumex acetosella	sheep sorrel
Rumex crispus	curly dock
Ranunculaceae	
Aconitum columbianum	Columbia monkshood
Delphinium stachydeum	Rocky Mountain larkspur
Ranunculus spp.	buttercup
Rosaceae	
Fragaria cuneifolia	common strawberry
Potentilla gracilis var. *glabrata*	slender cinquefoil
Purshia tridentata	antelope bitterbrush
Rosa woodsii	Wood's rose
Salicaceae	
Populus tremuloides	quaking aspen
Populus trichocarpa	black cottonwood
Salix spp.	willow

Family and Scientific Name	Common Name
Scrophulariaceae	
Castilleja spp.	paintbrush
Mimulus guttatus	common monkeyflower
Penstemon spp.	penstemon
Verbascum thapsus	flannel mullein
Veronica spp.	speedwell
Typhaceae	
Typha latifolia	common cattail
Umbelliferae	
Cicuta douglasii	western water hemlock
Urticaceae	
Urtica spp.	nettle
Urtica dioica	stinging nettle
Urtica gracilis	slim nettle
Zygophyllaceae	
Tribulus terrestris	caltrop

APPENDIX C

RESULTS OF CHEMICAL ANALYSES OF THREE FORAGE SPECIES COLLECTED OVER THE 1973 GROWING SEASON

Table C1. Results of chemical analyses of three forage species collected over the 1973 growing season.

Phenological Stage I

Ranch	Species	Date	Tryptophan (ug/mg)	Nitrogen (percent)	Crude Protein (percent)	Sulfur (percent)	$\frac{\text{Nitrogen}}{\text{Sulfur}}$
Lemcke	Nebraska sedge	5/24	2.67	2.23	13.91	0.14	15.93
Lemcke	Common rush	5/24	3.77	3.06	19.10	0.23	13.30
Lemcke	Kentucky bluegrass	5/24	5.11	3.67	22.99	0.27	13.59
Oliver	Nebraska sedge	5/24	4.19	2.99	18.70	0.27	11.07
Oliver	Common rush	5/24	3.98	2.56	16.06	0.22	11.64
Oliver	Kentucky bluegrass	5/24	5.92	4.31	26.94	0.21	20.52
Palmer	Nebraska sedge	5/24	2.93	2.07	12.94	0.16	12.94
Palmer	Common rush	5/24	3.10	2.33	14.57	0.17	13.71
Palmer	Kentucky bluegrass	5/24	2.40	2.03	12.67	0.20	10.15
Lemcke	Nebraska sedge	5/30	3.18	2.29	14.31	0.16	14.31
Lemcke	Common rush	5/30	3.26	2.78	17.38	0.23	12.09
Lemcke	Kentucky bluegrass	5/30	4.44	3.41	21.30	0.25	13.64
Oliver	Nebraska sedge	5/30	3.67	2.83	17.72	0.31	9.13
Oliver	Common rush	5/30	2.86	2.31	14.43	0.22	10.50
Oliver	Kentucky bluegrass	5/30	2.44	2.19	13.66	0.19	11.53
Palmer	Nebraska sedge	5/30	2.56	2.03	12.68	0.15	13.53
Palmer	Common rush	5/30	2.53	2.25	14.06	0.17	13.24
Palmer	Kentucky bluegrass	5/30	2.07	1.74	10.88	0.16	10.88
Lemcke	Nebraska sedge	6/6	2.74	2.34	14.63	0.18	13.00
Lemcke	Common rush	6/6	3.41	2.57	16.09	0.32	8.03
Lemcke	Kentucky bluegrass	6/6	4.39	3.21	20.07	0.25	12.84
Oliver	Nebraska sedge	6/6	3.38	2.36	14.76	0.24	9.83
Oliver	Common rush	6/6	3.15	2.63	16.44	0.26	10.12
Oliver	Kentucky bluegrass	6/6	2.00	1.91	11.92	0.23	8.30
Palmer	Nebraska sedge	6/6	2.56	2.33	14.55	0.17	13.71
Palmer	Common rush	6/6	2.71	2.17	13.58	0.15	14.47
Palmer	Kentucky bluegrass	6/6	1.59	1.58	9.89	0.14	11.29

Table C2. Results of chemical analyses of three forage species collected over the 1973 growing season.

Phenological Stage II

Ranch	Species	Date	Tryptophan (ug/mg)	Nitrogen (percent)	Crude protein (percent)	Sulfur (percent)	Nitrogen/Sulfur
Lemcke	Nebraska sedge	6/18	3.19	2.19	13.67	0.13	16.85
Lemcke	Common rush	6/18	2.34	1.92	11.99	0.18	10.67
Lemcke	Kentucky bluegrass	6/18	2.42	2.21	13.78	0.15	14.73
Oliver	Nebraska sedge	6/18	2.25	1.93	12.07	0.18	10.72
Oliver	Common rush	6/18	2.66	2.19	13.71	0.17	12.88
Oliver	Kentucky bluegrass	6/18	1.23	1.49	9.32	0.23	6.48
Palmer	Nebraska sedge	6/18	2.18	1.98	12.36	0.13	15.23
Palmer	Common rush	6/18	2.38	2.09	13.08	0.14	14.93
Palmer	Kentucky bluegrass	6/18	1.41	1.37	8.54	0.16	8.56
Lemcke	Nebraska sedge	7/3	2.14	2.04	12.74	0.14	14.57
Lemcke	Common rush	7/3	1.92	1.92	11.97	0.14	13.71
Lemcke	Kentucky bluegrass	7/3	1.60	1.40	8.77	0.19	7.37
Oliver	Nebraska sedge	7/3	1.70	1.59	9.94	0.31	5.13
Oliver	Common rush	7/3	2.40	2.11	13.22	0.24	8.79
Oliver	Kentucky bluegrass	7/3	0.71	1.09	6.80	0.16	6.81
Palmer	Nebraska sedge	7/3	2.52	2.22	13.87	0.16	13.88
Palmer	Common rush	7/3	1.85	1.60	9.99	0.16	10.00
Palmer	Kentucky bluegrass	7/3	1.02	1.12	7.02	0.17	6.59
Lemcke	Nebraska sedge	7/18	2.15	1.71	10.70	0.31	13.15
Lemcke	Common rush	7/18	1.84	1.70	10.62	0.16	10.63
Lemcke	Kentucky bluegrass	7/18	1.31	1.35	8.43	0.23	5.87
Oliver	Nebraska sedge	7/18	1.99	1.48	9.25	0.23	6.43
Oliver	Common rush	7/18	1.84	1.47	9.20	0.26	5.66
Oliver	Kentucky bluegrass	7/18	No sample				
Palmer	Nebraska sedge	7/18	2.37	2.10	13.14	0.20	10.50
Palmer	Common rush	7/18	1.62	1.75	10.96	0.14	12.50
Palmer	Kentucky bluegrass	7/18	1.12	1.21	7.57	0.18	6.72

Table C3. Results of chemical analyses of three forage species collected over the 1973 growing season.

Ranch	Species	Date	Tryptophan (ug/mg)	Nitrogen (percent)	Crude protein (percent)	Sulfur (percent)	Nitrogen / Sulfur
			Phenological Stage III				
Lemcke	Nebraska sedge	7/30	2.24	2.05	12.82	0.16	12.81
Lemcke	Common rush	7/30	1.23	1.40	8.73	0.31	4.52
Lemcke	Kentucky bluegrass	7/30	No sample				
Oliver	Nebraska sedge	7/30	2.27	1.82	11.37	0.27	6.74
Oliver	Common rush	7/30	1.54	1.58	9.90	0.17	9.29
Oliver	Kentucky bluegrass	7/30	No sample				
Palmer	Nebraska sedge	7/30	1.68	1.43	8.96	0.18	7.94
Palmer	Common rush	7/30	1.73	1.75	10.97	0.20	8.75
Palmer	Kentucky bluegrass	7/30	0.82	0.97	6.05	0.23	4.22
Lemcke	Nebraska sedge	8/21	1.21	1.26	7.86	0.33	3.82
Lemcke	Common rush	8/21	0.84	1.15	7.19	0.32	3.59
Lemcke	Kentucky bluegrass	8/21	No sample				
Oliver	Nebraska sedge	8/21	2.06	1.60	10.01	0.28	5.71
Oliver	Common rush	8/21	1.83	1.55	9.66	0.41	3.78
Oliver	Kentucky bluegrass	8/21	No sample				
Palmer	Nebraska sedge	8/21	1.14	1.09	6.79	0.17	6.41
Palmer	Common rush	8/21	1.64	1.49	9.33	0.15	9.93
Palmer	Kentucky bluegrass	8/21	0.97	1.04	6.53	0.25	4.16
Lemcke	Nebraska sedge	9/4	1.56	1.36	8.49	0.41	3.32
Lemcke	Common rush	9/4	1.34	1.31	8.18	0.43	3.05
Lemcke	Kentucky bluegrass	9/4	No sample				
Oliver	Nebraska sedge	9/4	1.60	1.20	7.52	0.26	4.62
Oliver	Common rush	9/4	1.87	1.55	9.71	0.24	6.46
Oliver	Kentucky bluegrass	9/4	No sample				
Palmer	Nebraska sedge	9/4	0.93	0.88	5.53	0.15	5.87
Palmer	Common rush	9/4	No sample				
Palmer	Kentucky bluegrass	9/4	0.89	0.99	6.20	0.20	4.95

APPENDIX D

RESULTS OF A QUESTIONNAIRE COMPLETED IN 1972 BY THE SIX COOPERATING RANCHERS HAVING SUSTAINED RECENT ACUTE BOVINE PULMONARY EMPHYSEMA LOSSES

Table D1. Results of a questionnaire completed in 1972 by the six cooperating ranchers having sustained recent acute bovine pulmonary emphysema losses.

Study ranches	Time of Turnout	Stress pasture "condition"	Inciting pasture "condition"	Inciting pasture size and portion covered by "wet meadows"
Boston Ranches	1970--15 Aug. 1971--1 Aug.	good to very poor	Used previously, good regrowth	1,000; 2,000 and 2,400 acres-- 1/3 meadow
Lemcke	1968--20 Jul. 1971--20 Aug.	fair	lush	1968--2,000 acres-- 1/3 meadow 1971--650 acres-- 1/7 meadow
Mascall	generally 20 Sept. to 10 Oct.	poor	lush regrowth after one cutting of hay	350 acres--all meadow
Oliver	Jul.	good	lush	1,000 acres-- 1/10 meadow
Palmer	mid Aug. to mid Oct.	fair	mowed portion short with little regrowth; creek bottom lush	160 acres-- 1/2 meadow
Wyllie	1970--12 Aug.	good on areas not easily entered; poor on creeks	lush	3,600 acres-- 1/10 meadow

Table D2. Results of a questionnaire completed in 1972 by the six cooperating ranchers having sustained recent acute bovine pulmonary emphysema losses.

Study Ranches	Inciting Pasture Fertilization	Inciting Pasture Water	Supplemental Feed and Minerals	Herd Size and Composition	Cattle Breed
Boston Ranches	none	Twelvemile and Grindstone Creeks, springs	Stress pasture--mineral blocks, salt blocks. Inciting pasture--same	12 bulls, 200 wet cows	Herefords, Angus, and Crosses
Lemcke	none	Silvies River, springs	Stress pasture--iodized salt Inciting pasture--same	12 bulls, 200 wet cows	Herefords
Mascall	none	John Day River, springs	Stress pasture--trace mineral beginning 110 days prior to rotation and continued. Inciting pasture--same	6 bulls, 220 cows (half are dry)	Herefords with some Angus and Charolais blood
Oliver	none	springs	Stress pasture--none Inciting pasture--none	6 bulls, 120 wet cows	Herefords
Palmer	120# 16-20-0 1970	Beaver Creek	Stress pasture--iodized salt Inciting pasture--same	8 bulls, 140 cows	Herefords and Hereford/ Angus crosses
Wyllie	none	Swicker Creek	Stress pasture--salt Inciting pasture--same	12 bulls, 300 wet cows	Herefords

Table D3. Results of a questionnaire completed in 1972 by the six cooperating ranchers having sustained recent acute bovine pulmonary emphysema losses.

Study Ranches	Stress Factors on Cattle	Number, Age, Sex and Period in Reproductive Cycle of Cattle Previously Affected	Percent Annual Morbidity
Boston Ranches	2-mile drive; minimal stress	70 mature wet cows (1971)	25% (1971)
Lemcke	short drive; minimal stress	7 mature wet cows and 1 bull in 1968; 7 mature wet cows in 1971; 2 mature wet cows and 1 bull in 1972	4% (1968) 4% (1970) 2% (1972)
Mascall	7-mile drive; minimal stress	1 bred heifer, 2 bulls, 1 mature dry cow, and 30 wet cows over a 10 year period	4% average
Oliver	short drive; minimal stress	2 mature wet cows--1966 3 mature wet cows--1967 3 mature wet cows--1968 2 mature wet cows--1969 6 mature wet cows, 2 bulls--1971	2% average (1966-1969) 7% (1971)
Palmer	short drive; minimal stress	22 mature wet cows, 1 bull--1963 5 mature wet cows--1970 5 mature wet cows--1971	3% (1970) 3% (1971)
Wyllie	3-mile drive in cool of morning; cattle were held in pen one night	14 mature wet cows	5% (1970)