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I am submitting herewith a thesis written by David Wayne Saylor entitled "Evaluation of Supplementary Mixtures Containing Magnesium for Prevention of Grass Tetany in Beef Cattle." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.


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EVALUATION OF SUPPLEMENTAL MIXTURES CONTAINING MAGNESIUM
FOR PREVENTION OF GRASS TETANY IN BEEF CATTLE

A Thesis
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Degree
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ABSTRACT

A study was conducted at The University of Tennessee, Highland Rim Experiment Station, Springfield, Tennessee, to evaluate the effects of free-choice salt-CSM-dry molasses-magnesium oxide and Mg Cl_2 -molasses mixtures on blood serum Mg levels and the incidence of grass tetany in pregnant beef cows. The cows grazed either non-nitrated or nitrated-fescue pastures and were supplemented with medium quality grass hay when the pastures were insufficient to support them. Blood and forage were collected monthly and analyzed for Mg, K and Ca. Soil samples were collected annually.

During the winter of 1972-73, the Mg blood serum level of the cows fed the MgO -salt mixture (1.61 mg/ml) was higher ($P < .05$) than that of the non-supplemented control cows (1.51 mg/ml). The mean serum Mg level of cows fed the MgO -salt (1.65) and Mg Cl_2 -molasses mixture were both higher ($P < .01$) than that of the control cows in 1973-74.

Hay and supplemental Mg consumption was lower for cows grazing nitrated fescue pastures than for those grazing non-nitrated pastures.

Mg supplementation, MgO -salt and Mg Cl_2 -molasses, partially prevented the severe drop in blood Mg level at calving which was observed in the control cows. In addition, the blood serum Mg level increased more rapidly following calving in the Mg supplemented groups.

There appeared to be a positive relationship between winter serum Mg level of the cows and the subsequent performance of her calf.

These results suggest that the problem of grass tetany can be reduced by supplemental Mg fed in the form of MgO -salt or Mg Cl_2 -

molasses mixtures. Variation among cows within a pasture with respect to serum Mg level tended to be a problem and probably reflected variation in individual consumption. These data suggest that early initiation of Mg supplementation and continuing measurement of consumption is vital to successful prevention of grass tetany by this means.

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CHAPTER I

INTRODUCTION

Grass tetany (hypomagnesemia) is a metabolic disorder or disease affecting, generally, older lactating beef cows. It has been known to exist for 100 years and was associated with magnesium deficiency by Sjollem in 1928. Since that time, it has been reported in virtually all areas where beef cows are maintained predominantly on forage.

The incidence of grass tetany varies from place to place and from year to year. However, the economic impact of grass tetany on the beef cattle industry is widely recognized and, according to Powell (1974), grass tetany is the leading cause of death in adult beef cows in Tennessee.

Many theories have been proposed with respect to the cause of and factors influencing grass tetany, and many procedures for its prevention have been proposed. Feeding of supplemental magnesium to beef cows has been the most effective method of grass tetany prevention. However, consumption of supplements high in magnesium has been a problem. In a research study at The University of Tennessee, increased incidence of clinical tetany and lower consumption of supplemental magnesium mixtures have been observed as forage production and utilization increased.

The objectives of this study were (a) to compare supplemental mixtures containing magnesium with respect to consumption and their effect on blood serum magnesium levels and (b) to evaluate the effect of nitrogen fertilization of fescue pastures on the incidence of grass tetany.

CHAPTER II

LITERATURE REVIEW

History of Grass Tetany

Grass tetany, a metabolic disorder of ruminants, has been known for over 100 years. The disease was first related to low serum magnesium by Sjollemma in the Netherlands in 1928, according to Grunes, Stout and Browne11 (1970). The nutritional condition is also known as lactation tetany, hypomagnesemia or "staggers," and this serious disorder frequently afflicts grazing animals.

Generally, only female animals are affected with grass tetany, although the disturbance has been reported in calves and steers by Crookshank and Sims (1955). However Fontenot, Wise and Webb (1973); Colby (1973); Hjerpe (1967); and Grumes et al. (1970) reported that virtually all cases of grass tetany were restricted to lactating female animals. They also suggested that the condition was related to low blood serum magnesium.

Physical symptoms of grass tetany reported by Hughes and Cornelius (1960), Stewart (1954), Sjollemma (1932) included undue excitement, incoordination, loss of appetite, viciousness, muscular twitching, profuse salivation, grinding of teeth, general tetanic contractions, labored breathing, pounding heart beat, comatose condition, convulsions and death. The physical symptoms were similar to those reported in the tetany of milk fever. Diagnosis of grass tetany by physical symptoms alone is difficult, because of this similarity to milk fever. Clinical finding reported by Stewart (1954) showed that a more positive diagnosis can be made when the Mg level of the blood is known.

Blood Magnesium Level

Reports of grass tetany in the United States usually involve beef cows during the early stages of lactation (Fontenot, 1972). Cases of grass tetany have been reported in ewes (Merchon and Custer, 1958) and infrequently in dairy cows (Sims and Crookshank, 1956).

Grass tetany occurs more commonly in older animals (Blaxter and McGill, 1956; Merchon et al., 1958). One reason for the increased susceptibility of older animals which was suggested by Thomas (1965) is that the labile reserve of body magnesium, found mostly in the bone, is less in older animals than in younger animals. He further concluded that lactating cattle are most susceptible during the first two months of lactation. Susceptibility increased with each lactation, and Hjerpe (1967) reported that by the sixth lactation a cow was 15 times as susceptible as during the first lactation. In the young animal each magnesium ion that leaves the bones is replaced by a calcium ion (Blaxter and McGill, 1956). Other reports have indicated that the disorder is a simple dietary deficiency resulting from low levels in forage or low intakes of forage.

Varying daily Mg requirements for beef cows have been reported. They ranged from 11 to 12 g of dietary magnesium (Leffel and Mason, 1959) to 12 to 30 mg per kilogram body weight per day (N.R.C., 1970). Nicholson (1972) recently found that two ounces of magnesium oxide (MgO) per day was effective in preventing the disease; however, he stated that preventive measures should be started before clinical cases appear.

Clinical symptoms usually occur when plasma magnesium levels decline to or below 1.0 mg/100 ml according to Hjerpe (1967); Bohman et al. (1969);

Stewart (1954). However, Jones et al. (1973) and Hansard and Merriman (1972) suggested that grass tetany usually occurs when the magnesium level falls below 1.5 mg/100 ml of blood serum. Although the average blood Mg level is usually lower in animals suffering from grass tetany, a low level of serum magnesium is not necessarily indicative of grass tetany. Sims et al. (1956) recorded blood magnesium levels as high as 3.2 mg/100 ml blood serum in cattle showing clinical symptoms of grass tetany. They also reported values as low as 0.75 mg/100 ml in normal cows.

Factors that Influence Grass Tetany

Some of the factors reported by Gross (1973) as implicated in the grass tetany syndrome are:

1. Forage containing less than 0.20% Mg.
2. Forage with a high concentration of K (over 2.5%).
3. A $\frac{K}{Ca + Mg}$ ratio above 2.2 (equivalent basis).
4. High N concentration in the forage (4.0% or greater).
5. A high protein - low carbohydrate relationship in the forage.
6. High levels of certain organic acids (trans-aconitate, citrate) in the forage.
7. Spring or fall growing conditions that are cold, cloudy and wet followed immediately by periods of "flush" growth.
8. Calving and high milk production (physiological stresses).
9. Undue stress on the animal that can act as a "trigger" (e.g., forced running) (Gross, 1973).

Allcroft and Green (1938) and Allcroft (1947) found that the highest serum magnesium levels occurred during periods of high temperature and

when there had been little precipitation during the preceding months. Low blood magnesium levels were found at low temperatures and after much precipitation.

McNaught et al., (1968); Reith (1963); and Voisin (1963) indicated that in England the concentration of Mg in mixed pasture grass was higher in summer than in the spring. Therefore, one reason grass tetany occurs more frequently in cool weather is that concentrations of Mg in forage are often lower during cool weather.

Grass tetany is not confined to one season, and Stewart (1954) classified grass tetany into three definite types. The spring type was first observed invariably occurring in late April or early May within a few days after spring grazing starts. It is the most common type and is associated with a grass factor, being caused either directly by a constituent in spring grass or indirectly by the spring grass altering the animals general metabolism.

The winter type generally occurred to confined cattle being fed winter rations in stalls or drylot. Stewart (1954) has not been able to correlate the ration of grass silage or dry hay as the principal cause as the tetany condition was as prevalent among dairy cows receiving concentrates. The disease usually occurs in November or December and is generally characterized by sudden deaths. Barta (1973) states that the incidence of winter tetany is rapidly declining due to the ease of magnesium supplementation, especially when the animals are being fed silage or hay. With the use of salt-magnesium oxide (MgO) mixtures to supplement the normal magnesium intake, this type of tetany has been virtually eliminated.

The third type occurs in cattle wintered outside on pasture (out-wintered) and poses the greatest problem. It is most common in the months of February and March, often just after the stress of calving. Within the last few years this type has spread widely and has caused a very heavy death rate. Often the deaths occurred in herds where supplementary rations were being fed. As intensified forage management programs are developed and utilized by beef producers, this type of tetany will become more of a problem. However, Burns (1974) indicates that we must continue to improve pasture production and at the same time develop methods of preventing outwinter grass tetany.

Forage Factors, Their Influence and Interactions

In the United States the first documented cases of grass tetany occurred in cattle grazing cereal forages (Fontenot, 1972). Since then it has been reported to be a serious problem in virtually every region of the United States. This metabolic deficiency may be due to a simple dietary Mg deficiency resulting from a low Mg level in forage, low intakes of forage, or from an impairment in utilization of Mg (Fontenot, 1972).

Rook and Storry (1962) examined several nutritional factors considered to adversely affect Mg utilization. Two of these factors were Nitrogen (N) and Potassium (K). The fact that animals have been particularly susceptible to grass tetany when grazing wheat pastures which were very high in N and K led Miller (1939) to also suspect these nutrients as causative factors in grass tetany. In contrast, it is also noted by Colby (1973) that cereal crops such as wheat, rye, barley and oats are poor accumulators of Mg. They are very susceptible to low Mg contents

in the spring or fall when conditions for tetany exist.

Pfander (1973) found that along with the various cereal forage, soil temperature was also implicated in the incidence of grass tetany. He reported that as the soil warms up in the spring, plants tend to take up K at a lower environmental temperature than they do Mg. However, many workers suggested that the actual K content in the soil is probably the main factor affecting the uptake of Mg by plants. They further indicated that K competes with Mg uptake and as available K increases there is a sharp drop in Mg uptake.

High levels of K fertilization were shown to result in lowered blood serum Mg by Hvidsten et al. (1959), Kemp (1960) and Colby (1973). In addition, House and Van Campen (1971), Newton et al. (1972) have shown that feeding a high K level increases fecal Mg by interfering with Mg absorption rather than increasing endogenous excretion into the intestine. It was noted by Bartlett et al. (1954) that severe decreases in serum Mg occurred following high K fertilization of pastures which contained little clover, but this effect was not noted when the pasture sward consisted predominantly of clover. Clover usually has a greater Mg content than grass species, and thus the Mg content of a sward as a whole was easy to maintain (Mudd, 1970).

Hughes and Cornelius (1960) collected random pasture samples at the time of an outbreak of grass tetany which contained 4.45% K and 0.13% Mg on a dry-weight basis. Samples taken three weeks later from the same pastures contained 2.78% K and 0.20% Mg.

Barta (1973), in his studies of Ohio pastures, encountered similar results. A similar Potassium-Magnesium relationship also existed in the

animals grazing the pastures. As the K intake entering the animal increased, the amount of Mg absorbed and the amount of blood serum Mg decreased (Colby, 1973).

Fertilization of pastures with high levels of N generally resulted in lowered blood serum Mg in ruminants (Fontenot et al., 1973). It was further noted that a high N level in forage resulted in an increase in urinary Mg excretion. Barta (1973) reported that consequently, even though N fertilized grasses may be higher in Mg, the animal may absorb and utilize less total Mg than it could with non-nitrogen fertilized grass. In contrast, Large (1968) and Groot (1967) stated that large quantities of N can be applied to pastures without any clinical signs of a detrimental effect. They also found that the availability of Mg was not changed by the application of high levels of N to forage fed to lactating cows.

Barta (1973) further reported that N fertilization of grass pastures resulted in an increase of Mg as well as crude protein in the plant. Higher levels of crude protein sharply reduced the "availability" of plant Mg to the animals. Consequently, even though N fertilized grasses were higher in Mg, it was found that animals absorbed and utilized less total Mg than in the case of non-nitrogen fertilized grass.

Forages that were associated with a high incidence of grass tetany were reported by Colby (1973) and Kemp (1960) to be frequently high in both N and K. Actually, the high N and high K effects in their studies were additive on both plant and animal--at least to some extent. Therefore, the combination was considered more dangerous than either one alone.

Recently, balance studies designed to separate the effects of N and K were conducted by Moore, Fontenot and Webb (1972). Feeding a ration high

in K level resulted in a significant increase in fecal Mg excretion and in serum Mg regardless of the N level of the ration. Feeding high N and high K levels in combination did not increase fecal Mg excretion above that of feeding the high K ration alone. Feeding the high N level resulted in small but significant increases in urinary Mg excretion. In this study, the effect of K appeared to be independent of the dietary N level.

The dry matter content of the forage also may complicate the problem of grass tetany. According to Colby (1973), early lush growth of grasses or cereal grains may contain less than 15% dry matter. He attributed part of the problem to the fact that animals simply cannot consume enough dry matter to fulfill their needs.

Prevention of Grass Tetany

Since grass tetany appears to be caused by a metabolic deficiency of Mg, supplementing the animal with Mg should help in preventing the disturbance, regardless of whether the tetany is due to a simple Mg deficiency or an impairment of Mg utilization. A large variety of Mg supplements which vary in content and extent of utilization of Mg are available. Both long and short term solutions to the problem have been examined.

A long term solution to this disease suggested by Barta (1973) is to increase the soil Mg content to a safe level. This was accomplished most economically by application of high Mg limestone when a soil test indicated a lime requirement. He emphasized that liming is a long term solution and, depending on the particular soil, positive effects may not be seen for 5 to 10 years or possibly longer.

Jones et al. (1973) emphasized that the failure of South Carolina farmers to adequately lime may have contributed to the incidence of grass tetany by reducing the level of available soil Mg. They further stated that many types of limestone carry the name "dolomitic" or Mg limestone, but the farmer should demand dolomitic limestone that contains no less than 10% Mg.

Reith (1954), Stewart and Reith (1956), Burns and Allcroft (1967), found that fertilization with Mg was effective in increasing Mg concentrations in plants grown on acid, coarse textured soils. McConaghy et al. (1963) and Todd (1967) indicated that on finer textured soils much larger amounts of magnesium-limestone were required to significantly increase the Mg content in pasture plants. Todd (1967) indicated that fertilization of finer-textured soils with Mg was not economical unless the cost per unit of Mg was low. He also concluded that Mg fertilization probably should be limited to coarse textured soils or soils of low pH or low K status.

Gross (1973) suggested the renovation of existing pastures and the seeding of Mg accumulating species, such as red clover and tall fescue or species that respond favorably to Mg fertilization. Gross (1973) and Nicholson (1972) proposed limited grazing or feeding of grass species, such as Timothy or smooth Brome grass, which are generally low in Mg as a preventative measure during periods when tetany may be a problem. Nicholson (1972) further emphasized that grass tetany can be prevented by limited grazing, feeding hay at night or by grazing lush pasture 10 days then putting the animals on dry pasture plus supplement for a week and back again, etc.

Many short-term options for the prevention of grass tetany have been proposed. Most forages contain at least 0.1% Mg dry basis (Reid, Post and Jung, 1970). If there are no factors in the forage which impair Mg utilization, this level would meet at least 50% of the Mg requirements of lactating cows according to O'Kelley and Fontenot (1969). Thus, supplementing these cows with approximately 10 g Mg/day would appear adequate for the prevention of tetany. However, if conditions such as high levels of K were present, they suggested that the level of supplementation would need to be considerably higher. Since Mg absorption is often lowered 40 to 50% by high dietary levels of K, supplementation would need to be increased correspondingly.

Barta (1973) and Gross (1973) obtained successful results by dusting pastures with MgO. An application of 25 - 30 pounds MgO per acre when the grass reached a height of 3 to 4 inches was an effective preventive measure that often lasted for weeks. As indicated by Burns and Allcroft (1967), weather conditions were very important for the success of this practice. Heavy rain tended to wash the powder off. Also dry and windy weather also resulted in removal of the powder.

Wilkinson et al. (1973) obtained effective control of grass tetany in Ky. 31 tall fescue pastures by spraying with a MgO-bentonite clay-water slurry that adheres to the foliage. This procedure afforded grazing animals a continuous Mg intake. The blood serum Mg level of the cattle was greatly increased and there were no tetany losses among the animals grazing the treated pastures.

Ritchie and Hemingway (1968) indicated the use of magnesium alloy bullets as a prophylaxis against grass tetany. The recommended dose of

two bullets was expected to liberate about 2 g of Mg daily. They found that the bullets had little effect on increasing blood Mg, although the incidence of tetany was reduced in the experimental animals. Grunes et al. (1970) suggested that additional research is needed on the utility of Mg rumen bullets in decreasing tetany.

After 25 years of research work with grass tetany, Stewart (1954) decided that seasonal grass tetany might be prevented by feeding a very high Mg supplement which provided the animal with an easily available supply of Mg during times of physiological stress. He used mineral mixtures containing 16% MgO or 10% Mg fed at the rate of 5 oz per animal per day during the period in which a hypomagnesemia usually occurred. The mixture was designed to increase the normal Mg intake of cattle on grass by 50%. Seasonal hypomagnesemia was much less severe when the mineral mixture was fed. Although there was a depression in blood Mg, the level apparantly remained high enough to prevent clinical symptoms. Colby (1973) further stated that the biggest problem with oral supplementation was obtaining an adequate consumption of the Mg supplement since MgO is relatively unpalatable.

A large number of commercial firms have developed palatable Mg mixtures. Nicholson (1972) noted that some commercial companies have products available that contain from 3% to 20% MgO plus cottonseed meal, calcium phosphorus, salt and trace minerals. They emphasized that success depends on adequate consumption of the material and in some cases the mixture was palatable enough to cause over consumption such that cost becomes excessive. The use of palatable energy feeds such as ground milo or corn as a carrier for the MgO was acceptable when the MgO is added at the rate of 1 ounce per pound of feed.

Frye, Fontenot and Webb (1972); Grunes et al. (1970); Nicholson (1972) all reported excellent results with grazing cows that were allowed free access to a mineral mixture consisting of 1:1:1 ratio of dry molasses, trace mineralized salt and MgO. Other mixtures were evaluated in which cottonseed meal or steamed bonemeal was substituted for dry molasses. In a recent study, grazing beef cows consumed 42.9 g of MgO when given access to a 1:1:1 mixture of cottonseed meal, trace mineralized salt and MgO, Frye et al. (1972).

Clinical Treatment of Grass Tetany

It is not always easy to distinguish hypomagnesemic grass tetany from hypocalcemic milk fever. This difficulty in diagnosis appears to have led, in almost all countries, to the injection of a mixture of calcium and Mg salts as clinical treatment of tetany according to Voisin (1963) and Bohman et al. (1969). In the United States, commercial solutions often used for intravenous injections contain Ca and Mg gluconate with added dextrose and phosphate, Burns and Allcroft (1967). They indicated that intravenous injections should be given slowly, and the response watched carefully, because of the danger of death from cardiac arrest. Follow-up treatment consisting of daily oral administration of about 30 g of Mg for one week was indicated.

Hjerpe (1967) reported excellent results from 500 ml of 20% calcium gluconate administered intravenously and 200 to 250 ml of 25 to 50% MgSO_4 solution given subcutaneously. Relapses are common and 50 gm/day of oral MgO for the balance of the tetany season was indicated. Voisin (1963) stated that the intraperitoneal injection of a mixture of Mg, Ca, K was a popular treatment and appeared to be a most effective treatment for British practitioners.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

This study was conducted at the University of Tennessee, Highland Rim Experiment Station, Springfield, Tennessee. Data were collected during the 2-year period from November 1972 to May 1974. Pregnant Hereford cows grazing fescue pastures were used to evaluate the effects of two supplemental mixtures containing magnesium (Mg) in the prevention of grass tetany. Evaluations were based on magnesium consumption, clinical symptoms of grass tetany and blood serum magnesium levels.

II. FACILITIES

Eight 10-acre pastures which were part of a pasture study involving intensive forage production and utilization were designated as experimental pastures. Two adjacent 6-acre pastures, which were similar with respect to forage composition and management, were used as control pastures.

Each year in October 4 to 10-year-old pregnant Hereford cows were randomly assigned to pastures to provide a stocking rate of one cow to approximately two acres of pasture. The eight experimental pastures were randomly assigned to treatments.

III. PASTURE MANAGEMENT

Assignment of pastures to treatment and general pasture management practices are shown in Table 1. Pasture management practices conformed to those required for the evaluation of year-round productivity of fescue

TABLE 1
DESIGN OF THE EXPERIMENT

Treatment ^a Number	Pasture Number	Type of Pasture
1	1 ^b	Nitrated fescue
	2	Non-nitrated fescue
	6 ^b	Fescue + ladino clover
	7	Fescue + ladino clover + lespedeza
	3 ^b	Fescue + ladino clover
	4	Fescue + ladino clover + lespedeza
	5	Non-nitrated fescue
	8 ^b	Nitrated fescue
2 ^c	9A ^b	Nitrated fescue
	9B ^b	Non-nitrated fescue

^aTreatment: 1 = Magnesium supplied free-choice in a 1:1:1:1 mixture of salt, CSM, dry molasses and magnesium oxide in 1972-73 and a 1:4:1:1 mixture in 1973-74. 2 = Magnesium supplied by a commercial urea liquid molasses mixture (Prolix) containing 75 lb magnesium chloride per ton of feed. 3 = Non-supplemented control.

^bCows grazing pastures 1, 3, 6, 8 and 9 were bled at monthly intervals.

^cTreatment 2 was not included in 1972-73.

pastures maintained under various management systems in the companion project.

All pastures were fertilized with potassium, phosphate and lime according to recommendations based on soil test results. In addition, pastures 1, 8 and 9A were fertilized with 75 lb nitrogen (225 lb ammonium nitrate) in May and September each year. Pastures 3 and 6 were overseeded with about one lb of ladino clover (Regal) seed in February when the stand of clover during the previous June indicated this overseeding was desirable. Pastures 4 and 7 were overseeded with one lb ladino clover and 8 lb of lespedeza when needed to maintain a favorable grass-legume ration during the entire summer grazing season. Pastures 2, 5 and 9B were not nitrated and were not overseeded with legume. One control pasture was nitrated in September, and in the other control pasture legumes were maintained without nitrogen fertilization.

During the spring-summer growing season, surplus growth on all pastures was removed by increasing the stocking rate temporarily. The calves were weaned in late September or early October. Fall excess growth was allowed to accumulate (stockpiled) and was used for winter feed. However, fall growth of all pastures was predominately fescue with some residual clover and lespedeza in some pastures.

IV. ANIMAL MANAGEMENT

The cows were maintained on the respective pastures without supplemental hay as long as pasture forage was sufficient to maintain pregnant cows. When the forage in an individual pasture was insufficient to support the cows, they were fed medium quality hay, generally fescue, free-choice. In

the spring when forage growth in a pasture was sufficient to support the cows, hay feeding was discontinued. The treatments were (1) magnesium provided in a mixture of salt, cottonseed meal, dry molasses and magnesium oxide (MgO); (2) magnesium provided in the form of a commercial urea-liquid molasses feed (Prolix) containing about 75 lb of magnesium chloride ($Mg Cl_2$) per ton; (3) the control which received no supplemental magnesium. The MgO mixture was fed free-choice in salt boxes and the $Mg Cl_2$ -molasses mixture was fed free-choice in a liquid feeder with a single lick wheel. Cows in Treatment 1 had free access to dicalcium phosphate while those in treatment 2 had access to a mixture of one part salt and one part dicalcium phosphate.

V. DATA COLLECTED

All animals were weighed at the beginning and the end of the experiment and at regular intervals. Notes on each animal's health and any symptoms of grass tetany were recorded.

Each pasture was scored monthly with respect to visual estimates of quality and quantity of forage available. Monthly-forage-grab samples representative of each pasture and/or hay were taken.

Weights of all supplemental feed were recorded weekly. This included the mineral and salt mixtures and the liquid molasses carrier (Prolix) which was furnished by the Pro-Lix Companies of Aliceville, Alabama. Soil samples were taken twice a year, once during the winter and once during the summer.

Blood samples were collected monthly from 10 representative cows on each treatment from December through March, and at a two or three month interval throughout the remainder of the year.

VI. CHEMICAL ANALYSIS

The grab samples of both pasture and hay were analyzed according to procedures outlined by A. O. A. C. (1970) with minor modifications for the University of Tennessee's laboratory. The samples were dried, ground and analyzed for mineral and protein content.

The individual blood samples were allowed to clot prior to centrifuging. The serum was then separated, and all chemical analyses were performed with a Perkin-Elmer Atomic Absorption Spectrophotometer using the procedure outlined in the manufacturer's manual. Magnesium, calcium and potassium concentrations of the samples were determined.

VII. STATISTICAL ANALYSIS

Least squares procedures were used to access the effect of magnesium supplementation and type of pasture on blood Mg, Ca and K levels and on the incidences of grass tetany. Coefficients of correlation among various blood and forage components and between blood serum Mg and subsequent calf performance were calculated. Regression analyses were used to study the relationship of other blood serum components and serum Mg levels.

CHAPTER IV

RESULTS AND DISCUSSION

Overall means and standard deviations for various traits during the winter of 1972-73 and 1973-74 are shown in Table 2. Means of blood serum mineral levels were averages of 135 samples. These samples were from 27 cows, and were taken between November 1 and April 15 each year. The values for blood serum magnesium were 1.60 and 1.55 for the two years, respectively, and were lower than the normal values of 2.0 to 2.5 mg/ml observed by Fontenot (1972) in Virginia and by Hansard and Merriman (1972) in Tennessee. These low values indicate that these winter months comprise a period of grass tetany susceptibility in Tennessee cattle.

Supplemental Magnesium Mixtures

Effects of supplemental magnesium on blood serum levels of magnesium (Mg), potassium (K) and calcium (Ca) levels are presented in Table 3. During the winter of 1972-73, the blood serum Mg level of beef cows fed the 1:1:1:1 salt-CSM-dry molasses-magnesium oxide (MgO) mixture (1.61 mg/ml) was higher ($P < .05$) than that of the control cows (1.51 mg/ml) which received no supplemental Mg. Mean squares presented in Tables 4 and 5 show that the mean serum levels of K and Ca were not influenced by consumption of the magnesium mixtures.

During the winter of 1973-74, mean blood serum Mg of the cows fed the 1:4:1:1 mixture of salt-CSM, dry molasses-MgO (1.65 mg/ml) and that of the cows fed Mg Cl_2 in liquid molasses (1.65) were higher

TABLE 2
OVERALL MEANS AND STANDARD DEVIATION

	1972-73	1973-74
Blood serum, mg/ml ^a		
Magnesium	1.60 ± .4373	1.55 ± .4373
Calcium	8.31 ± .7756	9.27 ± .8168
Potassium	21.34 ± 3.6250	24.17 ± 7.8678
Forage, % ^b		
Magnesium	0.54 ± .5739	0.20 ± .2160
Calcium	0.11 ± .1073	0.34 ± .1185
Potassium	0.48 ± .3801	1.72 ± .6911
Forage protein, %	14.55 ± 8.4003	16.38 ± 5.3626
ADG of calves, lb	1.69 ± .3091	1.97 ± .3998

^aMeans are averages of 5 samples taken at monthly intervals from 17 cows in 1972-73 and 27 cows in 1973-74.

^bMeans were calculated on a dry matter basis from forage samples collected between November and April of each year.

TABLE 3
THE EFFECT OF SUPPLEMENTAL MAGNESIUM ON BLOOD SERUM
MAGNESIUM, POTASSIUM AND CALCIUM LEVELS^a

Treatment	No. of Cows	Mg	K	Ca
1972-73				
Control ^b	7	1.51 ^e	21.47	7.99
MgO-Salt ^c	10	1.61 ^f	20.90	8.47
1973-74				
Control ^b	7	1.26 ^e	25.72	9.31
MgO-Salt ^c	10	1.65 ^f	23.25	9.16
Mg Cl ₂ ^d	10	1.65 ^f	23.97	9.36

^aMeans are reported as mg/ml of serum and are averages of 5 samples per cow collected between Nov. 1 and April 15 each year.

^bControl cows grazed nitrated and non-nitrated pasture without supplemental magnesium.

^cMagnesium oxide was fed in a 1:1:1:1 mixture of MgO, CSM, salt and dry molasses in 1972-73 and a 1:4:1:1 mixture in 1973-74.

^dMagnesium chloride was mixed with liquid molasses (Prolix) at the rate of 50 lb per ton and fed free choice.

^{e,f}Means in the same column, with a year, superscripted with the same letter are not significantly different ($P < .05$).

TABLE 4
ANALYSES OF VARIANCE OF THE EFFECTS OF SUPPLEMENTAL MAGNESIUM ON
BLOOD SERUM LEVELS DURING THE WINTER OF 1972-73

Source	df	Mean Squares		
		Mg	K	Ca
Treatment ^a	1	0.26*	4.64	2.57**
Pasture/Treatment	2	0.01	14.61	0.02
Cow/Pasture-Treatment	18	4.30**	447.87**	19.88**
Residual	64	0.16	10.00	0.55

^aTreatments were control (no supplemental magnesium) and magnesium oxide in a salt-CSM-dry molasses mixture.

*P<.05; **P<.01.

TABLE 5
ANALYSES OF VARIANCE OF THE EFFECTS OF SUPPLEMENTAL MAGNESIUM ON
BLOOD SERUM LEVELS DURING THE WINTER OF 1973-74

Source	df	Mean Squares		
		Mg	K	Ca
Treatment ^a	2	3.88**	128.10	1.03
Pasture/Treatment	3	1.25	195.37	2.84
Cow/Treatment-Pasture	22	6.41**	647.78**	20.76**
Residual	106	0.13	67.92	0.60

^aTreatments were control (no supplemental magnesium), magnesium oxide in a salt, CSM, dry molasses mixture and magnesium chloride in liquid molasses (Prolix).

*P<.05; **P<.01.

($P < .01$) than the Mg level of the control cows (1.26). However, the serum K and Ca levels of the three groups were similar.

Relationship of Serum Mg, K and Ca

Coefficients of correlation (Table 6) indicate a positive relationship between blood Mg and Ca and a negative relationship between Mg and K when individual samples were considered. Although the coefficients of correlation differed in magnitude during the two years, the directions of the relationships were the same. Coefficients of correlation between Mg and K were $-.09$ and $-.39$ for the first and second year, respectively. The correlation coefficients between serum Mg and Ca were similar during the two years (0.23 and 0.32 , respectively). These relationships were linear and the relationship is presented graphically in Figure 1 for the 1973-74 data. For each unit increase in blood serum magnesium, calcium increased 0.59 units and potassium decreased 7.00 units.

These data were not sufficient to suggest cause and effect or to evaluate factors affecting these relationships. However, Bartlett et al. (1974) observed similar severe decreases in serum magnesium with high potassium fertilization of pastures containing little clover. Results of soil-test analyses during the winter of 1972-73 and 1973-74, presented in Table 7, show that soils in all pastures were relatively high in both potassium and phosphate. According to Matthews (1974), soils containing 0 to 110 lb K_2O per acre are considered low in K, those containing 120 to 190 lb per acre are considered medium and those containing over 190 lb of K_2O per acre are considered high. These pastures had been fertilized according to or in excess of soil test recommendations for

TABLE 6
 COEFFICIENTS CORRELATION^a AMONG BLOOD SERUM LEVELS
 OF MAGNESIUM, POTASSIUM AND CALCIUM^b

	Mg	K	Ca
Mg	1.00	-.09	.23
K	-.39	1.00	.28
Ca	.32	-.23	1.00

^aCoefficients above the diagonal are for 1972-73 and those below for 1973-74.

^bThe coefficients were calculated from 5 samples collected between Nov. 1 and April 15 from all 25 cows each year.

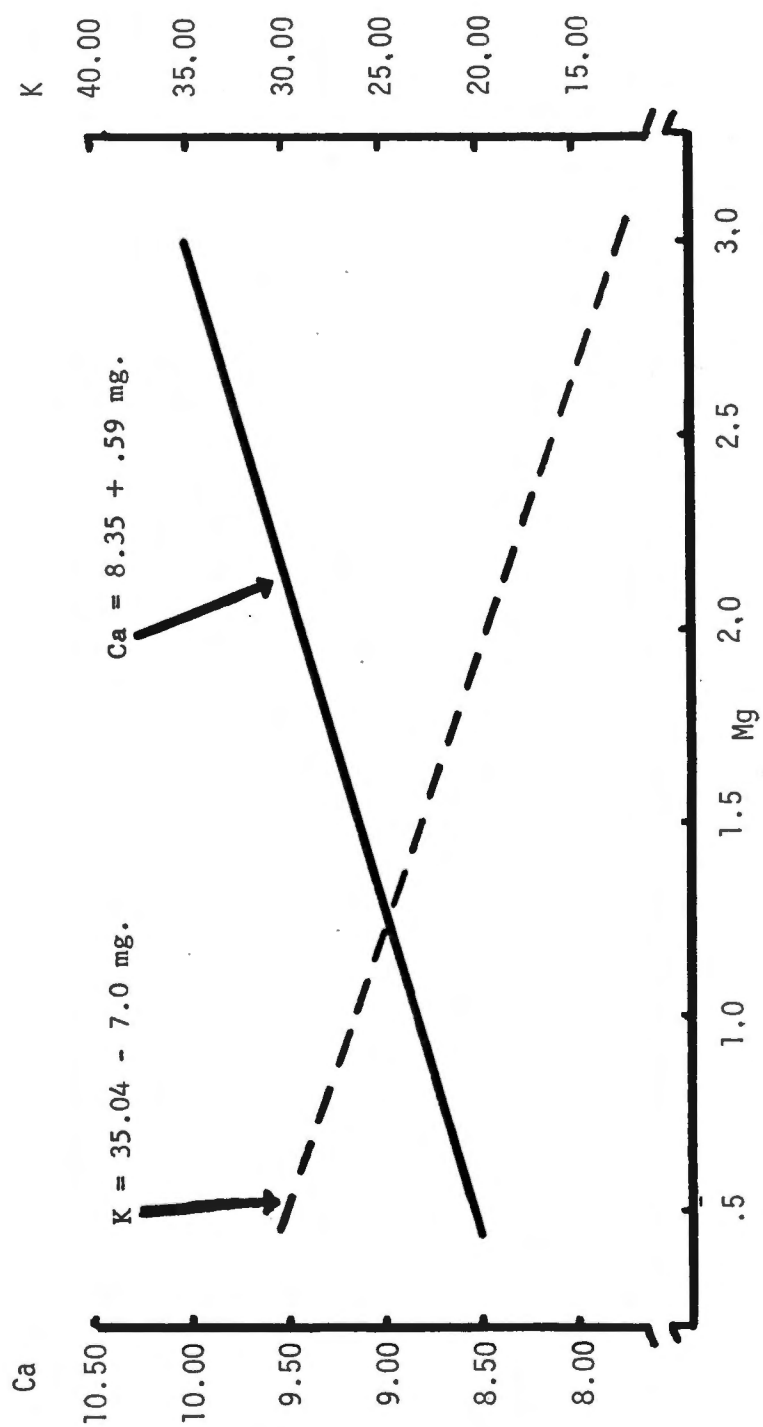


Figure 1. Relationship of calcium and potassium to magnesium blood serum levels.

TABLE 7
SOIL TEST RESULTS^a

Pasture No.	Treatment ^b	pH ^c	P ₂ O ₅	K ₂ O
			lb/Acre	
1 ^d	2	6.0/5.8	22/16	225/235
2	2	6.4/6.2	23/16	275/210
3	3	6.2/6.1	33/25	330/260
4	3	6.6/6.0	55/14	430/275
5	3	7.0/6.1	25/14	220/180
6	2	6.3/6.1	30/16	255/195
7	2	5.9/6.0	28/14	285/190
8 ^d	3	5.6/5.9	38/13	310/160
9	1	6.1/6.0	/40	/160

^aResults of soil analyses by The University of Tennessee, Agricultural Extension Service, Soil Testing Laboratory.

^bTreatment 1 = control, 2 = MgO-Salt mixture and 3 = Mg Cl₂-molasses mixture.

^cThe first value presented is for the 1972-73 sample and the value following the / is for the 1973-74 sample.

^dPastures 1 and 8 were fertilized with 75 lb of N semi-annually in May and September.

several years since they were part of a study involving intensive forage production and utilization. Colby (1973) suggested that as K intake of an animal increased, the amount of Mg absorbed decreased. O'Kelly and Fontenot (1969) concluded that Mg absorption was decreased 40 to 50 percent by high dietary levels of K.

Effect of Nitrogen Fertilization on Blood Serum Mg

Part of the cows fed the MgO-salt and Mg Cl₂-molasses mixtures grazed nitrated-fescue pastures and the remainder grazed non-nitrated fescue pastures. The effect of these pasture-management practices on blood serum mineral levels is shown in Table 8. In both years, the mean serum Mg levels of cows grazing non-nitrated fescue pastures were of greater magnitude than that of cows grazing nitrated fescue pastures (1.64 vs 1.58 and 1.77 vs 1.55 mg/ml). However, these differences in mean serum Mg were not significantly different and mean serum K and Ca levels were similar each year. The nitrated pastures received 75 lb of nitrogen (approximately 225 lb of ammonium nitrate) per acre in September each year. Fontenot et al. (1973) and Barta (1973) reported that high levels of N fertilization, generally, resulted in lower blood serum Mg in ruminants. Barta (1973) suggested also that N fertilization of grass pastures resulted in an increase of Mg as well as crude protein in the plant. Similar trends to those reported by Fontenot et al. (1973) were indicated by the coefficients of correlation between protein and mineral content of forages presented in Table 9.

Mean Mg blood levels for the three groups at approximately 30-day intervals during the second winter are shown in Figures 2 and 3. These serum Mg concentration curves suggest that supplementation of

TABLE 8
THE EFFECT OF TYPE OF PASTURE ON BLOOD SERUM MAGNESIUM,
POTASSIUM AND CALCIUM LEVELS^a

	Mg	K	Ca
1972-73 ^b			
Non-nitrated fescue ^c	1.64	20.11	8.51
Nitrated fescue ^d	1.58	21.69	8.42
1973-74			
Non-nitrated fescue ^c	1.77	22.53	9.38
Nitrated fescue ^d	1.55	24.79	9.19

^aMeans are reported on mg/ml of serum and are averages of 5 samples collected between Nov. 1 and April 15 each year.

^bOne pasture of each type was supplemented with a magnesium oxide salt mixture and one with magnesium oxide or magnesium chloride in liquid molasses in 1973-74.

^cFescue was not nitrated and at the beginning of winter contained a small percentage of residual clover.

^dNitrated at the rate of 75 lb Nitrogen (225 lb ammonium nitrate) per acre in September.

TABLE 9
CORRELATION AMONG VARIOUS CONSTITUENTS OF PASTURE FORAGE^a

	% Crude Protein ^b	Mg	K	Ca
% Crude Protein	1.000	-.345	-.477	-.102
Mg		1.000	0.685	0.930
K			1.000	0.685

^aCoefficients of correlation were calculated using values from 45 forage samples collected between November 1, 1972, and April 10, 1974.

^bProtein was calculated on a dry matter basis.

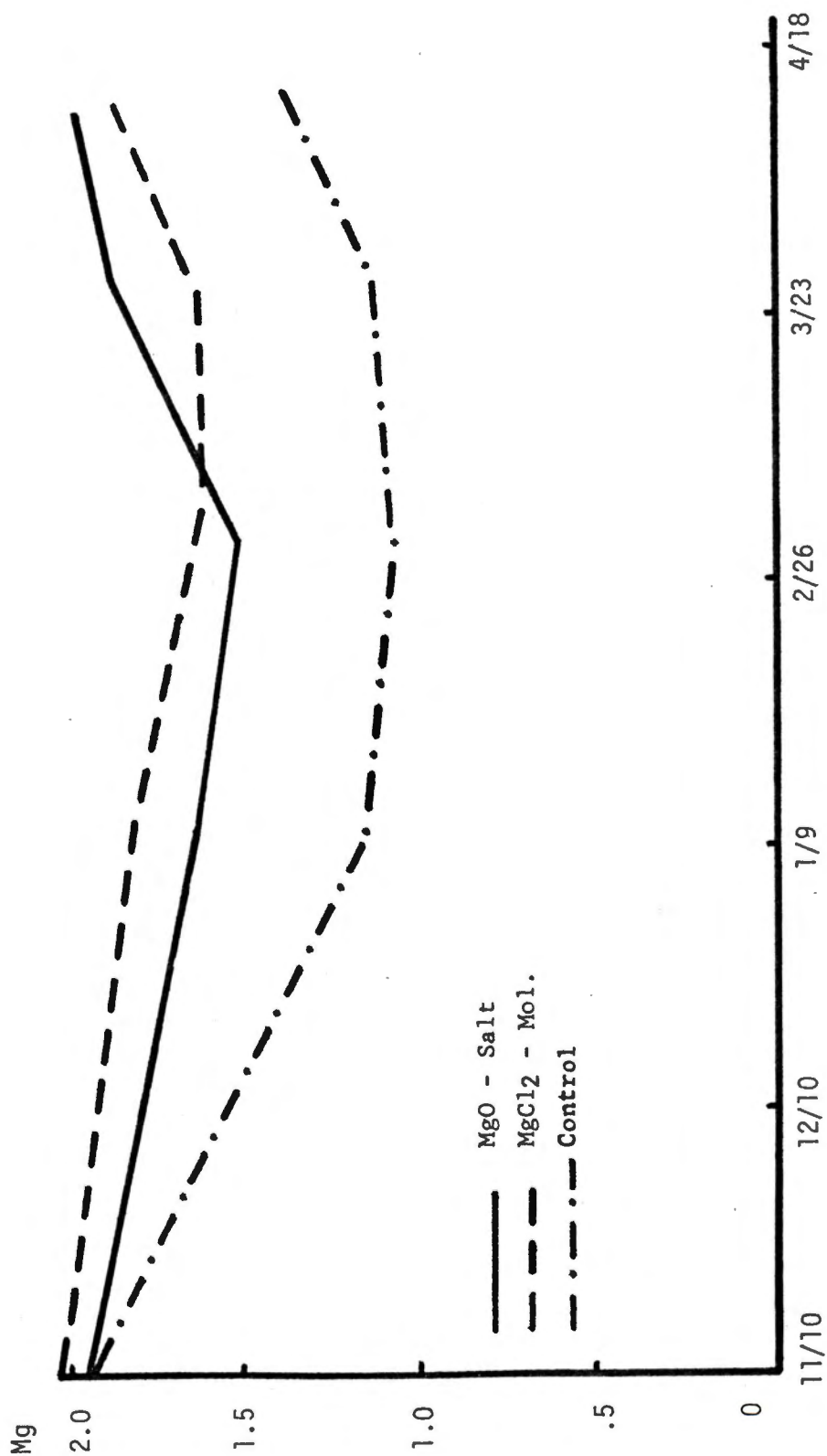


Figure 2. The effect of supplemental magnesium on blood serum magnesium level of cows grazing non-nitrated fescue pastures during the winter of 1973-74.

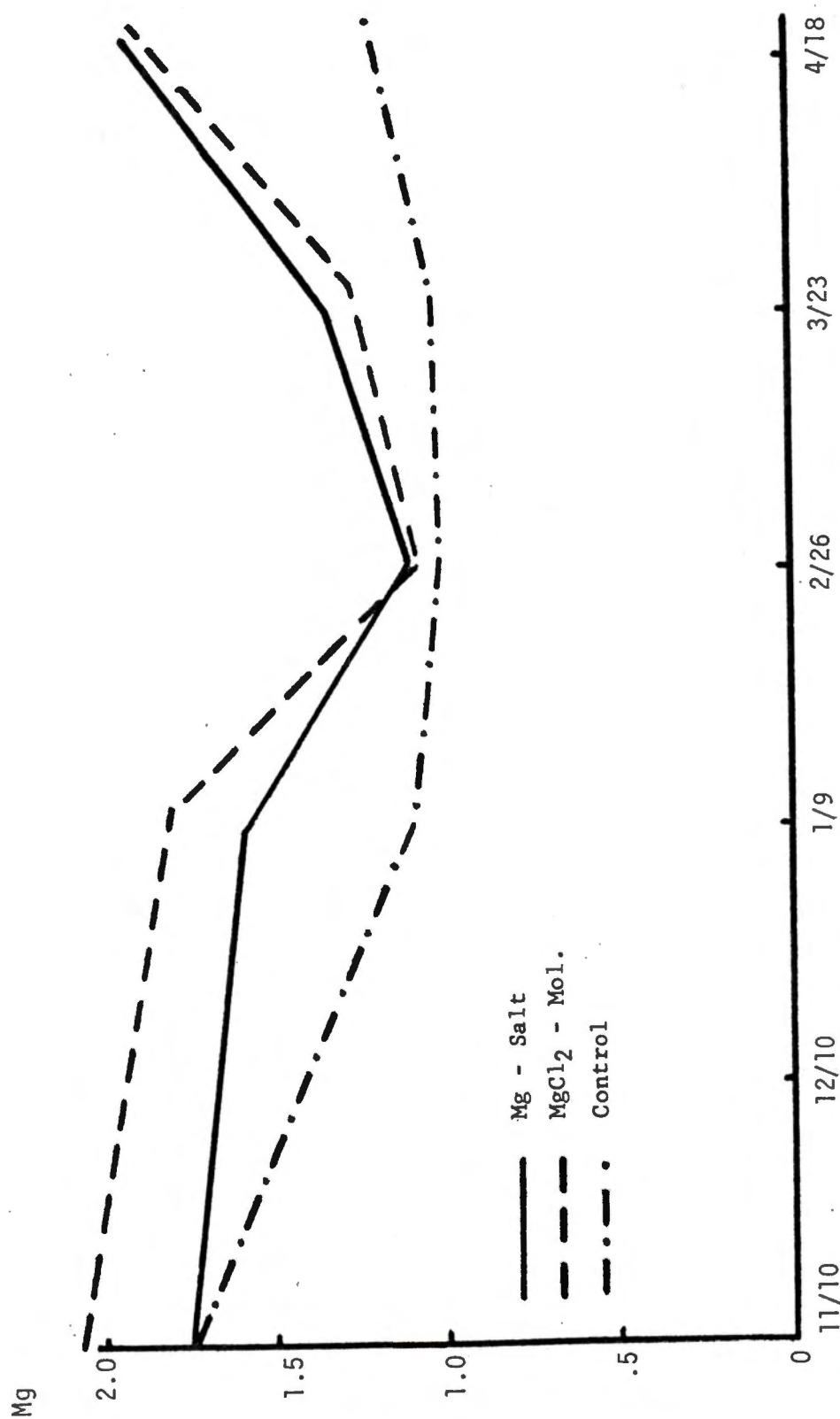


Figure 3. The effect of supplemental magnesium on blood serum magnesium level of cows grazing nitrated-fescue pastures during the winter of 1973-74.

cows grazing non-nitrated fescue pastures with MgO-salt or Mg Cl₂-molasses prevented a severe depression in serum Mg during late winter. Supplementation of cows grazing nitrated-fescue pastures was not as effective. The effect of type of pasture on serum Mg level was significant at the February sampling. It appeared that the Mg blood level of the supplemented cows increased more rapidly than those not supplemented following the mid-winter depression of serum Mg.

Magnesium Supplement and Hay Consumption

Each fall after their calves were weaned, the cows were allowed to graze residual or stockpiled (accumulated) fescue forage. When the pasture forage was insufficient to maintain the pregnant cows, they were fed medium quality grass hay free-choice (Tables 10 and 11). During the first winter all groups were fed hay ad lib. beginning approximately December 1. One group of cows grazing the nitrated pasture consumed 145 lb of hay per head during the 45-day period from December 29 to February 12. However, the group receiving the MgO-salt supplement and grazing non-nitrated fescue pasture consumed 1706 lb of hay per head during a 105-day period. This was similar to the 1544 lb per head consumed by the control group. During the second winter, the control group and those supplemented with MgO-salt and Mg Cl₂-molasses mixtures consumed 1096, 1350 and 1385 lb of hay per head, respectively. These variations in consumption were due, largely, to variation in amount and quality of pasture forage available.

Cows supplemented with the MgO-salt mixture consumed 8.3 and 9.6 g of magnesium per head per day during the two winters, respectively.

TABLE 10
SUPPLEMENTAL MAGNESIUM AND HAY CONSUMPTION,^a 1972-73

	Treatment ^b	
	Control	MgO
No. of cows	7	10
Feed consumption/hd		
Hay, lb	1544	925
Mg-salt mixture, lb		20
No. of days hay was fed	153	81
Hay, lb	9.13	11.42
Magnesium, g		8.34

^aThe winter period extended from Nov. 1 to April 1.

^bTreatments were control (no supplemental magnesium and a 1:1:1:1 mixture of salt, CSM, dry molasses and MgO).

TABLE 11
SUPPLEMENTAL MAGNESIUM AND HAY CONSUMPTION,^a 1973-74

	Treatment ^b		
	Control	MgO	Mg Cl ₂
No. of cows	7	20 ^c	20 ^c
Feed consumption, hd			
Hay, lb	1096	1350	1385
Liquid molasses, lb			271
Mg-salt mixture, lb		45	
No. of days hay was fed	88	84	87
Consumption/hd/day			
Hay, lb	12.5	12.8	15.9
Magnesium, g		9.6	8.5

^aThe winter period extended from Nov. 1 to April 1, 151 days.

^bTreatments were control (no supplemental magnesium); magnesium oxide in a 1:4:1:1 mixture of salt, CSM, dry molasses and MgO; and magnesium chloride in liquid molasses (Prolix).

^cTen cows (2 pastures) were bled at monthly intervals and 10 cows were not bled regularly.

During the second winter, cows supplemented with the Mg Cl_2 -molasses mixtures consumed 8.5 g of Mg per head per day. According to O'Kelly and Fontenot (1969), 10 g of Mg per day was adequate for prevention of grass tetany. However, Frye et al. (1972) reported higher consumption (49.2 g of MgO) when beef cows were fed a 1:1:1 mixture of CSM-salt- MgO free-choice. Based on reported magnesium requirements (11 to 12 g per day, Leffel and Mason, 1959; and 12 to 30 g, NRC, 1970), the consumption of supplemental Mg by cows in this study should have been sufficient to supply 50 to 75 percent of their daily Mg requirements.

Effect of Nitrogen Fertilization on Consumption

Consumption data with respect to the effects of N fertilization on hay and supplemental Mg during the second winter are shown in Table 12. Cows grazing non-nitrated-fescue pastures consumed more hay (1713 vs 331 lb) and more supplemental magnesium than cows grazing nitrated-fescue pastures. Consumption of supplemental Mg was similar (10.3 vs 9.5 g) for cows supplemented with MgO -salt and Mg Cl_2 -molasses on non-nitrated fescue pastures. However, the consumption of supplemental Mg supplied in the form of MgO -salt (7.3 g/day) by cows grazing nitrated-fescue pastures was slightly higher than for those supplemented with Mg Cl_2 -molasses (5.7). The carrier for the Mg Cl_2 was a commercial urea-molasses mixture (Prolix) and consumption could have been affected by the higher crude protein content of the nitrated pastures.

Incidence of Grass Tetany

The incidence of grass tetany among the three groups of cows

TABLE 12

THE EFFECT OF TYPE OF PASTURE ON HAY AND SUPPLEMENTAL
MAGNESIUM CONSUMPTION,^a 1973-74

	Type of Pasture			
	Non-Nitrated Fescue ^b		Nitrated Fescue ^c	
	MgO ^d	MgCl ₂ ^e	MgO ^d	MgCl ₂ ^e
No. of cows	15	15	5	5
No. of cows fed hay	102	101	28	24
Consumption/hd				
Hay, lb	1695	1731	315	346
MgO mixture, lb	48		34	
Liquid molasses, lb		301		181
Consumption/hd/day				
Hay, lb	16.6	16.1	11.3	14.4
Mg, g	10.3	9.5	7.3	5.7
Magnesium blood level, mg/ml	1.77	1.75	1.56	1.36

^aThe winter period extended from Nov. 1 to April 1, 151 days.

^bFescue was not nitrated and at the beginning of winter contained a small percentage of residual clover.

^cNitrated at the rate of 75 lb nitrogen (225 lb ammonium nitrate) per acre in September.

^dFed as a 1:4:1:1 mixture of salt, CSM, dry molasses and magnesium oxide free choice.

^eFed in liquid molasses (Prolix) at the rate of 50 lb of magnesium chloride per ton, free choice.

during the second winter is shown in Table 13. Two of the seven control cows showed clinical symptoms and were treated for grass tetany. Three additional cows had serum Mg levels below 1.00 mg per ml and were considered to be hypomagnesemic based on this criterion. One of the cows with access to the MgO-salt mixture showed clinical symptoms and three additional cows had blood serum levels less than 1.0. None of the cows with access to the Mg Cl₂-molasses mixture developed clinical symptoms and only two developed blood serum Mg levels below 1.0 mg per ml.

Defining grass tetany as the presence of clinical symptoms or blood serum Mg levels below 1.0 mg per ml, both mixtures reduced the incidence of grass tetany. However, fewer cases of tetany, defined by either criteria, were observed in cows with access to the Mg Cl₂-molasses mixture.

The chronological blood serum Mg levels presented in Figures 2 and 3, pages 31 and 32, respectively, indicated a more rapid recovery after the minimum level was reached by cows with access to the two supplements. However, these curves were confounded with time of calving. Since the minimum Mg level was associated with calving, the serum Mg level of each cow at calving, and at 30- and 60-days post-weaning were studied. These responses are presented in Figure 4. At calving, the mean serum Mg level of the control, MgO-salt and Mg Cl₂-molasses groups were 1.06, 1.42 and 1.26 mg per ml, respectively. At 30- and 60-days post-calving, they were 1.02, 1.54 and 1.69 and 1.16, 1.96 and 1.89 mg per ml, respectively. Serum Mg levels of the cows with access to supplemental Mg returned to normal levels faster than those of the

TABLE 13
INCIDENCE OF GRASS TETANY IN 1973-74

	Treatment ^a		
	Control	MgO	Mg Cl ₂
No. of cows bled ^b	7	10	10
No. of clinical cases ^c	2	1	0
No. of cases diagnosed ^d by blood level	3	3	2
Total no. of clinical cases in all cows	2	3	0

^aTreatments were control (no supplemental magnesium), magnesium oxide in a salt, CSM, dry molasses mixture and magnesium chloride in liquid.

^bThe control cows and 2 groups of 5 cows on each treatment were bled at monthly intervals. Two groups of 5 cows on each treatment were not bled regularly.

^cThese cases were diagnosed and treated by a practicing veterinarian.

^dIn this evaluation, cows with magnesium blood serum levels below 1.00 mg/ml were considered to be hypomagnesaemic.

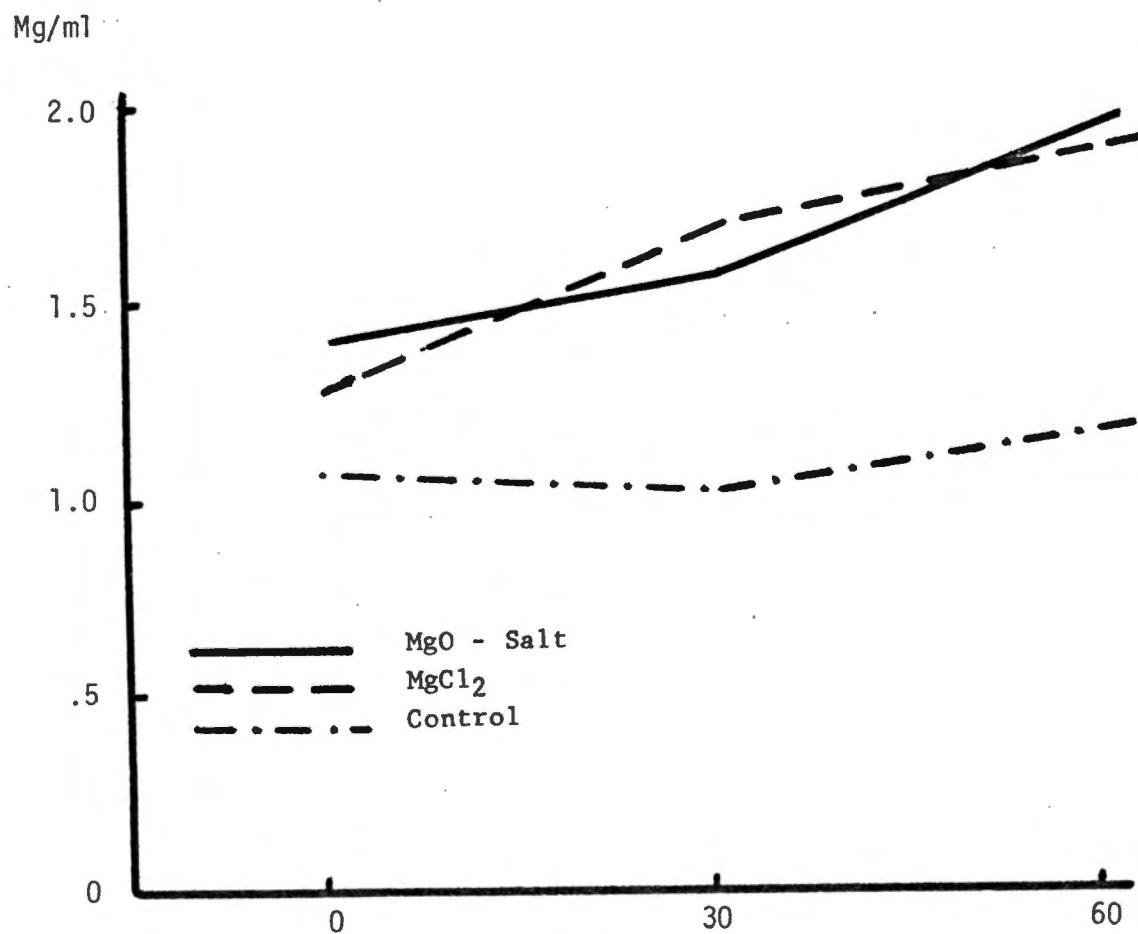


Figure 4. Response to the stress of calving and the recovery of blood serum magnesium levels post-calving.

non-supplemented cows following the stress of calving. These responses suggest supplemental Mg may be just as valuable in aiding recovery following depressed blood serum Mg level resulting from stress as it is in preventing the depression.

Relationship of Blood Magnesium Level and Calf Performance

Correlations between various blood mineral levels and calf performance are presented in Table 14. Coefficients of correlation of average Mg level, minimum Mg level and Mg level at calving with ADG ranged from 0.27 to 0.35 the first year and from 0.50 to 0.54 the second year. Some confounding between pastures which influenced lower blood Mg level in the cows and those which supported lower calf gain was observed. However, the correlations substantiate the theory that hypomagnesemia affects milk production and consequently calf performance. They further suggest that economic losses due to grass tetany may be greater than simply loss due to death of affected cows.

TABLE 14
CORRELATION AMONG BLOOD SERUM LEVELS^a OF MAGNESIUM,
CALCIUM AND POTASSIUM OF COWS DURING WINTER AND
SUBSEQUENT PERFORMANCE OF THEIR CALVES

	Average Mg Level	Mg Level at Calving	Min Mg Level	K	Ca	ADG of Calf
Avg. Mg level	1.00	.73	.81	.02	.05	.27
Mg level at calving	.76	1.00	.90	-.05	.13	.29
Min. Mg level	.84	.93	1.00	-.11	.12	.35
K	.04	-.10	-.14	1.00	.43	-.07
Ca	.27	.33	.29	.24	1.00	.38
ADG of calf ^b	.53	.50	.54	-.41	.22	1.00

^aValues above the diagonal represent correlations among values from 17 cows during 1972-73 and those below were derived from values collected on 25 cows during 1973-74.

^bAverage Daily Gain (ADG) refers to the performance of the calves of the respective cows during the subsequent spring-summer grazing season.

CHAPTER V

SUMMARY

A study was conducted at The University of Tennessee, Highland Rim Experiment Station, Springfield, Tennessee, to evaluate the effects of free-choice salt-CSM-dry molasses-magnesium oxide and Mg Cl_2 -molasses mixtures on blood serum Mg levels and the incidence of grass tetany in pregnant beef cows. The cows grazed either non-nitrated or nitrated-fescue pastures and were supplemented with medium quality grass hay when the pastures were insufficient to support them. Blood and forage were collected monthly and analyzed for Mg, K and Ca. Soil samples were collected annually.

During the winter of 1972-73, the Mg blood serum level of the cows fed the MgO -salt mixture (1.61 mg/ml) was higher ($P < .05$) than that of the non-supplemented control cows (1.51 mg/ml). The mean serum Mg level of cows fed the MgO -salt (1.65) and Mg Cl_2 -molasses mixture were both higher ($P < .01$) than that of the control cows in 1973-74.

Hay and supplemental Mg consumption was lower for cows grazing nitrated fescue pastures than for those grazing non-nitrated pastures.

Mg supplementation, MgO -salt and Mg Cl_2 -molasses, partially prevented the severe drop in blood Mg level at calving which was observed in the control cows. In addition, the blood serum Mg level increased more rapidly following calving in the Mg supplemented groups.

There appeared to be a positive relationship between winter serum Mg level of the cows and the subsequent performance of her calf.

These results suggest that the problem of grass tetany can be reduced by supplemental Mg fed in the form of MgO-salt or Mg Cl₂-molasses mixtures. Variations among cows within a pasture with respect to serum Mg level tended to be a problem and probably reflected variation in individual consumption. These data suggest that early initiation of Mg supplementation and continuing measurement of consumption is vital to successful prevention of grass tetany by this means.

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