Reprinted from *Agronomy Journal*
Vol. 73, March-April 1981, p. 337-347

Chemical Composition of Winter Wheat Forage Grown Where Grass Tetany and Bloat Occur[1]

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ABSTRACT

Winter wheat (*Triticum aestivum* L.) is widely used in the southern High Plains as a forage for beef cattle. Although grazing wheat is generally financially profitable, death losses often occur. Frothy bloat and grass tetany are often mentioned as causes, but the conditions under which these metabolic disorders occur are not completely understood. The objectives of the present study were: (1) to determine the changes in chemical composition of wheat forage during the normal wheat grazing season; (2) to determine the effect of N fertilizer on the chemical composition of the forage; and (3) to gain insight into the factors predisposing cattle grazed on wheat pasture to tetanic or bloat-related death. Wheat pastures at Bushland, Texas, and El Reno, Oklahoma, were studied for 3 years by taking forage samples almost weekly during the growing seasons. Samples were analyzed for N, K, Ca, Mg, P, ash alkalinity, aconitate, and total nonstructural carbohydrates. Significant changes in forage composition occurred within very short periods. For example, in 1978 at El Reno, the K concentration increased from 2 to 4.5% in 2 weeks. During the same period, large changes occurred in the N, aconitate, ash alkalinity, and total nonstructural carbohydrate concentrations; but Mg concentrations did not change significantly. Nitrogen fertilization clearly affected chemical composition of the forage and generally increased the indices that are commonly associated with high incidence of frothy bloat and grass tetany. Elimination of fertilizer N is not practical because of the resulting pronounced decrease in forage and grain production. Therefore, other management practices are required to minimize or prevent frothy bloat and grass tetany problems on winter wheat forage.

Additional index words: **Magnesium, Calcium, Potassium, Nitrogen, Hypomagnesemia, Organic acids, Carbohydrates.**

IN the southern Great Plains, winter wheat (*Triticum aestivum* L.) is a major source of pasture for beef cattle. The forage is highly nutritious. Remarkable growth rates (more than 1 kg daily) are common. Under favorable growing conditions, winter wheat is grazed from November until the middle of the following March, when cattle are removed so that a grain crop can be obtained from the same planting. Sometimes, particularly if grain prices are low and cattle prices high, the grain crop is forfeited and cattle left on the field to graze the wheat until June or until the crop is no longer suitable for pasture.

Although the benefits from grazing wheat can be great, death losses often occur and, under some circumstances, are devastating. Death losses of 2 to 3% are common, and losses as high as 20% have occurred on some wheat pastures. The causes of most deaths are not clearly understood.

Frothy bloat and grass tetany are frequently mentioned as causes, but the conditions under which these metabolic disorders occur are not completely understood. The bloat affects both male and female "stocker" cattle grazing rapidly growing wheat forage, generally in the spring. These cattle normally weigh 130 to 230 kg and are 7 to 14 months old. Grass tetany generally attacks older, lactating cattle. Death losses from both diseases are often associated with winter storms that stress the cattle. Losses also are generally higher if the wheat forage is high in N. Horn et al. (1977) reported that wheat forage samples from wheat pastures that tended to produce bloat contained less dry matter, fiber, and soluble carbohydrate and more crude protein and soluble N fractions than samples obtained from pastures where bloat problems were not observed. Grunes et al. (1970) reviewed data that indicated that high levels of crude protein in the forage increased the likelihood of grass tetany. In discussing the problem of cattle grazing wheat forage, Redmond (1950) stated, "It is our belief that continued excessive K intake in some way disturbs the normal mineral metabolism, thereby bringing on the condition known as wheat poisoning." Excessive K in relation to Ca and Mg is associated with grass tetany. Forage having a ratio of K/(Ca + Mg) greater than 2.2, expressed on a milliequivalent basis, is usually considered a hazard. For detailed reviews of the grass tetany problem, see Grunes (1973); Grunes et al. (1970); and Rendig and Grunes (1979). The Australian publication on bloat (Leng and McWilliam, 1973) contains a number of helpful articles. The review of Clark and Reid (1974) is also helpful.

The objectives of the studies reported here were: (1) to determine the changes in chemical composition of wheat forage during the growing season; (2) to determine the effect of N fertilizer on the chemical composition of the forage; and (3) to gain insight into the factors predisposing cattle grazed on wheat pasture to tetanic or bloat-related death.

MATERIALS AND METHODS

Winter wheat was grown under field conditions at Bushland, Tex., in 1973 to 1974, 1975 to 1976, and 1976 to 1977; and at El Reno, Okla. in 1975 to 1976, 1976 to 1977, and 1977 to 1978. The soil at Bushland was Pullman clay loam, a major soil in the southern High Plains, and a member of the fine, mixed, thermic family of Torrertic Paleustolls. The soil at El Reno was a Norge silt loam, which is a member of the fine-silty, mixed, thermic family of Udic Paleustolls. Table 1 shows selected data on the chemical and physical properties of the soils. Cations were determined on extracts obtained by soaking 10 g of soil with 1 *N* NH_4Ac at pH 7.0, filtering and leaching with additional increments until 100 ml of leachate was obtained. Cation exchange capacity (CEC) was determined by the sodium acetate method measuring Na in NH_4Ac solution with an ab-

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sorption spectrophotometer as described by Jackson (1958). Soil pH was measured on a 2:1 water:soil suspension. The calcium carbonate equivalent was measured by determining the weight loss from 10 g of soil in 50 ml of 3 *N* HCl. Organic matter was determined by the Walkley-Black method (Jackson, 1958). Mechanical analysis was run by the hydrometer method.

At Bushland the wheat was irrigated; at El Reno it was not. In 1973 to 1974, the Bushland study included three N fertilizer variables; 0, 120, and 240 kg of N/ha applied as NH_4NO_3 at the time of seeding in the fall. The plots were 8 × 20 m and were replicated three times. The 1975 to 1976 crop was grown on approximately a 10-ha field. Nitrogen fertilizer was not added because there was residual nitrate in the soil from previous crops. The 1976 to 1977 crop was grown on the same field as the 1975 to 1976 crop, but the field was split. One side was not fertilized while the other side received 120 kg of N/ha as anhydrous NH_3. No other nutrients were added because previous studies on this field showed that there was no response. At El Reno, N was not varied except in 1978 when one part of the field was topdressed with 50 kg of N/ha as NH_4NO_3 on 13 March. In all three seasons the field was fertilized with 70 kg of N/ha as anhydrous NH_3 at the time of seeding in the fall. 'Triumph' was the wheat variety used at El Reno. 'Sturdy' was used at Bushland in 1973 to 1974 and 'TAM 101' was used in 1975 to 1976 and 1976 to 1977. The rainfall and irrigation water received and the weekly mean air temperatures during the growing seasons are presented in Fig. 1 through 4 for 2 years at each location. Temperature measurements at Bushland and rainfall determinations at both Bushland and El Reno were made at the sites. Temperature data for El Reno were obtained from records of the weather station located approximately 15 km from the field site.

At Bushland, forage was hand-clipped periodically in grazed plots in 1973 to 1974 and in ungrazed plots in 1975 to 1976 and 1976 to 1977. At El Reno, forage was hand-clipped periodically under five cages in grazed plots in 1975 to 1976, 1976 to 1977, and 1977 to 1978. Cages were moved to a grazed area immediately after each sampling so that samples would represent the material available to livestock. In all cases, the area clipped was 0.4 m² and forage was clipped 3 cm above the soil surface and dried at 65 C and weighed to determine dry matter yields. Dried samples were ground through a 1-mm stainless steel screen and stored for analysis. Samples were digested with sulfuric acid and hydrogen peroxide in a block digestor (Thomas et al.,

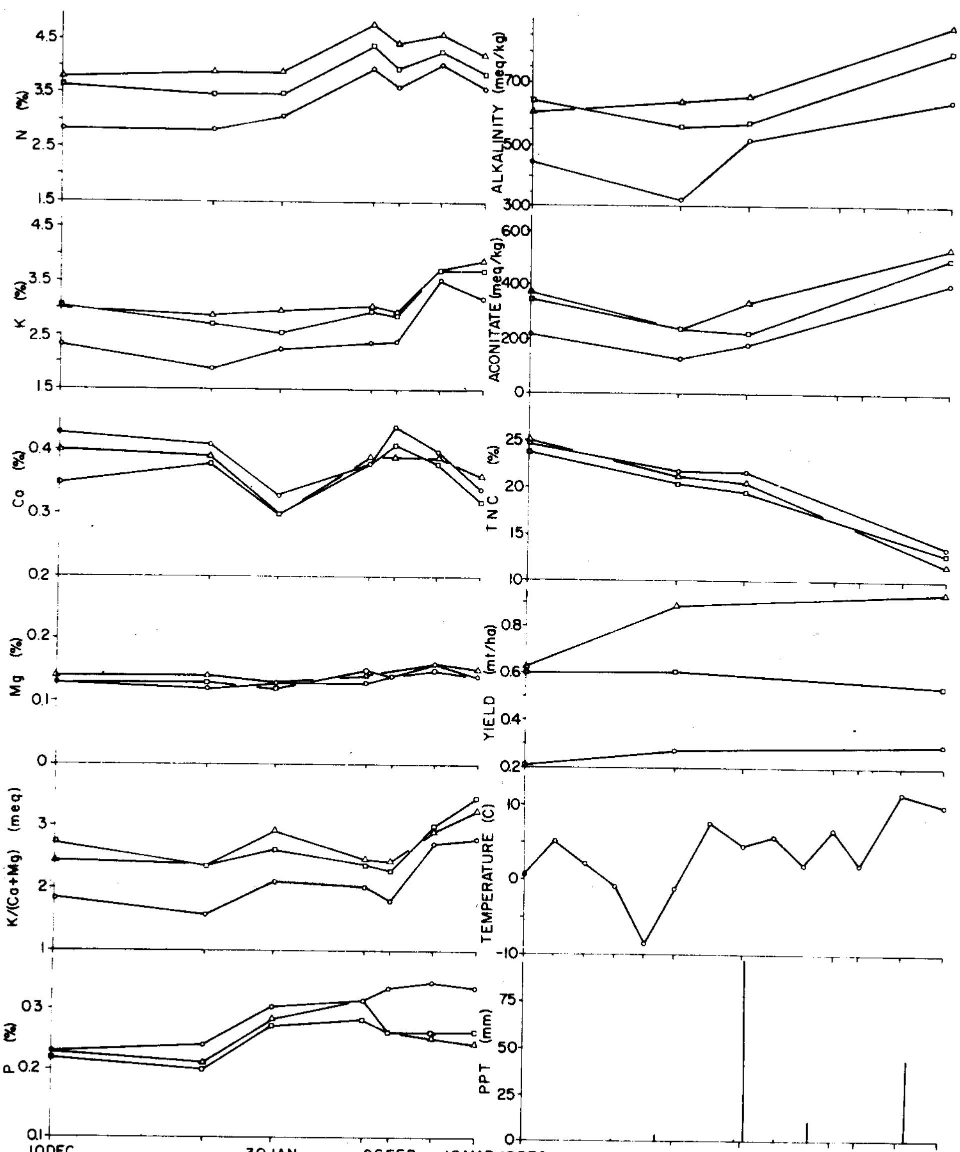

Fig. 1. Seasonal trends in the chemical composition of winter wheat forage at Bushland, Tex., in 1973 to 1974 as affected by 0 (○-○), 120 (□-□), or 240 (△-△) kg N/ha applied as NH_4NO_3. Precipitation and irrigation water and weekly mean air temperature values are also shown. Yields shown are not cumulative. (TNC is total nonstructural carbohydrates.)

Table 1. Chemical and physical properties of soil samples from sites used for plant sampling.

Depth	Ammonia acetate extractable Na	K	Ca	Mg	CEC†	Mg/CEC	Mg/K	Ca/Mg	pH	$CaCO_3$ equiv.	O.M.‡	Sand	Silt	Clay	Soil texture
cm	meq/100 g									%					
						Pullman clay loam—Bushland									
0-15	0.33	1.2	20.3	5.4	23.4	0.23	4.7	3.8	7.3	0.2	2.57	24	42	34	clay loam
15-30	0.40	0.8	25.0	5.2	25.9	0.20	6.5	4.8	7.6	0.4	1.72	19	45	36	silty clay loam
30-60	0.54	0.8	27.5	5.1	25.3	0.20	6.4	5.4	7.8	1.2	1.47	20	43	37	clay loam
60-90	0.74	0.8	26.4	5.1	25.4	0.20	6.4	5.2	7.9	1.8	1.08	23	44	33	clay loam
90-120	0.84	0.8	25.2	4.9	26.5	0.19	6.1	5.1	7.8	1.0	0.79	23	44	33	clay loam
						Norge silt loam—El Reno									
0-15	0.01	1.3	6.4	1.7	12.0	0.14	1.4	3.7	5.8	0.4	2.38	35	50	15	silt loam
15-30	0.01	1.0	7.5	1.9	12.3	0.16	2.0	3.9	6.2	0.2	2.16	35	50	15	silt loam
30-60	0.08	1.2	8.9	2.7	15.1	0.18	2.2	3.3	6.8	0.5	1.62	36	43	21	loam
60-90	0.23	0.6	11.4	3.7	18.1	0.20	6.1	3.1	6.7	0.5	1.32	30	40	30	clay loam
90-120	0.33	0.7	12.8	4.5	19.9	0.23	6.7	2.9	6.7	0.5	1.24	30	40	30	clay loam

† Cation exchange capacity. ‡ Organic matter.

1967) and analyzed for N and P by the Technicon[3] AutoAnalyzer Industrial Method No. 334-74W/B+ revised March 1977. Potassium, Ca, and Mg were determined on the same digest by absorption spectrophotometry. Total nonstructural carbohydrates were determined by the method of Smith (1969) modified by using amyloglucosidase in place of takadiastase.

Ash alkalinity was determined after ignition of a sample at 550 C for 2 hours (Van Tuil et al., 1964). Aconitate was determined by polaragraphy (Patterson et al., 1972).

RESULTS

Soil Properties

The soil was sampled from both sites in September of 1977. The Pullman soil at Bushland was a clay loam in the surface 15 cm and a silty clay loam in the second 15 cm (Table 1). We assumed that these were the depths from which wheat plants obtained large portions of their nutrients. The pH of the surface soil was above neutral and increased somewhat with depth. There was some free lime in the surface 30 cm, with much more below. Since there was some free lime in the 0 to 15 and 15 to 30 cm depths, the values for Ca and Mg probably represent not only exchangeable ions, but also some contribution from the lime. Therefore, the Ca and Mg values are greater than what was available for uptake by plant roots. The 1.2 meq/100 g value for K was very high, which was why K values in the plants were high. Good guidelines are not presently available for determining the relationship between plant and soil Mg and Ca levels on soils whose pH is above 7.0 and which contain appreciable amounts of free lime.

The Norge soil at El Reno was silt loam in the surface 30 cm. The pH was considerably less than 7.0 in the 0 to 15 and 15 to 30 cm depths, and approached neutrality below. The amount of K in the 0 to 15 and 15 to 30 cm depths was very high, which was undoubtedly why the plant K values were high. The ratio of Mg/CEC for the 0 to 15, and 15 to 30 cm depths was about 15%. In Ohio (Barta et al., 1973), the 15% level has been considered borderline for obtaining forage with enough Mg to prevent grass tetany. Horvath and Todd (1968) (also see Grunes et al., 1970) suggested that the ratio of Mg/K should be at least 2.0. Hooper (1967) (also see Grunes, 1973), reported that the soil Mg/K ratio should be 1.2 or higher to obtain 0.2% Mg in the forage. In the Norge soil, the Mg/K ratios were 1.4 and 2.0 in the 0 to 15 and 15 to 30 cm depths respectively, and higher below. Horvath and Todd (1968) (also see Grunes et al., 1970), recommended that the Ca:Mg ratio in the soil should not be greater than 5:1. In the Norge soil, the ratios were lower than 5.0 at all depths tested.

Forage Composition

The data are shown in Fig. 1 through 6. Only selected data from Bushland for 1975 to 1976 and from El Reno for 1976 to 1977 are included because of lack of space. Also, for Bushland in 1976 to 1977 (Fig. 2), only results from the N fertilized treatment are shown. The data not included showed essentially the same trends as that shown, and are discussed in relation to that shown. The data are presented by location and year, and some of the individual analyses are discussed. The experiments will be discussed as a whole in the Discussion Section.

Bushland, 1973 to 1974. The forage was sampled only seven times between 10 Dec. 1973, and 18 Mar. 1974 (Fig. 1). The response to added N fertilizer was marked. The K concentration in the forage was higher when N fertilizer was added. The Mg content showed no change that could be directly attributed to N content, and the Ca data was not really consistent enough to draw conclusions. Since K was markedly increased and Mg and Ca were not, the meq ratios of K/(Ca + Mg) were also increased. The ratios for the N fertilized forage were well above 2.2, the level often used as a guideline for identifying forage likely to cause grass tetany. The ratio increased rapidly in early March. The increase in the ratio corresponded with an increase in temperature. The ash alkalinity and aconitate values were also closely related to the N and K status of the forage.

Forage yields were increased by added N. The yields shown in Fig. 1 were taken from enclosures that were moved at the time of each sampling. The area was grazed by cattle. Therefore, the yields shown do not represent total growth and are included only to show

[3] Mention of a trade name does not constitute a recommendation for use by the U.S. Department of Agriculture.

that growth did respond to added N. There was very little growth from late December to late February. Since yield samples were not taken during this period, Fig. 1 does not show this period of slow growth.

Bushland, 1976 to 1977. The forage was sampled almost weekly from 18 October to 11 May so that changes in forage quality could be related to climatic and other environmental conditions (Fig. 2). There were also two N levels, but only the data for the highest N level are shown because the differences were not great and the effect was similar to that already shown by the 1973 to 1974 data presented in Fig. 1. By showing only one line for each constituent, the relationships can be more easily seen. The N and K concentrations for the unfertilized samples were generally from 0.2 to 0.3% lower than for the N fertilized samples, and these differences persisted throughout the sampling period.

The N and K contents of the forage were very high in October and then decreased till about early December, and then remained fairly constant through mid-February. The sudden and sharp decline about the middle of November seemed to be related to a sudden drop in temperature. The N and K contents increased rapidly around the middle of February, corresponding to an increase in temperature. They increased until late February or early March and then decreased gradually as growth accelerated. The Mg content of the forage gradually decreased throughout the season and showed little, if any, change that could be attributed to temperature. The Ca data was somewhat variable and no consistent trends were evident. There was a pronounced increase in the K/(Ca + Mg) ratios in February as a result of the increased K content. The ash alkalinity and aconitate values also increased rapidly during this period.

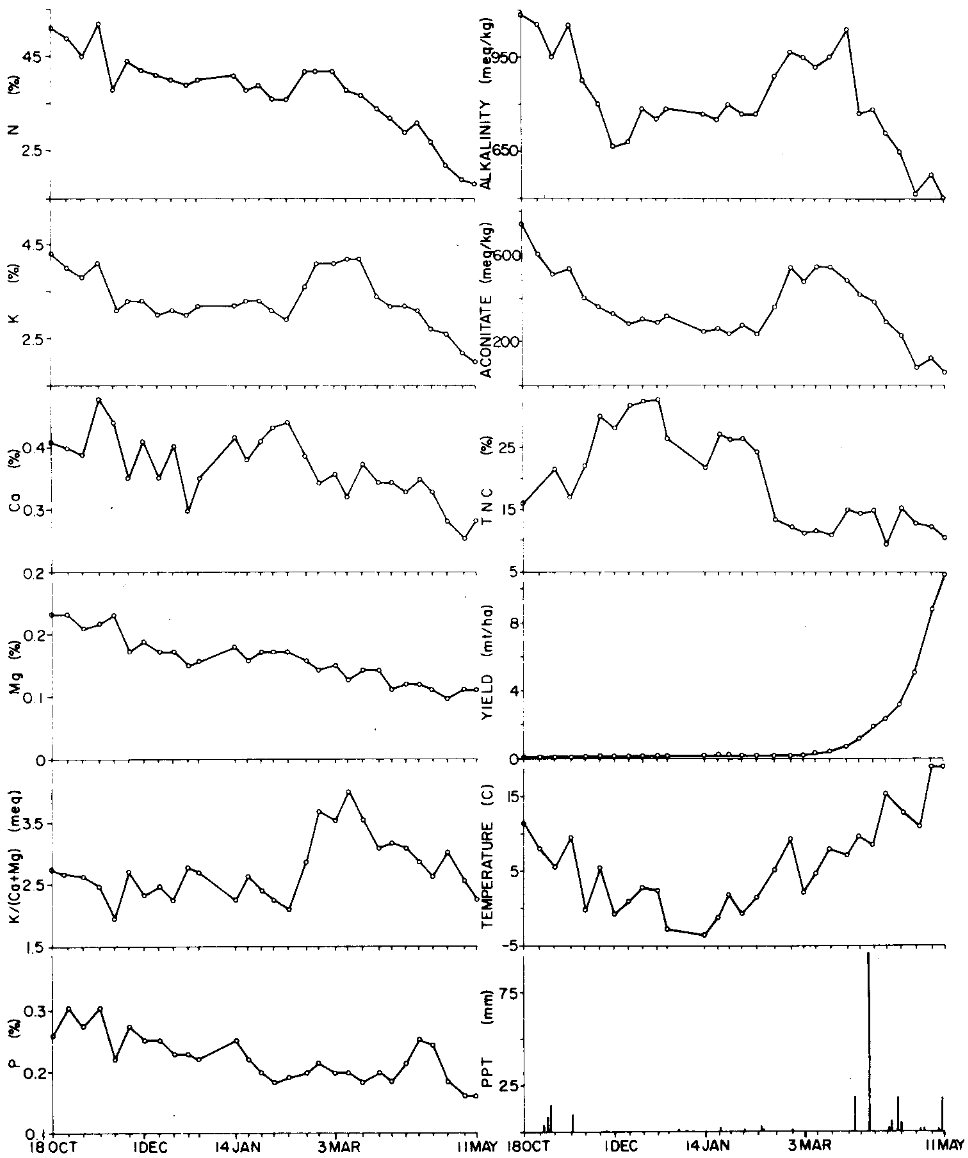

Fig. 2. Seasonal trends in the chemical composition of winter wheat forage at Bushland, Tex., in 1976 to 1977. Precipitation and irrigation water and weekly mean air temperature values are also shown. Yields shown are cumulative. (TNC is total nonstructural carbohydrates.)

Cattle did not graze the field during the sampling period, so the yield data shown represent total accumulated forage. There was very little fall growth and only small amounts of precipitation occurred during the winter. Significant growth did not begin until March, but the big increase in N and K concentrations occurred 2 to 3 weeks before.

El Reno, 1975 to 1976. As at Bushland in 1976 to 1977 (Fig. 2), the N and K concentrations at El Reno were also very high in the fall (Fig. 3). Potassium concentration exceeded 5.5% and the N level was 4.5%. These concentrations gradually decreased in parallel as average temperature decreased. As temperatures increased during February, N and K concentrations increased. These concentrations, however, began to decrease as growth became more pronounced and the plants matured. The Mg concentrations in the forage changed very little until spring growth, when they gradually decreased. Calcium concentrations fluctuated but showed no consistent trend except for a decrease during rapid growth in the spring.

The K/(Ca + Mg) ratios were very high in November and December. The ratio of 5 in late November is the highest value found from any sample obtained in the field. According to accepted grass tetany guidelines this forage would be very hazardous (Grunes et al., 1970).

Dry matter (DM) percentages of the forage were determined on the samples obtained at El Reno. In the fall of 1975, soil moisture and climatic conditions were excellent. The wheat grew rapidly and the forage was very lush. Figure 3 shows that dry matter during this period was only about 15%. As growing conditions deteriorated because of dropping temperatures, growth rates decreased and dry matter percentages increased. The N and K concentrations and the K/(Ca + Mg)

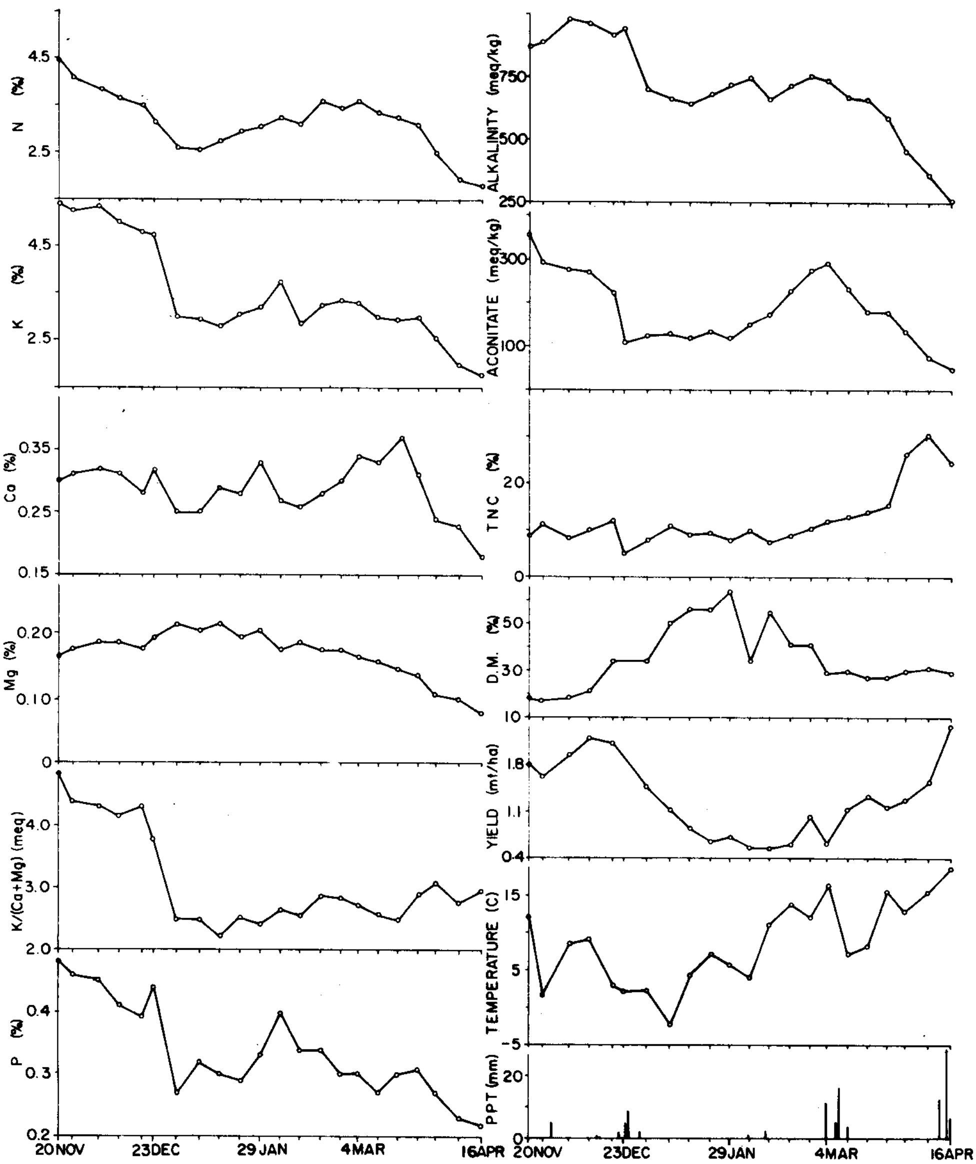

Fig. 3. Seasonal trends in the chemical composition of winter wheat forage at El Reno, Okla., in 1975 to 1976. Precipitation and weekly mean air temperature values are also shown. Yields shown are not cumulative. (TNC is total nonstructural carbohydrates.)

ratios decreased with the decrease in growth and the increase in dry matter percentage. The yield data shown in Fig. 3 were obtained in a grazed field from enclosures that were moved after each sampling. Thus, although the data do not represent accumulated yields, they do indicate periods of decreasing or increasing growth. There was almost an inverse relationship between dry matter percentage and the yield curve, indicating that the forage was very lush and low in dry matter percentage during rapid growing conditions, and relatively dry and high in dry matter percentage during poor growing conditions. However, there did seem to be a time lag in growth as compared with water and nutrient accumulation in the forage. The N, K, P, and water content of the forages increased about 2 weeks earlier than any measurable increase in yield. These relationships were even more clear in the 1977 to 1978 data.

El Reno, 1977 to 1978. Growing conditions in the fall of 1977 were favorable (Fig. 4). The N and K concentrations in the forage were high (in the 3.5 to 4.0 percentage range). Nitrogen, K, and Ca concentrations decreased with decreasing average temperature. The winter was exceptionally wet and cold so no forage was sampled from 12 January to 14 March. With the rapid rise in average temperature in the spring, both the quality and quantity of the forage increased dramatically. A topdressing of 50 kg of N/ha as NH_4NO_3 was added to a part of the field on 13 March so that the effect of N on forage composition could be determined.

The growing conditions during late March and April were almost ideal—soil water and temperatures were favorable. Between 13 March and 4 April, the N and K content of the forage increased suddenly. The K content increased from 2 to more than 4.5% within

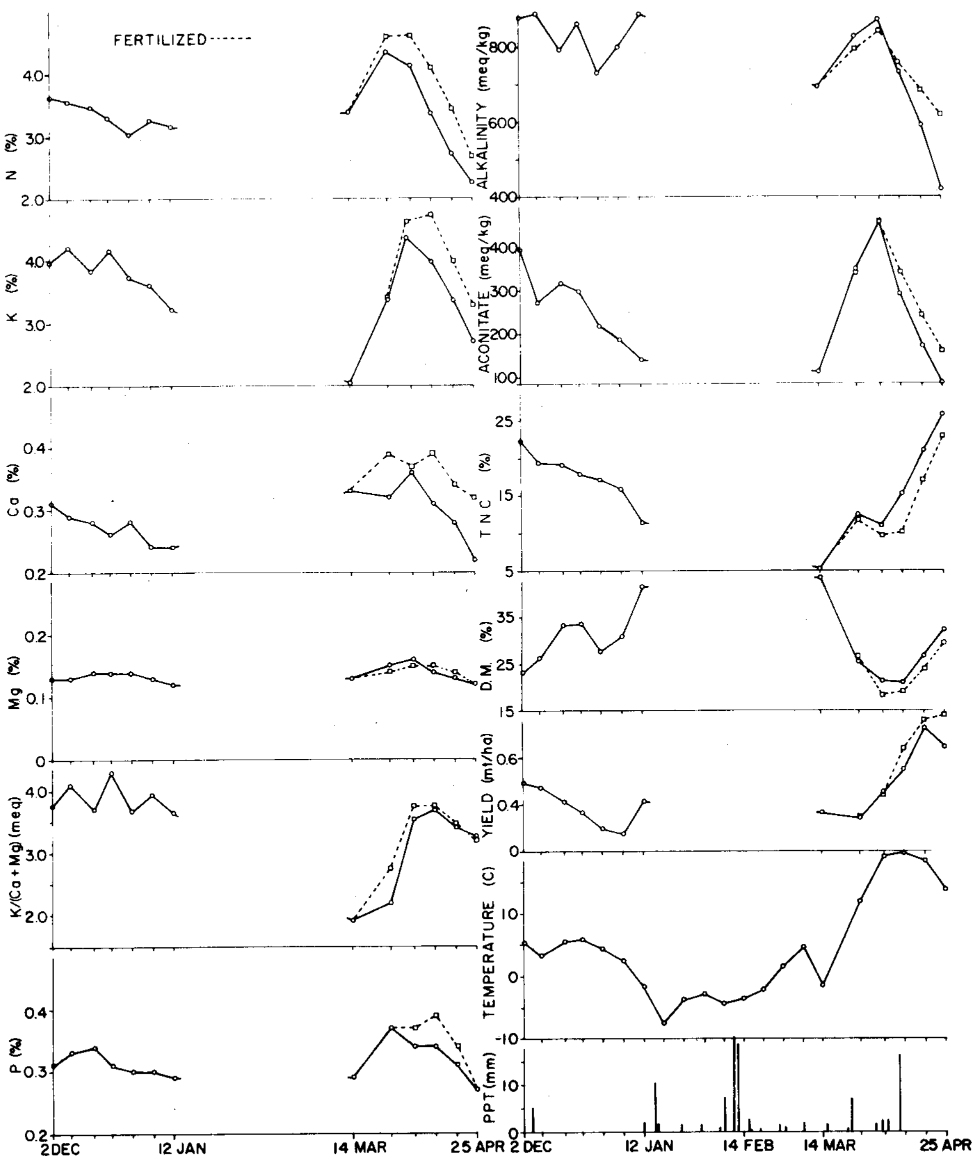

Fig. 4. Seasonal trends in the chemical composition of winter wheat forage at El Reno, Okla., in 1977 to 1978 when fertilized at time of seeding (○—○), and additionally topdressed with 50 kg/ha NH_4NO_3 early in 1978 (□ · · · □). Precipitation and weekly mean air temperature values are also shown. Yields shown are not cumulative. (TNC is total nonstructural carbohydrates.)

2 weeks. Because the Mg and Ca concentrations changed very little, the K/(Ca + Mg) ratio increased markedly. The average temperature was also increasing sharply during this time. Yield, however, did not increase until after the 27 March sampling. This again showed that growth lagged several days behind the plants rapid uptake of nutrients and water in the spring. The dry matter percentages shown in Fig. 4 show a sharp decrease as the nutrient concentrations increased. This shows that the plants took up water and nutrients simultaneously. As the yield increases became very significant, the concentration of all nutrients measured decreased due to dilution effect.

Bushland, 1975 to 1976 and El Reno, 1976 to 1977. Only selected data are shown for these years because the relationships between constituents were very similar to those already presented. The N, K, ash alkalinity, and aconitate are shown, however, to represent the changes for these years. The 1975 to 1976 data for Bushland, shown in Fig. 5, show a very close relationship between constituents. There were sharp decreases in concentrations in late fall, and then sharp increases in early spring, followed by another decrease as spring growth continued. The 1976 to 1977 growing season at El Reno was marked by very dry conditions which had a pronounced effect on plant growth. Consequently, the seasonal variations of N, K, ash alkalinity, and aconitate, shown in Fig. 6, were much less than for the other years shown earlier. These data further illustrate the extreme influence that environmental conditions, particularly soil water and temperature, can have on the quality, as well as quantity, of wheat forage.

DISCUSSION

The data were presented in Fig. 1 through 6 by year and location. In this section, the results are discussed as a whole for specific nutrients or components and are compared with the literature.

Nitrogen and Potassium Concentrations

A very close relationship between N and K was evident in all cases. The N content in the forage was influenced by the amount of fertilizer N added and by the average air temperature and soil water status. In general, the N concentration was very high (4% or greater) in late fall when grazing commonly begins. It gradually decreased during the winter months, probably as a result of less favorable growing conditions

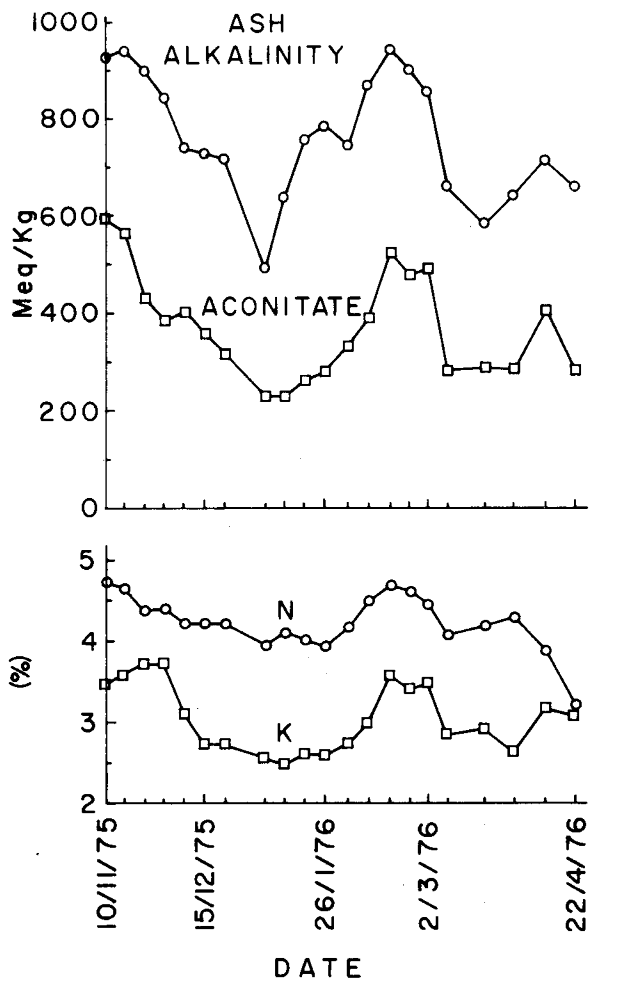

Fig. 5. Seasonal trends in N, K, ash alkalinity, and aconitate concentrations of winter wheat forage at Bushland, Tex., in 1975 to 1976.

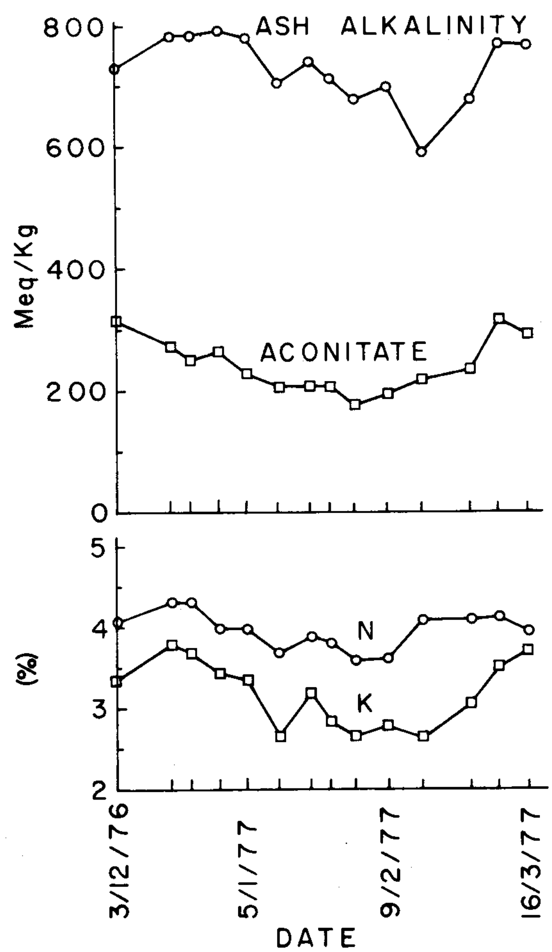

Fig. 6. Seasonal trends in N, K, ash alkalinity, and aconitate concentrations of winter wheat forage at El Reno, Okla., in 1976 to 1977.

usually dominated by cold temperatures. As temperature increased each spring, the N concentration increased rapidly and consistently, sometimes even exceeding concentrations in the fall. The K concentrations of the forage always followed the trends in N. At El Reno, the K concentration was often higher than the N concentration, whereas at Bushland, the N concentration was generally higher. The close relationship between the two nutrients, however, was similar at both locations. Mayland et al. (1976) grew spring wheat under field conditions in Idaho and found K concentrations of only about 3% when the N concentrations were in the range of 5%. Schwartz and Kafkafi (1978), working in Israel, found K concentrations in young wheat tissue as high as 6%, which decreased steadily with time after seeding. This result differs from our data for winter wheat; we found a steady decrease in nutrient concentration during late fall but then a marked increase during the spring followed by another steady decrease as growth accelerated and the plants matured.

Magnesium, and Calcium, and Phosphorus

The Mg and Ca concentrations were not significantly affected by N fertilization levels. There was some evidence at El Reno in 1977 through 1978 that top-dressing N in the spring increased Ca concentration, but this was the only case where this was true. In general, the Mg and Ca concentrations remained fairly constant during the fall and winter and then decreased as growth accelerated in the spring. This was in sharp contrast to the K concentrations discussed above. These data are similar to findings of George and Thill (1979). They studied N- and K-fertilized bromegrass and measured K, Ca, and Mg every 2 days during the spring grass tetany season. They found that K concentrations increased, but that Ca and Mg concentrations did not change significantly.

The Ca concentrations in the wheat forage were consistently higher at Bushland than those in forage at El Reno, in line with the higher values for ammonium acetate soluble Ca in the soils (Table 1). There was no consistent relationship between the Mg concentrations for the two locations, but there did seem to be some relationship between K concentration and Mg concentration. For example, both K and Mg concentrations were higher at Bushland in 1976 to 1977 than in 1973 to 1974. At El Reno, both K and Mg concentrations were higher in 1975 to 1976 than in 1977 to 1978.

Our finding that N level had little or no effect on Mg and Ca concentrations contrast somewhat with those of Mayland et al. (1975) and Schwartz and Kafkafi (1978), who showed that higher N levels were generally accompanied by higher Mg levels. This is probably due to the fact that the K status of soils in our study was high and K, therefore, was the principal cation that increased with increasing N concentrations. This agrees with studies of Follett et al. (1975) on cool season bromegrass grown on a soil high in K in North Dakota.

Phosphorus concentrations tended to parallel Ca concentrations with a ratio of about 1:1. There was some difference between the two locations. Calcium was generally higher at Bushland and P generally higher at El Reno. The levels of Ca and P in the wheat forage were low or minimal, at least for rapidly growing young stocker cattle and for lactating cows. The recommended nutrient requirements for beef cattle (National Research Council, 1976) are 0.46 and 0.36% for Ca and P, respectively, for 150-kg yearlings that are gaining 0.7 kg/day. For 450-kg cows nursing calves, the recommended Ca and P levels are 0.40 and 0.37%, respectively. Although the Mg content of the forage did not vary greatly with either time or N treatment, the Mg content was generally less than the requirement listed for lactating cows (0.18 to 0.20% Mg in the diet) during most of the grazing season.

K/(Ca + Mg) Ratios

The ratios of K/(Ca + Mg) were primarily controlled by the K concentration since K was affected much more significantly by N and climatic factors than was either Ca or Mg. In all years at both El Reno and Bushland, the ratios were higher than 2.2 during much of the grazing period. At the beginning of the grazing period in late fall and during the initial growth period in early spring, the ratios were often higher than 4 and in some cases as high as 5. One rather surprising finding in our study was how rapidly and to what extent the ratio changed under field conditions. These sudden and large changes were generally associated with changes in temperature and soil water. During the coldest part of the winter, growth essentially ceased and generally some soil water accumulated. Then, when a sudden warming occurred in the spring, conditions became favorable for a surge of growth and forage composition changed drastically.

In the Netherlands a nomograph using forage concentrations of N, K, and Mg is used for predicting levels of Mg in the blood of dairy cattle (Committee on Mineral Nutrition, 1973; Mayland et al., 1976; Mayland and Grunes, 1979). When we attempted to evaluate the forages from our study using this nomograph, however, we often found very low or negative estimates of blood Mg.

Ash Alkalinity and Aconitate

The ash alkalinity (difference between inorganic cations and inorganic anions) is an accepted estimate of the total organic acid content (Van Tuil et al., 1964). In the present study, the amounts of organic acids, expressed as meq/kg, were closely related to the K concentrations in the forage. As K concentration increased or decreased, there was a corresponding change in the organic acid content. The aconitate concentration paralleled the total organic acid concentration. Previous studies have indicated that most aconitate in grasses is present in the trans-form, and greater than 1% (1% aconitate equals 172 meq aconitate/kg plant material) transaconitic acid has been associated with increased tetany hazards (Stout et al., 1967). We observed values of over 4% at Bushland in October 1976, and over 3% several times at both El Reno and Bushland. The relationship between aconitate and K/(Ca + Mg) ratios was also close, which was not surprising since both parameters are closely associated with K concentrations.

Total Nonstructural Carbohydrates (TNC) and Total N/TNC

Nonstructural carbohydrates are sources of readily available energy that enhance rumen microbial activity and forage utilization. Changes in TNC concentrations with time in several plant species have been discussed by Jung et al. (1974, 1976). Those authors indicated that carbohydrate concentrations were considerably lower in N-fertilized herbage than in unferlized controls during flower-stem elongation, but N had little effect in TNC concentrations at full bloom.

Mayland and Grunes (1979) discussed the value of carbohydrates in decreasing grass tetany and in increasing Mg availability to ruminants. They also discussed the detrimental effect of high N/carbohydrate ratios. Mayland et al. (1974) found that when the ratio of N to total water soluble carbohydrates (TWSC) increased rapidly, and was 0.4 and higher, the incidence of grass tetany increased markedly. Horn et al. (1977) indicated that values for soluble carbohydrates were lower on bloat-provocative pastures than where bloat was not observed.

In the present study, the plants were analyzed for TNC instead of TWSC. The values for TNC are probably about 10% higher than those for TWSC, so that a N/TNC ratio of 0.36 would be equivalent to an N/TWSC ratio of 0.40.

In 1973 to 1974 at Bushland, N fertilization decreased the carbohydrate concentrations, which also decreased with time (Fig. 1). Ratios of N/TNC were highest at the later sampling dates. At the last sampling date, the ratio was 0.37 for the high N rate.

In 1976 to 1977, the TNC values were highest in the fall, and decreased later on (Fig. 2). The N/TNC ratio was 0.37 on 4 March, when N was high and TNC was low.

At El Reno, in 1975 to 1976, the carbohydrate concentrations were fairly low until early April (Fig. 3). The ratio of N/TNC dropped in mid-February, giving an N/TNC ratio of 0.47. At El Reno, in 1977 to 1978, the TNC also increased in April, but the highest value for N/TNC (0.63) was obtained on 14 March. Fertilization with N decreased TNC concentrations.

In summary, the N/TNC ratios were not consistently higher than the suggested critical level. However, N fertilization did consistently increase the ratios because added N increased N concentrations while reducing total nonstructural carbohydrates.

Dry Matter Percentages

The dry matter percentages were obtained only for El Reno samples. The data suggested that dry matter could serve as an indicator for predicting the occurrence of grass tetany where the K and Mg status of the soil would lead to high values for K and low values for Mg in the forage. The K/(Ca + Mg) ratios were always highest when the dry matter percentages were lowest. The dry matter percentages also changed simultaneously with the changes noted in K and N concentrations. These findings are not surprising because conditions that lead to lush forage are the same that lead to high concentrations of these soluble nutrients when the supply is adequate. The amounts and ratios of various nutrients depend on the inherent fertility of the soil and on the fertilizer applied, as well as on the temperature and soil moisture levels (Mayland and Grunes, 1979).

Relationship Between Grass Tetany and Bloat

The results and discussion have been presented primarily as related to grass tetany. Many of the deaths associated with wheat pasture, however, occur on stocker cattle, which are not normally affected by grass tetany. Frothy bloat is generally believed responsible for many of the deaths among these cattle. Horn et al. (1977) determined the chemical composition of wheat forage where bloat was not observed as compared with pastures that tended to produce bloat. They found in the bloat-producing pastures that dry matter and soluble carbohydrate values were lower; and that crude protein, soluble N, soluble protein N, and soluble nonprotein N values were higher. Interestingly, these indices occur in the same relative standings in forages that tend to produce grass tetany. Consequently, forages that are hazardous for grass tetany may also be hazardous for bloat. Horn et al. (1977) also found that bloat-producing pastures were lower in total fiber, but this constituent has not been related to grass tetany.

As indicated in the review by Clarke and Reid (1974), the relationship of minerals to the incidence of bloat is confusing and contradictory. However, mineral supplements high in Mg, and sometimes those high in Ca, are commonly sold as a means of reducing bloat of stocker cattle on wheat pasture. The effectiveness of these supplements has not been proven. Horn et al. (1977) indicated that rumen fermentation gases may become entrapped in ruminal fluid froth or foam, and cannot be eructated regardless of the functionality of the rumen and other digestive organs. Laby (1975) reported that the lipid present in bloat foam was associated with small yellow bubbles that could be isolated from rumen contents by flotation. These yellow bubbles were extremely persistent, and contained at least 30% crude lipid. The presence of yellow bubbles in the rumen increased with the onset of bloat. The lipids of the yellow bubbles were typically mono- and diglycerides and fatty acid salts (Laby and Weenink, 1966). Laby (1975) postulated that the fatty acid salts contain a large component of Ca soaps, which would be relatively insoluble. We infer that Ca soaps could form the substrate of the bubbles, and indeed, Laby (1975) showed that when yellow bubbles were present the Ca associated with the bubbles was high and the Mg was much lower. Possibly, the Ca soaps are less soluble than Mg soaps, and therefore, would form a more stable substrate for the formation of bubbles.

We found that K concentrations in the wheat forage were high when the N was high and the dry matter percentages low. This would be the time that grass tetany of older animals is most likely to occur. Forage Mg, available to stocker cattle, might be decreased as a result of high forage K. High forage N concentrations are accompanied by increased concentrations of higher fatty acids in the forage (Mayland and Grunes, 1979), and Mg soaps may form, decreasing the Mg available to the cattle. The resultant hypomagnesemia might decrease rumen motility, causing the animals to be less able to eliminate rumen fermentation gases, and bloat could then occur.

We found (Fig. 1 through 4) that the nonstructural carbohydrate levels were not very high early in the spring when dry matter concentrations were low and N and K concentrations were high, at the time grass tetany would be most likely. As indicated earlier, Horn et al. (1977) reported that the forage from bloat-producing pastures was lower in soluble carbohydrates than that from pastures where bloat did not occur.

High levels of readily fermentable carbohydrates would probably decrease rumen pH (Grunes et al., 1970). Jones et al. (1978) reported that fraction 1 leaf proteins produce rigid foams, which have been regarded as the surfactants responsible for rumen foams. These workers suggested that the fraction 1 proteins produce foams of maximum persistence and rigidity at pH values close to 6.0. If rumen pH were decreased below 6.0 by high levels of readily fermentable or nonstructural carbohydrates, the stability of the foam would decrease and bloat would be less likely.

Although both fall and spring forage may be tetanogenic, tetany is more likely to occur in the spring than fall because cows usually calve during the spring; lactating cows are more prone to tetany than pregnant cows.

Thus, on pastures where grass tetany is a hazard for older lactating cattle, the forage may also promote bloat of stocker cattle. Nitrogen fertilization, although essential for promoting good growth, may increase the bloat hazard, because bloat is clearly affected by the protein content of forage. Also, K concentrations in the forage increased as N concentrations increased, thus increasing the likelihood of tetany problems. Elimination of fertilizer N is not practical because this would decrease forage production too much. Therefore, good management is required to minimize or prevent the incidence of grass tetany or bloat.

One possible technique might be manipulation of the dry matter percentage of the diet or a change in management procedures when the dry matter content of the forage is low. In our study, dry matter percentages were inversely related to N and K concentrations in the forage. This suggests that dry matter percentages could be correlated with incidence of grass tetany and bloat. Therefore, when dry matter percentages are low, a management practice such as the use of an antifoaming agent, could be used until the dry matter percentage rose above a level considered safe, or a dry component such as grain or hay could be added to the diet. Additional data are needed to evaluate these possibilities. Unfortunately, such management techniques are expensive, and the rancher is not likely to use them unless some animals show signs of grass tetany or bloat.

Many of the cow-calf producers do not have enough control of the drinking water to respond with Mg salts after the onset of tetany. Also, consumption of Mg through conventional supplements is rarely adequate unless the supplement is fed all season long. The lack of control of drinking water also makes control of bloat more difficult, since antifoaming agents are frequently added in the drinking water. However, Bartley et al. (1975) reported that antifoaming agents can be added in molasses-salt blocks or molasses liquid supplements. Where available, the use of hay or dry grass pastures should help decrease the incidence of both grass tetany and bloat.

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