E-861

Vitamin and Mineral Nutrition of Grazing Cattle

• Department of Animal Science •
• Oklahoma Cooperative Extension Service •
• Division of Agricultural Resources and Natural Resources •
• Oklahoma State University •

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September 2004

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Objectives

- Discuss mineral composition of Oklahoma forages.
- Consider mineral needs of cattle.
- Discuss the effects of mineral deficiencies.
- Recommend mineral supplementation programs.

Proper mineral and vitamin nutrition contributes to strong immune systems, reproductive performance, and calf weight gain. A properly balanced mineral program requires consideration of previous cow and calf mineral nutrition, hay, or pasture forage intake and mineral concentration, and feed or mineral supplement intake and mineral concentration. Diets with mineral imbalances may cause poor animal performance, resulting in reduced profitability.

Mineral requirements are dependent on forage mineral content, animal age, and stage of production. However, simply knowing the animal's requirement is only one component in evaluating an animal's mineral status. Mineral needs also tend to be area specific and change with soil type, fertilization rates, rainfall, and other factors. An understanding of the need for minerals is necessary for making decisions about what and how much mineral to feed. Major attention here will be focused on those minerals most likely to pose a problem in Oklahoma.

Typical Mineral Composition of Common Oklahoma Forages

As a general rule, Oklahoma forages do not have severe mineral deficiencies or high levels of mineral antagonists compared to forages in many other states. Mineral antagonists are those minerals that, when in high enough amounts, may block the availability of other minerals to the animal. Specific antagonists are discussed more extensively in the next section. However, forage mineral concentration is extremely variable and site-specific mineral problems in Oklahoma have been identified.

Table 1 shows average mineral concentration in four types of forages common to Oklahoma and compares these averages with requirements of growing cattle. The data shown in Table 1 was summarized from two large data sets over a period of several years. These data represent forage mineral concentration when samples were harvested during mid-summer. Remember that forage will contain much higher concentration of most minerals when it is immature and rapidly growing compared to more mature, weathered forage.

From these data, several general principles are evident relative to supplementing minerals to grazing beef cattle in Oklahoma. Almost all forage requires salt supplementation as a source of sodium. Summer native range and prairie hay require phosphorus supplementation. Most

Table 1. Average mineral concentration of common Oklahoma forages and dietary requirements of beef cattle.

	Forage Type				
Mineral	Alfalfa/Clover	Bermudagrass	Fescue	Native	Dietary Requirement of Beef Cattle[a]
Phosphorus, %	0.27	0.21	0.23	0.08	0.15 to 0.3
Sodium, %	0.08	0.04	0.02	0.01	0.06 to 0.08
Iron, ppm	198	114	110	190	50.0
Copper, ppm	12.4	6.3	5.0	5.7	10.0
Zinc, ppm	23	22.4	17.8	22.5	30.0
Selenium, ppm	0.3	0.15	0.09	0.21	0.10
Manganese, ppm	47.6	83.9	122	51.6	20.0

a Adapted from NRC, 2000.

grasses common to Oklahoma are marginal to deficient in copper and zinc. It is apparent that good quality legume-based forages require very little if any mineral supplementation with the exception of zinc and salt, depending on the amount of this type of hay provided in the total diet. In addition, fescue forage is usually marginal to deficient in selenium, while bermudagrass forage is marginal. Remember that these values represent averages and that variation from location to location can be quite extreme.

As discussed in the next section, each of these marginal to deficient minerals has been shown to impact immune function, reproduction, or both. Therefore, it is recommended that producers make certain that beef cows receive supplemental sources of these elements at least 60 days prior to calving through breeding and 30 to 60 days prior to weaning. Similarly, weaned calves and purchased stocker cattle should receive adequate copper, zinc, and selenium through a concentrate feed supplement or free-choice mineral.

Macro Mineral Considerations

Calcium

Calcium is an important mineral for beef cattle, both in terms of the relative requirement and the diversity of functions in the body. It is a major component of the skeleton, which also serves as a calcium storage site. In fact, about 99% of the total calcium in the body is found in the bones and teeth.

Calcium is involved in blood clotting, muscle contraction, transmission of nerve impulses, regulation of the heart, secretion of hormones, and enzyme activation and stabilization. Fortunately, calcium is available in adequate amounts in high quality forages, although calcium can be deficient in weathered or mature forage. The most frequently observed cases of calcium deficiency occur in cattle fed high amounts of concentrate feed and in cattle grazing small grain forages. Availability of dietary calcium is also quite variable. Consequently, the National Research Council assumed dietary calcium availability was only 50% when calcium requirements were calculated. Signs of calcium deficiency include:

- Rickets: weak, soft bones in young cattle. Retards bone growth and performance of young growing cattle.
- Osteomalacia: weak brittle bones caused by demineralization of bones in adult animals.
- Urinary calculi: hard masses of mineral salts and tissue cells that form in the kidney or bladder and can cause water belly in growing steers and bulls.

In the case of cattle consuming high amounts of concentrate feed and small grain forages, problems may arise because of low calcium content of grains, small grain forage, and many by-product feeds. While forages tend to be adequate in calcium and deficient in phosphorus, the opposite is true of small grain forage and grains such as corn, milo, barley, oats, and wheat. These grains will typically contain about 0.03% calcium and about 0.3% phosphorus. Similarly, corn gluten feed, wheat middlings, barley malt sprout pellet products, and many other concentrate feeds contain 0.5% to over 1% phosphorus. The phosphorus content is adequate for most cattle but the calcium content is extremely low compared to the animal's requirement. In this situation, the problem of low dietary calcium is compounded by the low ratio of calcium to phosphorus.

When dietary phosphorus exceeds dietary calcium, absorption of calcium from the digestive tract is further reduced. Therefore, when significant amounts of these concentrates are fed without supplemental calcium, the animal will metabolize bone calcium to meet the body requirement. However, the calcium in the bone is stored in combination with phosphorus and both must be mobilized at the same time, thus both calcium and phosphorus in the bone will be depleted.

Another nutritional disease that can develop in growing male cattle with adequate or high phosphorus and low calcium is "water belly" or urinary calculi. The most effective method to prevent urinary calculi development in growing male cattle is to maintain total dietary calcium to phosphorus ratio of between 1.5:1 and 3:1. Most nutritionists formulate rations and mineral supplements to achieve a ratio of around 2:1. Calcium is an inexpensive mineral to add and a general rule of 1% added limestone will balance the calcium requirement in most grain-based rations.

A second method to minimize the risk of this disease is to make certain the cattle have access to salt or the total diet contains 0.5% up to 4% salt. Salt increases water intake, which increases mineral solubility and dilutes the urine.

Cattle can tolerate calcium to phosphorus ratios of up to about 7:1. However, excessive calcium has been shown to reduce absorption of phosphorus and many of the essential trace minerals. Therefore, producers should strive to maintain dietary Ca:P ratios of less than 3:1 and above 1.5:1.

The other calcium deficiency sometimes observed in Oklahoma occurs when pregnant and lactating cows graze lush cool-season forage, such as small grains, brome, and fescue. These cool-season forages are high in phosphorus and low in calcium during immature stages of growth. When cows in late pregnancy and early lactation graze this type of forage, grass tetany is frequently observed. Originally, the problem was thought to be solely the result of magnesium deficiency. However, more recent studies have shown that tetany may result from calcium deficiency as well as from magnesium deficiency. Symptoms of tetany from deficiencies of both minerals are indistinguishable without blood tests and the treatment consists of intravenous injections of calcium and magnesium gluconate, which supplies both minerals. Cows grazing lush small grains pastures should be fed mineral mixes containing both calcium and magnesium.

Phosphorus

Phosphorus is often discussed in conjunction with calcium because these minerals interact in many bodily functions and because they are both stored in bone tissue. Phosphorus, along with calcium, is a major component in bone structure with over 80% of the phosphorus in the body residing in bone and teeth. However, phosphorus has many other important physiological roles including cell growth and differentiation; energy utilization and transfer; cell membrane structure, primarily as phospholipids; and acid-base and osmotic balances. Phosphorus is also required by ruminal microorganisms for growth and cellular metabolism. Signs of phosphorus deficiency include:

- Osteomalacia: weak, brittle bones caused by demineralization of bones in adult animals
- Infertility
- Reduced feed intake, growth, and feed efficiency
- Reduced milk production

Phosphorus may be deficient in Oklahoma forages during several months of the year, with great apparent variation from area to area. However, forage phosphorus concentration and digestibility declines with advanced maturity and weathering. Figure 1 shows the decline of phosphorus concentration in stockpiled bermuda-grass forage through the winter months. In this and subsequent figures, the arc represents the range in phosphorus requirements for most classes of beef cattle, according to NRC. It is apparent that this forage resource contained adequate phosphorus during the early fall months, although phosphorus would need to be supplemented for all classes of cattle during late winter because forage phosphorous declined by 39%.

The wide range in phosphorus content of forages in the state highlights the need for forage testing. A forage test that includes calcium and phosphorus will cost around $30. Considering the potential cost of over feeding phosphorus when it is not needed or the potential lost performance when phosphorus is underfed, the advantages of sampling are obvious. It should be remembered that phosphorus deficient cattle may show varying degrees of unthriftiness long before classical signs such as bone and joint deformities appear. The rumen will likely be

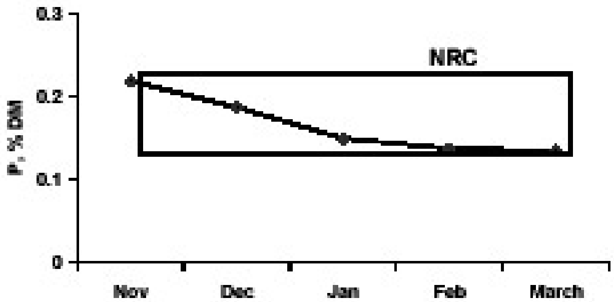

Figure 1. Effects of weathering on phosphorus concentration of stockpiled bermudagrass forage. Source: Lalman, et al., 2002.

phosphorus deficient before the animal's body has mobilized bone reserves. Phosphorus deficient animals will appear malnourished.

Potassium

Potassium (K) is the third most abundant mineral in the body. It is important in acid-base balance, regulation of osmotic pressure and water balance, muscle contractions, nerve impulses, and certain enzyme reactions. Signs of potassium deficiency include:

- Reduced feed intake and reduced weight gain
- Pica (chewing and gnawing wood and other objects)
- Rough haircoat
- Muscular weakness

When forage is growing and immature, potassium concentration is high and generally exceeds the requirements of all classes of cattle. However, potassium is soluble in plant tissue and is rapidly depleted in standing forage or hay that is rained on after cutting and before baling. Figure 2 shows a 76% decline in K concentration in standing forage from November to March. Nebraska research showed that winter supplements should contain about 2% potassium when fed at rates of 1.5 to 2.0 lb/head/day, or about 10 grams of supplemental potassium per head per day.

Common sources of supplemental potassium include potassium chloride (KCL) and potassium carbonate (K2CO3). The carbonate form is more palatable than the chloride form.

Because soybean meal and cottonseed meal both contain more than 1.5% K and sunflower meal and peanut meal contain more than 1.2% K, the requirement for potassium is met when natural protein supplements are fed. Alfalfa hay, cubes, and dehydrated pellets are also excellent

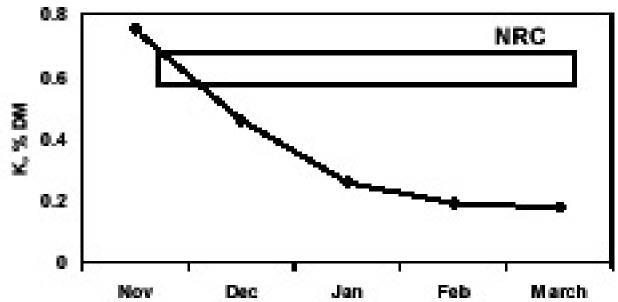

Figure 2. Effects of weathering on potassium concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

sources of potassium, containing between 1.5 to 3%. If grainbased urea supplements are fed that do not contain substantial amounts of the oilseed meals, potassium will need to be added. KCL is the most common source used in livestock rations.

Magnesium

Magnesium is closely related to calcium and phosphorus in function and distribution in the body. This mineral is known to activate at least 300 different enzymes. Magnesium is essential in energy metabolism, transmission of the genetic code, membrane transport, and nerve impulse transmissions. Magnesium is available in several common forms with the most common being magnesium oxide and magnesium sulfate (epsom salts). Signs of magnesium deficiency include:

- Excitability
- Anorexia
- Hyperemia
- Convulsions and muscular twitching
- Frothing at the mouth
- Profuse salivation
- Calcification of soft tissue
- Grass tetany

Figure 3 indicates that the reduction in standing forage magnesium concentration can be substantial during the winter months. In fact, in this experiment, bermudagrass forage magnesium concentration declined about 50% from November through March.

Grass tetany typically occurs in beef cows during early lactation and is more prevalent in older cows. Older cows are thought to be less able to mobilize magnesium reserves from bone compared to younger cows. Grass tetany most frequently occurs when cattle are grazing lush

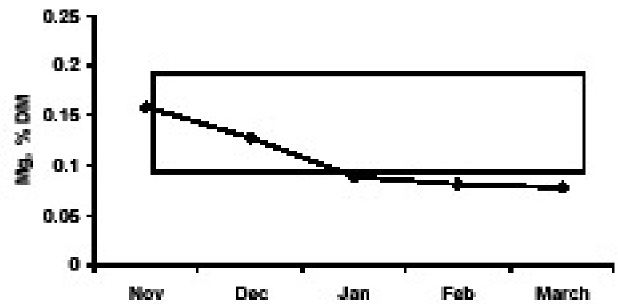

Figure 3. Effects of weathering on magnesium concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

immature grasses or small grains pastures and tends to be more prevalent during periods of cloudy weather. Symptoms include uncoordination, salivation, excitability (cows may charge humans), and, in the final stages, tetany, convulsions, and death. Grass tetany is occasionally encountered on fescue pastures but the incidence is much lower than seen on small grains.

It is known that factors other than simply the magnesium content of the forage can increase the probability of grass tetany. Some of these factors are discussed in the phosphorus section. High levels of potassium in forages can decrease absorption of magnesium, and many lush, immature forages are high in potassium. Consequently, the incidence of grass tetany on wheat pasture often occurs in central and western Oklahoma on soils that are quite high in potassium. High levels of nitrogen fertilization have also been shown to increase the incidence of tetany, possibly because an insoluble precipitate of magnesium-ammonium-phosphate forms in the digestive tract and is excreted by the animal. Feeding supplements containing high concentrations of non-protein nitrogen to cattle grazing lush forage would also increase the risk of grass tetany. Feeding oilseed meal-based protein supplements has not been shown to increase the incidence of tetany, although this could contribute to the bloating problem especially with stocker cattle. Other factors such as the presence of certain organic acids in tetany-prone forages have been linked with tetany. It is likely that a combination of factors, all related to characteristics of lush forage, are involved.

When conditions for occurrences of tetany are suspected, cows should be provided a mineral supplement containing between 6 and 30% magnesium with daily mineral intake ranging from 2 to 4 ounces per day. The higher inclusion rate and level of intake is appropriate for high-risk situations. In high-risk situations, cows should consume around 1 ounce of magnesium oxide per day. This is difficult because magnesium oxide is very unpalatable to cattle. Most commercial products formulated for the purpose of minimizing the risk of grass tetany contain between 6 and 15% magnesium. It is best for the high-magnesium supplements to be provided at least one month ahead of the period of tetany danger so that proper intake can be established. Because tetany can occur when calcium is low as discussed in the phosphorus section, calcium supplementation should also be included. Examples of high-magnesium mineral supplements are shown in Table 4 **on page 129**.

A key point should be made here. Magnesium supplementation does not cure or prevent bloat in cattle grazing wheat pasture. Tetany and bloat are two different problems with tetany affecting older cows and bloat being a major problem with younger stocker cattle. While calcium and magnesium may be very effective in preventing tetany, they are ineffective for preventing bloat.

Sulfur

Sulfur is needed for synthesis of methionine and cystine, which are sulfur-containing amino acids, as well as the B vitamins, thiamin, and biotin. Sulfur is required by ruminal microorganisms for normal growth and metabolism. In fact, ruminal microorganisms are capable of synthesizing all organic sulfur containing compounds required by the animal from inorganic sulfur.

Although sulfur deficiency is very uncommon in Oklahoma, signs of sulfur deficiency include:

- Anorexia, weakness, dullness, emaciation
- Excessive salivation
- Death

Sulfur concentration was above that suggested by NRC as the dietary requirement and declined only slightly (16%) in standing bermudagrass forage through the winter (Figure 4).

Marginal deficiencies would be expected to result in reduced feed or forage intake and digestibility due to reduced ruminal microorganism growth and metabolism. Sulfur supplementation might be considered when urea-based protein supplements containing little natural protein are fed. Otherwise, there is little likelihood that supplemental sulfur will be needed.

Cattle are very sensitive to excessive sulfur intake through water and feed. The maximum tolerable concentration of dietary sulfur has been estimated to be 0.4%. Sulphate sulfur in drinking water should not exceed 500 mg/L. Diets high in sulfur can cause polioencephalomalicia (PEM). Signs of PEM include restlessness, diarrhea, muscular twitching,

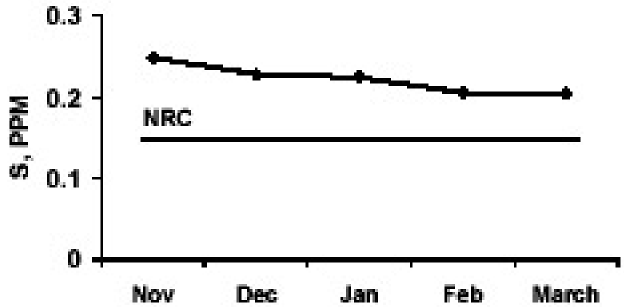

Figure 4. Effects of weathering sulfur concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

dyspnea (labored breathing), blindness, and in prolonged cases, inactivity followed by death. It is important for cattle producers to recognize that some common feed commodities, such as soybean meal, distillers grains, corn gluten feed, and barley malt sprout pellets, may contain between 0.4 and 1% sulfur. Therefore, if feeds high in sulfur make up a high percentage of the animal's daily dry matter intake, PEM is a real threat. Generally, if forage, water, and other feed sources are low in sulfur concentration, feeding up to 1% of body weight of high sulfur containing supplements will not cause a problem. Obviously, if there is a concern or a question about the sulfur concentration of any feed source, a representative sample should be submitted to a commercial feed testing laboratory for sulfur analysis.

Diets that contain greater than 0.35% sulfur and water containing high sulfur concentration have been implicated in initiating copper deficiency in cattle. High levels of forage sulfur are likely when ammonium sulfate or other fertilizer sources high in sulfur are used.

Trace Mineral Considerations

Trace minerals are those that are required only in extremely small amounts. Because such small daily quantities of trace minerals are needed, dietary requirements are generally expressed in parts per million (ppm), rather than percent. Trace mineral requirements are not well defined and deficiencies are frequently difficult to pinpoint due to the inconspicuousness and overlap of deficiency symptoms among minerals.

Cobalt

Cobalt's primary role in ruminants is a building block for vitamin B12. This essential vitamin can be manufactured in the rumen by the microorganisms when cobalt and other precursors are available. Vitamin B12 catalyzes enzymes that are essential in energy metabolism and methionine, an amino acid, metabolism. Very little cobalt is stored in body tissues. Therefore, cobalt status in cattle is assessed using blood serum concentrations of vitamin B12. Cattle with 200 ng/mL or higher serum B12 concentration are thought to have adequate ruminal B12 synthesis. Signs of cobalt deficiency include:

- Reduced appetite
- Reduced growth rate or failure to moderate weight loss in cows
- Pale skin and mucous membranes
- Reduced ability of neutrophils to kill yeast
- Reduced disease resistance

Young rapidly growing cattle seem more susceptible to cobalt deficiency than mature cattle. Feed-grade sources of cobalt include sulfate, carbonate, and chloride forms as well as commercial products containing organic forms of cobalt.

Copper

Copper is an important cofactor in many enzyme systems including those involved in hemoglobin formation, iron absorption and mobilization, connective tissue metabolism, and immune function. Copper status in cattle is quite susceptible to a number of antagonists, including molybdenum, sulfur, iron, and zinc. When total intake (dietary and water) of these potential antagonists is within the normal or adequate range, copper status is likely not affected. However, when daily intake of one or more of these antagonists is higher than what is needed to meet the animal's requirements, reduced copper status can occur. In these cases, copper supplementation must be increased accordingly to gradually restore the animal to normal copper status. Signs of copper deficiency include:

- Anemia
- Reduced growth rate
- Depigmentation (dulling) of hair and rough hair coat
- Diarrhea
- Reduced fertility
- Increased incidence of abomasul ulcers in newborn calves
- Reduced immune function; increased bacterial infections

Copper concentration of stockpiled bermudagrass forage was well below the NRC suggested requirement, and concentration declined by 20% between November and March (Figure 5).

Copper status is best assessed by collecting liver tissue via biopsy and analyzing the wet tissue for mineral concentration. Copper oxide is extremely low in terms of its availability to the animal, whereas the sulfate and various organic forms are much higher in availability. Copper

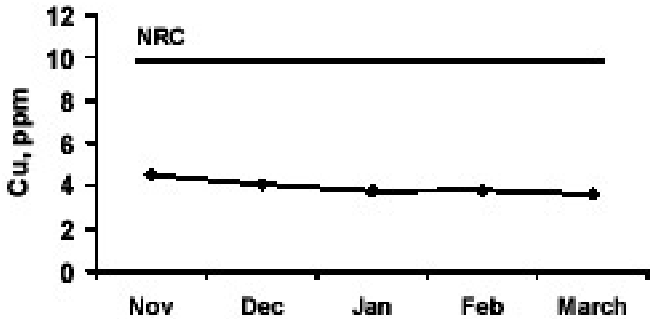

Figure 5. Effects of weathering on copper concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

oxide should not be used to supplement cattle when a copper deficiency has been determined to exist.

Molybdenum and sulfur in the rumen combine to form thiomolybdates, which form a complex with copper that is essentially unavailable to the animal. Most nutritionists agree that the dietary copper to molybdenum ratio should be maintained between 4:1 and 10:1 in order to minimize the risk of molybdenum induced copper deficiency. Therefore, when forage copper concentration is adequate (around 10 ppm) and forage molybdenum concentration is high, a supplemental source of copper will still be needed.

Copper and zinc are absorbed through similar pathways creating a competition for absorption sites. Therefore, mineral supplements should be formulated with a copper to zinc ratio of around 1:2 or 1:3.

Forage-based diets containing between 250 and up to 1200 ppm iron in the form of iron carbonate reduces copper status in cattle. For some reason ironinduced copper deficiency has yet to result in typical clinical signs associated with copper deficiency, particularly growth rate and reproduction effects. However, iron-induced copper deficiency has resulted in pancreatic damage and impaired neutrophil function, suggesting reduced function of the immune system.

Iodine

Iodine is an essential component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3), which regulate the rate of energy metabolism in the body. Iodine requirements may be elevated in cattle consuming goitrogenic substances, which interfere with iodine metabolism. The cyanogenetic goitrogens include the thiocyanate derived from cyanide in white clover and the glucosinolates found in some forages such as kale, turnips, and rape. These goitrogens impair iodine uptake by the thyroid, and their effect can be overcome by increasing dietary iodine. Signs of iodine deficiency include:

- Swelling of the thyroid gland, particularly in the newborn
- Hairless, weak calves at birth
- Low reproductive rate in cows
- Retained placenta
- Decreased libido and semen quality in males

Clinical signs of iodine deficiency may not be apparent for up to one year after the iodine deficient diet is initiated. Iodine supplementation is inexpensive and easily provided through iodized salt. Iodine is usually provided in supplements in the form of calcium iodate or ethylinediamine dihydroiodide (EDDI), an organic form of iodine. High temperatures, high humidity, and rain volatilize and leach iodine in salt and mineral mixtures.

Iron

Iron is an essential component in the structure of proteins involved in transportation and utilization of oxygen. Examples include hemoglobin, myoglobin, cytochromes, and iron-sulfur proteins involved in the electron transport chain. Additionally, as with many other trace minerals, several enzymes either contain or are activated by iron. Signs of iron deficiency may include:

- Anemia
- Anorexia
- Reduced growth rate or increased rate of weight loss
- Listlessness
- Pale mucous membranes
- Atrophy of the papillae of the tongue

Iron deficiency in grazing cattle is unlikely because most forages contain more iron than is necessary to meet this requirement (Figure 6). Additionally, most feed grains and oilseed meals contain significant amounts of iron. Cattle can also ingest iron through the water source and soil ingestion. In fact, many soils in Oklahoma contain high concentrations of iron oxide, which gives it the red or reddish-brown appearance. This high soil concentration leads to high forage iron concentration. Heavy parasite infestations or other diseases causing chronic blood loss can lead to an iron deficiency.

Supplemental iron sources include ferrous (iron) sulfate, ferrous carbonate, and ferric (iron) oxide. Availability of ferrous sulfate is high, while ferric oxide is very low in availability. Many commercial mineral mixes include ferric oxide to give it the traditional red appearance.

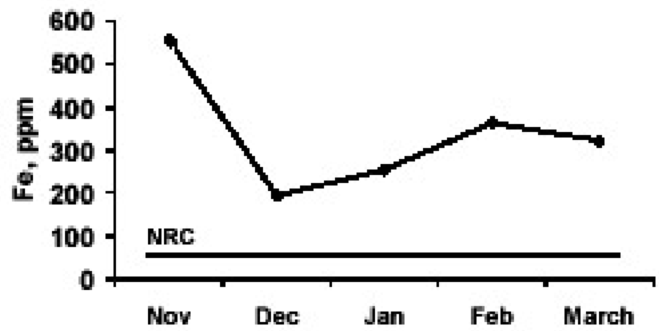

Figure 6. Effects of weathering on iron concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

Dietary iron concentrations as low as 250 to 500 ppm have caused copper deficiency in cattle. Many water sources and forages in Oklahoma are high in iron concentration. In these situations, copper supplementation may need to be provided to prevent copper deficiency. High iron intake has also been implicated in reducing manganese absorption in cattle.

Manganese

Manganese is important in bone growth and formation in young animals and in maintaining optimum fertility in female cattle. The role of manganese in metabolism includes a component of the enzymes pyruvate carboxylase, arginase, superoxide dismutase, and several others. Signs of manganese deficiency include:

- Skeletal abnormalities in young cattle resulting in stiffness, twisted legs, enlarged joints, and reduced bone strength
- Low reproductive performance in mature cattle
- Abortions
- Stillbirths
- Low birth weights

The necessity for manganese supplementation in grazing cattle remains unclear. Forage and feed manganese concentrations are generally well above the concentration suggested for the dietary requirement of cattle (20 to 40 ppm) as shown in Figure 7. In this study, bermudagrass forage manganese concentration was more than twice the dietary requirement throughout the winter.

However, limited research suggests that the availability of forage manganese is quite low (less than 20%). Until more research is available, and considering the importance of manganese in cow fertility and in young calf development, it seems logical to focus supplementation and diet evaluation efforts prior to and immediately following calving.

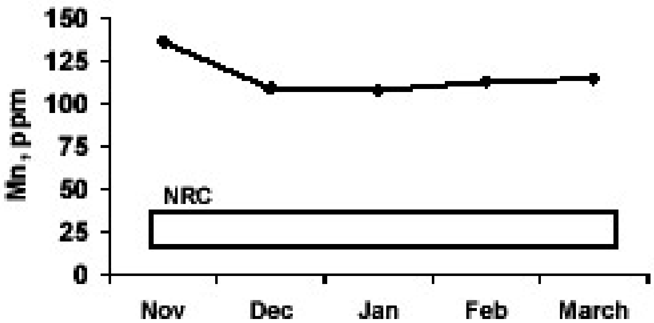

Figure 7. Effects of weathering on manganese concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

Effective manganese sources include manganese sulfate, manganese oxide, and various organic forms of manganese. Relative availability of organic sources of manganese is approximately 120% of manganese sulfate with manganese oxide having lower availability than manganese sulfate. High intake of phosphorous, calcium, and iron results in reduced manganese absorption.

Selenium

Early attention was drawn to selenium because of severe selenium toxicity in grazing cattle in some parts of the United States. More recently, forage selenium concentration has been shown to be marginal to deficient in several areas. Unlike many other trace minerals, the range between dietary toxicity and deficiency is quite narrow. In fact, the USDA regulates the inclusion rate of selenium in feeds and supplements with levels not to exceed 3 mg per day or about 0.14 mg/lb of total diet (0.3 ppm). This amount is equivalent to only 0.27 gm of total selenium per ton of feed.

Selenium is required in the body for synthesis of an enzyme that breaks down harmful oxidizing agents. Selenium and vitamin E are somewhat related because vitamin E acts to protect cells from the harmful effects of the oxidizing agents. Vitamin E also acts as an antioxidant. Therefore, a deficiency of either selenium or vitamin E will increase the requirement for the other. Early work suggested that selenium supplementation may moderate the negative effects of fescue toxicosis. Unfortunately, initial positive claims for beneficial effects of selenium against fescue toxicity have not been substantiated in studies at the University of Missouri. However, on average, fescue forage is marginal to low in selenium concentration, suggesting that a low level of supplementation may improve animal performance. Signs of selenium deficiency include:

- White muscle disease: degeneration and necrosis of skeletal and cardiac muscle
- Reproductive failure
- Increased incidence of retained placenta in dairy cows
- Increased calf mortality and reduced calf weaning weights
- Immune suppression

Sodium selenite is the most common form of selenium supplementation, although several organic forms of selenium have recently been developed.

Producers should be cautioned against attempting to mix their own formulation with selenium. The toxic level for selenium is only 10 times the requirement and any math error or mixing mistake can lead to serious consequences.

Zinc

Zinc is an essential component of a number of important metabolic enzymes and it serves to activate numerous other enzymes. Enzymes that require zinc are involved in protein, nucleic acid, and carbohydrate metabolism as well as enzymes associated with immune function. Signs of zinc deficiency include:

- Reduced feed intake and growth rate
- Listlessness
- Excessive salivation
- Reduced testicular growth
- Swollen, cracked hooves
- Skin lesions (parakeratosis)
- Failed or slowed wound healing
- Reduced fertility in cows and bulls

Most forages are marginal to low in zinc concentration compared to the suggested requirement (30 ppm). Figure 8 shows the zinc concentration in stockpiled bermudagrass forage throughout the winter. Although zinc concentration was below the requirement, forage zinc concentration did not decline as the winter grazing season progressed.

Previously it was noted that mineral supplements should contain a copper to zinc ratio between 1:2 and 1:3. Zinc sulfate, zinc oxide, and organic forms of zinc are common supplementation sources. Absorption or availability is lower for the oxide compared to the sulfate and organic forms.

Vitamins

Vitamins and vitamin precursors are organic components of forage and feeds, although they are distinct from carbohydrates, protein, fat, and

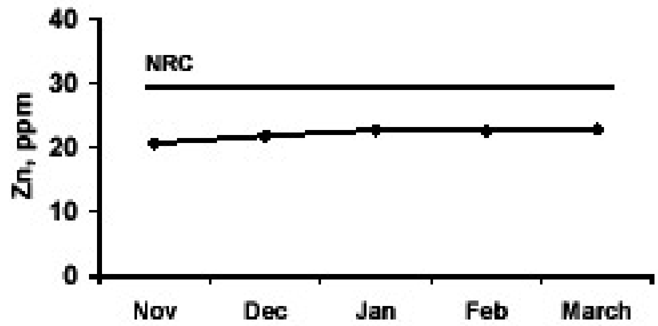

Figure 8. Effects of weathering on zinc concentration of stockpiled bermudagrass forage. Source: Lalman et al., 2002.

water. Vitamins are essential for the development and maintenance of different tissues and they are involved in numerous metabolic activities. Vitamins also differ from other essential nutrients in that they do not enter into the structural portions of the body. Vitamins are classified as either fat-soluble (A, D, E, and K) or water-soluble (B, thiamin, niacin, and choline) based upon their structure and function. Fat-soluble vitamins contain only carbon, hydrogen, and oxygen, whereas the water-soluble B-vitamins contain these elements and either nitrogen, sulfur, or cobalt. Fat-soluble vitamins may occur in plant tissues as a provitamin (a precursor to the vitamin). A good example is carotene in forages, which is readily converted to vitamin A by ruminant animals. No provitamins are known to exist for the watersoluble vitamins. However, rumen microorganisms have the ability to synthesize water-soluble vitamins. As a result, the supplementation of water-soluble vitamins is generally not necessary in ruminants. Only the vitamins thought to be of significant concern for grazing cattle in Oklahoma will be discussed.

Thiamin

Thiamin functions in all cells as a coenzyme cocarboxylase. Thiamin is the coenzyme responsible for all enzymatic carboxylations of keto-acids in the tricarboxylic acid cycle, which provides energy to the body. Thiamin also plays a key role in glucose metabolism.

Synthesis of thiamin by rumen microflora makes it difficult to establish a ruminant requirement. Generally, animals with a functional rumen can synthesize adequate amounts of thiamin.

In all species, a thiamin deficiency results in central nervous system disorders, because thiamin is an important component of the biochemical reactions that break down the glucose supplying energy to the brain. Other signs of thiamin deficiency include weakness, retracted head, and cardiac arrhythmia. As with other water-soluble vitamins, deficiencies can result in slowed growth, anorexia, and diarrhea.

Vitamin A

Vitamin A is considered by many to be the most important vitamin regarding the need for supplementation. Vitamin A is necessary for proper bone formation, growth, vision, skin and hoof tissue maintenance, and energy metabolism (glucose synthesis). Deficiency symptoms include:

- Night blindness
- Reproductive failure
- Skeletal deformation
- Skin lesions

Plant materials contain the provitamin, carotene. Green leafy forage, green hay, silages, dehydrated alfalfa meal, yellow corn, whole milk, and fish oils are rich sources of carotene. In cattle, 1 mg of betacarotene is converted to the equivalent of about 400 international units (IU) of vitamin A. Lush immature forage contains high concentrations of carotene, although carotene is destroyed rapidly as the plant matures and with exposure to sunlight, air, and high temperatures (Figure 9).

The liver does store vitamin A, and these stores can serve to prevent deficiency in times when carotene or vitamin A intake is low. It is generally thought that vitamin A stores can last only 2 to 4 months if a severe dietary deficiency exists. Situations where cattle are particularly susceptible to vitamin A deficiency includes times when cattle consume:

- High-concentrate diets
- Winter pasture, crop residues, or hay growing during drought conditions
- Feeds receiving excess exposure to sunlight, air, and high temperature
- Feeds that have been heavily processed or mixed with oxidizing materials, such as minerals
- Forages that have been stored for long periods of time

Vitamin B12

B-vitamins are abundant in milk and other feeds. B-vitamins are synthesized by rumen microorganisms, beginning soon after a young animal begins feeding. As a result, B-vitamin deficiency is limited to situations where an antagonist is present or the rumen lacks the precursors to make the vitamin.

Vitamin B12 is the generic descriptor for a group of compounds having vitamin B12 activity. One feature of vitamin B12 is that it contains 4.5% cobalt. The naturally occurring forms of vitamin B12 are adenosylcobalamin and methyl cobalamin. These are found in both

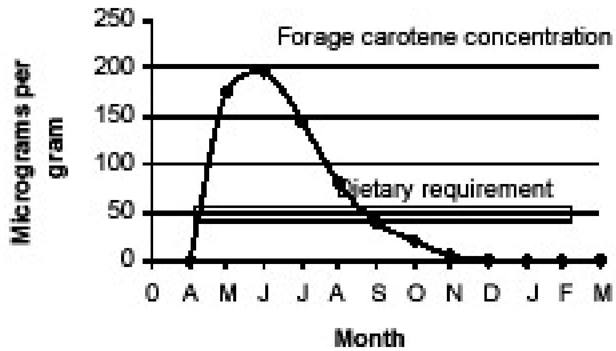

Figure 9. Concentration of carotene in native range forage. Source: Wuller et al., 1972.

plant and animal tissues. The primary functions of vitamin B12 involve metabolism of nucleic acids, proteins, fats, and carbohydrates. Vitamin B12 is of special interest in ruminant nutrition because of its role in propionate metabolism, as well as the practical incidence of vitamin B12 deficiency as a secondary result of cobalt deficiency. Primarily, cobalt content of the diet is the limiting factor for ruminal microorganism synthesis of vitamin B12.

A vitamin B12 deficiency is difficult to distinguish from a cobalt deficiency. The signs of deficiency may not be specific and can include poor appetite, retarded growth, and poor condition. In severe deficiencies, muscular weakness and demyelination of peripheral nerves occurs. In young ruminant animals, vitamin B12 deficiency can occur when rumen microbial flora have not reached adequate populations or are depleted due to stress.

Vitamin D

Vitamin D is essential for bone growth and maintenance because it is directly involved in calcium absorption as well as phosphorus absorption from the kidney and it is involved in osteoblast (bone cell) formation and calcification. It also plays an important role in phosphorylation of carbohydrates, which is part of the energy metabolism process, and it has a regulatory role in immune cell function. There are two primary forms of vitamin D: ergocalciferol (vitamin D2) derived from the plant steroid, ergosterol, and cholecalciferol (vitamin D3), which is found only in animal tissues or products and derived from the precursor 7-dehydrocholesterol. One IU of vitamin D is equivalent to 0.025 microgram of vitamin D3 or vitamin D2. Similarly, 1 mg of either source contains 40,000 IU activity.

Sun-cured hay, irradiated yeast, and certain fish liver oils contain high concentrations of vitamin D. However, because vitamin D is synthesized by beef cattle when exposed either to sunlight or fed suncured forages, they rarely require vitamin D supplementation.

Examples of situations conducive to moderate vitamin D deficiency would include cattle housed indoors for long periods of time and fed a highconcentrate ration (little or no sun-cured forage), and cattle consuming extremely low quality forage during long periods with little or no sunlight.

Severe vitamin D deficiency results in a disease referred to as rickets, which is caused by the bones failure to assimilate and use calcium and phosphorus normally. Accompanying evidence frequently includes a decrease in calcium and inorganic phosphorus in the blood, swollen and stiff joints, anorexia, irritability, tetany, and convulsions. Osteomalacia is a related disease that affects older animals with vitamin D deficiency, resulting in weak, fragile bones.

Vitamin E

Vitamin E occurs naturally in feedstuffs as alpha tocopherol. Vitamin E is not stored in the body in large concentrations, although small quantities can be found in the liver and adipose tissue. This vitamin serves several functions including a role as an inter- and intra-cellular antioxidant and in the formation of structural components of biological membranes. Vitamin E is important in muscle growth and structure.

The vitamin E requirement for cattle has not been firmly established. For young growing cattle, the requirement is estimated to be between 7 and 27 IU/lb of feed dry matter. However, 50 to 100 IU per head per day has been suggested for older growing and finishing cattle (NRC, 2000).

Vitamin E deficiencies can be initiated by the intake of unsaturated fats. Examples of common sources of unsaturated fats include whole cottonseed, soybeans, and whole sunflowers, among others.

Signs of deficiencies in young calves are characteristic of white-muscle disease including general muscular dystrophy, weak leg muscles, crossover walking, impaired suckling ability caused by dystrophy of tongue muscles, heart failure, paralysis, and hepatic necrosis.

Diagnosis of Mineral Deficiencies

Diagnosis of mineral deficiencies is difficult due to extreme variation in current and historical dietary mineral supply, the presence of potential antagonists, differences in the availability of minerals in various supplement sources, and only a cloudy view of specific dietary mineral requirements, particularly for trace minerals. An effective diagnosis may include several of the following evaluations: clinical signs, soil analysis, forage analysis, water analysis, mineral concentrations in feed or supplement, mineral concentrations in tissue (primarily blood, blood components, and liver tissue), as well as the animal's response to treatment.

Average dietary availability of minerals was considered when these requirements were determined. Although availability of forage mineral varies with the specific mineral, soil mineral concentrations, and forage maturity and weathering, most data indicate that minerals of forage origin are between 50 and 90% available to the ruminant animal. The exception to these higher absorption values is manganese, which may be considerably lower.

Perhaps the most useful starting point in evaluating mineral status is obtaining a complete mineral profile of all forages, feeds, and supplements provided to the cattle. An estimate of average daily intake of each component will also be necessary. Tabular values and feed tags should not be relied on for estimating trace element intakes. Once a "mineral balance" profile (daily supply minus daily requirement) has been constructed, marginal and severe deficiencies can be identified. If this exercise does not reveal the potential cause of severe or even marginal deficiency signs, such as low pregnancy rates or high morbidity and mortality rates in weaned calves, tissue and water source evaluations may be necessary.

Liver concentrations of copper, manganese, selenium, and zinc provide the best indication of trace mineral status (Table 2). Unfortunately, obtaining liver samples is somewhat expensive, invasive, and time consuming compared to blood samples. Liver iodine and iron concentration are not indicative of nutritional status.

Concentrations of minerals in whole blood or blood components are frequently used because they are correlated to nutritional status, particularly for iodine, iron, selenium, and zinc (Table 3). However, blood concentrations of most minerals change rapidly and are influenced by many factors other than dietary supply, such as calving, lactation, and other sources of stress or disease. Therefore, blood concentrations of any mineral should be interpreted with caution and in conjunction with other assessment criteria.

Concentration of various blood enzymes and metabolites are also used as indicators of mineral status in cattle. For example, glutathione peroxidase is an indicator of selenium status, while alkaline phosphatase, superoxide dismutase, and metallothionein are indicators of zinc status. Similarly, ceruloplasmin, superoxide dismutase, and metallothionein are

Table 2. Criteria for classification of mineral status in cattle using liver mineral concentrations.

	Deficient	Marginal	Adequate	High	Toxic
Cobalt	<0.005		0.020-0.085	0.085-8.70	5.0-300
Copper	< 33	33 - 125	125 - 600	600 - 1250	> 1250
Iodine	<0.094		0.094-2.0		>0.781
Iron	<40		45-300	53-700	
Magnesium	<40-200		100-250		
Manganese	< 5	5 - 10	10 - 15	15 - 25	
Phosphorus	6-14		6-14		
Potassium					
Selenium	< 0.5	0.6 – 1.25	1.25 - 2.50	> 2.5	
Zinc	<20	20 - 40	25 - 200	300 - 600	> 1000

Source: Puls (1988) and Kincaid (1999).

Table 3. Criteria for classification of trace mineral status in cattle using whole blood, plasma, or serum mineral concentrations.

	Deficient	Marginal	Adequate	High	Toxic
Copper, plasma, microgram/mL	< 0.5	0.5 – 0.7	0.7 – 0.9	0.9 – 1.1	> 1.2
Iodine, serum, microgram/100 mL	< 5		10 - 40	70 - 300	
Iron, serum, microgram/100 mL	< 120		130 - 250	400 – 600	
Manganese, whole blood, ng/mL	< 20	20 - 60	70 - 200		
Manganese, serum, ng/mL	< 5	5 - 6			
Selenium, whole blood, ng/mL	< 60	60 - 200	210 – 1,200	> 1,200	
Zinc, plasma, microgram/mL	<0.4	0.5 – 0.8	0.8 – 1.4	2 - 5	3 - 15

Source: Puls (1988) and Kincaid (1999).

Table 4. Recommended maximum levels of minerals and mineral compounds in livestock drinking water (all units are mg/L except pH).

Aluminum	<5.0
Arsenic	<0.05
Barium	<1.0
Boron	<5.0
Cadmium	<0.01
Calcium	<1000.0
Chloride	<1000.0
Chromium	<0.05
Cobalt	<1.0
Copper	<1.0
Cyanide	<0.20
Fluoride	<1.2
Hardness (CaC03)	<2000.0
Iodine	<1.0
Iron	<0.4
Lead	<0.05
Magnesium	<1000.0
Manganese	<0.05

used as indicators of copper status. Vitamin B12 and methylmalonic acid are used as indicators of cobalt status.

Water intake and water mineral concentration can also provide instructive information when assessing mineral status of cattle. Table 4 provides recommended maximum levels of minerals and mineral compounds in livestock drinking water.

Supplementing Minerals

The most common method of providing supplemental minerals to cattle is through a protein/energy supplement or through a free-choice mineral supplement. Animal to animal variation in intake is greatest with free-choice mineral supplements. Some cattle consume no supplement, while others may consume as much as four or five times the intended daily amount. This variation is reduced considerably when minerals are incorporated into protein/energy supplements that are provided on a regular basis.

It is important to monitor and record average daily intake of free-choice supplements so that the supplement formula can be adjusted if necessary to increase or reduce intake. Cattle will consume salt in excess. This is why salt is used as the base ingredient in free-choice supplements. Phosphorus and magnesium sources are unpalatable and may reduce mineral supplement consumption. When providing a complete free-choice mineral supplement, all other sources of salt should be removed from the pasture.

The mineral formulas provided in Table 5 are provided as examples of relatively simple free-choice mineral mixes designed for beef cows grazing native range during late summer and winter in Oklahoma. These formulas would also be appropriate for cows consuming other low quality forage, such as dormant bermudagrass and fescue during late summer or mid-winter. An example of a magnesium-fortified mineral supplement and a highmagnesium supplement is also provided. Producers should not attempt to mix mineral supplements containing small amounts of trace minerals at home due to potential mixing errors and the potential to cause mineral toxicity due to inadequate mixing.

Lush growing forage and forage with a substantial legume component contains significantly higher concentrations of most minerals. For example, in the study of Lalman et al., 2002, mineral concentration of fertilized, stockpiled bermudagrass forage contained relatively high concentrations of phosphorous, potassium, sulfur, iron, and manganese during the month of November, when the forage regrowth was lush (high quality). Therefore, mineral supplements should contain lower concentrations of these minerals during times when cattle have access to high quality forage. As a general rule, free-choice mineral supplements

Table 5. Free-choice mineral supplements for beef cows grazing low quality forage.

Ingredient	Free-choice mineral for beef cows[a]	Magnesium-fortified mineral for beef cows[b]	High-magnesium mineral for beef cows[c]
		Pounds per ton (as fed basis)	
Dicalcium phosphate	900	700	250
Salt	570.4	435.4	500
Cottonseed meal	150	200	500
Limestone, 38%	140	140	250
Dried molasses	75	100	
Selenium	600	40	40
Magnesium oxide	30	300	500
Vitamin A-30,000 IU/g	30	30	
Mineral oil	20	20	
Zinc sulfate	16.6	16.6	
Potassium chloride	10	-	
Manganous oxide	8.0	8.0	
Copper sulfate	8.0	8.0	
Vitamin E-50% 227,600 IU/lb	2.0	2.0	
		Nutrient composition (as fed basis)	
Calcium, %	12	10	7
Phosphorus, %	8	6	2.5
Magnesium, %	1	8	15
Sulfur, %	0.5	0.5	-
Copper, ppm	1000	1000	-
Iron, ppm[d]	6250	5000	-
Manganese, ppm	2500	2500	-
Selenium, ppm	12	12	-
Zinc, ppm	3000	3000	-

a Example of a free-choice mineral for beef cows grazing native range or bermudagrass pasture. Do not feed this mineral to sheep. Daily intake should range from 2 to 4 ounces per day.

b,c Magnesium mineral supplement should be provided when beef cattle, particularly cows, graze rapidly-growing cool-season grass or small-grains pasture. Do not feed this mineral to sheep. Daily intake should range from 2 to 4 ounces per day.

c This mineral formula does not contain micro minerals and thus can be safely mixed at the home operation. Part or all of the cottonseed meal can be replaced with dried molasses.

d Do not add iron oxide or other ingredients high in iron since most Oklahoma forages contain excessive iron.

for high quality, fresh forage should contain greater than 12% calcium and less than 6% phosphorus. Some producers have fed very simple free-choice mineral supplements to beef cows with excellent growth, animal health, and reproductive performance year after year. For example, one popular homemade mineral supplement includes 50% trace-mineralized salt and 50% dicalcium phosphate. A simple formula for supplying supplemental magnesium in high-risk situations is included in Table 5. Obviously, the major advantage of these simple formulas is that they are inexpensive and they can be mixed at home. If a simple program like this has been used with success (animal health, growth, and reproduction meets or exceeds the expectations of the producer), there may be no need to use a more complicated and expensive program. However, producers should keep in mind the potential for a production-limiting deficiency to develop. As discussed above, the greatest potential deficiencies in Oklahoma include vitamin A, phosphorus, copper, and zinc. Over a long period of time, these deficiencies may be revealed through reduced animal health and performance.

There are situations where salt is the most effective and economical supplementation program. This is particularly true when cattle consume high quality, lush forage, legume based forage, and/or substantial concentrate supplementation. For example, when stocker cattle are shipped into Oklahoma for dry wintering, followed by summer grazing, little if anything is known about their previous dietary mineral status. Additionally, since many loads of cattle represent more than one previous owner and origin, previous dietary mineral status will be quite variable. Some, if not most of these cattle may be deficient in one or several vitamins and minerals when they arrive in the fall. However, if the cattle are wintered with a wellformulated supplement designed to improve vitamin and mineral status, it is unlikely that these cattle would respond to mineral supplementation during the 90 to 150 day spring and summer grazing season. Forages contain considerably higher concentrations of highly available provitamins, vitamins, and minerals during lush growing periods compared to forage in more mature stages of growth or dormancy.

Conclusion

Forage mineral concentration varies considerably and is dependent on many factors including forage species, soil mineral concentrations, fertilization, climatic conditions, season of the year, and weathering. Even though forage mineral concentration data is not difficult or expensive to obtain, this information must frequently be combined with additional assessment criteria because forage mineral availability is also variable and unknown in many cases. Numerous mineral interactions exist to influence the availability of dietary minerals. In fact, some minerals, such as copper and manganese, may need to be provided beyond the suggested requirement when high concentrations of antagonists are present. Deficiency signs for various minerals have been provided. Many of these clinical signs are not evident until a severe deficiency exists because bone, blood, liver, and other organs provide a substantial pool from which cattle can draw during times of dietary inadequacy. The minerals that are most likely to be deficient for cattle grazing moderate to low-quality Oklahoma forage are phosphorous, potassium (for cattle grazing dormant standing forage), copper, and zinc. Supplementation of manganese and selenium may also be necessary in many cases and magnesium supplementation is frequently necessary during spring.

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