

Pasture Forage Quality in West Virginia - 1999 to 2001¹

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Nutrients are divided into macronutrients and micronutrients based on the relative amount needed on a daily basis. Macronutrients are those needed in relatively large amounts measurable in pounds and ounces or as a percentage of the ration. Examples of macronutrients are water, crude protein (CP), total digestible nutrients (TDN), and minerals such as calcium (Ca) and phosphorus (P). Micronutrients are those needed in relatively small amounts measurable in parts per million or milligrams in the ration. Examples of micronutrients are copper (Cu) and zinc (Zn).

The nutrient requirement of an animal is determined by the animal's species, age, size, and production level. Young animals need nutrients for growth. A young heifer needs nutrients for growth and milk production when lactating. Animals with the genetic ability for high growth rates need more macronutrients than those producing at lower levels if they are to achieve their genetic potential. The requirement for micronutrients is less well-defined and is usually made as a recommended concentration in the total ration.

After water, digestible energy is the nutrient needed in the greatest abundance and its availability is dependent on the forage's digestibility. The animal's need for protein is related to the animal's energy intake and level of production. For animals fed cool-season forages, energy will usually limit production. When feeding energy supplements on pasture, if the supplements are fed in excess to the availability of CP in the forage, protein supplements will also be required. (A listing of abbreviations used in this bulletin is contained in Appendix Table 1.)

Mineral intake from pasture is dependent on the concentration and availability of the mineral in the forage and forage intake by the animal. Mineral content in forage is a function of plant species, plant maturity, and soil fertility. However, on a soil low in a mineral required for plant growth, a forage species adapted to using that mineral in low amounts will be most competitive and will be the dominant species in the stand. Such adapted plants usually have lower concentrations of the mineral than plants that have

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higher requirements for the mineral. A classic example is sweet vernal grass that is adapted to low soil phosphorus and soil pH. This grass is common in West Virginia and is often the dominant species on soils low in phosphorus. When the site is treated with phosphorus and limed, orchardgrass is able to grow better and can then out-compete the sweet vernal grass and become dominant in the field.

The availability of minerals to animals varies with forage species, animal species and breed and the presence of other interacting minerals in the forage, water, and mineral supplements consumed. In some locations minerals in spring and well water can be a major contributor of minerals in the diet. Also, water high in salt will affect animal consumption of supplemental minerals that are used with salt as a carrier.

Forage dry matter intake (DMI) is a function of animal size, production status, and forage quality. Large animals eat more than small animals. High-producing animals generally consume more than less productive animals. Intake is highest for young forages low in neutral detergent fiber (NDF) and decreases as NDF increases with plant maturity. Legumes are lower in NDF than grasses and as their content increases allow livestock to consume more forage. As a plant matures, NDF increases but TDN and CP content decrease. Animal intake of pasture is also determined by plant height and density and rate of supplemental feeding. Pastures that are too short reduce intake since the animal cannot get much feed in each bite. Pastures that are too tall are usually over-mature with high NDF content. Feeding supplements on pasture tend to reduce forage intake.

Lack of adequate minerals in the diet shows up as poor animal performance and health problems rather than classic mineral deficiency symptoms. Because of this, supplemental salt and minerals are usually fed to livestock. However, when supplemental minerals are fed free-choice year-round, the expense can be high. The strategic feeding of appropriate minerals at selected times in the animal production cycle can reduce production costs and maintain healthy livestock. To do this, livestock producers need to know the risk of a mineral deficiency to the health of their livestock. This project was developed to determine the concentration of minerals in West Virginia pastures so that effective mineral supplements could be developed to ensure good animal health and production.

Methods

To determine the nutritive value of pastures in West Virginia, Extension agents and farmers sampled pastures across the state. Pasture samples were taken during the 1997 to 2001 growing seasons for nutrient analysis, with multi-county samples taken from 1999 to 2001. Faculty members (and their county) participating in this on-farm research were:

| Bobby Bailey (Mercer) | 1999 | | |
|----------------------------|------|------|------|
| Wayne Bennett (Putnam) | | 2000 | |
| Larry Campbell (Tucker) | | 2000 | 2001 |
| Debra Friend (Gilmer) | | 2000 | 2001 |
| Ronnie Helmondollar (Taylo | r) | | 2001 |

| Bruce Loyd (Lewis) | | 2000 | 2001 |
|---------------------------|------|------|------|
| Beth Massey (Monongalia) | | 2000 | 2001 |
| Roger Nestor (Barbour) | | 2000 | 2001 |
| Jennifer Ours (Upshur) | | 2000 | |
| Ed Rayburn (Monongalia) | 1999 | 2000 | 2001 |
| Dave Richmond | | | |
| (Raleigh, Summers) | 1999 | 2000 | 2001 |
| Ed Smolder (Jackson) | 1999 | 2000 | 2001 |
| Dave Snively (Randolph) | 1999 | 2000 | 2001 |
| William Shockey (Preston) | | 2000 | 2001 |
| Brad Smith (Grant) | | 2000 | |
| Rodney Wallbrown (Mason) | 1999 | 2000 | 2001 |
| Dave Workman (Hardy) | 1999 | 2000 | 2001 |
| Craig Yohn (Jefferson) | 1997 | 1998 | 1999 |

The 1999 growing season experienced one of the worst droughts in 50 years; 2000 started dry and then had above-average rainfall much of the summer, followed by a drier late summer and fall; 2001 was cool in the spring with adequate rainfall with spotty summer dry periods. In 1999, 119 samples were taken on 29 farms in 6 counties. In 2000, 165 samples were taken on 28 farms in 14 counties. In 2001, 134 samples were taken on 24 farms in 12 counties. In Jefferson County another 60 samples were taken on 2 pastures on each of 4 farms over 3 years from 1997 to 1999. This represents 105 site-years of data with samples taken monthly over the growing season, for 479 total samples. West Virginia Soil Conservation Agency grassland technicians provided another 128 samples. These samples were taken from demonstration farms administered by that agency. Forage samples were sent to commercial forage testing laboratories of fiber, protein, and mineral analysis. Samples were not analyzed for all nutrients due to changes in project protocol over the years.

Results and Discussion

The primary forage species in the pastures sampled were cool-season grasses and clovers typical to the Appalachian region. Fescue, unidentified grasses, bluegrass, orchardgrass, and clovers were the number one species in 95% of the pastures. Clover, orchardgrass fescue and bluegrass were the number two species on 94% of pastures. Clover, bluegrass, orchardgrass, fescue, and crabgrass were the number three species on 91% of pastures (Table 1). (Common and scientific names of plant species present in the sampled pastures are shown in Appendix Table 2.)

The majority of the pastures in this study (64%) were continuously grazed, as is the general custom for many livestock producers. This resulted in a range in sward height, fiber content, and estimated energy content of the pastures since there was less control of forage utilization by the livestock over the season.

Mean pasture condition and nutrient content are summarized in Table 2. Since a number of these nutrients do not have a normal distribution about the mean, the mean and standard deviation do not accurately estimate the probability of a pasture being within the nutritional needs of a given class of livestock.

Grazing management (continuous stocking vs. rotational stocking of paddocks) had an effect on pasture quality by affecting plant height and maturity. Continuously grazed pastures were shorter height than rotationally grazed pastures (5.7 vs. 9.8 inches respectively) and had lower ADF (31.5 vs. 32.8) and Ca (0.65 vs. 0.74) but were higher in ash (10.2 vs. 8.6) that resulted in higher micromineral content for Fe (480 vs. 253), Zn (37.8 vs. 28.6), Cu (11.7 vs. 9.4), Mn (122.8 vs. 86.7).

In a study evaluating the quality of rotationally grazed pastures in New York to Maine (Rayburn, 1994) it was found that pasture quality was higher than in these predominantly continuously grazed pastures in West Virginia. For the Northeast pastures, average values for ADF, NDF, NSC, and CP were 27, 47, 17, and 22 percent, respectively. These same or higher-quality average values were obtained in Jefferson County, WV (27, 46, 19, 22) where all pastures were managed under rotational grazing. (Lower value for NDF is higher pasture quality being less mature or higher in legumes.)

To identify the risk of pastures not meeting the needs of a given class of livestock, the percentile ranking (cumulative distribution) of nutrients in the sampled pastures is provided in Table 3 to Table 7. These tables identify the percent of samples that fall below a given nutritional concentration. The mineral nutrient requirements of beef cattle, dairy cattle, and sheep are given in Tables 8, 9, and 10.

To use the percentile ranking tables, identify the requirement for the livestock grazing on the pasture based on age and production of the animal. Using the table for the nutrient in question, find the value of the nutrient needed by the animal. Project across to the percentile rank column. This value is the percentage of pastures that do not meet this nutritional requirement. If the value of interest is not listed, interpolate between listed values that are above and below the value of interest. For practical purposes, when using the percentile ranking tables, rounding to the nearest 5% is reasonable.

Risk of Pasture Not Meeting Animals' Nutritional Needs

The different classes of livestock have different needs for nutrient supplementation on pasture because they have different nutrient requirements. In many cases, improving the pasture management can improve the pasture quality so that purchased supplements are not needed.

Lactating Cows

The lactating cow has the highest nutrient requirement at peak milk, just before breeding.

Table 11 shows this animal's requirement for several of the macronutrients based on the animal's size and level of peak milk production. As the cow's size goes up, her total nutrient requirement goes up and her feed intake increases.

Energy is the first limiting factor for the lactating cow on pasture. A cow producing 30 lbs milk at peak requires 62-65% total digestible nutrients (TDN) in the pasture (Table 11). At the 62% TDN requirement, 40% of pastures sampled in this study would not meet the TDN requirement (Table 5). At the 65% TDN requirement, about 60% of pastures would not have adequate TDN. However, spring pastures averaged 3 to 4 units higher in TDN in April and May, which provides additional energy to spring calving cows in early lactation.

This cow's requirement for CP (11.8-12.9%), P (0.23-0.24%), and Ca (0.35-0.38%) means that only 5-10% of pastures are deficient in CP (Table 3), 10-15% deficient in P (Table 6) and 5% deficient in Ca (Table 6). Many more pastures are deficient in energy for the high-producing beef cow at peak lactation than there are pastures deficient in protein, Ca or P. If cows with potential for high milk production are grazing energy-deficient pastures, they may not achieve their potential milk production, or they may lose excess body condition and not breed back in a timely manner.

Cows producing 20 lbs of milk at peak would find 20%-30% of pasture deficient in TDN and 5% of pastures deficient in CP, P, and Ca. At 10 lbs of peak milk cows would find only 10% of pasture deficient in TDN, 5% deficient in P, and 1% deficient in CP and Ca.

Cows with good genetics for milk production need high-quality pasture to achieve their potential. Pasture management that provides young, rapidly growing grass, high in TDN, achieves this goal. If management cannot economically provide the pasture quality needed, then selecting cattle with lower milk production genetics is an option.

Bred Replacement Heifers

The nutritional needs of bred replacement heifers are presented in Table 12. Pastures meet the needs of the early- and mid-gestation heifer for TDN, CP, Ca, and P 99% of time. Spring calving heifers will usually be on winter feed during the last trimester of gestation. Fall calving heifers on pasture in the last trimester of gestation will find pasture TDN below their needs about 30% of time, followed by P 10% and CP and Ca 5% of time.

Growing cattle

Under conventional management, performance of growing animals is often limited by lack of adequate forage in mid-summer. When pasture height drops below about 4 inches, intake will decrease. Of the pastures studied, 40% had heights less than or equal to 4 inches. Even though individual animal performance may drop at these higher grazing pressures, animal production per acre will increase as better utilization of the forage

occurs. However, too-close grazing is detrimental to animal production per acre and pasture health.

In a highly managed, rotational grazing system the manager may want to maximize the growth of one set of animals and use a second set of animals to follow up behind to clean up the pasture. This is called "first and second" or "top and bottom" grazing. The nutritional needs of growing cattle are presented in Tables 13, 14, and 15 for steers having different finish weights and heifers at different mature weights. If a growing animal has the genetic potential to finish at 1200 lbs and it weighs 780 lbs, and the manager wants the animal to gain at 2.0 lbs per day, the animal needs 60% TDN, 9.2% CP, 0.32% Ca, and 0.17% P content in the pasture (Table 14). Again, the first limiting factor for this animal is TDN. About 25% of pastures had TDN value not meeting the 60% TDN requirement (Table 5) while only 5% of pastures had values below the required CP (Table 3), Ca, or P (Table 6) levels.

Other Macronutrients

Magnesium (Mg) - The forage Mg content was at or below the recommended 0.20% of dry matter in 25% of the pastures sampled. Pasture Mg was lower than average in May and June pasture samples by 0.04%. The Mg content of pasture was above average when pastures had legumes listed as species one or species two, increasing Mg content by 0.05 and 0.02 % respectively. For lactating cows on lush spring pasture it is recommended that the Mg in the diet be raised to 0.25 to 0.30% to prevent the occurrence of grass tetany (NRC 1989, p. 28). Forage Mg content was lowest in the spring and increased into the summer and fall. Therefore, it is recommended that Mg supplements be provided during the spring grazing season since 80% of pastures were below the 0.30% Mg content recommended for safety.

Potassium (K) - Forage K content needed by livestock was adequate in over 99% of the pastures tested. Pastures in April and May are often high in K, causing an increased risk that Mg will not be absorbed and that grass tetany will occur. The risk of grass tetany can be decreased by not fertilizing pastures with nitrogen and K fertilizers in the spring and by using high Mg lime and P fertilizer as needed to ensure adequate plant Mg content and availability. Feeding Mg supplements in the spring is a standard recommended practice for decreasing the risk of grass tetany, as mentioned previously.

Sulfur (S) - The S content in pasture and the need by the animal is closely related to the sulfur-containing amino acids in forage and those made by the rumen bacteria. The recommended S content for beef cattle (0.15%) was adequate in 95% of pastures. The content of S was higher in plants having high CP content. The upper limit of S in the diet should not exceed 0.40%. Pasture containing high levels of S in conjunction with water high in S can cause reduced feed intake if the total S intake exceeds 0.40% of diet dry matter. These excess levels of S also reduce the absorption of Cu from the animal's diet.

Sodium (Na) - The Na content is deficient in 95% of pastures sampled. It can be supplemented readily by providing free-choice salt on pasture. However, if the water

source has high Na content this may limit intake of salt-containing minerals so that the livestock do not consume as much mineral as anticipated. It is a good management practice to weigh salt and minerals and record how much is being consumed per head per day to ensure that they are consuming an adequate amount.

Micronutrients

Iodine (I) - Pasture samples were not tested for I. Deficiency of I may occur when feeding recommended level of I if as much as 25% of the ration is strongly goitrogenic crops such as the brassicas kale, rape, or turnips. When feeding these crops it is recommended that the dietary iodine be 0.5 ppm for growing and non-lactating cows and 1.0 ppm for late-gestation and lactating cows (NRC 1988).

Selenium (Se) - Pasture samples were not tested for Se. Supplementation of Se is recommended in West Virginia. Deficiency in Se is most likely to occur when forage is grown on acidic soils. It is legal to supplement Se to beef cattle at 0.30 mg/kg of total diet up to 3 mg/head/day (NRC Beef Update 2000, p.68). Forage samples were not analyzed for I or Se.

Cobalt (Co) - Pasture samples were not tested for Co. Supplementation for Co is recommended.

Manganese (Mn) - Pasture content of Mn was sufficient in over 95% of pastures tested.

Iron (Fe) - The content of Fe was sufficient in 99% of pastures to meet cattle's nutrient requirement. Almost 10% of pastures exceed the recommended 1000-ppm of Fe in the DM, which is considered the maximum tolerable allowance of Fe. When Fe exceeds 400 ppm, which occurred in 30% of pastures, it can reduce the availability of Cu in the diet. It is recommended that Fe not be supplemented to cattle on pasture.

Molybdenum (Mo) - There is no stated requirement for Mo for grazing ruminants.

Copper (Cu) - The Cu content of pasture forage was below the 10 ppm recommended for beef cattle in about 40% of pastures. The Agricultural Research Council (Europe's counterpart to NRC) recommends up to 20 ppm Cu in cattle diets. Supplementation with Cu was shown to reduce the risk of Cu deficiency in beef cattle (APHIS, 2000a).

Cattle breeds differ in their need for Cu with Simmental and Charolais cattle requiring higher levels of Cu than Angus (NRC 2000). Among dairy breeds, Jerseys are more efficient at Cu retention than Holsteins (NRC 2001).

Dietary S and Mo inhibit the absorption of Cu. In the northeast, high levels of S in the forage is a primary contributing factor to lower levels of Cu absorption since Mo levels are not excessively high. The forage content of S and Mo are also positively correlated, meaning that forages high in S tend to be high in Mo (Table 16). Across the United

States 21% of tested water exceeded the sulfate content considered safe for cattle (APHIS, 2000 b).

Zinc (Zn) – Pastures were deficient in Zn in 50% of pasture samples analyzed. Pastures sampled in August and September were higher in Zn than average. Supplementation with Zn was shown to reduce the risk of Zn deficiency in beef cattle (APHIS, 2000c).

Mineral Supplement calculator

As a part of this project a mineral supplement calculator spreadsheet was developed. This spreadsheet allows the user to enter the animal's size and expected pasture DMI and daily mineral intake, the mineral requirement of the animal, and the expected mineral concentration in pasture. The examples use pasture mineral values at the 10th percentile level. This is the level that will ensure that cattle on 90% of the sampled pastures would receive adequate mineral in their diet from the combined pasture and supplement. Based on a manager's risk aversion, a different percentile level can be used.

The spreadsheet then calculates the concentration of mineral needed in the mineral supplement to provide adequate supplementation to the pasture. When having supplements mixed it is important to ensure that each mineral source used in the mix is adequately available to the animal. These calculations do not account for the interactions of minerals contained in drinking water, the pasture, or other supplemental feeds.

When the goal is to minimize the cost of mineral supplementation, use a trace mineral salt program year-round that provides adequate levels of Co (13-16 ppm), Cu (396-480), I (66-80 ppm), Se (26-32 ppm), and Zn (1320-1600). The first number represents the needs of a 660-lb calf eating 2.5% body weight DMI and 2 oz. of supplement. The second number represents a 1200-lb cow consuming 2.5% body weight DMI and 3 oz. of supplement. These values are for providing 90% of pastures adequate levels of the microminerals measured in this study. The Se levels are for supplying 0.2 ppm of the total ration, which is less than the legal allowance of 0.3 ppm total ration, to provide a safety factor if the animals eat more supplement than expected. Levels for Co and I are for the basic NRC requirements, all of which are provided by the supplement. Given the high S and Fe content in West Virginia's pastures it is recommended that no Fe be added to the trace mineral supplement, to ensure adequate Cu absorption in cattle.

For seasonal needs this trace mineral salt package can, where necessary, be supplemented using dicalcium or monocalcium phosphate to provide Ca and P. For grass tetany protection in the spring, this trace mineral salt package can be supplemented with magnesium oxide and a palatability enhancer such as corn meal or dry molasses to ensure adequate intake.

Conclusions

Most pastures in West Virginia are adequate for average-producing cattle used in a cow/calf production system, the primary pasture use in the state. Where animals of above-average production ability are desired, above-average management is needed to provide adequate forage quantity and quality over the grazing season. This management needs to include proper stocking rate, the use of a buffer in the grazing system (aftermath grazing or warm-season grasses), and the use of rotational grazing with proper control of pre- and post-grazing pasture height.

Liming, fertilization, seeding, and grazing management determine forage species present in a pasture and the forage nutrient content. Compared to other pastures, pastures having legumes as species number one or two were often higher in TDN, CP, Ca, P, Cu, Mg, Mn, Mo; and Lower in NDF than those having grass or weeds as species number one. Legume management in pasture will increase forage quality and can provide as much animal gain per acre of yearling cattle as the same grass fertilized with 200 pounds of nitrogen fertilizer (Blazer et al, 1969).

Energy is the first limiting nutrient for animals grazing pastures. It was demonstrated that in West Virginia the energy value of pastures is increased (ADF and NDF were decreased) through the use of well managed rotational grazing.

Pasture content of Ca and P may be inadequate for high-producing beef cows at peak lactation and fast-growing calves in 5-15% of pastures. Pasture mineral content of Mg continues to justify the use of Mg supplements to reduce the risk of animal death due to grass tetany in the spring.

The microminerals Co, Cu, I, Se, and Zn are needed in trace mineral supplements. With the high content of Fe in pasture forage samples it is recommended that Fe not be used in trace mineral supplements. A good trace mineral salt can then be supplemented strategically with Ca, P, and Mg to meet the seasonal needs of all classes of grazing animals.

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| Species 1 | Count Pe | ercent | Species 2 | Count Per | rcent | Species 3 | Count | Percent |
|----------------|----------|--------|--------------|-----------|-------|--------------|-------|---------|
| Fescue | 171 | 42 | Clover | 115 | 37 | Clover | 106 | 42 |
| Grass | 106 | 26 | Orchardgrass | 111 | 36 | Bluegrass | 45 | 18 |
| Bluegrass | 46 | 11 | Fescue | 39 | 13 | Orchardgrass | 42 | 17 |
| Orchardgrass | 34 | 8 | Bluegrass | 25 | 8 | Fescue | 27 | 11 |
| Clover | 32 | 8 | Timothy | 7 | 2 | Crabgrass | 8 | 3 |
| Timothy | 6 | 1 | Crabgrass | 6 | 2 | Grass | 6 | 2 |
| Crabgrass | 5 | 1 | Weeds | 4 | 1 | Velvet grass | 6 | 2 |
| Quackgrass | 2 | <1 | Grass | 3 | 1 | Sweet Vernal | 5 | 2 |
| Sweet Vernal | 2 | <1 | Broomsedge | 2 | 1 | Timothy | 5 | 2 |
| Weeds | 2 | <1 | | | | Weeds | 2 | 1 |
| Broomsedge | 1 | <1 | | | | Broomsedge | 1 | <1 |
| Dandelions | 1 | <1 | | | | Ragweed | 1 | <1 |
| Ryegrass | 1 | <1 | | | | | | |
| Switchgrass | 1 | <1 | | | | | | |
| Total reported | J 410 | 100 | 1 | 312 | 100 | | 254 | 100 |

Table 1. Frequency of pasture species being reported as ranked as number one, two, or three in the pasture sampled.

| ltem | Count | Mean | SD | Min | Max |
|---------------|------------|--------------|------------|-------|--------|
| | | Descripti | on | | |
| Height | 249 | 6.2 | 4.9 | 0.0 | 28.0 |
| | Fiber, Car | rbohydrates | , Fats and | Ash | |
| ADF | 401 | 32.07 | 5.45 | 18.60 | 49.60 |
| NDF | 401 | 54.42 | 8.38 | 28.00 | 77.90 |
| NSC | 398 | 15.86 | 5.42 | 0.23 | 31.70 |
| LIG | 280 | 5.14 | 1.34 | 0.00 | 9.22 |
| Fat | 135 | 4.06 | 0.83 | 2.28 | 6.44 |
| Ash | 280 | 9.30 | 1.73 | 0.00 | 14.44 |
| | | Protein (| %) | | |
| СР | 566 | 18.4 | 4.8 | 4.8 | 34.6 |
| SP (% of CP) | 281 | 36.3 | 7.7 | 20.0 | 57.1 |
| DP (% of CP) | 280 | 66.6 | 6.0 | 39.2 | 78.0 |
| | Calculated | d Energy an | d Feed Va | lues | |
| TDN % | 401 | 63.2 | 5.6 | 31.0 | 75.9 |
| NEM meg. cal. | 384 | 0.64 | 0.10 | 0.00 | 0.83 |
| NEG meg. cal. | 399 | 0.37 | 0.08 | 0.11 | 0.54 |
| Horse TDN % | 195 | 57.8 | 7.6 | 43.4 | 82.0 |
| RFV | 399 | 113 | 26 | 65 | 243 |
| | Μ | lacro Minera | als (%) | | |
| Ca | 606 | 0.68 | 0.22 | 0.21 | 1.94 |
| Р | 607 | 0.34 | 0.09 | 0.10 | 0.59 |
| Mg | 607 | 0.25 | 0.06 | 0.11 | 0.58 |
| К | 607 | 2.46 | 0.58 | 0.33 | 4.50 |
| S | 440 | 0.24 | 0.06 | 0.05 | 0.48 |
| | Mi | cro Minerals | s (ppm) | | |
| AI | 167 | 254 | 395 | 10 | 4172 |
| Cu | 589 | 10.9 | 4.4 | 2.0 | 55.0 |
| Fe | 589 | 403 | 465 | 45 | 4042 |
| Mn | 589 | 110 | 67 | 0 | 562 |
| Мо | 240 | 1.08 | 0.73 | 0.13 | 3.96 |
| Na | 585 | 0.24 | 5.00 | 0.00 | 121.00 |
| Zn | 588 | 34.7 | 30.8 | 11.0 | 384.8 |

Table 2. Mean, standard deviation (SD), minimum (Min) and maximum (Max) values of pasture measurements and sample analysis.

| Percentile | Height | CP | SP | DP |
|------------|--------|------|------|------|
| 99 | 24.0 | 31.3 | 55.6 | 75.0 |
| 95 | 18.0 | 27.2 | 49.2 | 73.0 |
| 90 | 12.0 | 25.0 | 44.9 | 71.7 |
| 85 | 10.0 | 23.9 | 42.4 | 70.6 |
| 80 | 8.6 | 22.6 | 40.6 | 69.3 |
| 75 | 7.5 | 21.9 | 39.2 | 68.9 |
| 70 | 6.5 | 21.2 | 37.9 | 68.0 |
| 65 | 6.0 | 20.5 | 36.9 | 67.3 |
| 60 | 6.0 | 20.0 | 36.0 | 66.9 |
| 55 | 6.0 | 19.2 | 34.6 | 65.9 |
| 50 | 5.0 | 18.6 | 34.0 | 65.1 |
| 45 | 4.0 | 17.8 | 33.0 | 64.9 |
| 40 | 4.0 | 17.4 | 32.2 | 64.5 |
| 35 | 3.5 | 16.7 | 31.1 | 64.0 |
| 30 | 3.0 | 15.7 | 30.2 | 62.7 |
| 25 | 3.0 | 15.3 | 29.2 | 61.9 |
| 20 | 2.4 | 14.5 | 28.0 | 61.0 |
| 15 | 2.0 | 13.5 | 27.2 | 59.4 |
| 10 | 2.0 | 12.7 | 26.1 | 56.8 |
| 5 | 1.5 | 11.6 | 23.8 | 54.5 |
| 1 | 0.5 | 8.8 | 20.0 | 51.2 |

Table 3. Percentile ranking of pastures based on pasture ruler height, crude protein (CP), solubility of crude protein (SP), and degradability of crude protein (DP).

| Percentile | ADF | NDF | LIG | NSC | Fat | Ash |
|------------|------|------|-----|------|-----|------|
| 99 | 43.4 | 71.0 | 9.2 | 28.4 | 6.4 | 14.4 |
| 95 | 38.9 | 64.3 | 8.1 | 25.0 | 5.6 | 12.9 |
| 90 | 36.3 | 61.5 | 7.3 | 23.6 | 5.3 | 12.1 |
| 85 | 35.4 | 59.4 | 6.9 | 22.1 | 5.0 | 11.5 |
| 80 | 34.5 | 58.1 | 6.5 | 21.2 | 4.8 | 11.2 |
| 75 | 33.8 | 56.9 | 6.2 | 20.6 | 4.6 | 10.9 |
| 70 | 33.2 | 56.3 | 5.9 | 19.8 | 4.4 | 10.5 |
| 65 | 32.7 | 55.4 | 5.6 | 19.1 | 4.3 | 10.4 |
| 60 | 32.2 | 54.4 | 5.5 | 18.4 | 4.2 | 10.2 |
| 55 | 31.6 | 53.3 | 5.3 | 17.8 | 4.0 | 10.0 |
| 50 | 30.9 | 52.1 | 5.1 | 17.1 | 4.0 | 9.8 |
| 45 | 30.4 | 51.3 | 4.9 | 16.5 | 3.9 | 9.6 |
| 40 | 29.8 | 50.5 | 4.8 | 15.8 | 3.8 | 9.4 |
| 35 | 29.0 | 49.8 | 4.6 | 14.9 | 3.6 | 9.3 |
| 30 | 28.0 | 48.6 | 4.5 | 14.2 | 3.5 | 9.0 |
| 25 | 27.3 | 47.5 | 4.4 | 13.3 | 3.4 | 8.8 |
| 20 | 26.7 | 46.5 | 4.2 | 12.7 | 3.4 | 8.6 |
| 15 | 26.0 | 45.1 | 3.9 | 11.5 | 3.2 | 8.3 |
| 10 | 24.8 | 43.6 | 3.6 | 10.8 | 3.1 | 8.0 |
| 5 | 23.3 | 39.7 | 3.3 | 9.4 | 2.8 | 7.5 |
| 1 | 19.7 | 33.3 | 2.5 | 4.3 | 2.4 | 5.8 |

Table 4. Percentile ranking of pastures based on acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin (LIG), non-structural carbohydrate (NSC), fat and ash content of pastures.

| Percentile | TDN | NEL | NEM | NEG | RFV |
|------------|------|------|------|------|-----|
| 99 | 74.0 | 0.76 | 0.80 | 0.52 | 207 |
| 95 | 72.3 | 0.71 | 0.77 | 0.50 | 165 |
| 90 | 71.0 | 0.70 | 0.76 | 0.48 | 149 |
| 85 | 69.4 | 0.69 | 0.74 | 0.46 | 139 |
| 80 | 68.0 | 0.68 | 0.72 | 0.44 | 135 |
| 75 | 67.0 | 0.68 | 0.71 | 0.43 | 132 |
| 70 | 66.5 | 0.67 | 0.69 | 0.42 | 127 |
| 65 | 66.0 | 0.66 | 0.69 | 0.42 | 123 |
| 60 | 65.2 | 0.64 | 0.68 | 0.41 | 121 |
| 55 | 64.9 | 0.63 | 0.66 | 0.40 | 118 |
| 50 | 64.1 | 0.62 | 0.65 | 0.38 | 115 |
| 45 | 63.0 | 0.61 | 0.64 | 0.37 | 112 |
| 40 | 62.2 | 0.60 | 0.61 | 0.35 | 111 |
| 35 | 61.9 | 0.59 | 0.60 | 0.34 | 107 |
| 30 | 61.0 | 0.59 | 0.59 | 0.33 | 104 |
| 25 | 60.5 | 0.58 | 0.58 | 0.32 | 102 |
| 20 | 59.4 | 0.57 | 0.57 | 0.31 | 99 |
| 15 | 57.9 | 0.55 | 0.54 | 0.28 | 96 |
| 10 | 56.7 | 0.53 | 0.52 | 0.26 | 93 |
| 5 | 54.6 | 0.49 | 0.48 | 0.23 | 87 |
| 1 | 52.0 | 0.43 | 0.44 | 0.19 | 72 |

Table 5. Percentile ranking of pastures based on estimated total digestible nutrients (TDN), net energy lactation (NEL), net energy maintenance (NEM), net energy gain (NEG) and relative feed value (RFV) of pastures sampled.

| Percentile | Ca | Р | Mg | K | Na | S |
|------------|------|------|------|------|-------|-------|
| 99 | 1.47 | 0.57 | 0.38 | 3.91 | 0.132 | 0.400 |
| 95 | 1.08 | 0.51 | 0.34 | 3.54 | 0.050 | 0.350 |
| 90 | 0.96 | 0.47 | 0.32 | 3.28 | 0.040 | 0.340 |
| 85 | 0.88 | 0.45 | 0.30 | 3.16 | 0.030 | 0.320 |
| 80 | 0.83 | 0.43 | 0.29 | 3.06 | 0.030 | 0.304 |
| 75 | 0.78 | 0.41 | 0.28 | 2.94 | 0.024 | 0.290 |
| 70 | 0.76 | 0.39 | 0.27 | 2.84 | 0.020 | 0.290 |
| 65 | 0.71 | 0.37 | 0.27 | 2.74 | 0.020 | 0.280 |
| 60 | 0.68 | 0.36 | 0.26 | 2.68 | 0.020 | 0.270 |
| 55 | 0.66 | 0.35 | 0.25 | 2.60 | 0.017 | 0.260 |
| 50 | 0.64 | 0.33 | 0.24 | 2.53 | 0.013 | 0.260 |
| 45 | 0.61 | 0.33 | 0.23 | 2.47 | 0.011 | 0.250 |
| 40 | 0.59 | 0.31 | 0.22 | 2.40 | 0.010 | 0.250 |
| 35 | 0.57 | 0.30 | 0.22 | 2.33 | 0.010 | 0.240 |
| 30 | 0.55 | 0.29 | 0.21 | 2.27 | 0.010 | 0.230 |
| 25 | 0.53 | 0.27 | 0.20 | 2.14 | 0.010 | 0.220 |
| 20 | 0.50 | 0.26 | 0.19 | 2.04 | 0.010 | 0.210 |
| 15 | 0.48 | 0.24 | 0.18 | 1.93 | 0.010 | 0.200 |
| 10 | 0.44 | 0.23 | 0.17 | 1.76 | 0.009 | 0.180 |
| 5 | 0.37 | 0.20 | 0.16 | 1.47 | 0.006 | 0.150 |
| 1 | 0.28 | 0.15 | 0.12 | 1.01 | 0.003 | 0.101 |

Table 6. Percentile ranking of pastures based on major mineral content for calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), and sulfur (S).

| Percentile | Fe | Zn | Cu | Mn | Мо | Cu Absorption |
|------------|------|-----|------|-----|------|------------------|
| 99 | 3030 | 223 | 24.9 | 377 | 3.58 | 0.054 |
| 95 | 1386 | 62 | 19.0 | 271 | 2.58 | 0.051 |
| 90 | 873 | 51 | 15.9 | 204 | 2.14 | 0.050 |
| 85 | 686 | 45 | 14.9 | 181 | 2.00 | 0.048 |
| 80 | 582 | 41 | 14.0 | 164 | 1.82 | 0.047 |
| 75 | 506 | 38 | 13.2 | 147 | 1.60 | 0.046 |
| 70 | 442 | 36 | 13.0 | 135 | 1.56 | 0.046 |
| 65 | 393 | 35 | 12.0 | 121 | 1.42 | 0.045 |
| 60 | 354 | 33 | 11.7 | 112 | 1.30 | 0.044 |
| 55 | 315 | 32 | 11.0 | 105 | 1.24 | 0.043 |
| 50 | 281 | 31 | 10.9 | 98 | 1.11 | 0.043 |
| 45 | 246 | 29 | 10.2 | 92 | 1.00 | 0.042 |
| 40 | 225 | 28 | 10.0 | 88 | 0.89 | 0.041 |
| 35 | 209 | 26 | 9.8 | 82 | 0.84 | 0.040 |
| 30 | 189 | 25 | 9.0 | 77 | 0.73 | 0.039 |
| 25 | 174 | 24 | 8.9 | 69 | 0.64 | 0.039 |
| 20 | 151 | 23 | 8.1 | 63 | 0.57 | 0.037 |
| 15 | 137 | 21 | 8.0 | 58 | 0.50 | 0.036 |
| 10 | 123 | 20 | 7.0 | 52 | 0.47 | 0.035 |
| 5 | 103 | 18 | 6.3 | 46 | 0.34 | 0.033 |
| 1 | 64 | 13 | 5.0 | 35 | 0.18 | 0.030 |

Table 7. Percentile ranking of pastures based on micro mineral content iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), and copper absorption.

| Mineral | Suggested Value | Range | Maximum Tolerable |
|-----------------------|------------------|-----------|-------------------|
| | | | Level |
| Ca, % [†] | 0.16-0.58 (0.32) | | 2 |
| Co, ppm | 0.10 | 0.07-0.11 | 5 |
| Cu, ppm | 10 | 4-10 | 115 |
| I, ppm | 0.5 | 0.20-2.0 | 50 |
| Fe, ppm | 50 | 50-100 | 1000 |
| Mg, % | 0.20 | 0.05-0.25 | 0.40 |
| Mn, ppm | 40 | 20-50 | 1000 |
| Mo, ppm | | | 6 |
| P, % [†] | 0.17-0.39 (0.21) | | 1 |
| K, % | 0.70 | 0.5-0.7 | 3 |
| Se, ppm ^{††} | 0.10 | 0.05-0.30 | 2 |
| Na, % | 0.10 | 0.06-0.10 | 10 |
| Cl, % | | | |
| S, % | 0.15 | 0.08-0.15 | 0.40 |
| Zn, ppm | 30 | 20-40 | 500 |

Table 8. Suggested mineral requirements of beef cattle with value for Ca and P in parenthesis calculated for 1000-lb cow making 20 lbs milk. (Adapted from <u>Nutrient Requirements of Beef Cattle</u>, National Research Council, 2000.)

[†] Depending on age and production status.

†† It is legal to supplement Se to beef cattle at the level of 0.30 mg/kg of the total diet up to 3 mg/head/day (NRC Beef Update 2000, p.68).

| Table 9. Suggested mineral requirements of dairy cattle with values in parenthesis for a |
|--|
| 1200-lb cow producing 80 lbs of milk. (Adapted from the Nutrient Requirements of |
| Dairy Cattle, National Research Council, 2001.) |

| Mineral | Suggested Value | Range | Maximum Tolerable |
|--------------------|------------------|-----------|-------------------|
| | | | Level |
| Ca, % [†] | 0.29-0.77 (0.64) | | 2 |
| Co, ppm | 0.10 | 0.07-0.11 | 5 |
| Cu, ppm | 10 | 4-10 | 115 |
| I, ppm | 0.25-0.60 | 0.20-2.0 | 50 |
| Fe, ppm | 50 | 50-100 | 1000 |
| Mg, % | 0.16-0.25 | 0.05-0.25 | 0.40 |
| Mn, ppm | 40 | 20-50 | 1000 |
| Mo, ppm | | | 6 |
| P, % [†] | 0.19-0.48 (0.41) | | 1 |
| K, % | 0.65-1.00 | 0.5-0.7 | 3 |
| Se, ppm | 0.30 | 0.05-0.30 | 2 |
| Na, % | 0.10-0.18 | 0.06-0.10 | 10 |
| Cl, % | 0.20-0.25 | | |
| S, % | 0.16-0.25 | 0.08-0.15 | 0.40 |
| Zn, ppm | 40 | 20-40 | 500 |

† Depending on age and production status.

| Mineral | Suggested Value | Maximum Tolerable Level |
|--------------------|-----------------|-------------------------|
| Ca, % [†] | 0.20-0.82 | 2 |
| Co, ppm | 0.10-0.20 | 10 |
| Cu, ppm | 7-11 | 25 |
| I, ppm | 0.10-0.80 | 50 |
| Fe, ppm | 30-50 | 500 |
| Fl, ppm | | 60-150 |
| Mg, % | 0.12-0.18 | 0.40 |
| Mn, ppm | 20-40 | 1000 |
| Mo, ppm | 0.5 | 10 |
| P, % [†] | 0.16-0.38 | 1 |
| K, % | 0.50-80 | 3 |
| Se, ppm | 0.10-0.20 | 2 |
| Na, % | 0.09-0.18 | 10 |
| Cl, % | | |
| S, % | 0.14-0.26 | 0.40 |
| Zn, ppm | 20-33 | 750 |

Table 10. Suggested mineral requirements of sheep. (Adapted from the <u>Nutrient</u> <u>Requirements of Sheep</u>, National Research Council, 1985.)

† depending on age and production status

| | | Peak Milk lbs | | |
|------------------------------|------|---------------|------|------|
| | 10 | 1 | 20 | 30 |
| 1000 11. | 10 | | 20 | 30 |
| 1000-16 0 | JOW | | | |
| Dry Matter Intake lbs | 22 | | 25 | 28 |
| Dry Matter Intake %BW | 2.20 |) | 2.50 | 2.80 |
| Total Digestible Nutrients % | 57 | | 61 | 65 |
| Crude Protein % | 9.1 | | 11.1 | 12.9 |
| Calcium % | 0.23 | 5 | 0.32 | 0.38 |
| Phosphorus % | 0.1 | 7 | 0.21 | 0.24 |
| 1200-lb (| Cow | | | |
| Dry Matter Intake lbs | 25 | | 28 | 31 |
| Dry Matter Intake %BW | 2.08 | 3 | 2.33 | 2.58 |
| Total Digestible Nutrients % | 56 | | 60 | 63 |
| Crude Protein % | 8.8 | | 10.7 | 12.2 |
| Calcium % | 0.23 | 5 | 0.31 | 0.36 |
| Phosphorus % | 0.1 | 7 | 0.21 | 0.23 |
| 1400-lb (| Cow | | | |
| Dry Matter Intake lbs | 28 | | 31 | 33 |
| Dry Matter Intake %BW | 2.00 |) | 2.21 | 2.36 |
| Total Digestible Nutrients % | 56 | | 59 | 62 |
| Crude Protein % | 8.6 | | 10.3 | 11.8 |
| Calcium % | 0.2: | 5 | 0.30 | 0.35 |
| Phosphorus % | 0.1 | 7 | 0.20 | 0.23 |

Table 11. Dry matter intake, total digestible nutrient, crude protein, calcium, and phosphorus requirements of beef cows at three weights and three levels of peak milk production prior to rebreeding (adapted from NRC 2000).

Table 12. Dry matter intake and ration content of total digestible nutrient, crude protein, calcium, and phosphorus requirements of bred heifers in mid and last trimester of gestation (adapted from NRC 2000).

| Ration Component | Mid Gestation | Last Trimester |
|-----------------------------|---------------|----------------|
| Dry Matter Intake %BW | 1.7 | 2.1 |
| Total Digestible Nutrient % | 50 | 61 |
| Crude Protein % | 7.2 | 10.0 |
| Calcium % | 0.21 | 0.32 |
| Phosphorus % | 0.16 | 0.23 |

| Body Wt. | TDN % | 5 DMI | DMI | ADG | % CP | % Ca % | P % |
|----------|-------|-------------|--------------|----------|------------|--------|------|
| Lbs. | | Lbs. | % B.Wt. | | | | |
| | 1000 | Lbs. Finish | ned Steer of | r Mature | Heifer Wei | ght | |
| 550 | 50 | 15.2 | 2.76 | 0.64 | 7.1 | 0.21 | 0.13 |
| 550 | 60 | 16.1 | 2.93 | 1.77 | 9.8 | 0.36 | 0.19 |
| 550 | 70 | 15.7 | 2.85 | 2.68 | 12.4 | 0.49 | 0.24 |
| 550 | 80 | 14.8 | 2.69 | 3.34 | 14.9 | 0.61 | 0.29 |
| 600 | 50 | 16.2 | 2.70 | 0.64 | 7.0 | 0.21 | 0.13 |
| 600 | 60 | 17.2 | 2.87 | 1.77 | 9.5 | 0.34 | 0.18 |
| 600 | 70 | 16.8 | 2.80 | 2.68 | 11.9 | 0.45 | 0.23 |
| 600 | 80 | 15.8 | 2.63 | 3.34 | 14.3 | 0.56 | 0.27 |
| 650 | 50 | 17.3 | 2.66 | 0.64 | 6.9 | 0.20 | 0.12 |
| 650 | 60 | 18.2 | 2.80 | 1.77 | 9.2 | 0.32 | 0.17 |
| 650 | 70 | 17.8 | 2.74 | 2.68 | 11.5 | 0.42 | 0.21 |
| 650 | 80 | 16.8 | 2.58 | 3.34 | 13.7 | 0.52 | 0.26 |
| 700 | 50 | 18.2 | 2.60 | 0.64 | 6.8 | 0.19 | 0.12 |
| 700 | 60 | 19.3 | 2.76 | 1.77 | 8.8 | 0.30 | 0.16 |
| 700 | 70 | 18.8 | 2.69 | 2.68 | 10.9 | 0.39 | 0.20 |
| 700 | 80 | 17.8 | 2.54 | 3.34 | 13.0 | 0.48 | 0.24 |
| 750 | 50 | 19.2 | 2.56 | 0.64 | 6.7 | 0.19 | 0.12 |
| 750 | 60 | 20.3 | 2.71 | 1.77 | 8.5 | 0.28 | 0.16 |
| 750 | 70 | 19.8 | 2.64 | 2.68 | 10.3 | 0.37 | 0.19 |
| 750 | 80 | 18.7 | 2.49 | 3.34 | 12.2 | 0.45 | 0.23 |
| 800 | 50 | 20.2 | 2.53 | 0.64 | 6.5 | 0.19 | 0.12 |
| 800 | 60 | 21.3 | 2.66 | 1.77 | 8.1 | 0.27 | 0.15 |
| 800 | 70 | 20.8 | 2.60 | 2.68 | 9.8 | 0.34 | 0.18 |
| 800 | 80 | 19.6 | 2.45 | 3.34 | 11.5 | 0.42 | 0.22 |

Table 13. Total digestible nutrient (TDN), dry matter intake (DMI), average daily gain (ADG), crude protein (CP), calcium (Ca), and phosphorus (P) requirements of a steer that will finish at 1000 lbs or heifer maturing at 1000 lbs (adapted from NRC 2000).

| Body Wt. Lbs. | TDN 9 | % DMI | DMI | ADG | % CP 9 | 6 Ca % | P % |
|---------------|-------|---------------|--------------|----------|------------|--------|------|
| | | Lbs. | % B.Wt. | | | | |
| | 1200 |) Lbs. Finish | ned Steer of | r Mature | Heifer Wei | ght | |
| 660 | 50 | 17.5 | 2.65 | 0.72 | 7.3 | 0.22 | 0.13 |
| 660 | 60 | 18.4 | 2.79 | 2.00 | 10.2 | 0.36 | 0.19 |
| 660 | 70 | 18.0 | 2.73 | 3.04 | 13.0 | 0.49 | 0.24 |
| 660 | 80 | 17.0 | 2.58 | 3.78 | 15.8 | 0.61 | 0.29 |
| 720 | 50 | 18.6 | 2.58 | 0.72 | 7.1 | 0.21 | 0.13 |
| 720 | 60 | 19.7 | 2.74 | 2.00 | 9.7 | 0.34 | 0.18 |
| 720 | 70 | 19.2 | 2.67 | 3.04 | 12.2 | 0.45 | 0.23 |
| 720 | 80 | 18.2 | 2.53 | 3.78 | 14.6 | 0.56 | 0.27 |
| 780 | 50 | 19.8 | 2.54 | 0.72 | 6.9 | 0.20 | 0.13 |
| 780 | 60 | 20.9 | 2.68 | 2.00 | 9.2 | 0.32 | 0.17 |
| 780 | 70 | 20.4 | 2.62 | 3.04 | 11.4 | 0.42 | 0.21 |
| 780 | 80 | 19.3 | 2.47 | 3.78 | 13.6 | 0.52 | 0.26 |
| 840 | 50 | 20.9 | 2.49 | 0.72 | 6.8 | 0.20 | 0.13 |
| 840 | 60 | 22.1 | 2.63 | 2.00 | 8.8 | 0.30 | 0.16 |
| 840 | 70 | 21.6 | 2.57 | 3.04 | 10.8 | 0.39 | 0.20 |
| 840 | 80 | 20.4 | 2.43 | 3.78 | 12.8 | 0.48 | 0.24 |
| 900 | 50 | 22.0 | 2.44 | 0.72 | 6.6 | 0.19 | 0.12 |
| 900 | 60 | 23.3 | 2.59 | 2.00 | 8.4 | 0.28 | 0.16 |
| 900 | 70 | 22.7 | 2.52 | 3.04 | 10.2 | 0.37 | 0.19 |
| 900 | 80 | 21.5 | 2.39 | 3.78 | 12.0 | 0.44 | 0.23 |
| 960 | 50 | 23.1 | 2.41 | 0.72 | 6.5 | 0.19 | 0.12 |
| 960 | 60 | 24.4 | 2.54 | 2.00 | 8.1 | 0.27 | 0.15 |
| 960 | 70 | 23.9 | 2.49 | 3.04 | 9.7 | 0.34 | 0.19 |
| 960 | 80 | 22.5 | 2.34 | 3.78 | 11.3 | 0.41 | 0.22 |

Table 14. Total digestible nutrient (TDN), dry matter intake (DMI), average daily gain (ADG), crude protein (CP), calcium (Ca), and phosphorus (P) requirements of a steer that will finish at 1200 lbs or heifer maturing at 1200 lbs (adapted from NRC 2000).

| Body Wt. Lbs. | TDN 9 | % DMI | DMI | ADG | CP % | Ca % | P % |
|---------------|-------|---------------|--------------|----------|-------------|------|------|
| | | Lbs. | %B.Wt. | % | | | |
| | 1400 |) Lbs. Finisł | ned Steer or | Mature H | leifer Weig | ht | |
| 770 | 50 | 19.6 | 2.55 | 0.80 | 7.3 | 0.22 | 0.13 |
| 770 | 60 | 20.7 | 2.69 | 2.20 | 10.1 | 0.36 | 0.19 |
| 770 | 70 | 20.2 | 2.62 | 3.38 | 12.9 | 0.49 | 0.24 |
| 770 | 80 | 19.1 | 2.48 | 4.20 | 15.6 | 0.61 | 0.29 |
| 840 | 50 | 20.9 | 2.49 | 0.80 | 7.1 | 0.21 | 0.13 |
| 840 | 60 | 22.1 | 2.63 | 2.20 | 9.6 | 0.34 | 0.18 |
| 840 | 70 | 21.6 | 2.57 | 3.38 | 12.1 | 0.45 | 0.23 |
| 840 | 80 | 20.4 | 2.43 | 4.20 | 14.5 | 0.56 | 0.27 |
| 910 | 50 | 22.2 | 2.44 | 0.80 | 6.9 | 0.21 | 0.13 |
| 910 | 60 | 23.5 | 2.58 | 2.20 | 9.1 | 0.32 | 0.17 |
| 910 | 70 | 22.9 | 2.52 | 3.38 | 11.3 | 0.42 | 0.22 |
| 910 | 80 | 21.6 | 2.37 | 4.20 | 13.5 | 0.51 | 0.26 |
| 980 | 50 | 23.5 | 2.40 | 0.80 | 6.7 | 0.20 | 0.13 |
| 980 | 60 | 24.8 | 2.53 | 2.20 | 8.7 | 0.30 | 0.17 |
| 980 | 70 | 24.2 | 2.47 | 3.38 | 10.7 | 0.39 | 0.20 |
| 980 | 80 | 22.9 | 2.34 | 4.20 | 12.6 | 0.47 | 0.24 |
| 1050 | 50 | 24.7 | 2.35 | 0.80 | 6.6 | 0.20 | 0.13 |
| 1050 | 60 | 26.1 | 2.49 | 2.20 | 8.3 | 0.28 | 0.16 |
| 1050 | 70 | 25.5 | 2.43 | 3.38 | 10.1 | 0.37 | 0.20 |
| 1050 | 80 | 24.1 | 2.30 | 4.20 | 11.9 | 0.44 | 0.23 |
| 1120 | 50 | 25.9 | 2.31 | 0.80 | 6.5 | 0.19 | 0.13 |
| 1120 | 60 | 27.4 | 2.45 | 2.20 | 8.0 | 0.27 | 0.16 |
| 1120 | 70 | 26.8 | 2.39 | 3.38 | 9.6 | 0.32 | 0.19 |
| 1120 | 80 | 25.3 | 2.26 | 4.20 | 11.2 | 0.41 | 0.22 |

Table 15. Total digestible nutrient (TDN), dry matter intake (DMI), average daily gain (ADG), crude protein (CP), calcium (Ca), and phosphorus (P) requirements of a steer that will finish at 1400 lbs or heifer maturing at 1400 lbs (adapted from NRC 2000).

| | СР | SP | DP | ADF | NDF | LIG | NSC | Fat | Ash | TDN | RFV |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| CP | 1.00 | 0.18 | 0.34 | -0.75 | -0.75 | -0.25 | 0.04 | 0.72 | 0.50 | 0.46 | 0.77 |
| SP | 0.18 | 1.00 | 0.47 | -0.04 | 0.00 | -0.20 | -0.12 | 0.00 | -0.01 | 0.20 | 0.01 |
| DP | 0.34 | 0.47 | 1.00 | -0.33 | -0.18 | -0.57 | 0.03 | 0.30 | -0.16 | 0.54 | 0.25 |
| ADF | -0.75 | -0.04 | -0.33 | 1.00 | 0.86 | 0.40 | -0.50 | -0.63 | -0.34 | -0.77 | -0.89 |
| NDF | -0.75 | 0.00 | -0.18 | 0.86 | 1.00 | 0.21 | -0.63 | -0.55 | -0.45 | -0.50 | -0.96 |
| LIG | -0.25 | -0.20 | -0.57 | 0.40 | 0.21 | 1.00 | -0.13 | -0.41 | 0.23 | -0.62 | -0.27 |
| NSC | 0.04 | -0.12 | 0.03 | -0.50 | -0.63 | -0.13 | 1.00 | -0.18 | -0.03 | 0.36 | 0.59 |
| Fat | 0.72 | 0.00 | 0.30 | -0.63 | -0.55 | -0.41 | -0.18 | 1.00 | 0.32 | 0.62 | 0.57 |
| Ash | 0.50 | -0.01 | -0.16 | -0.34 | -0.45 | 0.23 | -0.03 | 0.32 | 1.00 | -0.02 | 0.36 |
| TDN | 0.46 | 0.20 | 0.54 | -0.77 | -0.50 | -0.62 | 0.36 | 0.62 | -0.02 | 1.00 | 0.55 |
| RFV | 0.77 | 0.01 | 0.25 | -0.89 | -0.96 | -0.27 | 0.59 | 0.57 | 0.36 | 0.55 | 1.00 |
| Ca | 0.32 | 0.04 | 0.07 | -0.20 | -0.39 | 0.15 | 0.19 | -0.11 | 0.19 | -0.07 | 0.37 |
| Р | 0.57 | 0.28 | 0.22 | -0.31 | -0.42 | -0.11 | -0.09 | 0.40 | 0.40 | 0.08 | 0.39 |
| Mg | 0.35 | 0.06 | 0.07 | -0.13 | -0.19 | 0.01 | -0.09 | 0.26 | 0.28 | 0.03 | 0.15 |
| K | 0.70 | 0.11 | 0.16 | -0.53 | -0.59 | -0.21 | 0.01 | 0.60 | 0.47 | 0.27 | 0.58 |
| Na | 0.01 | 0.16 | 0.28 | 0.06 | 0.10 | -0.12 | -0.08 | 0.05 | -0.16 | 0.07 | -0.05 |
| Fe | -0.02 | -0.09 | -0.14 | 0.06 | 0.04 | 0.19 | -0.13 | -0.16 | 0.45 | -0.12 | -0.07 |
| Zn | 0.19 | -0.07 | 0.01 | -0.22 | -0.15 | 0.08 | -0.02 | 0.17 | 0.22 | 0.23 | 0.15 |
| Cu | 0.20 | -0.14 | -0.07 | -0.20 | -0.19 | 0.10 | 0.04 | 0.27 | 0.47 | 0.15 | 0.16 |
| Mn | -0.20 | -0.05 | -0.24 | 0.09 | 0.09 | 0.21 | -0.02 | -0.07 | 0.17 | -0.13 | -0.10 |
| Mo | 0.30 | -0.21 | -0.11 | -0.30 | -0.35 | 0.02 | 0.10 | 0.16 | 0.29 | 0.09 | 0.34 |
| S | 0.68 | -0.04 | -0.02 | -0.56 | -0.53 | -0.10 | 0.01 | 0.65 | 0.54 | 0.35 | 0.52 |
| Height | -0.21 | -0.12 | -0.12 | 0.23 | 0.30 | 0.11 | -0.11 | -0.10 | -0.25 | -0.12 | -0.27 |
| Days Rot | -0.07 | -0.02 | -0.08 | -0.02 | -0.27 | 0.31 | 0.04 | 0.17 | 0.19 | -0.10 | 0.21 |
| Al | -0.03 | 0.04 | -0.14 | -0.06 | -0.03 | 0.18 | -0.05 | 0.00 | 0.06 | 0.10 | 0.03 |
| DOY | 0.03 | -0.31 | -0.35 | 0.15 | 0.15 | 0.21 | -0.17 | 0.06 | 0.19 | -0.21 | -0.18 |
| CF | -0.82 | 0.00 | 0.00 | 1.00 | 0.89 | 0.00 | -0.34 | 0.00 | 0.00 | -0.98 | -0.93 |
| ADF/NDF | -0.09 | -0.04 | -0.31 | 0.39 | -0.13 | 0.43 | 0.14 | -0.15 | 0.23 | -0.59 | 0.01 |
| Grass Fraction | 0.07 | 0.02 | 0.28 | -0.39 | 0.11 | -0.43 | -0.10 | 0.15 | -0.24 | 0.59 | 0.00 |

Table 16. Correlation coefficients between various measured pasture characteristics.

| | Ca | Р | Mg | K | Na | Fe | Zn | Cu | Mn | Мо | S | Al |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| CP | 0.32 | 0.57 | 0.35 | 0.70 | 0.01 | -0.02 | 0.19 | 0.20 | -0.20 | 0.30 | 0.68 | -0.03 |
| SP | 0.04 | 0.28 | 0.06 | 0.11 | 0.16 | -0.09 | -0.07 | -0.14 | -0.05 | -0.21 | -0.04 | 0.04 |
| DP | 0.07 | 0.22 | 0.07 | 0.16 | 0.28 | -0.14 | 0.01 | -0.07 | -0.24 | -0.11 | -0.02 | -0.14 |
| ADF | -0.20 | -0.31 | -0.13 | -0.53 | 0.06 | 0.06 | -0.22 | -0.20 | 0.09 | -0.30 | -0.56 | -0.06 |
| NDF | -0.39 | -0.42 | -0.19 | -0.59 | 0.10 | 0.04 | -0.15 | -0.19 | 0.09 | -0.35 | -0.53 | -0.03 |
| LIG | 0.15 | -0.11 | 0.01 | -0.21 | -0.12 | 0.19 | 0.08 | 0.10 | 0.21 | 0.02 | -0.10 | 0.18 |
| NSC | 0.19 | -0.09 | -0.09 | 0.01 | -0.08 | -0.13 | -0.02 | 0.04 | -0.02 | 0.10 | 0.01 | -0.05 |
| Fat | -0.11 | 0.40 | 0.26 | 0.60 | 0.05 | -0.16 | 0.17 | 0.27 | -0.07 | 0.16 | 0.65 | 0.00 |
| Ash | 0.19 | 0.40 | 0.28 | 0.47 | -0.16 | 0.45 | 0.22 | 0.47 | 0.17 | 0.29 | 0.54 | 0.06 |
| TDN | -0.07 | 0.08 | 0.03 | 0.27 | 0.07 | -0.12 | 0.23 | 0.15 | -0.13 | 0.09 | 0.35 | 0.10 |
| RFV | 0.37 | 0.39 | 0.15 | 0.58 | -0.05 | -0.07 | 0.15 | 0.16 | -0.10 | 0.34 | 0.52 | 0.03 |
| Ca | 1.00 | 0.19 | 0.38 | 0.09 | 0.03 | 0.08 | 0.07 | 0.05 | -0.14 | 0.21 | 0.17 | -0.06 |
| Р | 0.19 | 1.00 | 0.35 | 0.59 | -0.04 | 0.10 | 0.00 | 0.10 | -0.15 | 0.19 | 0.34 | -0.11 |
| Mg | 0.38 | 0.35 | 1.00 | 0.20 | 0.02 | 0.09 | 0.09 | 0.07 | -0.17 | 0.05 | 0.36 | -0.05 |
| K | 0.09 | 0.59 | 0.20 | 1.00 | -0.05 | -0.02 | 0.14 | 0.08 | -0.10 | 0.24 | 0.61 | -0.10 |
| Na | 0.03 | -0.04 | 0.02 | -0.05 | 1.00 | -0.03 | -0.01 | 0.15 | -0.06 | -0.12 | -0.01 | -0.11 |
| Fe | 0.08 | 0.10 | 0.09 | -0.02 | -0.03 | 1.00 | 0.11 | 0.36 | 0.40 | 0.04 | 0.10 | 0.89 |
| Zn | 0.07 | 0.00 | 0.09 | 0.14 | -0.01 | 0.11 | 1.00 | 0.27 | 0.11 | 0.10 | 0.30 | 0.03 |
| Cu | 0.05 | 0.10 | 0.07 | 0.08 | 0.15 | 0.36 | 0.27 | 1.00 | 0.21 | 0.16 | 0.17 | 0.39 |
| Mn | -0.14 | -0.15 | -0.17 | -0.10 | -0.06 | 0.40 | 0.11 | 0.21 | 1.00 | -0.25 | 0.03 | 0.45 |
| Мо | 0.21 | 0.19 | 0.05 | 0.24 | -0.12 | 0.04 | 0.10 | 0.16 | -0.25 | 1.00 | 0.32 | 0.11 |
| S | 0.17 | 0.34 | 0.36 | 0.61 | -0.01 | 0.10 | 0.30 | 0.17 | 0.03 | 0.32 | 1.00 | 0.08 |
| Height | -0.11 | -0.04 | -0.25 | -0.02 | 0.08 | -0.29 | -0.16 | -0.26 | -0.13 | 0.01 | -0.22 | 0.00 |
| Days Rot | 0.21 | 0.06 | 0.09 | 0.06 | 0.00 | -0.15 | 0.22 | 0.02 | -0.09 | 0.20 | 0.13 | 0.00 |
| Al | -0.06 | -0.11 | -0.05 | -0.10 | -0.11 | 0.89 | 0.03 | 0.39 | 0.45 | 0.11 | 0.08 | 1.00 |
| DOY | 0.08 | -0.06 | 0.40 | 0.02 | -0.05 | 0.23 | 0.22 | 0.08 | 0.07 | 0.01 | 0.24 | 0.10 |
| CF | -0.23 | -0.62 | -0.15 | -0.66 | 0.03 | 0.09 | -0.24 | -0.10 | 0.25 | 0.00 | -0.63 | 0.15 |
| ADF/NDF | 0.35 | 0.16 | 0.11 | 0.01 | -0.06 | 0.05 | -0.16 | -0.04 | 0.03 | 0.09 | -0.14 | -0.07 |
| Grass Fraction | -0.37 | -0.15 | -0.14 | -0.02 | 0.06 | -0.05 | 0.13 | 0.04 | -0.01 | -0.09 | 0.14 | 0.10 |

Table 16 (continued). Correlation coefficients between various measured pasture characteristics.

| | DOY | CF | ADF/NDF | Grass Fraction | Height | Days Rot |
|----------------|-------|-------|---------|-------------------|--------|----------|
| СР | 0.03 | -0.82 | -0.09 | 0.07 | -0.21 | -0.07 |
| SP | -0.31 | 0.00 | -0.04 | 0.02 | -0.12 | -0.02 |
| DP | -0.35 | 0.00 | -0.31 | 0.28 | -0.12 | -0.08 |
| ADF | 0.15 | 1.00 | 0.39 | -0.39 | 0.23 | -0.02 |
| NDF | 0.15 | 0.89 | -0.13 | 0.11 | 0.30 | -0.27 |
| LIG | 0.21 | 0.00 | 0.43 | -0.43 | 0.11 | 0.31 |
| NSC | -0.17 | -0.34 | 0.14 | -0.10 | -0.11 | 0.04 |
| Fat | 0.06 | 0.00 | -0.15 | 0.15 | -0.10 | 0.17 |
| Ash | 0.19 | 0.00 | 0.23 | -0.24 | -0.25 | 0.19 |
| TDN | -0.21 | -0.98 | -0.59 | 0.59 | -0.12 | -0.10 |
| RFV | -0.18 | -0.93 | 0.01 | 0.00 | -0.27 | 0.21 |
| Ca | 0.08 | -0.23 | 0.35 | -0.37 | -0.11 | 0.21 |
| Р | -0.06 | -0.62 | 0.16 | -0.15 | -0.04 | 0.06 |
| Mg | 0.40 | -0.15 | 0.11 | -0.14 | -0.25 | 0.09 |
| K | 0.02 | -0.66 | 0.01 | -0.02 | -0.02 | 0.06 |
| Na | -0.05 | 0.03 | -0.06 | 0.06 | 0.08 | 0.00 |
| Fe | 0.23 | 0.09 | 0.05 | -0.05 | -0.29 | -0.15 |
| Zn | 0.22 | -0.24 | -0.16 | 0.13 | -0.16 | 0.22 |
| Cu | 0.08 | -0.10 | -0.04 | 0.04 | -0.26 | 0.02 |
| Mn | 0.07 | 0.25 | 0.03 | -0.01 | -0.13 | -0.09 |
| Мо | 0.01 | 0.00 | 0.09 | -0.09 | 0.01 | 0.20 |
| S | 0.24 | -0.63 | -0.14 | 0.14 | -0.22 | 0.13 |
| Height | -0.19 | 0.00 | -0.12 | 0.14 | 1.00 | 0.42 |
| Days Rot | -0.01 | 0.00 | 0.31 | -0.27 | 0.42 | 1.00 |
| Al | 0.10 | 0.15 | -0.07 | 0.10 | 0.00 | 0.00 |
| DOY | 1.00 | 0.08 | 0.02 | -0.04 | -0.19 | -0.01 |
| CF | 0.08 | 1.00 | 0.53 | -0.55 | 0.00 | 0.00 |
| ADF/NDF | 0.02 | 0.53 | 1.00 | -0.97 | -0.12 | 0.31 |
| Grass Fraction | -0.04 | -0.55 | -0.97 | 1.00 | 0.14 | -0.27 |

Table 16 (continued). Correlation coefficients between various measured pasture characteristics.

Table 17. Example of mineral concentrations needed in a pasture mineral supplement intended to cover 90 percent of pastures for a 1200 lb cow, producing 30 pounds of milk, consuming 3 oz of supplement per day.

Minerals Supplement Calculator.

Enter data in market cells.

Animal description:

| | Lactating | |
|-------------------|-------------|------------|
| | cow, 30 lbs | |
| | milk | _ |
| Body weight | 1200 | Lbs |
| Dry matter intake | 2.50 | % body wt. |
| Mineral intake | 3 | oz/day |
| | 85.23 | gm/day |
| | | |

Feed intake

30 lbs/day 13.64 kg/day

| Mineral | Recommended in ration | Expected in pasture | Needed | Supplied | Amount needed from Supplement | | Concentration needed in supplement |
|---------|-----------------------|---------------------|----------|-----------|----------------------------------|----|--|
| Ca% | 0.38 | 0.44 | 51.82 gm | 60.00 gm | -8.18 | gm | |
| P% | 0.24 | 0.23 | 32.73 gm | 31.36 gm | 1.36 | gm | 1.6% |
| K% | 0.7 | 1.76 | 95.45 gm | 240.00 gm | -144.55 | gm | |
| Mg% | 0.2 | 0.17 | 27.27 gm | 23.18 gm | 4.09 | gm | 4.8% |
| Na% | 0.1 | 0.009 | 13.64 gm | 1.23 gm | 12.41 gm | | 14.6% |
| S% | 0.15 | 0.18 | 2.05 gm | 2.45 gm | -0.41 | gm | |
| | | | | | | | |
| Zn ppm | 30 | 20 | 409.1 mg | 272.7 mg | 136.4 | mg | 1600 ppm |
| Mn ppm | 40 | 52 | 545.5 mg | 709.1 mg | -163.6 | mg | |
| Cu ppm | 10 | 7 | 136.4 mg | 95.5 mg | 40.9 | mg | 480 ppm |
| Fe ppm | 50 | 123 | 681.8 mg | 1677.3 mg | -995.5 | mg | |
| | | | | | | | |
| Co ppm | 0.1 | | 1.36 mg | 0.00 mg | 1.36 | mg | 16 ppm |
| I ppm | 0.5 | | 6.82 mg | 0.00 mg | 6.82 | mg | 80 ppm |
| Se ppm | 0.1 | | 1.36 mg | 0.00 mg | 1.36 | mg | 16 ppm |

Se can be supplemented at up to 0.30 ppm of diet.

Table 18. Example of mineral concentrations needed in a pasture mineral supplement intended to cover 90% of pastures for 660-lb steers, consuming 2 oz. of supplement.

Minerals Supplement Calculator.



| Mineral | Recommended in ration | Expected in pasture | Needed | Supplied | Amount needed from Supplement | | Concentration needed in supplement |
|---------|-----------------------|---------------------|----------|-----------|-------------------------------|----|--|
| Ca% | 0.36 | 0.44 | 27.00 gm | 33.00 gm | -6.00 | gm | |
| P% | 0.19 | 0.23 | 14.25 gm | 17.25 gm | -3.00 | gm | |
| K% | 0.7 | 1.76 | 52.50 gm | 132.00 gm | -79.50 | gm | |
| Mg% | 0.2 | 0.17 | 15.00 gm | 12.75 gm | 2.25 gm | | 4.0% |
| Na% | 0.1 | 0.009 | 7.50 gm | 0.68 gm | 6.83 gm | | 12.0% |
| S% | 0.15 | 0.18 | 1.13 gm | 1.35 gm | -0.23 | gm | |
| | | | | | | | |
| Zn ppm | 30 | 20 | 225.0 mg | 150.0 mg | 75.0 | mg | 1320 ppm |
| Mn ppm | 40 | 52 | 300.0 mg | 390.0 mg | -90.0 | mg | |
| Cu ppm | 10 | 7 | 75.0 mg | 52.5 mg | 22.5 | mg | 396 ppm |
| Fe ppm | 50 | 123 | 375.0 mg | 922.5 mg | -547.5 | mg | |
| | | | | | | | |
| Co ppm | 0.1 | | 0.75 mg | 0.00 mg | 0.75 | mg | 13 ppm |
| I ppm | 0.5 | | 3.75 mg | 0.00 mg | 3.75 | mg | 66 ppm |
| Se ppm | 0.1 | | 0.75 mg | 0.00 mg | 0.75 | mg | 13 ppm |

Se can be supplemented at up to 0.30 ppm of diet.

Appendix Table 1. Common and scientific names of forages represented in the pasture samples.

Cool Season Grasses

orchardgrass (*Dactylis glomerata*, L.) Kentucky bluegrass (*Poa pratensis* L.) smooth bromegrass (*Bromus inermis* Leyss.) tall fescue (*Festuca arundinacea* Schreb.) timothy (*Phleum pratense* L.) quackgrass (*Agropyron repens* L.) velvet grass (*Holcus lanatus* L.) sweet vernal grass (*Anthoxanthum odoratum* L.) perennial ryegrass (*Lolium perenne* L.)

Legumes

white clover (*Trifolium repens* L.) red clover (*Trifolium pratense* L.) alfalfa (*Medicago sativa* L.)

Herbs/Forbes

common plantain (*Plantago rugelii* Dcne.) buckhorn plantain (*Plantago lanceolata* L.) English plantain common dandelion (*Taraxacum officinale* Weber.) curly dock (*Rumex crispus* L.) yellow dock lamb's quarter (*Chenopodium album* L.) common ragweed (*Ambrosia artemisifolia* L.)

Warm Season Grasses

switchgrass (*Panicum virgatum* L.) broomsedge (*Andropogon virginicus* L.) crabgrass (*Digitaria sanguinalis* L.)

| DM | dry matter |
|-----------|---|
| Count | number of samples in the mean |
| СР | crude protein |
| ADF | acid detergent fiber |
| Mean | average |
| NDF | neutral detergent fiber |
| NSC-CHO | nonstructural carbohydrates |
| NEL | net energy lactation |
| NEG | net energy gain |
| NEM | net energy maintenance |
| TDN | total digestible nutrients |
| RFV | relative feed value |
| Ca | calcium |
| Р | phosphorus |
| Κ | potassium |
| Mg | magnesium |
| Mo | molybdenum |
| Na | sodium |
| Zn | zinc |
| Mn | manganese |
| Cu | copper |
| Fe | iron |
| Al | aluminum |
| S | sulfur |
| Std Error | standard error |
| 95% LCL | lower confidence limit on mean at the 95% probability level |
| 95% UCL | upper confidence limit on mean at the 95% probability level |
| | |

Appendix Table 2. Abbreviations used in tables and figures.

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