# Herbage Quality and Range Cow Requirements

# Annual Nutritional Quality Curves for Graminoids in the Northern Plains

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## Introduction

Agricultural production from mixed grass prairie rangelands and domesticated grasslands of the Northern Plains can be substantially increased through the implementation of strategies that more efficiently capture the nutrients produced and convert them to a saleable product. Perennial grasses and sedges change in nutritional quality as they develop and mature through phenological stages. Annual nutritional quality curves for forage plants show these changes in nutrient content during the year. Coordination of annual nutritional quality curves of the available perennial forage plants with livestock nutritional requirement curves is necessary for development of biologically effective management strategies.

The major perennial graminoid plants used as forage by livestock are separated into four categories based on the period during which most of the plant growth occurs: domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses. This report summarizes published information on the annual nutritional quality curves of these graminoids.

## Methods

Three publications have reported the nutritional quality of perennial domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses growing on the Northern Plains region of mixed grass prairie from central North Dakota to eastern Montana. The percent crude protein, phosphorus, and moisture, and the growth stage data from these three publications were reported in Manske (1999a,b,c,d) and have been summarized in this paper.

Whitman, Bolin, Klosterman, Klostermann, Ford, Moomaw, Hoag, and Buchanan (1951) published data on the carotene, protein, and phosphorus content of grasses and sedges in western North Dakota. Graminoid species samples were collected weekly in 1946 and 1947 from the Dickinson Experiment Station at Dickinson, North Dakota. Only current year's growth was included in the sample; previous year's growth was separated and discarded. An attempt to collect ungrazed samples was made for available species except Kentucky bluegrass, which had been grazed, and smooth bromegrass, which was cut for hay in mid June. Data were reported as percent of oven-dry weight. Plant condition by stage of plant development and growth habit was reported for each species on sample dates. These data were reported as phenological growth stage in Manske (1999a,b,c,d). A summary of these data is included in this report.

Marsh, Swingle, Woodward, Payne, Frahm, Johnson, and Hide (1959) reported percent crude protein and phosphorus data from three major native range grasses from the USDA Experiment Station at Miles City, Montana. Samples were collected by clipping every 28 days from August 1948 to June 1953 except when snow covered the vegetation. Data were reported as percent of oven-dry weight. Phenological growth stages of plants on sample dates were not reported. A summary of the crude protein and phosphorus data was reported in Manske (1999c,d).

Hopper and Nesbitt (1930) reported the chemical composition of native range grasses and upland sedges and domesticated cool-season grasses collected by J.T. Sarvis from the Northern Great Plains Field Station at Mandan, North Dakota. The years of sample collection were apparently 1920, 1921, and 1925. The results of the chemical analyses, which were calculated to a uniform moisture content of 15 percent, have been recalculated to 0% moisture to facilitate comparison with other data. A brief description of physical characteristics was made for each species on the sample dates; this information is presented in Manske (1999a,b,c,d) as phenology. Percent crude protein data were summarized and reported in Manske (1999a,b,c,d).

Table 1. Common and scientific names of forage plants from (A) Whitman et al. 1951, (B) Marsh et al. 1959, and (C) Hopper and Nesbitt 1930.

| Common Names | Reference Citation | Scientific Names |
|---|---|---|
| **Domesticated grasses** | | |
| Crested wheatgrass | A, C | *Agropyron cristatum* |
| Smooth bromegrass | A, C | *Bromus inermis* |
| Timothy | C | *Phleum pratense* |
| Fowl bluegrass | C | *Poa palustris* |
| **Upland Sedges** | | |
| Threadleaf sedge | A, C | *Carex filifolia* |
| Sun sedge | C | *Carex heliophila* |
| **Cool-season native grasses** | | |
| Slender wheatgrass | C | *Agropyron caninum majus* |
| Bearded wheatgrass | C | *Agropyron caninum unilaterale* |
| Western wheatgrsss | A,B,C | *Agropyron smithii* |
| Ticklegrass | C | *Agrostis hyemalis* |
| Red threeawn | C | *Aristida purpurea* |
| Plains reedgrass | A | *Calamagrostis montanensis* |
| Canada wildrye | C | *Elymus canadensis* |
| Prairie Junegrass | A, C | *Koeleria pyramidata* |
| Kentucky bluegrass | A | *Poa pratensis* |
| Prairie wedgegrass | C | *Sphenopholis obtusata* |
| Needle and thread | A,B,C | *Stipa comata* |
| Porcupine grass | C | *Stipa spartea* |
| Green needlegrass | A, C | *Stipa viridula* |
| **Warm-season native grasses** | | |
| Big bluestem | A, C | *Andropogon gerardii* |
| Little bluestem | A, C | *Andropogon scoparius* |
| Side oats grama | C | *Bouteloua curtipendula* |
| Blue grama | A,B,C | *Bouteloua gracilis* |
| Buffalo grass | C | *Buchloe dactyloides* |
| Prairie sandreed | A, C | *Calamovilfa longifolia* |
| Inland saltgrass | C | *Distichlis spicata* |
| Plains muhly | C | *Muhlenbergia cuspidata* |
| Switchgrass | C | *Panicum virgatum* |

## Results

The nutritional quality of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses changes with the plants' phenological development. Early season vegetative leaves of graminoids are generally high in crude protein and water. As the plants mature, their fiber content increases and percent crude protein, percent water, and digestibility decrease. The patterns of change in nutritional quality are similar from year to year because phenological development is regulated primarily by photoperiod (Manske 1998a,b), although annual variations in temperature, evaporation, and water stress may result in slight variations in nutritional quality from year to year. Nutritional quality is also related to rates of plant growth and plant senescence. These are affected by the level of photosynthetic activity, which in turn is affected by temperature. Rates of senescence increase with higher temperatures and with water stress, a result of water deficiency in the environment.

Coordination of the nutritional quality curves of ungrazed plants with livestock nutritional requirement curves is essential in the development of biologically effective management strategies. Livestock nutritional requirements (NRC 1996) change with production levels and size of the animals. A 1000-pound mature cow with average milk production requires 10.5% crude protein and 0.20% phosphorus during the first month of lactation. She requires an average of 9.6% crude protein and 0.18% phosphorus from her diet in order to maintain body weight and average lactation during the second through sixth months of lactation. She requires an average of 6.2% crude protein and 0.11% phosphorus during the dry portion of the second trimester of pregnancy and 7.8% crude protein and 0.15% phosphorus during the third trimester of pregnancy.

### *Domesticated Cool-Season Grass*

The domesticated grass species included in the two published articles reporting nutritional quality of domesticated forage grasses of the Northern Plains are listed in table 1. Summaries of crude protein levels for ungrazed crested wheatgrass are shown in figure 1. Domesticated cool-season grasses contain the highest levels of crude protein during the early stages of development. As seed stalks begin to develop, crude protein levels begin to decrease. Crude protein levels remain above 9.6% until late June. Between the flowering stage and the seed mature stage, crude protein levels decrease rapidly. During seed development, which occurs shortly after the flowering stage, crude protein levels drop below 9.6%. They fall below 7.8% by early July and below 6.2% in early August. Phosphorus levels drop below 0.18% in late July.

One replication of smooth bromegrass in Whitman’s study was not cut for hay. Summaries of crude protein levels for smooth bromegrass not cut for hay are shown in figure 2. Crude protein levels of smooth bromegrass remain above 9.6% from the early growth of the plant until late June. Crude protein levels of uncut smooth bromegrass drop below 9.6% after late June. From mid July to mid September crude protein levels decrease from around 7.8% to 5.0%. Phosphorus levels of mature uncut smooth bromegrass drop below 0.18% in early August.

Grasses that are hayed have nutrient curves different from those of grasses not cut for hay because defoliation manipulates the mechanisms that regulate vegetative reproduction. Data to illustrate this difference are limited to one example from the historical literature for the Northern Plains. Whitman’s study includes one replication of data from hayed smooth bromegrass. Summaries of crude protein levels for hayed smooth bromegrass are shown in figure 3. The smooth bromegrass was cut for hay in mid June; the crude protein levels of the immature tillers that grew after the cutting event remained above 9.6% until after late September. These data from hayed smooth brome show that secondary tillers have crude protein levels above 9.6% for at least 2.5 months longer than undefoliated plants. Additional research data need to be collected on the effects haying and grazing produce on the crude protein and mineral levels of domesticated cool-season grasses.

Crude protein levels for ungrazed timothy and fowl bluegrass (Hopper and Nesbitt 1930, Manske 1999a) follow a pattern similar to that followed by other domesticated cool-season grasses. The grasses contain the highest levels of crude protein in the early stages of development. As seed stalks begin to develop, crude protein levels begin to decrease. Between the flowering stage and seed mature stage, crude protein levels rapidly decrease, usually falling below 9.6% shortly after the plant has reached flowering stage.

### *Native Range Upland Sedge*

The native range upland sedge species included in the two published articles reporting nutritional quality of sedge plants of the Northern

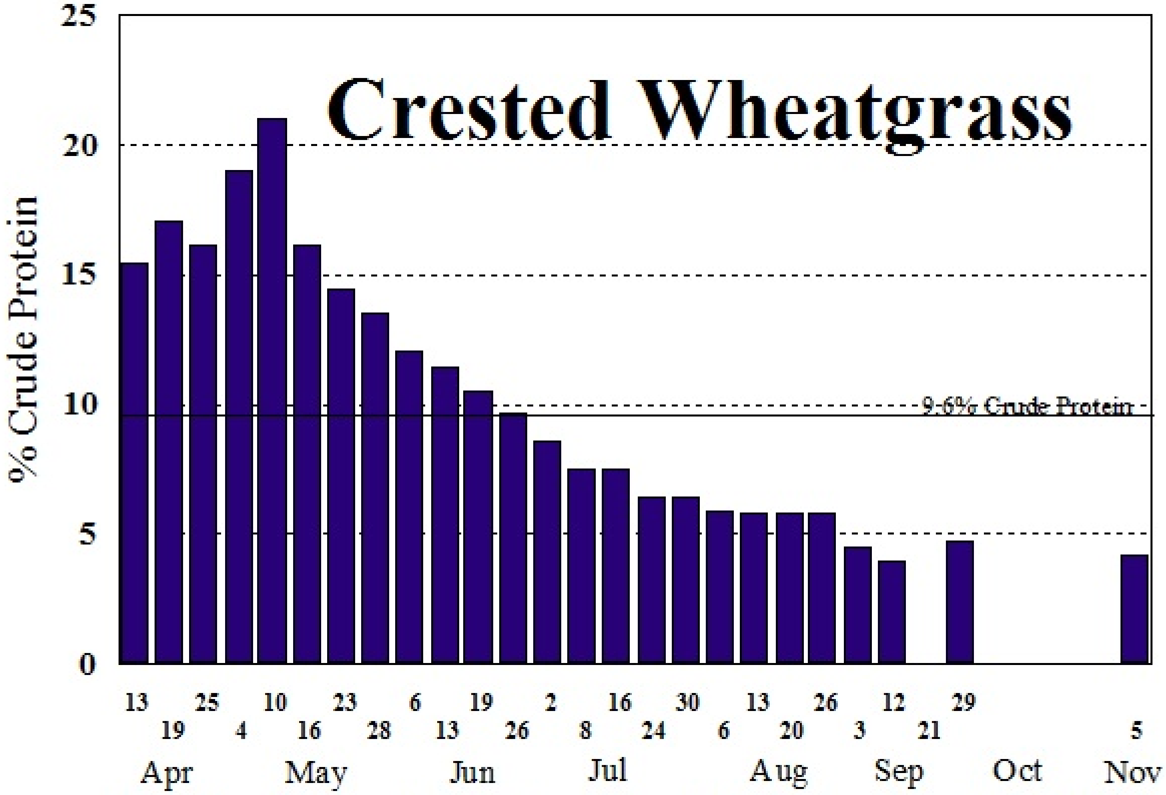

Fig 1. Mean percent crude protein of ungrazed crested wheatgrass in western North Dakota, data from Whitman et al. 1951.

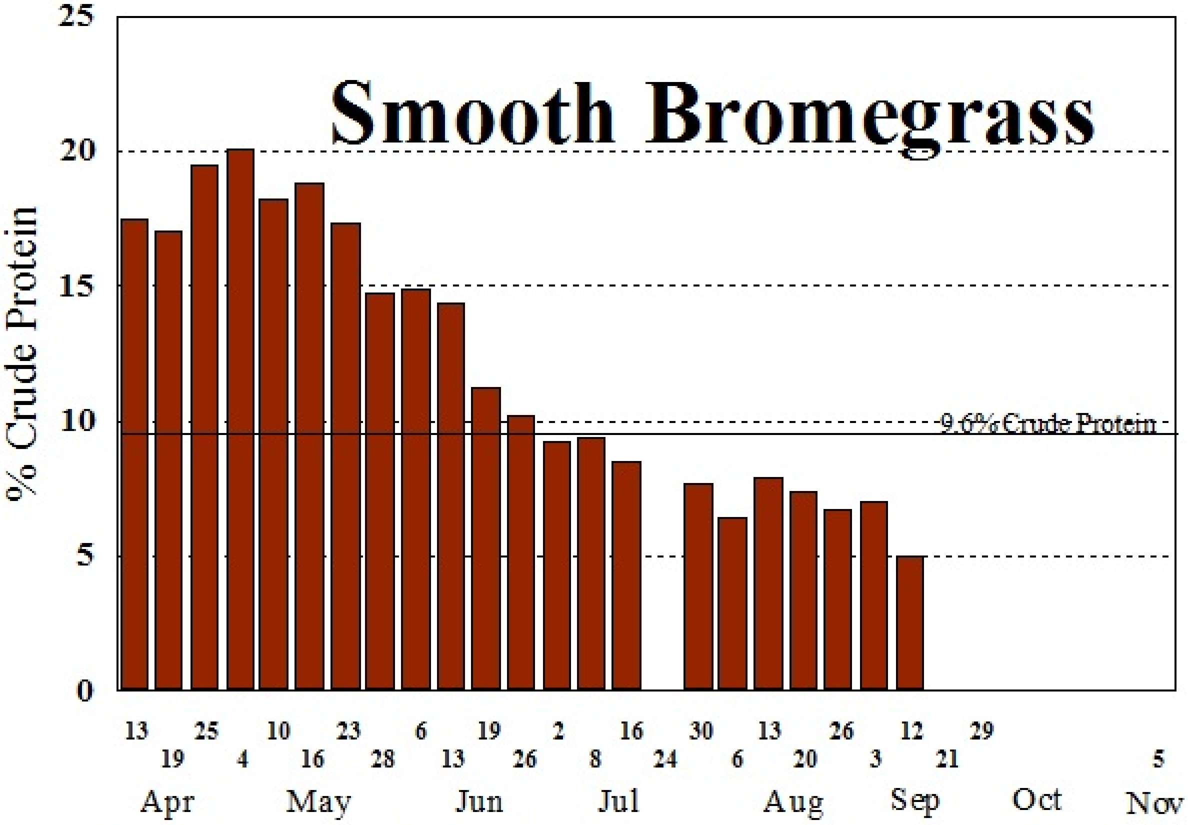

Fig 2. Mean percent crude protein of smooth bromegrass not cut for hay in western North Dakota, data from Whitman et al. 1951.

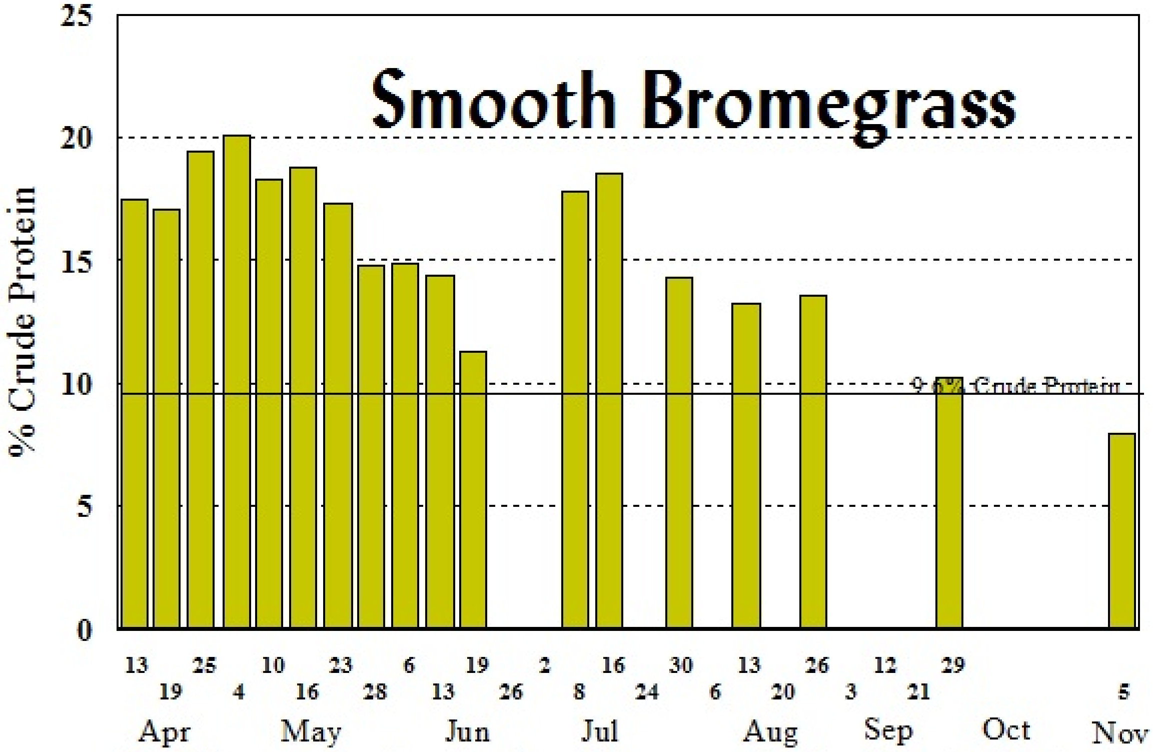

Fig 3. Mean percent crude protein of smooth bromegrass cut for hay at flowering stage in mid June in western North Dakota, data from Whitman et al. 1951.

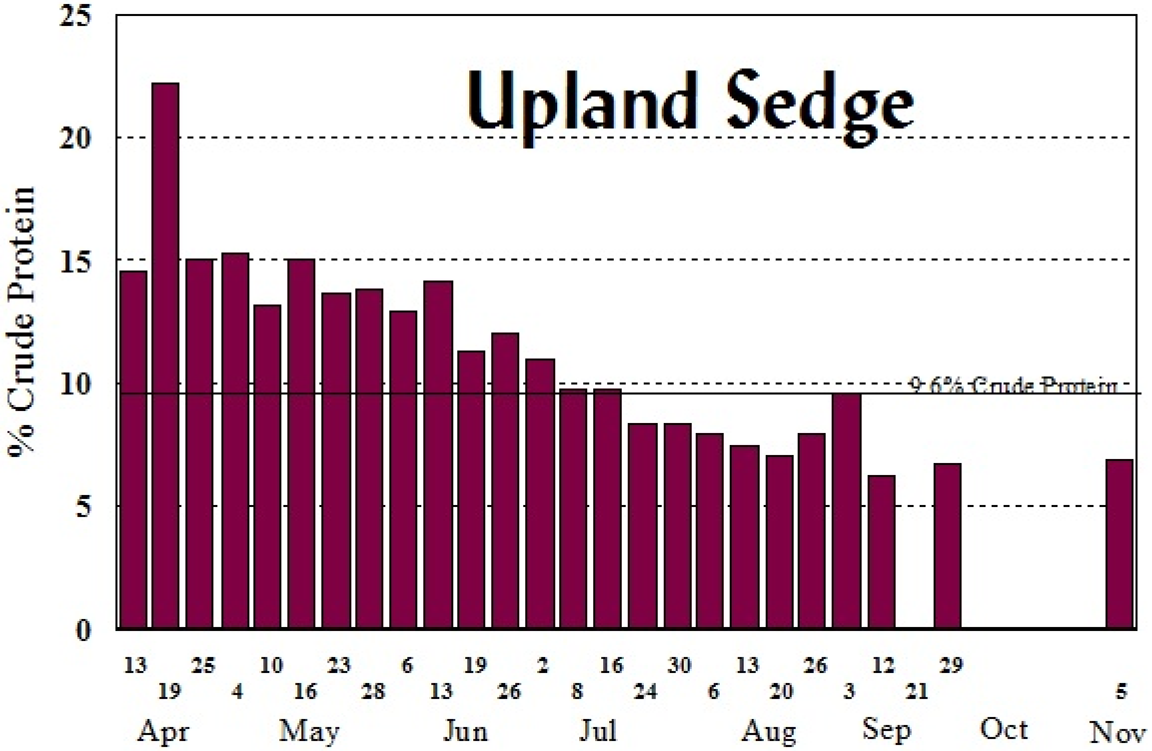

Fig 4. Mean percent crude protein of ungrazed native range upland sedges in western North Dakota, data from Whitman et al. 1951.

Plains are listed in table 1. Summaries of crude protein levels for ungrazed upland sedges are shown in figure 4. Sedges contain the highest levels of crude protein during the early stages of development. Crude protein curves of the upland sedges do not follow the same relationship with phenological growth stage as do the crude protein curves of cool-season grasses. Crude protein levels in upland sedges remain high through flowering and seed maturing stages and decrease with increases in senescence. Upland sedges grow very early and produce seed heads in late April to early May. Crude protein levels remain above 9.6% after seed mature stage, until mid July. Crude protein levels decrease below 7.8% in early August but do not fall below 6.2% for the remainder of the year. Phosphorus levels drop below 0.18% in mid May.

Graminoids defoliated by grazing and haying have nutrient curves different from those of ungrazed plants because defoliation manipulates the mechanisms that regulate vegetative reproduction. The reviewed literature contains no examples of defoliation's effects on the nutrient curves for native range upland sedges. Additional research data need to be collected on the effects grazing produces on the crude protein and mineral levels of native range upland sedges.

### *Native Range Cool-Season Grass*

The native range cool-season grass species included in the three published articles reporting nutritional quality of forage grasses of the Northern Plains are listed in table 1. Summaries of crude protein levels for ungrazed cool-season grasses are shown in figure 5. One cool-season species in Whitman's study, Kentucky bluegrass, was not available in ungrazed condition, so grazed samples were collected. A summary of these data is shown in figure 6.

Crude protein levels of ungrazed cool-season native range grasses are very closely related to the phenological stages of growth and development, which are triggered primarily by the length of daylight. The length of daylight increases during the growing season to mid June and then decreases. The longest day length occurs at summer solstice, 21 June, when the sun's apparent path is farthest north of the equator. Ungrazed cool-season native range grasses contain the highest levels of crude protein during the early stages of development. Most cool-season plants are long-day plants which reach the flower phenological stage after exposure to a critical photoperiod and during the period of increasing daylight between mid April and mid June (21 June) (Weier et al. 1974, Leopold and Kriedemann 1975). Cool-season grasses usually reach flowering phenophase before 21 June. Crude protein levels remain above 9.6% at flower stage but decrease rapidly during seed development and seed mature stages, dropping below 7.8% by early August and below 6.2% in late August.

Crude protein levels are also related to rates of plant growth and senescence. These are affected by the level of photosynthetic activity, which in turn is affected by temperature. The optimum temperature range for photosynthesis for cool-season plants, which are $C_3$ photosynthesis pathway plants, is 50° to 77° F (10° to 25° C) (Coyne et al. 1995). Temperatures below 50° F (10° C) during the day or temperatures above 77° F (25° C) limit the growth rate of cool-season grasses because photosynthetic rates are reduced. Rates of senescence increase with higher temperatures and with water stress, a result of water deficiency in the environment. Water deficiencies occur about 50% of the time during August, September, and October (Manske 1998a, 1999e). Cool-season grasses do not use water as efficiently as do warm-season grasses, a factor that contributes to cool-season grasses functioning at optimum temperatures lower than those of warm-season grasses. Crude protein levels of ungrazed cool-season grasses decrease below 9.6% in mid July, dropping below 7.8% in early August and below 6.2% in late August. Phosphorus levels of ungrazed cool-season grasses drop below 0.18% in late July.

Grazed grasses have nutrient curves different from those of ungrazed grasses because defoliation manipulates the mechanisms that regulate vegetative reproduction. Data to illustrate this difference are limited to one example from the historical literature for the Northern Plains. Whitman's study includes data from grazed Kentucky bluegrass. Crude protein levels of grazed Kentucky bluegrass did not drop below 9.6% as did crude protein levels of ungrazed cool-season grasses; during most sample periods, crude protein levels of grazed Kentucky bluegrass remained at or above 9.6% until late September. Phosphorus levels of grazed Kentucky bluegrass remained above 0.18% through late September. Kentucky bluegrass is not an ideal example to illustrate the effects of grazing on the crude protein curves of all cool-season native range grasses because the lead tiller of Kentucky bluegrass has weak hormonal control of axillary bud activity and does not inhibit secondary tillering to the same extent that the lead tillers of other native range grasses do. However, these data show that secondary tillers have

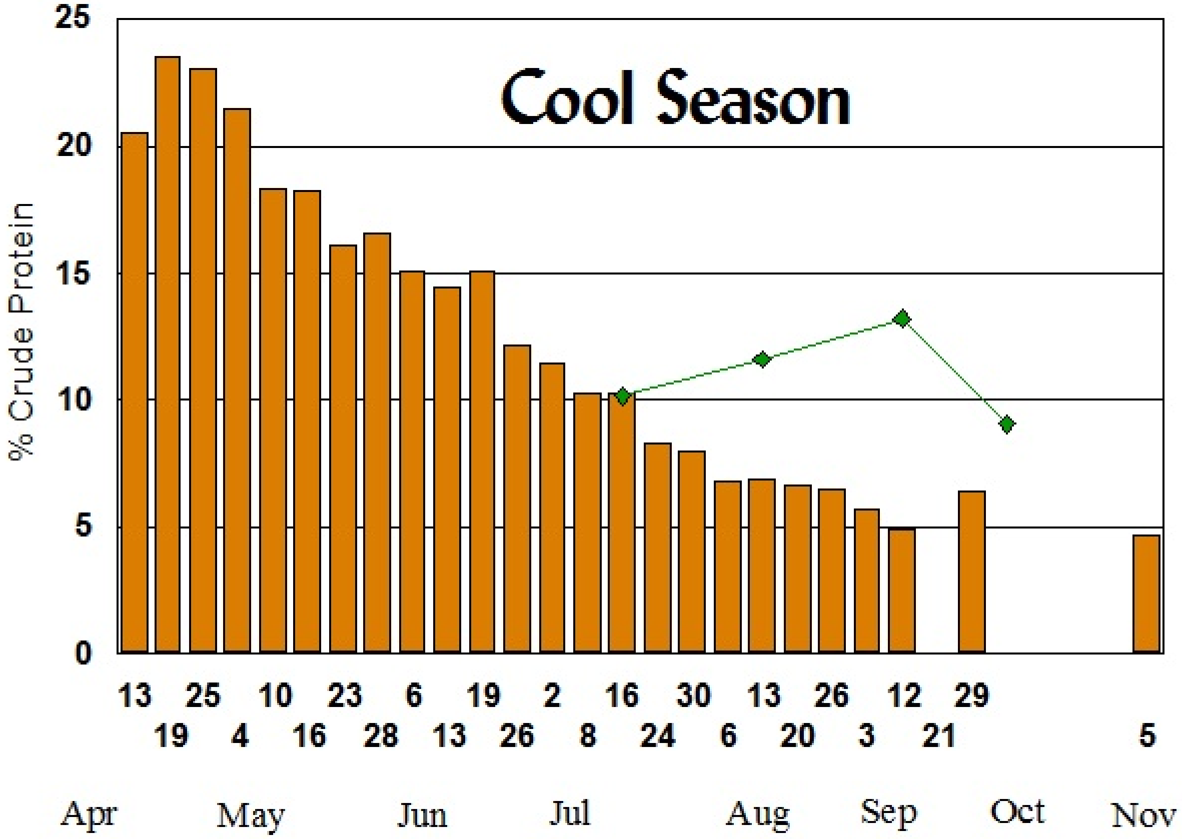

Fig 5. Mean percent crude protein of ungrazed native range cool season grasses in western North Dakota, data from Whitman et al. 1951 and secondary tiller data from Sedivec 1999.

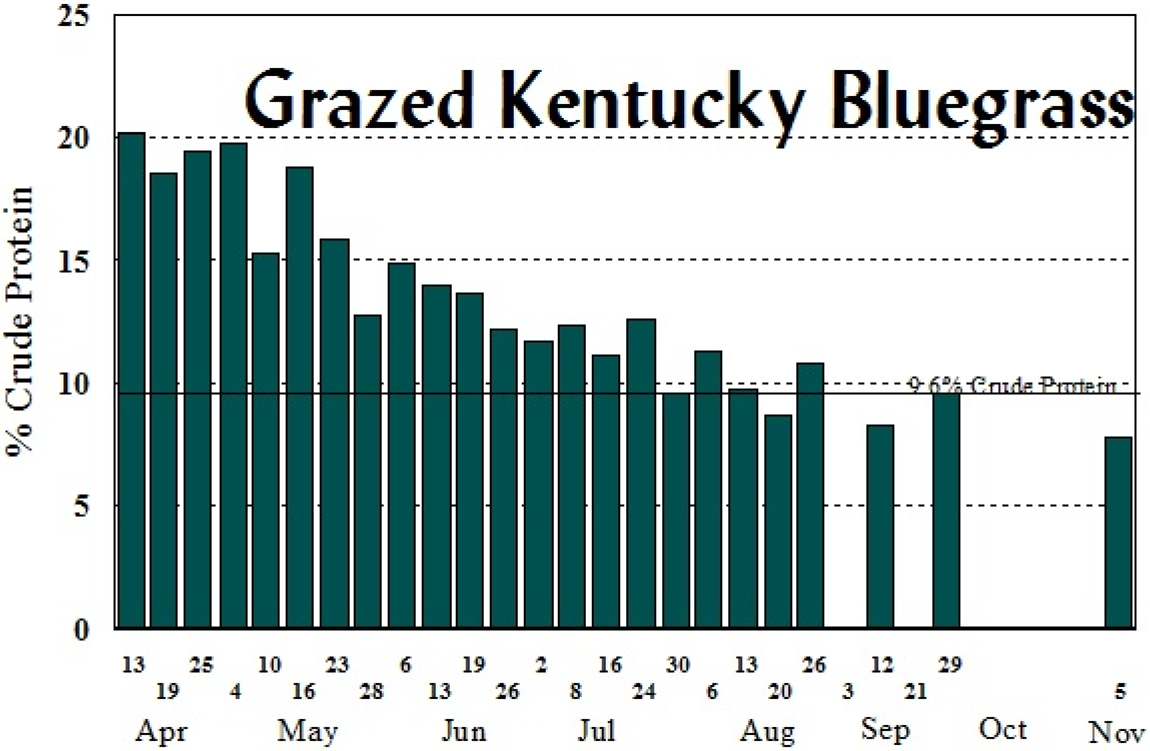

Fig 6. Mean percent crude protein of grazed Kentucky bluegrass in western North Dakota, data from Whitman et al. 1951.

crude protein levels above 9.6% for at least 2.5 months longer than ungrazed plants. Sedivec (1999) determined mean percent crude protein for grazing stimulated native range cool-season secondary tillers on twice-over rotation treatments in central North Dakota. Crude protein levels of cool-season secondary tillers increased during July and August to 13.2% in early September, decreased during September, and dropped below 9.6% in early to mid October (figure 5). Additional research data need to be collected on the effects grazing produces on the crude protein and mineral levels of native range cool-season grasses.

### *Native Range Warm-Season Grass*

The native range warm-season grass species included in the three published articles reporting nutritional quality of forage grasses of the Northern Plains are listed in table 1. Summaries of crude protein levels for ungrazed warm-season grasses are shown in figure 7.

Crude protein levels of ungrazed warm-season native range grasses are very closely related to phenological stages of growth and development, which are triggered primarily by the length of daylight. The length of daylight increases during the growing season to mid June and then decreases. The longest day length occurs at summer solstice, 21 June, when the sun's apparent path is farthest north of the equator. Ungrazed warm-season native range grasses contain the highest levels of crude protein during the early stages of development. Most warm-season plants are short-day plants which are induced to flower by day lengths that are shorter than a critical length and that occur during the period of decreasing day length after mid June (21 June). Short-day plants are technically responding to the increase in the length of night period rather than to the decrease in the day length (Weier et al. 1974, Leopold and Kriedemann 1975). Warm-season grasses usually reach flowering phenophase after 21 June. Crude protein levels remain above 9.6% at flower stage but decrease rapidly during seed development and seed mature stages.

Crude protein levels are also related to rates of plant growth and plant senescence. These are affected by the level of photosynthetic activity, which in turn is affected by temperature. The optimum temperature range for photosynthesis for warm-season plants, which are $C_4$ photosynthesis pathway plants, is 86° to 105° F (30° to 40° C) (Coyne et al. 1995). Temperatures below 86° F (30° C) or above 95° F to 105° F (35° to 40° C) limit the growth rate of warm-season grasses because photosynthetic rates are reduced. Warm-season grasses use water more efficiently than do cool-season grasses, a characteristic that enables warm-season grasses to function efficiently at higher temperatures. Rates of senescence increase with higher temperatures and with water stress, a result of water deficiency in the environment. Water deficiencies occur about 50% of the time during August, September, and October (Manske 1998a, 1999e). Crude protein levels of ungrazed warm-season grasses decrease below 9.6% in late July, when plants are mature, and below 6.2% in early September. Phosphorus levels of ungrazed warm-season grasses drop below 0.18% in late August.

Grazed grasses have nutrient curves different from those of ungrazed grasses because defoliation manipulates the mechanisms that regulate vegetative reproduction. The reviewed literature contains no examples of defoliation's effects on the nutrient curves for native range warm-season grasses. Sedivec (1999) determined mean percent crude protein for grazing stimulated native range warm-season secondary tillers on twice-over rotation treatments in central North Dakota. Crude protein levels of warm-season secondary tillers increased during August to 10.0% in early September, decreased during September, and dropped below 9.6% in late September (figure 7). Additional research data need to be collected on the effects grazing produces on the crude protein and mineral levels of native range warm-season grasses.

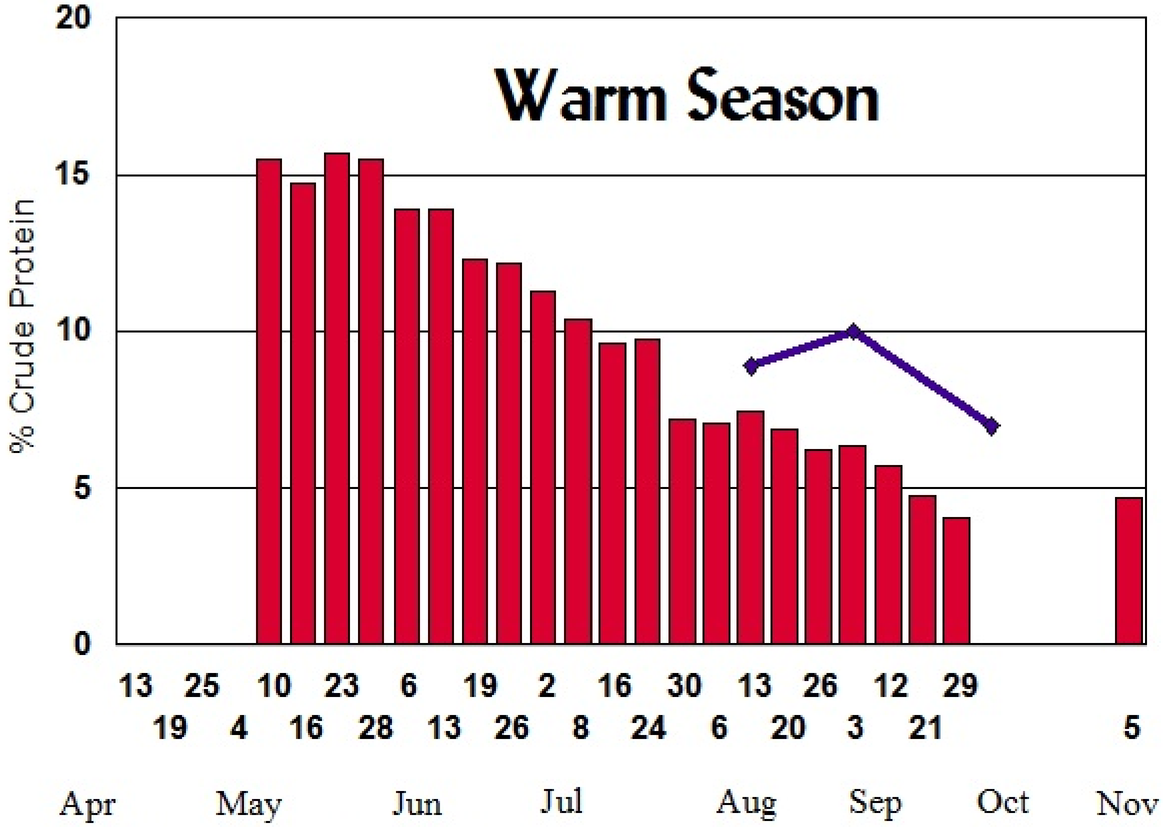

Fig 7. Mean percent crude protein of ungrazed native range warm season grasses in western North Dakota, data from Whitman et al. 1951 and secondary tiller data from Sedivec 1999.

## Discussion

This report summarizes the limited published data reporting sequential nutritional quality of domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses used on the Northern Plains and interprets the relationships between the changes in nutritional quality and the changes in phenological development of ungrazed plants.

The changes in nutritional quality of ungrazed domesticated cool-season grasses follow the plants' phenological stages. Plants contain the highest levels of crude protein in the earliest stages of development. As seed stalks develop, nutrient content begins to decrease, falling rapidly between the flowering stage and the seed mature stage. Crude protein levels of ungrazed domesticated cool-season grasses drop below 9.6% in late June and below 7.8% in early or mid July. Phosphorus levels of ungrazed domesticated cool-season grasses drop below 0.18% in late July or early August.

The nutritional quality of ungrazed native range upland sedges decreases as the plants mature, but the changes in nutritional quality do not follow the same relationships to phenological stages as do the changes in nutritional quality of cool-season grasses. The levels of crude protein are high in the early stages of sedge development. Crude protein levels remain high through flower stalk development, flowering, seed maturing, and seed shedding stages. Nutritional quality decreases with increased senescence in mature sedges. Crude protein levels of ungrazed native range upland sedges drop below 9.6% in mid July and below 7.8% in early August. Phosphorus levels drop below 0.18% in mid May.

The nutritional quality of ungrazed native range cool-season grasses changes with the stages of phenological development. Plants contain the highest levels of crude protein in the early stages of development. As seed stalks develop, nutrient levels begin to decrease, falling rapidly between the flowering stage and the seed mature stage. Levels of crude protein in ungrazed native range cool-season grasses drop below 9.6% in mid July, below 7.8% in early August, and below 6.2% in late August. Grazing stimulated cool-season secondary tillers provide levels of crude protein above 9.6% from mid July through late September during a 2.5 month period when levels of crude protein are below 9.6% in the lead tillers. The phosphorus content of cool-season grasses falls below 0.18% in late July.

The changes in nutritional quality of ungrazed native range warm-season grasses follow the changes in the phenological stages of growth and development. The plants contain the highest levels of crude protein during the early stages of development. As seed stalks develop, nutrient content begins to decrease, falling rapidly between the flowering stage and the seed mature stage. Crude protein levels of ungrazed native warm-season grasses drop below 9.6% in late July and below 6.2% in early September. Grazing stimulated warm-season secondary tillers provide levels of crude protein at or above 9.6% during August and September when levels of crude protein are below 9.6% in the lead tillers. Phosphorus levels of ungrazed native warm-season grasses drop below 0.18% in late August.

The crude protein requirements of 9.6% for cows with average lactation are not met by ungrazed domesticated cool-season grasses after late June, by ungrazed native range upland sedges after mid July, by ungrazed native range cool-season grasses after mid July, and by ungrazed native range warm-season grasses after late July. Grazing stimulated cool-season and warm-season secondary tillers extend the period of crude protein at levels above 9.6% for two to two and a half months until late September or mid October.

Grazing and haying affect grass plant biological mechanisms that regulate vegetative reproduction. These effects are not the same at all phenological growth stages during the growing season. Additional research should be conducted to study the effects defoliation by grazing and haying has on phenological development, vegetative reproduction, and changes in nutritional quality of the forage plants during the growing season.

## Conclusion

Developing management strategies for operations that graze livestock on pastures and cut perennial forages for hay where the vegetation has changeable nutritional quality is challenging. Biologically effective pasture and harvested forage management strategies must protect the health of the plants and still allow the capture of the nutrients produced on the rangelands and grasslands and the conversion of these nutrients into a saleable product at a relatively low cost. Such management strategies match the herbage nutritional quality curves, the herbage production quantity curves, the forage plant phenological development curves, and the livestock nutritional requirement curves. These management strategies include a combination of forage types that have their phenological development and nutritional quality curves at different periods of the year. Complementary forage types are used in the appropriate sequence and proportions to meet the minimum nutritional requirements of livestock during the entire grazing and feeding season.

Nutritional quality data from ungrazed plants show the natural progression and development of the vegetation without alteration from defoliation. Nutritional data from ungrazed plants can be used to evaluate the biological effectiveness of management strategies. Nutrient curves of forage plants that have been defoliated by grazing or haying are different from the nutrient curves of undefoliated plants because defoliation manipulates the mechanisms that regulate vegetative reproduction.

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## Literature Cited

**Coyne, P.I., M.J. Trlica, and C.E. Owensby. 1995.** Carbon and nitrogen dynamics in range plants. p. 59-167. *in* D.J. Bedunah and R.E. Sosebee (eds.). Wildland plants: physiological ecology and development morphology. Society for Range Management, Denver, CO.

**Hopper, T.H., and L.L. Nesbitt. 1930.** The chemical composition of some North Dakota pasture and hay grasses. North Dakota Agricultural Experiment Station. Bulletin 236. Fargo, ND. 38p.

**Leopold, A.C., and P.E. Kriedemann. 1975.** Plant growth and development. McGraw-Hill Book Co., New York, NY.

**Manske, L.L. 1998a.** Environmental factors' effects on range plants. NDSU Dickinson Research Extension Center. Summary Range Research Report DREC 98-3006. Dickinson, ND. 3p.

**Manske, L.L. 1998b.** General description of grass growth and development and defoliation resistance mechanisms. NDSU Dickinson Research Extension Center. Range Management Report DREC 98-1022. Dickinson, ND. 12p.

**Manske, L.L. 1999a.** Annual nutritional quality curves for domesticated cool season grasses. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1024. Dickinson, ND. 13p.

**Manske, L.L. 1999b.** Annual nutritional quality curves for native range upland sedges. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1025. Dickinson, ND. 7p.

**Manske, L.L. 1999c.** Annual nutritional quality curves for native range cool season grasses. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1026. Dickinson, ND. 16p.

**Manske, L.L. 1999d.** Annual nutritional quality curves for native range warm season grasses. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1027. Dickinson, ND. 13p.

**Manske, L.L. 1999e.** Environmental factors to consider during planning of management for range plants in the Dickinson, North Dakota, region, 1892-1998, NDSU Dickinson Research Extension Center. Range Research Report DREC 99-1018b. Dickinson, ND. 36p.

**Marsh, H., K.F. Swingle, R.R. Woodward, G.F. Payne, E.E. Frahm, L.H. Johnson, and J.C. Hide. 1959.** Nutrition of cattle on an eastern Montana range. Montana Agricultural Experiment Station. Bulletin 549. Bozeman, MT. 91p.

**National Research Council. 1996.** Nutrient requirements of beef cattle. 7th rev. ed. National Academy Press, Washington, DC.

**Sedivec, K. 1999.** Nutritional quality of selected rangeland plants. Summary Report. NDSU Animal and Range Sciences Department. Research Report. Fargo, ND.

**Weier, T.E., C.R. Stocking, and M.G. Barbour. 1974.** Botany: an introduction to plant biology. John Wiley and Sons, New York, NY.

**Whitman, W.C., D.W. Bolin, E.W. Klosterman, H.J. Klostermann, K.D. Ford, L. Moomaw, D.G. Hoag, and M.L. Buchanan. 1951.** Carotene, protein, and phosphorus in range and tame grasses of western North Dakota. North Dakota Agricultural Experiment Station. Bulletin 370. Fargo, ND. 55p.

# Annual Mineral Quality Curves for Graminoids in the Northern Plains

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## Introduction

Beef cows require seventeen minerals to maintain proper body functions: seven macrominerals in large quantities and ten microminerals in trace amounts. The quantities of each mineral required vary with cow size, level of milk production, and production period (dry gestation, 3rd trimester, early lactation, lactation). Livestock mineral requirement curves show the amount of each mineral animals require during the production periods. Many essential minerals are provided to the animals by the forages they consume. The mineral content of perennial forage grasses and sedges changes as the plants develop and mature through phenological stages. Annual mineral quality curves for forage plants show these changes in mineral content during the year. Coordination of annual mineral quality curves of available perennial forage plants with livestock mineral requirement curves is necessary for the development of management strategies that efficiently provide the quantities of minerals animals require at each production stage.

The major perennial graminoid plants livestock use as forage are separated into four categories based on the period during which most of the plant growth occurs: domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses. This report summarizes published information on the annual mineral quality curves of these four graminoid categories.

## Methods

Two publications have reported the changes in mineral content of perennial grasses growing on the Northern Plains mixed grass prairie of western North Dakota and eastern Montana. In the historical literature for the Northern Plains, changes in mineral content and related phenological growth stages of perennial graminoids are reported only for phosphorus. Phosphorus is the mineral most commonly deficient in diets of cattle grazing forages. Calcium and salt (sodium and chlorine) are the other minerals most likely to be deficient in forage diets.

Whitman et al. (1951) published a bulletin on the nutrient content of grasses and sedges in western North Dakota. Graminoid species samples were collected weekly in 1946 and 1947 from the Dickinson Experiment Station at Dickinson, North Dakota. Only current year's growth was included in the sample; previous year's growth was separated and discarded. An attempt to collect ungrazed samples was made for available species except Kentucky bluegrass, which had been grazed, and smooth bromegrass, which was cut for hay in mid June. Data were reported as percent of oven-dry weight. Plant condition by stage of plant development and growth habit was reported for each species on sample dates. These data were presented as phenological growth stage in Manske (1999a, b, c, d). Weekly percent phosphorus of graminoid species reported by Whitman et al. (1951) was summarized by species and included in Manske (1999a, b, c, d). These data have been summarized and presented in four graminoid categories in this report.

Marsh et al. (1959) reported nutrient content of three grasses from the USDA Experiment Station at Miles City, Montana. Samples were collected by clipping every 28 days from August 1948 to June 1953 except when snow covered the vegetation. Data were reported as percent of oven-dry weight. Phenological growth stages of plants on sample dates were not reported. A summary of the phosphorus data by species was presented in Manske (1999c, d). These data have been summarized and presented in two graminoid categories in this report.

## Results

The mineral quality of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses changes with the phenological development of the plants. Early season vegetative growth of graminoids is generally high in phosphorus. As the plants mature, their phosphorus content decreases. Phenological development patterns are similar from year to year because they are regulated primarily by photoperiod (Manske 1998b, 2000), although annual differences in temperature, evaporation, and water stress may result in slight variation.

### *Daily Mineral Requirements*

Understanding both the mineral quality curves for perennial forage plants and the mineral requirement curves for beef cows is necessary for efficient nutritional management of livestock. Beef cow daily nutritional requirements (NRC 1996), including phosphorus and calcium requirements, change with cow size, level of milk production, and production period. During the dry gestation period, beef cows with average milk production and live weights of 1000 lbs, 1200 lbs, and 1400 lbs require 0.11%, 0.12%, and 0.12% phosphorus in diet dry matter, respectively; during the 3rd trimester period, they require 0.15%, 0.16%, and 0.17% phosphorus in diet dry matter, respectively; during the early lactation period, they require 0.20%, 0.19%, and 0.19% phosphorus in diet dry matter, respectively; and during the lactation period, they require 0.18%, 0.18%, and 0.18% phosphorus in diet dry matter, respectively (table 1). During the dry gestation period, beef cows with average milk production and live weights of 1000 lbs, 1200 lbs, and 1400 lbs require 0.15%, 0.15%, and 0.16% calcium in diet dry matter, respectively; during the 3rd trimester period, they require 0.24%, 0.25%, and 0.26% calcium in diet dry matter, respectively; during the early lactation period, they require 0.30%, 0.29%, and 0.28% calcium in diet dry matter, respectively; and during the lactation period, they require 0.27%, 0.26%, and 0.26% calcium in diet dry matter, respectively (table 1). Beef cattle require greater amounts of calcium than of phosphorus. However, because perennial grasses contain considerably more calcium than phosphorus, diets of cattle grazing forages are more likely to be deficient in phosphorus.

### *Domesticated Cool-Season Grass*

The domesticated grass species included in the study by Whitman et al. (1951) were crested wheatgrass and smooth bromegrass. Ungrazed or uncut domesticated cool-season grasses (table 2, figs. 1 and 2) contain their highest levels of phosphorus in early May, during the early stages of development. As the plants continue to develop, the percentage of phosphorus decreases. Phosphorus levels drop below 0.18% (the percentage required by lactating cows) in late July, when plants reach the mature seed stage.

One replication of smooth bromegrass in Whitman's study was cut for hay in mid June. Phosphorus levels of the immature tillers that grew after the cutting remained above 0.18% until early September (table 2, fig. 3). These data from hayed smooth bromegrass show that secondary tillers have phosphorus levels above 0.18% for at least one month longer than undefoliated plants. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of domesticated cool-season grasses.

### *Native Range Upland Sedge*

The native range upland sedge species included in the study by Whitman et al. (1951) was threadleaf sedge. Ungrazed upland sedges (table 2, fig. 4) contain their highest levels of phosphorus during the early stages of development, in late April. As the plants continue to develop, the percentage of phosphorus decreases. Upland sedges grow very early and produce seed heads in late April to early May. Phosphorus levels drop below 0.18% (the percentage required by lactating cows) in mid May, when plants reach the mature seed stage.

Defoliation by grazing or haying affects the mineral content of graminoids. The reviewed literature contains no examples of defoliation's effects on the mineral curves of native range upland sedges. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of native range upland sedges.

### *Native Range Cool-Season Grass*

The ungrazed native range cool-season grasses included in the study by Whitman et al. (1951) were western wheatgrass, plains reedgrass, prairie Junegrass, needle and thread, and green needlegrass. The grazed cool-season grass for which Whitman et al. (1951) reported data was Kentucky bluegrass. The native range cool-season grasses for which Marsh et al. (1959) reported data were western wheatgrass and needle and thread. Ungrazed native range cool-season grasses (table 2, fig. 5) contain their highest levels of phosphorus during the early stages of development, in April, May, and early June. As the plants continue to develop, the percentage of phosphorus decreases. In western North Dakota, phosphorus levels of ungrazed native range cool-season grasses drop below 0.18% (the percentage required by lactating cows) in late July, when plants reach the mature seed stage (table 2). In eastern Montana, phosphorus levels drop below 0.18% in late June (table 3). This difference between phosphorus levels of plants in two geographic areas suggests that the rate of leaf senescence may have an effect on mineral levels of grasses.

One cool-season species in Whitman's study, Kentucky bluegrass, was not available in ungrazed condition, so grazed samples were collected. During the grazing season, the grazed plants of Kentucky bluegrass were generally higher in phosphorus content than were ungrazed plants of the other cool-season species (table 2, fig. 6). Phosphorus levels of grazed Kentucky bluegrass remained above 0.18% through late September. Kentucky bluegrass is not an ideal example to illustrate the effects of grazing on the mineral curves of cool-season native range grasses because the lead tiller of Kentucky bluegrass has weak hormonal control of axillary bud activity and does not inhibit secondary tillering to the same extent that the lead tillers of other native range grasses do (Manske 2000). However, these data show that the secondary tillers of Kentucky bluegrass have phosphorus levels above 0.18% for at least two months longer than the undefoliated cool-season plants. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of native range cool-season grasses.

***Native Range Warm-Season Grass***

The ungrazed native range warm-season grasses included in the study by Whitman et al. (1951) were big bluestem, little bluestem, blue grama, and prairie sandreed. The native range warm-season grass for which Marsh et al. (1959) reported data was blue grama. Ungrazed native range warm-season grasses (table 2, fig. 7) contain their highest levels of phosphorus in May, June, and July, during the early stages of development. As the plants continue to develop, the percentage of phosphorus decreases. In western North Dakota, phosphorus levels of ungrazed native range warm-season grasses drop below 0.18% (the percentage required by lactating cows) in late August, when plants reach the mature seed stage (table 2). In eastern Montana, the phosphorus levels drop below 0.18% in early July (table 3). This difference between phosphorus levels of plants in two geographic areas suggests that the rate of leaf senescence may have an effect on mineral levels of grasses.

Defoliation by grazing or haying affects the mineral content of graminoids. The reviewed literature contains no examples of defoliation's effects on the mineral curves of native range warm-season grasses. Additional research data need to be collected on the effects haying and grazing have on the mineral levels of native range warm-season grasses.

Table 1. Daily phosphorus and calcium requirements in pounds and percent dry matter for beef cows with average milk production during four production periods (data from NRC 1996).

| Production Periods | | 1000 lb cows | | 1200 lb cows | | 1400 lb cows | |
|---|---|---|---|---|---|---|---|
| | | Phosphorus | Calcium | Phosphorus | Calcium | Phosphorus | Calcium |
| Dry Gestation | pounds (lb) | 0.02 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 |
| | percent (%) | 0.11 | 0.15 | 0.11 | 0.15 | 0.12 | 0.16 |
| 3rd Trimester | pounds (lb) | 0.03 | 0.05 | 0.04 | 0.06 | 0.05 | 0.07 |
| | percent (%) | 0.15 | 0.24 | 0.16 | 0.25 | 0.17 | 0.26 |
| Early Lactation | pounds (lb) | 0.05 | 0.07 | 0.05 | 0.08 | 0.06 | 0.08 |
| | percent (%) | 0.20 | 0.30 | 0.19 | 0.29 | 0.19 | 0.28 |
| Lactation | pounds (lb) | 0.04 | 0.06 | 0.05 | 0.07 | 0.05 | 0.08 |
| | percent (%) | 0.18 | 0.27 | 0.18 | 0.26 | 0.18 | 0.26 |

Table 2. Weekly percent phosphorus content of graminoids in western North Dakota, means of 1946 and 1947, data from Whitman et al. (1951).

| | | Domesticated | | Native Range | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | cool-season | | upland sedge | | cool-season | | warm-season | |
| | | uncut | hayed[1] | ungrazed | grazed | ungrazed | grazed[2] | ungrazed | grazed |
| Apr | 1 | | | | | | | | |
| | 13 | 0.263 | 0.269 | 0.270 | | 0.315 | 0.314 | | |
| | 19 | 0.280 | 0.244 | 0.317 | | 0.346 | 0.313 | | |
| | 25 | 0.289 | 0.264 | 0.210 | | 0.320 | 0.232 | | |
| May | 4 | 0.306 | 0.302 | 0.210 | | 0.301 | 0.299 | | |
| | 10 | 0.285 | 0.285 | 0.185 | | 0.303 | 0.258 | 0.267 | |
| | 16 | 0.246 | 0.236 | 0.170 | | 0.276 | 0.280 | 0.226 | |
| | 23 | 0.253 | 0.260 | 0.176 | | 0.239 | 0.268 | 0.231 | |
| | 28 | 0.247 | 0.247 | 0.162 | | 0.237 | 0.264 | 0.264 | |
| Jun | 6 | 0.248 | 0.264 | 0.160 | | 0.253 | 0.258 | 0.299 | |
| | 13 | 0.254 | 0.253 | 0.160 | | 0.258 | 0.287 | 0.286 | |
| | 19 | 0.233 | 0.240 | 0.179 | | 0.244 | 0.267 | 0.286 | |
| | 26 | 0.222 | - | 0.152 | | 0.232 | 0.231 | 0.275 | |
| Jul | 2 | 0.211 | - | 0.153 | | 0.228 | 0.272 | 0.245 | |
| | 8 | 0.210 | 0.302 | 0.155 | | 0.205 | 0.243 | 0.245 | |
| | 16 | 0.202 | 0.277 | 0.128 | | 0.203 | 0.246 | 0.222 | |
| | 24 | 0.178 | - | 0.122 | | 0.186 | 0.238 | 0.226 | |
| | 30 | 0.189 | 0.220 | 0.115 | | 0.176 | 0.229 | 0.208 | |
| Aug | 6 | 0.148 | - | 0.097 | | 0.149 | 0.237 | 0.175 | |
| | 13 | 0.158 | 0.184 | 0.109 | | 0.157 | 0.255 | 0.186 | |
| | 20 | 0.169 | - | 0.118 | | 0.153 | 0.145 | 0.194 | |
| | 26 | 0.167 | 0.190 | 0.091 | | 0.141 | 0.189 | 0.150 | |
| Sep | 3 | 0.132 | - | 0.135 | | 0.124 | - | 0.153 | |
| | 12 | 0.106 | - | 0.085 | | 0.119 | - | 0.121 | |
| | 21 | | - | | | | - | 0.189 | |
| | 29 | 0.106 | 0.127 | 0.083 | | 0.120 | 0.234 | 0.076 | |
| Oct | | | | | | | | | |
| Nov | 5 | 0.100 | 0.109 | 0.096 | | 0.116 | 0.155 | 0.085 | |

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[1] Hayed cool-season grass includes only smooth bromegrass data.

[2] Grazed cool-season grass includes only Kentucky bluegrass data.

Table 3. Monthly percent phosphorus content of grasses in eastern Montana, means of 1948-1953, data from Marsh et al. (1959).

| Dates | Native Range | |
|---|---|---|
| | cool-season | warm-season |
| Jan 24 | 0.073 | - |
| Feb 21 | 0.058 | 0.060 |
| Mar 24 | 0.070 | 0.073 |
| Apr 23 | 0.102 | 0.088 |
| May 20 | 0.186 | 0.155 |
| Jun 15 | 0.176 | 0.200 |
| Jul 14 | 0.119 | 0.158 |
| Aug 9 | 0.111 | 0.154 |
| Sep 6 | 0.089 | 0.118 |
| Oct 5 | 0.095 | 0.106 |
| Nov 4 | 0.087 | 0.100 |
| Dec 1 | 0.077 | 0.073 |
| Dec 27 | 0.088 | 0.085 |

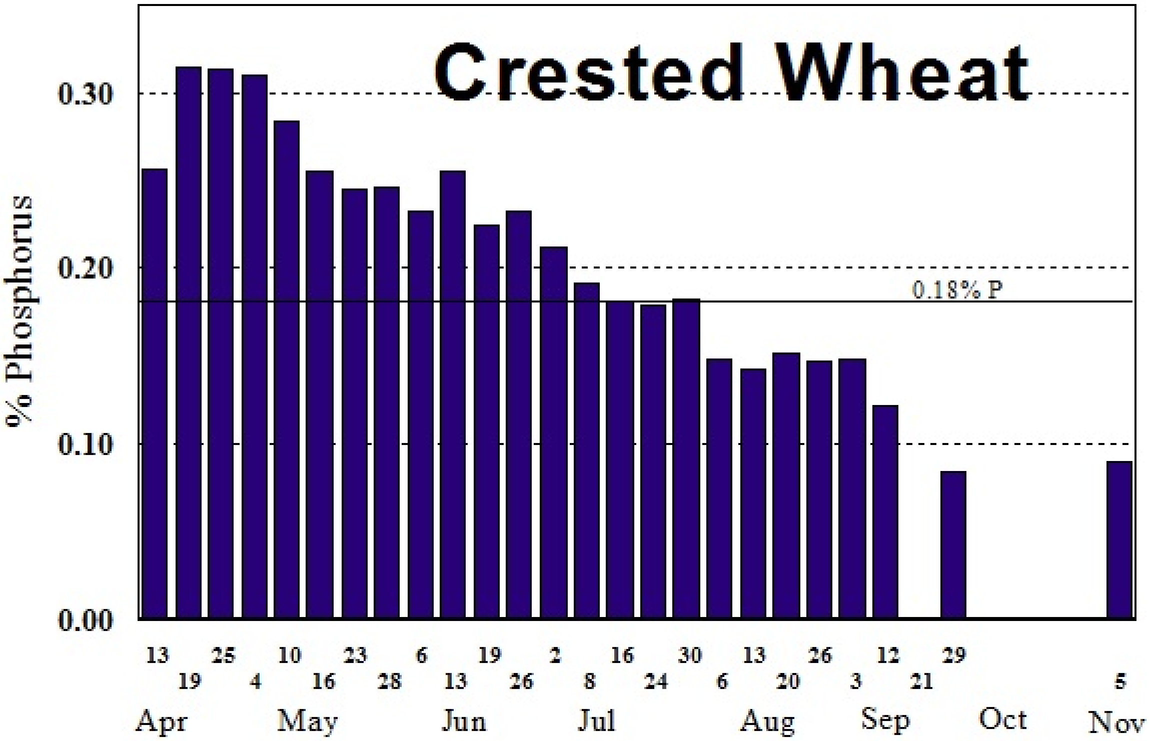

Fig 1. Mean percent phosphorus of ungrazed crested wheatgrass in western North Dakota, data from Whitman et al. 1951.

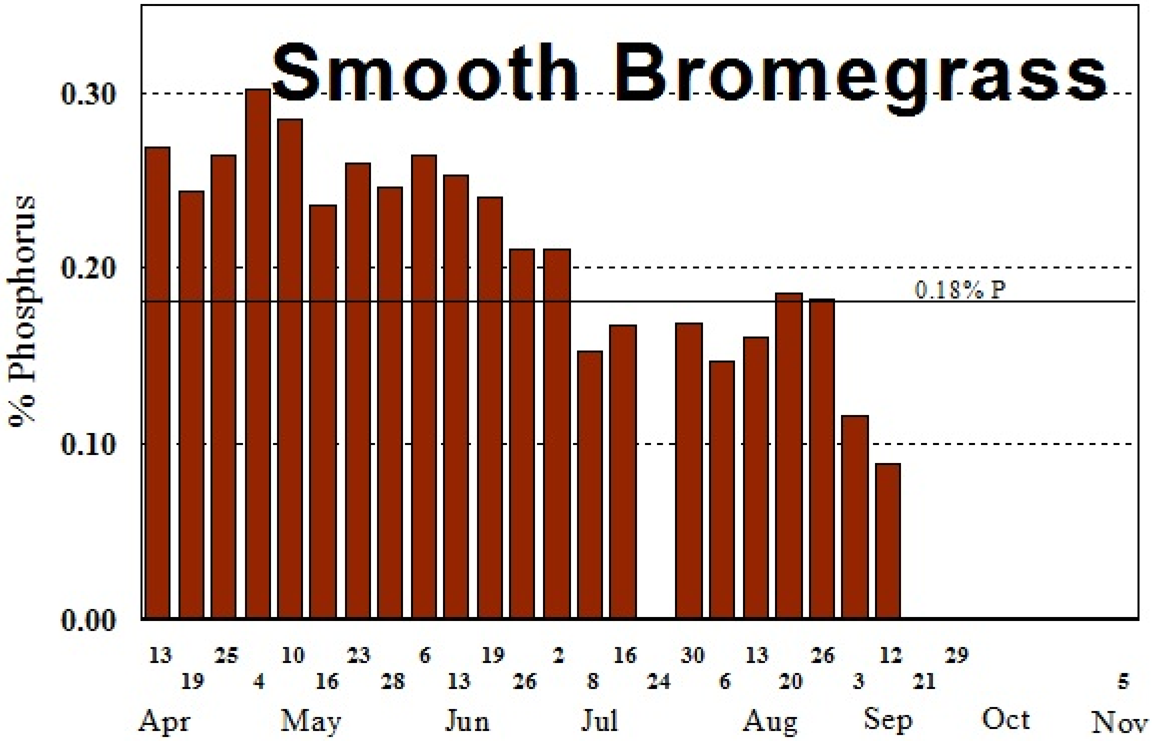

Fig 2. Mean percent phosphorus of smooth bromegrass not cut for hay in western North Dakota, data from Whitman et al. 1951.

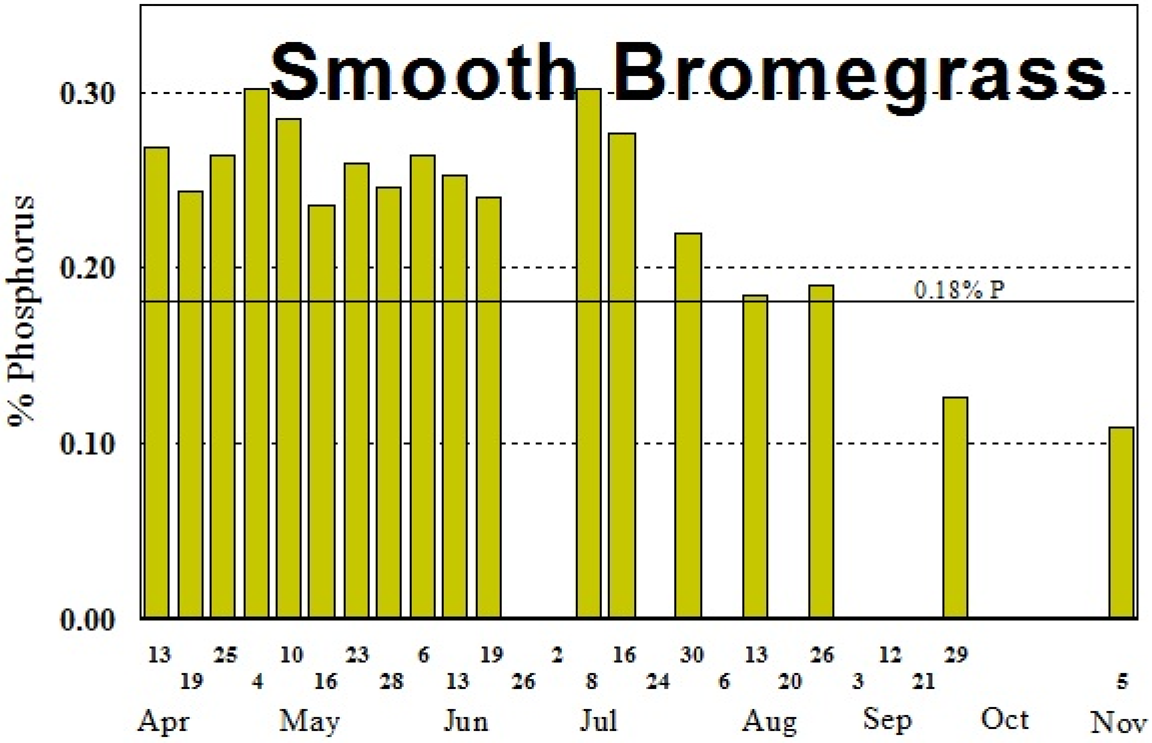

Fig 3. Mean percent phosphorus of smooth bromegrass cut for hay at flowering stage in mid June in western North Dakota, data from Whitman et al. 1951.

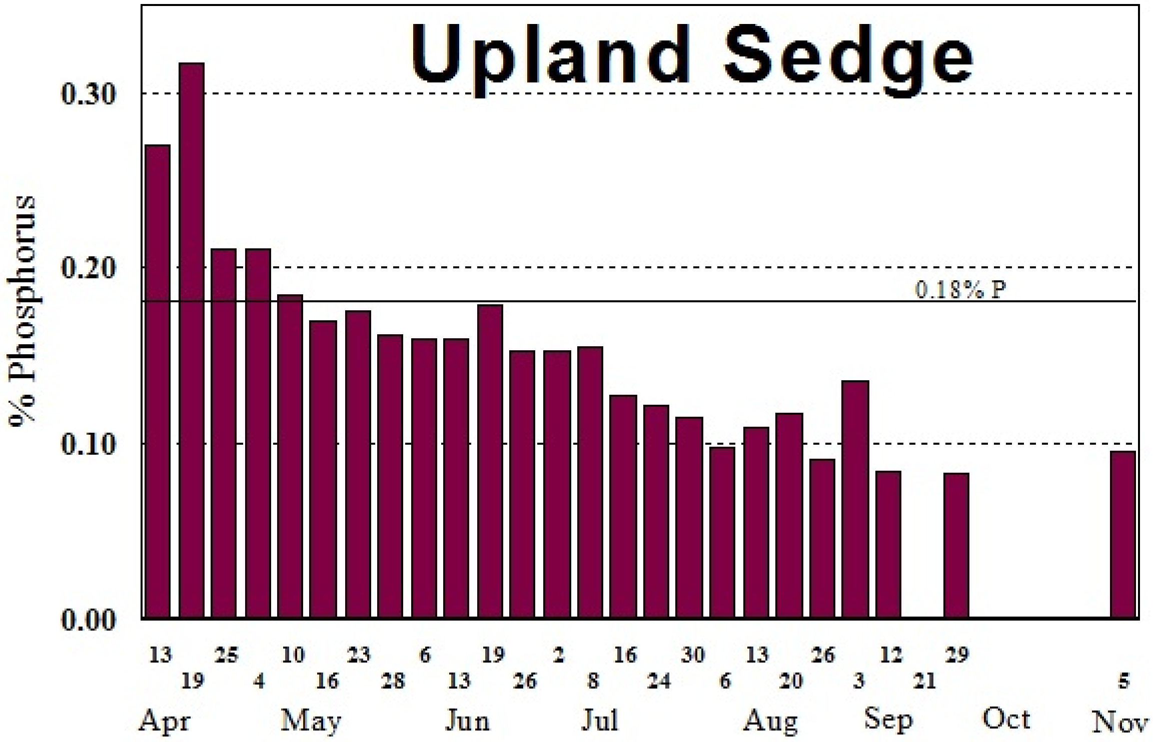

Fig 4. Mean percent phosphorus of ungrazed native range upland sedge in western North Dakota, data from Whitman et al. 1951.

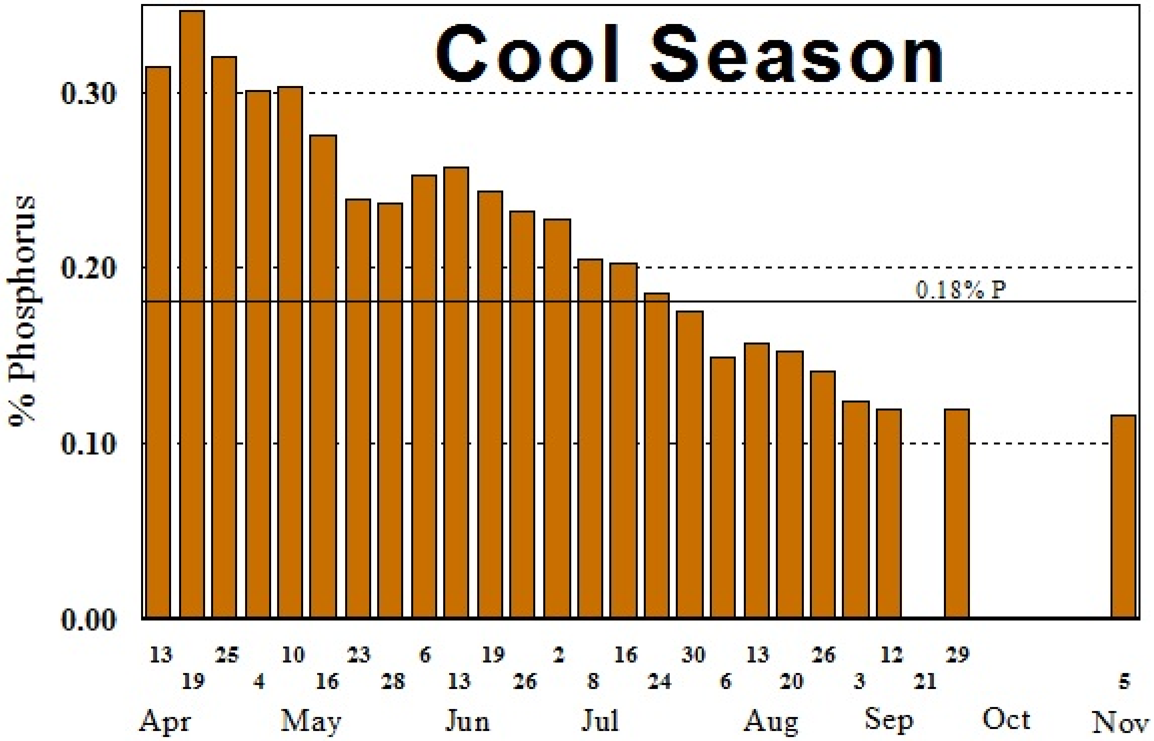

Fig 5. Mean percent phosphorus of ungrazed native range cool season grasses in western North Dakota, data from Whitman et al. 1951.

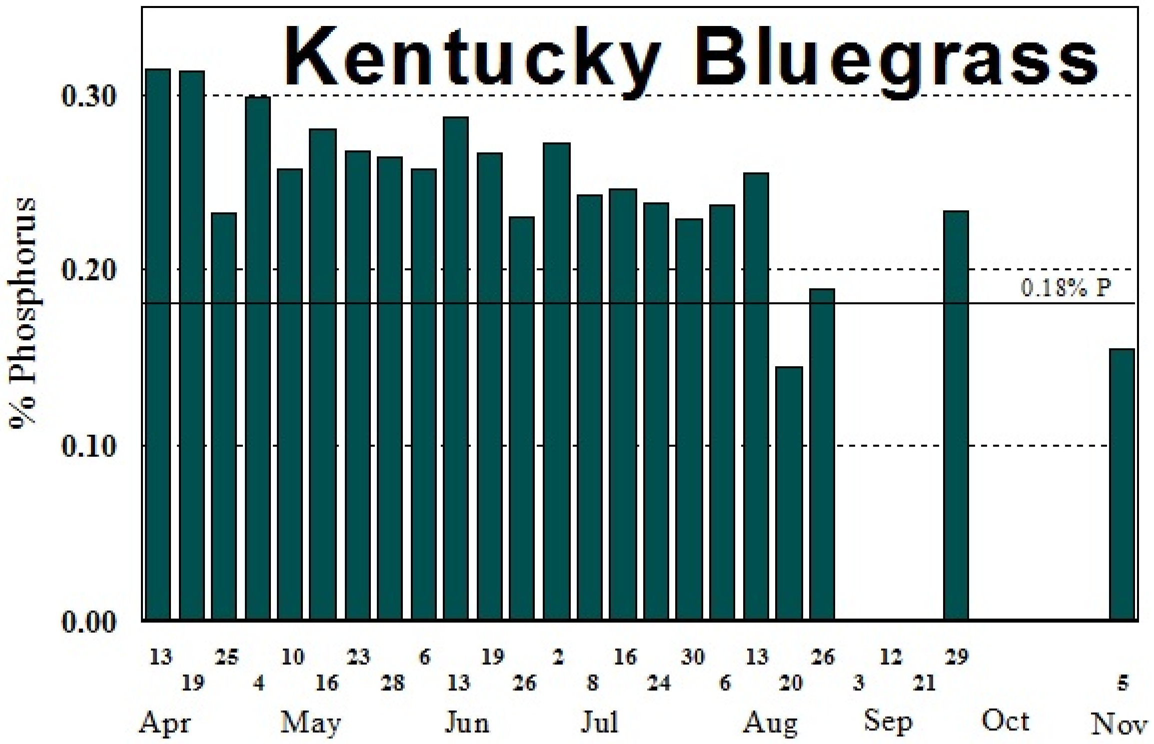

Fig 6. Mean percent phosphorus of grazed Kentucky bluegrass in western North Dakota, data from Whitman et al. 1951.

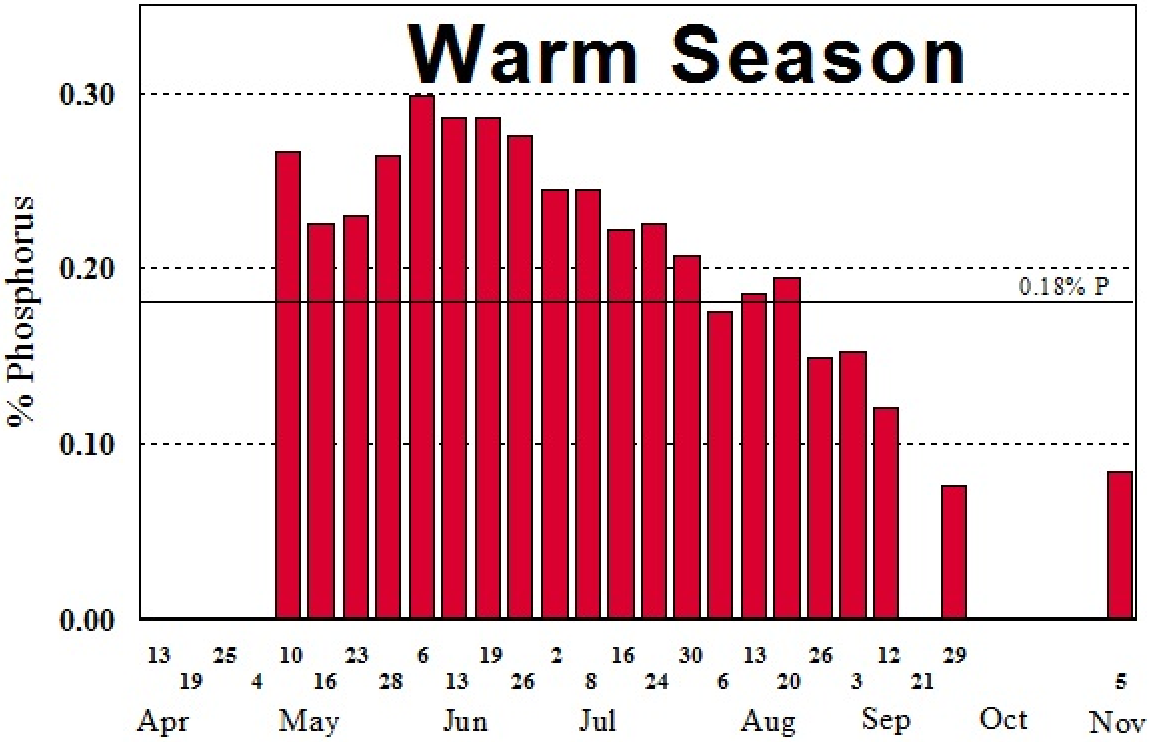

Fig 7. Mean percent phosphorus of ungrazed native range warm season grasses in western North Dakota, data from Whitman et al. 1951.

## Discussion

Phosphorus content is high in domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses during early phenological stages. At this time, these forages provide adequate levels of phosphorus (above 0.18%) for lactating beef cows. As the plants mature and continue to develop, the percentage of phosphorus decreases. Phosphorus levels drop below 0.18% during the mature seed phenological stage. In western North Dakota, ungrazed domesticated cool-season grasses develop mature seeds in late July; ungrazed native range upland sedges, in mid May; ungrazed native range cool-season grasses, in late July; and ungrazed native range warm-season grasses, in late August.

Defoliation of grasses manipulates the mechanisms that regulate vegetative reproduction (Manske 2000), causing changes in plant growth and mineral quality curves. Data to illustrate these changes in mineral quality curves are limited to one example of a domesticated cool-season grass cut for hay in mid June and one example of a grazed native range cool-season grass. The data from hayed smooth bromegrass show that secondary tillers have phosphorus levels above 0.18% until early September. The data from grazed Kentucky bluegrass show that secondary tillers have phosphorus levels above 0.18% through late September. Defoliation by haying extended the period that domesticated cool-season grasses contained phosphorus levels above 0.18% from late July to early September, and grazing extended the period that native range cool-season grasses contained phosphorus levels above 0.18% from late July through late September. Mineral quality curves of forage plants defoliated by haying or grazing are different from mineral quality curves of undefoliated plants.

Lactating beef cows grazing crested wheatgrass or smooth bromegrass spring pastures can obtain adequate phosphorus from the forage during May and June. After mid May, upland sedges do not contain adequate phosphorus levels to meet the requirements of a lactating beef cow. In western North Dakota, lactating beef cows grazing native range seasonlong can obtain adequate phosphorus from cool- and warm-season grasses during June and the early portion of July. In eastern Montana, phosphorus levels of cool- and warm-season grasses are below the requirements of a lactating cow in late June and early July. During late summer, phosphorus levels of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses are below the levels required by lactating beef cows, and during fall and winter, phosphorus levels of these forages are below the levels required by dry gestating cows. Supplementation of phosphorus is needed after late June on native range pastures grazed seasonlong in eastern Montana, after mid July on native range pastures grazed seasonlong in western North Dakota, and on all pastures grazed late summer, fall, or winter.

## Conclusion

This report summarizes the limited published data reporting sequential phosphorus content of domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses used on the Northern Plains and interprets the relationships between the changes in phosphorus content and the phenological development of ungrazed plants. This report also summarizes the beef cow daily requirements for phosphorus and calcium, which change with cow size, level of milk production, and production period.

The changes in mineral content of ungrazed domesticated cool-season grasses, native range upland sedges, native range cool-season grasses, and native range warm-season grasses follow the phenological stages of the plants. Plants contain the highest levels of phosphorus in the early stages of development. As seed stalks develop, phosphorus content decreases. During the mature seed stage, phosphorus content drops below 0.18%, the level required by lactating cows with average milk production. The mature seed stage occurs in late July for domesticated cool-season grasses, in mid May for native range upland sedges, in late July for native range cool-season grasses, and in late August for native range warm-season grasses. Supplemental phosphorus should be provided to livestock during periods when forages do not contain sufficient levels.

Grazing and haying affect the biological mechanisms that regulate vegetative reproduction in grass plants. These effects are not the same at all phenological growth stages during the growing season. Additional research should be conducted to study the effects defoliation by grazing and haying has on phenological development, vegetative reproduction, and changes in mineral content of forage plants during the growing season.

The mineral requirements for beef cows change during the year with the production periods. The mineral content of perennial forage grasses and sedges changes as the plants develop and mature through phenological stages. At some phenological stages, forage plants have insufficient mineral content to meet nutritional requirements of cattle. During these times, forage diets must be supplemented to meet livestock mineral needs. Biologically effective management strategies efficiently supply combinations of forages and supplements to provide the quantities of minerals livestock require at each production period. Such strategies can be developed through coordination of annual mineral quality curves, which illustrate the changes in forage plant mineral content during the year, and livestock mineral requirement curves, which illustrate beef cow mineral requirements at each production period.

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## Literature Cited

**Church, D.C., and W.G. Pond. 1975.** Basic animal nutrition and feeding. O & B Books, Corvillis, OR.

**Manske, L.L. 1998a.** Range management practices addressing problems inherent in the Northern Great Plains grasslands. NDSU Dickinson Research Extension Center. Summary Range Management Report DREC 98-3002. Dickinson, ND. 3p.

**Manske, L.L. 1998b.** Environmental factors' effects on range plants. NDSU Dickinson Research Extension Center. Summary Range Research Report DREC 98-3006. Dickinson, ND. 3p.

**Manske, L.L. 1999a.** Annual nutritional quality curves for domesticated cool-season grasses. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1024. Dickinson, ND. 13p.

**Manske, L.L. 1999b.** Annual nutritional quality curves for native range upland sedges. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1025. Dickinson, ND. 7p.

**Manske, L.L. 1999c.** Annual nutritional quality curves for native range cool-season grasses. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1026. Dickinson, ND. 16p.

**Manske, L.L. 1999d.** Annual nutritional quality curves for native range warm-season grasses. NDSU Dickinson Research Extension Center. Range Management Report DREC 99-1027. Dickinson, ND. 13p.

**Manske, L.L. 2000.** Management of Northern Great Plains Prairie based on biological requirements of the plants. NDSU Dickinson Research Extension Center. Range Science Report DREC 00-1028. Dickinson, ND. 13p.

**Marsh, H., K.F. Swingle, R.R. Woodward, G.F. Payne, E.E. Frahm, L.H. Johnson, and J.C. Hide. 1959.** Nutrition of cattle on an eastern Montana range. Montana Agricultural Experiment Station. Bulletin 549. Bozeman, MT. 91p.

**National Research Council. 1996.** Nutrient requirements of beef cattle. 7th rev. ed. National Academy Press, Washington, DC.

**Whitman, W.C., D.W. Bolin, E.W. Klosterman, H.J. Klostermann, K.D. Ford, L. Moomaw, D.G. Hoag, and M.L. Buchanan. 1951.** Carotene, protein, and phosphorus in range and tame grasses of western North Dakota. North Dakota Agricultural Experiment Station. Bulletin 370. Fargo, ND. 55p.

# Mineral Requirements for Beef Cows Grazing Native Rangeland

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## Introduction

Beef cows grazing native rangeland require seven macrominerals and ten microminerals for normal body functions. Understanding livestock mineral requirements, functions of each mineral, and mineral concentrations that result in deficiencies or toxicities is necessary to maintain beef cows at high levels of production. The quantities of each mineral required vary with cow size, level of milk production, and production period (dry gestation, 3rd trimester, early lactation, and lactation). Animals acquire most of these essential minerals from forages. Forage plant growth can be altered by differential defoliation treatment effects on plant growth processes (Manske 2000). Mineral concentrations in native range herbage are not constant, and the patterns of change during the grazing season differ with management treatment. Supplementation of minerals during periods when concentrations in herbage are below those required by beef cattle is necessary to maintain optimum livestock performance. This report summarizes information on the mineral requirements for beef cows grazing native rangeland of the mixed grass prairie in the Northern Plains.

## Beef Cow Macromineral Requirements

The macrominerals required by beef cattle are calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), chlorine (Cl), and sulfur (S). Phosphorus and calcium make up about 70% to 75% of the mineral matter in beef cattle, including over 90% of the mineral matter in the skeleton. Calcium is the most abundant mineral in the cow's body, with 98% of the calcium in the bones and teeth and the remainder in the extracellular fluids and soft tissue (NRC 1996). About 80% of the phosphorus in the cow's body is in the bones and teeth; the remainder occurs in soft tissue, mostly in organic forms. Phosphorus and calcium function together with magnesium in bone formation, and these minerals are required for normal skeletal development and maintenance (NRC 1996). Phosphorus exists in blood serum both in organic forms, as a constituent of lipids, and in inorganic forms. Phosphorus is a component of phospholipids, which are important in lipid transport and metabolism and in cell-membrane structure and cell growth. As a component of AMP, ADP, ATP, and creatine phosphate, phosphorus functions in energy metabolism, utilization, and transfer. Phosphorus is required for protein synthesis as phosphate, a component of RNA and DNA. Calcium exists in blood serum in both organic and inorganic forms. Slight changes in calcium, potassium, magnesium, and sodium concentrations control muscle contractions and the transmission of nerve impulses. Calcium and sulfur are required for normal blood coagulation (Church and Pond 1975, NRC 1996). Phosphorus, calcium, potassium, and magnesium are constituents of several enzyme systems. Phosphorus, calcium, potassium, magnesium, sodium, chlorine, and sulfur function in regulating fluid balance by maintaining osmotic pressure and the acid-base balance of the entire system. The blood contains more sodium and chlorine than other minerals. Sodium and chlorine are electrolytes and function in maintaining osmotic pressure in the body cells. Chlorine is required to form hydrochloric acid in gastric juice (Church and Pond 1975, NRC 1996). Phosphorus and sulfur are required by ruminal microorganisms for their growth and cellular metabolism (NRC 1996).

Relative levels of calcium and phosphorus are important. Dietary calcium to phosphorus ratios between 1:1 and 7:1 result in similar normal animal performance. Dietary phosphorus absorption (NRC 1996) occurs rapidly in the small intestine by passive diffusion across the intestine cell membrane against a concentration gradient in the presence of calcium. Cattle are not known to have an active transport system for phosphorus. About 68% of dietary phosphorus is absorbed. Dietary calcium absorption (NRC 1996) occurs in the first two sections of the small intestine both by passive diffusion and by active transport with a vitamin D-dependent protein carrier. About 50% of dietary calcium is absorbed. Calcium is maintained at a relatively constant concentration in the blood plasma by an elaborate control system that involves calcium deposition in and resorption from the bones, variations in reabsorption rate in the kidneys, and variations in the levels of absorption in the intestines. During periods when blood phosphorus or calcium concentrations are low, the kidney tubules can reabsorb an increased amount of the deficient minerals and the body can thereby conserve them. The skeleton of mature animals provides a large reserve of phosphorus and calcium that can be drawn on during periods of inadequate phosphorus or calcium intake. Skeletal reserves can subsequently be replenished during periods when phosphorus and calcium intake are high relative to requirements (Church and Pond 1975, NRC 1996).

The concentrations of calcium and phosphorus required by beef cows during lactation are 0.26%-0.27% and 0.18% diet dry matter, respectively (NRC 1996). A deficiency of either calcium or phosphorus can adversely affect the skeletal system. In young growing animals inadequate calcium or phosphorus can cause rickets, which develops when the blood becomes low or deficient in calcium, phosphorus, or both, and normal deposition of calcium and phosphorus in growing bones cannot occur. The bones become soft and weak. In severe cases, bones can become deformed, and with increased severity of the condition, bones can break or fracture readily. A deficiency of calcium or phosphorus in older mature animals can cause osteoporosis, which develops when large amounts of calcium and phosphorus are withdrawn from the bones to meet other systems' needs for these minerals. During prolonged periods of calcium and phosphorus deficiency, the bones become porous and weak, and in severe cases, they can break easily (Church and Pond 1975, NRC 1996).

Pregnancy and lactation produce high demands for calcium and phosphorus. Production of one pound of milk requires 0.020 ounces of calcium and 0.015 ounces of phosphorus (NRC 1996). Most cases of calcium deficiency occur early in lactation, during the period when milk production causes large drains on body calcium reserves. Calcium deficiency during lactation causes milk fever. Severe calcium deficiency produces hypocalcemia (low blood calcium) and interferes with the role calcium plays in normal muscle contractions, including those of the heart, and in normal transmission of nerve impulses; this condition results in tetany, convulsions, and, if not treated early, possibly death (Church and Pond 1975, NRC 1996).

Even when cattle diets are only slightly deficient in calcium or phosphorus, animal performance may suffer. Calcium deficiency causes reduced feed intake, loss of body weight, and failure of cows to come into heat regularly. Calcium deficiency also causes a reduction in the quantity of milk produced: the quality of the milk is not changed, and the mineral content of the milk remains relatively constant; however, reduction in the quantity of milk produced by a cow results in lower calf daily gain (Manske 1998). Phosphorus deficiency in beef cattle results in reduced growth and feed efficiency, decreased feed intake, impaired reproduction, reduced milk production, and weak, fragile bones. Cattle grazing forages low in phosphorus experience lower fertility and lighter calf weaning weights (NRC 1996).

Deficiencies of other macrominerals are also detrimental to beef cattle. Adequate quantities of supplemental minerals should be provided to livestock during periods when forages do not contain sufficient levels.

The concentration of magnesium required by beef cows during lactation is 0.17%-0.20% diet dry matter (NRC 1996). Magnesium deficiency causes grass tetany (hypomagnesemia or low blood magnesium), occurring most commonly in lactating cows grazing lush spring pastures high in protein and potassium. Magnesium deficiency in beef cattle results in nervousness, reduced feed intake, muscular twitching, and staggering gait. In advanced stages of magnesium deficiency, convulsions occur, the animal cannot stand, and death soon follows (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of magnesium has been estimated at 0.40% diet dry matter (NRC 1996).

Intake of proper amounts of potassium, the third most abundant mineral in beef cattle, is important. The concentration of potassium required by beef cows during lactation is 0.70% diet dry matter (NRC 1996). Deficiency of potassium causes decreased feed intake and reduced weight gain. Cattle consuming diets with more than 3% potassium while grazing lush spring pastures experience reduced magnesium absorption and the related magnesium deficiency symptoms (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of potassium has been set at 3.0% diet dry matter because of potassium's antagonistic action to magnesium absorption. High levels of potassium are not known to cause any other adverse effects (NRC 1996).

The concentration of sulfur required by beef cows is 0.15% diet dry matter (NRC 1996). Deficiency of sulfur, a component of some amino acids and some vitamins, causes reduced feed intake and decreased microbial digestion and protein synthesis. Severe sulfur deficiency results in diminished feed intake, major loss of body weight, weak and emaciated condition, excessive salivation, and death (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of dietary sulfur has been estimated at 0.40% diet dry matter, but sulfur toxicity is not a practical problem because absorption of inorganic sulfur is low (Church and Pond 1975, NRC 1996).

Grazing cattle require supplemental salt (sodium and chlorine) because forages do not contain adequate amounts. The concentration of sodium required by beef cows during lactation is 0.10% diet dry matter (NRC 1996). The concentration of chlorine required by beef cows is not well defined, but the amounts supplied by dietary salt appear to be adequate (Church and Pond 1975, NRC 1996). Severe salt deficiency causes reduced feed intake, rapid loss of body weight, and reduced milk production. In some arid and semi-arid regions of the country, a portion of the required amount of salt is provided by the alkaline water. Supplemental salt can be provided free-choice in loose or block forms. Cattle grazing pastures consume more salt during spring and early summer when the forage is more succulent than later in the season when the forage is drier. High levels of dietary salt reduce feed intake. Cattle occasionally consume greater amounts of salt than required but will generally not consume excessive amounts except after experiencing periods without sufficient quantities (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of dietary salt is estimated at 9.0% diet dry matter. Salt in drinking water is much more toxic; the maximum tolerable concentration of sodium in water is 0.70% (NRC 1996).

Toxicity of magnesium, potassium, sodium, or chlorine is unlikely because amounts in excess of those required are readily excreted by the kidneys. Toxicity problems can develop, however, when drinking water intake is restricted, drinking water contains more than 7,000 mg Na/kg (ppm), or the kidneys malfunction (Church and Pond 1975, NRC 1996).

### Beef Cow Micromineral Requirements

The microminerals required by beef cattle are chromium (Cr), cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn). Microminerals are primarily components of enzymes and organic compounds or are elements for activation of enzyme systems. The functions of microminerals are determined by the function of the compounds of which the microminerals are a part.

Chromium (Cr) is a cofactor in the action of insulin and is important in glucose utilization and the synthesis of cholesterol and fatty acids. Beef cattle may need supplemental chromium in some situations, but the current data are not sufficient to allow accurate determination of requirements. The maximum tolerable concentration in diet dry matter is estimated to be 1,000 mg Cr/kg (ppm) (Church and Pond 1975, NRC 1996).

Cobalt (Co) functions as a component of vitamin $B_{12}$. Two vitamin $B_{12}$-dependent enzymes are known to occur in cattle. Cattle are not dependent on a dietary source of vitamin $B_{12}$ because ruminal microorganisms can synthesize $B_{12}$ from dietary cobalt. The recommended concentration of cobalt in beef cattle diets is approximately 0.10 mg Co/kg (ppm) diet dry matter. Early signs of cobalt deficiency are decreased appetite, reduced milk production, and either failure to grow or moderate weight loss. With severe deficiency, animals exhibit unthriftiness, rapid weight loss, fatty degeneration of the liver, and pale skin and mucous membrane as a result of anemia. Cobalt concentrations in forages are dependent on levels of cobalt in the soil. Availability of cobalt in soil is highly dependent on soil pH, and some soils are deficient in cobalt. Legumes are generally higher in cobalt than grasses. Cobalt can be supplemented in mineral mixtures as cobalt sulfate and cobalt carbonate. Cobalt toxicity is not likely to occur because cattle can tolerate approximately 100 times the dietary requirements. Signs of cobalt toxicity are decreased feed intake, reduced body weight gain, anemia, emaciation, hyperchromia, debility, and increased liver cobalt (Church and Pond 1975, NRC 1996).

Copper (Cu) functions as an essential component of a number of enzymes and is required for normal red blood cell formation, normal bone formation, normal elastin formation in the aorta and cardiovascular system, normal myelination of the brain cells and spinal cord, and normal pigmentation of hair. Copper is important to the functions of the immune system. The recommended concentration of copper in beef cattle diets is 10 mg Cu/kg (ppm) diet dry matter. Copper requirements are affected by dietary molybdenum (Mo) and sulfur (S). Antagonistic action of molybdenum occurs at levels above 2 mg Mo/kg diet, and antagonistic action of sulfur occurs at levels above 0.25% sulfur. Molybdenum and sulfur interact in the rumen to form thiomolybdates, compounds that react with copper to form insoluble complexes that are poorly absorbed. Thiomolybdates also reduce metabolism of copper post absorption. Sulfur can react with copper to form copper sulfide, which also reduces absorption of copper. High concentrations of iron and zinc also reduce copper status. Copper deficiency is a widespread problem in many areas of North America. Signs of copper deficiency are anemia; reduced growth rate; changes in the growth, physical appearance, and pigmentation of hair; cardiac failure; fragile bones that easily fracture; diarrhea; and low reproduction levels resulting from delayed or depressed estrus. Copper concentrations in forages are highly variable, depending on plant species and availability of copper in the soil. Legumes are usually higher in copper than grasses. Copper can be supplemented in mineral mixtures in the sulfate or carbonate forms. Feed-grade copper oxide is largely biologically unavailable but has been used as a source of slow-release copper because it remains in the digestive tract for months. The maximum tolerable concentration of copper for cattle has been estimated at 100 mg Cu/kg (ppm) diet dry matter, but this amount is dependent on the concentrations of molybdenum, sulfur, and iron in the diet. The liver can accumulate large amounts of copper before signs of toxicity are observed (Church and Pond 1975, NRC 1996).

Iodine (I) is an essential component of thyroid hormones, which regulate the rate of energy metabolism. Iodine requirements of beef cattle have not been determined with certainty, but 0.5 mg I/kg (ppm) diet dry matter should be adequate. Signs of iodine deficiency are enlargement of the thyroid, calves born weak or dead, and reduced reproduction that results from irregular cycling, low conception rate, and retained placenta in cows and from decreased libido and semen quality in bulls. Iodine concentrations in forage depend on the availability of iodine in the soil, and many of the soils in central North America are deficient in iodine. Iodine can be supplemented in iodized salt or in mineral mixtures as calcium iodate or an organic form of iodine. Cattle tolerate maximum iodine levels of 50 mg I/kg (ppm) diet dry matter. Signs of iodine toxicity are coughing, excessive nasal discharge, reduced feed intake, and reduced weight gain (Church and Pond 1975, NRC 1996).

Iron (Fe) is a component of hemoglobin in red blood cells, myoglobin in muscles, and other proteins involved in transport of oxygen to tissues or utilization of oxygen. Iron is also a constituent of several enzymes associated with the mechanisms of electron transport, and iron is a component of several metalloenzymes. Iron is important to the functions of the immune system. The iron requirement of beef cattle is approximately 50 mg Fe/kg (ppm) diet dry matter. Iron requirements of older cattle are not well defined but are probably lower than those of young calves, in which blood volume is increasing. Iron deficiency is unlikely in cattle because adequate levels of iron are available from numerous sources. Iron concentration in forages is highly variable, but most forages are high in iron, containing from 70 to 500 mg Fe/kg. Water and ingested soil can be significant sources of iron for beef cattle. When iron needs to be supplemented, it can be added to mineral mixtures as ferrous sulfate or ferrous carbonate. Ferric oxide is basically biologically unavailable. Dietary iron concentrations as low as 250 to 500 mg/kg have caused copper depletion in cattle. In areas where drinking water or forages are high in iron, dietary copper may need to be increased to prevent copper deficiency. The maximum tolerable concentration of iron for cattle has been estimated at 1,000 mg Fe/kg (ppm) diet dry matter. Signs of iron toxicity are diarrhea, metabolic acidosis, hypothermia, reduced feed intake, and reduced weight gain (Church and Pond 1975, NRC 1996).

Manganese (Mn) is a component of a few metalloenzymes that function in carbohydrate metabolism and lipid metabolism. Manganese also stimulates and activates a number of other enzymes. Manganese is important in cattle reproduction because it is required for normal estrus and ovulation in cows and for normal libido and spermatogenesis in bulls. Manganese is essential for normal bone formation and growth. Manganese is important to the functions of the immune system. The recommended concentration of manganese for breeding cattle is 40 mg Mn/kg (ppm) diet dry matter. Signs of manganese deficiency are skeletal abnormalities in young animals and, in older animals, low reproductive performance resulting from depressed or irregular estrus, low conception rate, abortion, stillbirths, and low birth weights. Manganese concentrations in forage are generally adequate but are variable, depending on the availability of manganese because of soil pH and soil drainage. Manganese can be supplemented in mineral mixtures as manganese sulfate, manganese oxide, or various organic forms. Manganese oxide is less readily available biologically than manganese sulfate. Maximum tolerable concentration of manganese is set at 1,000 mg Mn/kg (ppm) diet dry matter (Church and Pond 1975, NRC 1996).

Molybdenum (Mo) is a component of a metalloenzyme and other enzymes. The requirements for molybdenum have not been established. No evidence that molybdenum deficiency occurs in cattle under practical conditions has been found. Metabolism of molybdenum is affected by copper and sulfur, which are antagonistic. Sulfide and molybdate interact in the rumen to form thiomolybdates, compounds that cause decreased absorption and reduced post absorption metabolism of molybdenum and increased urinary excretion of molybdate. Molybdenum concentrations in forages are generally adequate but vary greatly, depending on soil type and soil pH. Neutral or alkaline soils coupled with high moisture and organic matter favor molybdenum uptake by forages. High concentrations of molybdenum can cause toxicity. The maximum tolerable concentration of molybdenum for cattle has been estimated to be 10 mg Mo/kg (ppm) diet dry matter. Signs of molybdenum toxicity are diarrhea, anorexia, loss of weight, stiffness, and changes in hair color. Supplementation of large quantities of copper will overcome molybdenosis (Church and Pond 1975, NRC 1996).

Nickel (Ni) is an essential component of urease in rumen bacteria. Nickel deficiency in animals can be produced experimentally, but the function of nickel in mammalian metabolism is unknown. Research data are not sufficient to determine nickel requirements of beef cattle. Nickel can be supplemented in mineral mixtures as nickel chloride. The maximum tolerable concentration of nickel is estimated to be 50 mg Ni/kg (ppm) diet dry matter (Church and Pond 1975, NRC 1996).

Selenium (Se) is part of at least two metalloenzymes, and its functions are interrelated with vitamin E. Failure of functions involving selenium can result in nutritional muscular dystrophy. Selenium is also a component of an enzyme that has a role in maintaining integrity of cellular membranes. Selenium is required for normal pancreatic morphology and is involved in normal absorption of lipids and tocophenols. Selenium is important to the functions of the immune system. The factors that affect selenium requirements are not well defined, but beef cattle requirements can be met by 0.1-0.2 mg Se/kg (ppm) diet dry matter. Selenium deficiency results in degeneration of muscle tissue (white muscle disease) in young animals. Signs of deficiency are stiffness, lameness, and possible cardiac failure. Signs of selenium deficiency in older animals are unthriftiness, weight loss, diarrhea, anemia, and reduced immune responses. Selenium concentrations in forages vary greatly and depend primarily on the selenium content of the soil. Soils developed from Cretaceous or Eocene shales contain high levels of selenium. Some species of milkvetch (*Astragalus spp.*) absorb selenium more readily than other native plants. Cattle grazing plants high in selenium can consume toxic amounts. The maximum tolerable concentration of selenium has been estimated to be 2 mg Se/kg (ppm) diet dry matter. Signs of selenium toxicity are lameness, anorexia, emaciation, loss of vitality, liver cirrhosis, inflamed kidneys, loss of hair from the tail, and cracked, deformed, and elongated hoofs. Signs of acute selenium toxicity are labored breathing, diarrhea, loss of coordination, abnormal posture, and death from respiratory failure (Church and Pond 1975, NRC 1996).

Zinc (Zn) is a constituent of many enzymes and many metalloenzyme systems, and zinc is effective in activation of a large number of other enzymes. Zinc is required for normal protein synthesis and metabolism. A component of insulin, zinc functions in carbohydrate metabolism. Zinc is important for normal development and functioning of the immune system. The recommended requirement of zinc in beef cattle diets is 30 mg Zn/kg (ppm) diet dry matter, although zinc requirements of beef cattle fed forage-based diets and requirements for reproduction and milk production are not well defined. Dietary factors that affect zinc requirements in ruminants are not understood. Subclinical deficiencies of zinc cause decreased weight gain, reduced milk production, and reduced reproductive performance. Signs of severe zinc deficiency are listlessness, excessive salivation, reduced testicular growth, swollen feet, loss of hair, failure of wounds to heal, reduced growth, reduced feed intake, reduced feed efficiency, and lesions with horny growths on legs, neck, and head and around the nostrils. The zinc content of forages is affected by a number of factors, including plant species, plant maturity, and soil zinc. Legumes are generally higher in zinc than grasses. A relatively large portion of the zinc in forages is associated with the plant cell wall, but it is not known whether zinc's association with fiber reduces absorption. Zinc can be supplemented in mineral mixtures with feed-grade sources of bioavailable zinc in the form of zinc oxide, zinc sulfate, zinc methionine, and zinc proteinate. The maximum tolerable concentration of zinc is 500 mg Zn/kg (ppm) diet dry matter, a much greater amount than required. Signs of zinc toxicity are reduced feed intake, reduced feed efficiency, and decreased weight gain (Church and Pond 1975, NRC 1996).

## Daily Mineral Requirements

Understanding mineral requirements for beef cows is necessary for effective nutritional management of livestock grazing native rangeland. Beef cow daily nutritional requirements (NRC 1996) change with cow size, level of milk production, and production period. Requirements for some macrominerals change with cow production period. Fetal development requires increased amounts of dietary calcium, phosphorus, and magnesium. Lactation requires increased amounts of dietary calcium, phosphorus, magnesium, potassium, and sodium. Milk production increases the demand for iodine and zinc, but dietary requirements do not increase because the demands are likely met by increases in absorption (NRC 1996). Daily macromineral and micromineral requirements for 1000-, 1200-, and 1400-pound cows with average milk production are shown in tables 1-6. Lactating cows grazing native rangeland require diet dry matter containing 0.26-0.27% calcium, 0.18% phosphorus, 0.17-0.20% magnesium, 0.70% potassium, 0.10% sodium, and 0.15% sulfur. Lactating cows require diet dry matter containing the following micromineral concentrations: 0.10 ppm cobalt, 10.0 ppm copper, 0.50 ppm iodine, 50.0 ppm iron, 40.0 ppm manganese, 0.10 ppm selenium, and 30.0 ppm zinc. The amounts of chlorine, chromium, molybdenum, and nickel lactating cows require from diet dry matter are not known.

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Table 1. Daily macromineral requirements in pounds per day and percent diet dry matter for 1000-pound beef cows with average milk production during four production periods (data from NRC 1996).

| | | Production Periods | | | |
|---|---|---|---|---|---|
| Macrominerals | | Dry Gestation | 3rd Trimester | Early Lactation | Lactation |
| Dry matter | lbs | 21 | 21 | 24 | 24 |
| Calcium | % | 0.15 | 0.24 | 0.30 | 0.27 |
| | lbs/day | 0.03 | 0.05 | 0.07 | 0.06 |
| Phosphorus | % | 0.11 | 0.15 | 0.20 | 0.18 |
| | lbs/day | 0.02 | 0.03 | 0.05 | 0.04 |
| Magnesium | % | 0.12 | | 0.17-0.20 | |
| | lbs/day | 0.03 | | 0.04-0.05 | |
| Potassium | % | 0.60 | | 0.70 | |
| | lbs/day | 0.13 | | 0.17 | |
| Sodium | % | 0.06-0.08 | | 0.10 | |
| | lbs/day | 0.01-0.02 | | 0.02 | |
| Chlorine | % | requirements are not well defined but a deficiency does not seem likely in practical conditions | | | |
| | lbs/day | | | | |
| Sulfur | % | 0.15 | | 0.15 | |
| | lbs/day | 0.03 | | 0.04 | |

Table 2. Daily macromineral requirements in pounds per day and percent diet dry matter for 1200-pound beef cows with average milk production during four production periods (data from NRC 1996).

| | | Production Periods | | | |
|---|---|---|---|---|---|
| Macrominerals | | Dry Gestation | 3rd Trimester | Early Lactation | Lactation |
| Dry matter | lbs | 24 | 24 | 27 | 27 |
| Calcium | % | 0.15 | 0.25 | 0.29 | 0.26 |
| | lbs/day | 0.04 | 0.06 | 0.08 | 0.07 |
| Phosphorus | % | 0.12 | 0.16 | 0.19 | 0.18 |
| | lbs/day | 0.03 | 0.04 | 0.05 | 0.05 |
| Magnesium | % | 0.12 | | 0.17-0.20 | |
| | lbs/day | 0.03 | | 0.045-0.05 | |
| Potassium | % | 0.60 | | 0.70 | |
| | lbs/day | 0.14 | | 0.19 | |
| Sodium | % | 0.06-0.08 | | 0.10 | |
| | lbs/day | 0.01-0.02 | | 0.03 | |
| Chlorine | % | requirements are not well defined but a deficiency does not seem likely in practical conditions | | | |
| | lbs/day | | | | |
| Sulfur | % | 0.15 | | 0.15 | |
| | lbs/day | 0.04 | | 0.04 | |

Table 3. Daily macromineral requirements in pounds per day and percent diet dry matter for 1400-pound beef cows with average milk production during four production periods (data from NRC 1996).

| | | Production Periods | | | |
|---|---|---|---|---|---|
| Macrominerals | | Dry Gestation | 3rd Trimester | Early Lactation | Lactation |
| Dry matter | lbs | 27 | 27 | 30 | 30 |
| Calcium | % | 0.16 | 0.26 | 0.28 | 0.26 |
| | lbs/day | 0.04 | 0.07 | 0.08 | 0.08 |
| Phosphorus | % | 0.12 | 0.17 | 0.19 | 0.18 |
| | lbs/day | 0.03 | 0.05 | 0.06 | 0.05 |
| Magnesium | % | 0.12 | | 0.17-0.20 | |
| | lbs/day | 0.03 | | 0.05-0.06 | |
| Potassium | % | 0.60 | | 0.70 | |
| | lbs/day | 0.16 | | 0.21 | |
| Sodium | % | 0.06-0.08 | | 0.10 | |
| | lbs/day | 0.016-0.022 | | 0.03 | |
| Chlorine | % | requirements are not well defined but a deficiency does not seem likely in practical conditions | | | |
| | lbs/day | | | | |
| Sulfur | % | 0.15 | | 0.15 | |
| | lbs/day | 0.04 | | 0.05 | |

Table 4. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1000-pound beef cows with average milk production during four production periods (data from NRC 1996).

| | | Production Periods | | | |
|---|---|---|---|---|---|
| Microminerals | | Dry Gestation | 3rd Trimester | Early Lactation | Lactation |
| Dry matter | lbs | 21 | 21 | 24 | 24 |
| Chromium | mg/kg (ppm) | current information is not sufficient to determine requirements | | | |
| | g/day | | | | |
| Cobalt | mg/kg (ppm) | 0.10 | 0.10 | 0.10 | 0.10 |
| | g/day | 0.0010 | 0.0010 | 0.0011 | 0.0011 |
| Copper | mg/kg (ppm) | 10.0 | 10.0 | 10.0 | 10.0 |
| | g/day | 0.0953 | 0.0953 | 0.1089 | 0.1089 |
| Iodine | mg/kg (ppm) | 0.50 | 0.50 | 0.50 | 0.50 |
| | g/day | 0.0048 | 0.0048 | 0.0054 | 0.0054 |
| Iron | mg/kg (ppm) | 50.0 | 50.0 | 50.0 | 50.0 |
| | g/day | 0.4763 | 0.4763 | 0.5443 | 0.5443 |
| Manganese | mg/kg (ppm) | 40.0 | 40.0 | 40.0 | 40.0 |
| | g/day | 0.3810 | 0.3810 | 0.4355 | 0.4355 |
| Molybdenum | mg/kg (ppm) | requirements are not established but there is no evidence that deficiency occurs | | | |
| | g/day | | | | |
| Nickel | mg/kg (ppm) | research data are not sufficient to determine requirements | | | |
| | g/day | | | | |
| Selenium | mg/kg (ppm) | 0.10 | 0.10 | 0.10 | 0.10 |
| | g/day | 0.0010 | 0.0010 | 0.0011 | 0.0011 |
| Zinc | mg/kg (ppm) | 30.0 | 30.0 | 30.0 | 30.0 |
| | g/day | 0.2858 | 0.2858 | 0.3266 | 0.3266 |

Table 5. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1200-pound beef cows with average milk production during four production periods (data from NRC 1996).

| | | Production Periods | | | |
|---|---|---|---|---|---|
| Microminerals | | Dry Gestation | 3rd Trimester | Early Lactation | Lactation |
| Dry matter | lbs | 24 | 24 | 27 | 27 |
| Chromium | mg/kg (ppm) | current information is not sufficient to determine requirements | | | |
| | g/day | | | | |
| Cobalt | mg/kg (ppm) | 0.10 | 0.10 | 0.10 | 0.10 |
| | g/day | 0.0011 | 0.0011 | 0.0012 | 0.0012 |
| Copper | mg/kg (ppm) | 10.0 | 10.0 | 10.0 | 10.0 |
| | g/day | 0.1089 | 0.1089 | 0.1225 | 0.1225 |
| Iodine | mg/kg (ppm) | 0.50 | 0.50 | 0.50 | 0.50 |
| | g/day | 0.0054 | 0.0054 | 0.0061 | 0.0061 |
| Iron | mg/kg (ppm) | 50.0 | 50.0 | 50.0 | 50.0 |
| | g/day | 0.5443 | 0.5443 | 0.6124 | 0.6124 |
| Manganese | mg/kg (ppm) | 40.0 | 40.0 | 40.0 | 40.0 |
| | g/day | 0.4355 | 0.4355 | 0.4899 | 0.4899 |
| Molybdenum | mg/kg (ppm) | requirements are not established but there is no evidence that deficiency occurs | | | |
| | g/day | | | | |
| Nickel | mg/kg (ppm) | research data are not sufficient to determine requirements | | | |
| | g/day | | | | |
| Selenium | mg/kg (ppm) | 0.10 | 0.10 | 0.10 | 0.10 |
| | g/day | 0.0011 | 0.0011 | 0.0012 | 0.0012 |
| Zinc | mg/kg (ppm) | 30.0 | 30.0 | 30.0 | 30.0 |
| | g/day | 0.3266 | 0.3266 | 0.3674 | 0.3674 |

Table 6. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1400-pound beef cows with average milk production during four production periods (data from NRC 1996).

| | | Production Periods | | | |
|---|---|---|---|---|---|
| Microminerals | | Dry Gestation | 3rd Trimester | Early Lactation | Lactation |
| Dry matter | lbs | 27 | 27 | 30 | 30 |
| Chromium | mg/kg (ppm) | current information is not sufficient to determine requirements | | | |
| | g/day | | | | |
| Cobalt | mg/kg (ppm) | 0.10 | 0.10 | 0.10 | 0.10 |
| | g/day | 0.0012 | 0.0012 | 0.0014 | 0.0014 |
| Copper | mg/kg (ppm) | 10.0 | 10.0 | 10.0 | 10.0 |
| | g/day | 0.1225 | 0.1225 | 0.1361 | 0.1361 |
| Iodine | mg/kg (ppm) | 0.50 | 0.50 | 0.50 | 0.50 |
| | g/day | 0.0061 | 0.0061 | 0.0068 | 0.0068 |
| Iron | mg/kg (ppm) | 50.0 | 50.0 | 50.0 | 50.0 |
| | g/day | 0.6124 | 0.6124 | 0.6804 | 0.6804 |
| Manganese | mg/kg (ppm) | 40.0 | 40.0 | 40.0 | 40.0 |
| | g/day | 0.4899 | 0.4899 | 0.5443 | 0.5443 |
| Molybdenum | mg/kg (ppm) | requirements are not established but there is no evidence that deficiency occurs | | | |
| | g/day | | | | |
| Nickel | mg/kg (ppm) | research data are not sufficient to determine requirements | | | |
| | g/day | | | | |
| Selenium | mg/kg (ppm) | 0.10 | 0.10 | 0.10 | 0.10 |
| | g/day | 0.0012 | 0.0012 | 0.0014 | 0.0014 |
| Zinc | mg/kg (ppm) | 30.0 | 30.0 | 30.0 | 30.0 |
| | g/day | 0.3674 | 0.3674 | 0.4082 | 0.4082 |

## Literature Cited

**Church, D.C., and W.G. Pond. 1975.** Basic animal nutrition and feeding. O & B Books, Corvallis, OR.

**Manske, L.L. 1998.** Range management practices addressing problems inherent in the Northern Great Plains grasslands. NDSU Dickinson Research Extension Center. Summary Range Management Report DREC 98-3002. Dickinson, ND. 3p.

**Manske, L.L. 2000.** Management of Northern Great Plains Prairie based on biological requirements of the plants. NDSU Dickinson Research Extension Center. Range Science Report DREC 00-1028. Dickinson, ND. 13p.

**National Research Council. 1996.** Nutrient requirements of beef cattle. 7th rev. ed. National Academy Press, Washington, DC.