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Annual Nutritional Quality Curves for Graminoids in the Northern Great Plains

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Introduction

Agricultural production from mixed grass prairie rangelands and domesticated grasslands of the Northern Great 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 to the development of 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 Great 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 are 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 were 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 were summarized and reported in Manske (1999a,b,c,d).

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 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.

Results-Domesticated Cool Season Grass

The domesticated grass species included in the two published articles reporting nutritional quality of domesticated forage grasses of the Northern Great 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 Great 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 the 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.

Results-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 Great 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.

Results-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 Great 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 50E to 77E F (10E to 25E C) (Coyne et al. 1995). Temperatures below 50E F (10EC) during the day or temperatures above 77E F (25E 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, drop 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 Great 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 crude protein levels above 9.6% for at least 2.5 months longer than ungrazed plants. 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.

Results-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 Great 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 86E to 105E F (30E to 40E C) (Coyne et al. 1995). Temperatures below 86E F (30EC) or above 95E F to 105E F (35E to 40E C) limit 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. 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.

Discussion

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. Effective pasture and 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 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.

Conclusion

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 Great 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. 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% crude protein in late July and below 6.2% in early September. 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 and haying affect grass plants’ 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.

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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*

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

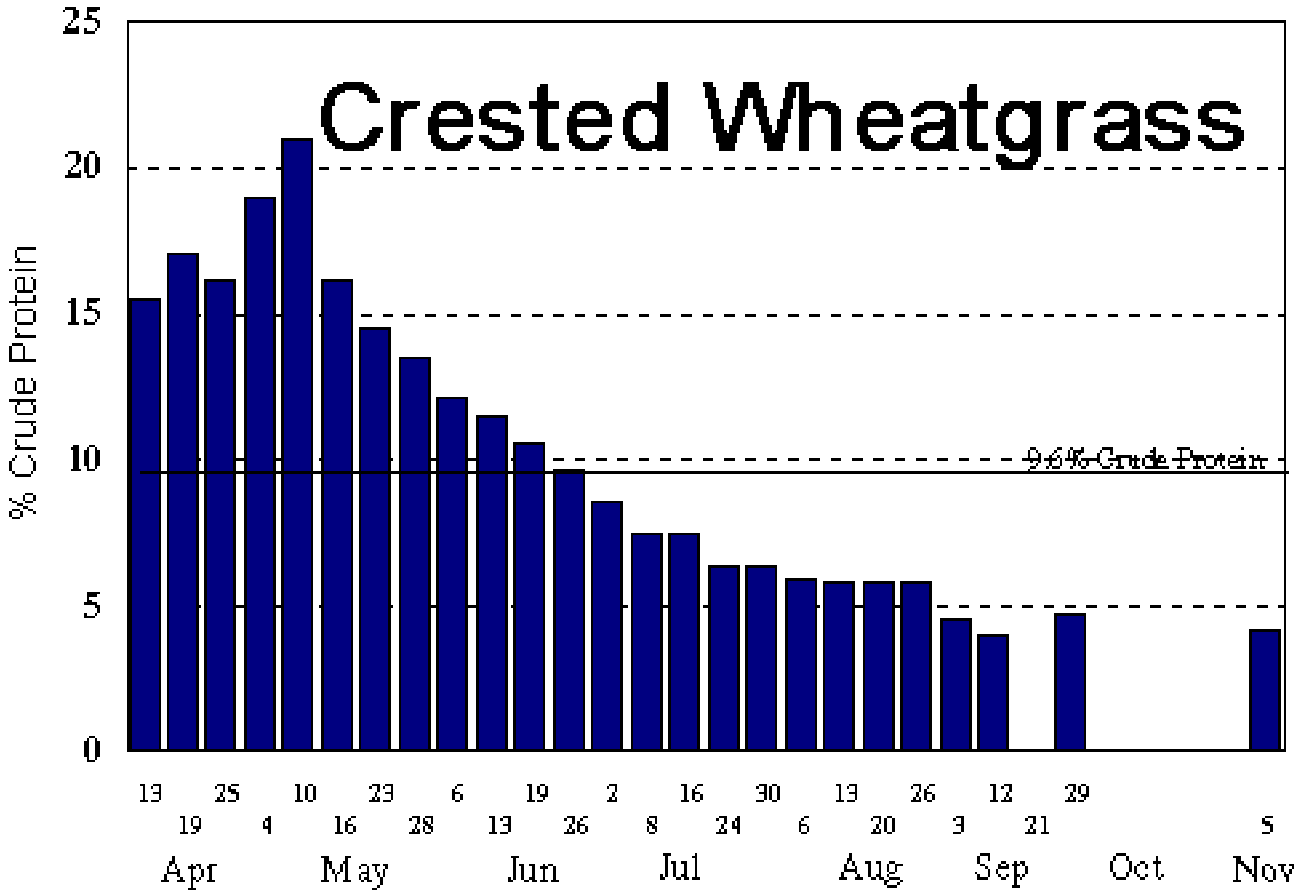


Fig 2. Mean percent crude protein of smooth bromegrass not cut for hay in western North Dakota, data from Whitman et al. 1951.

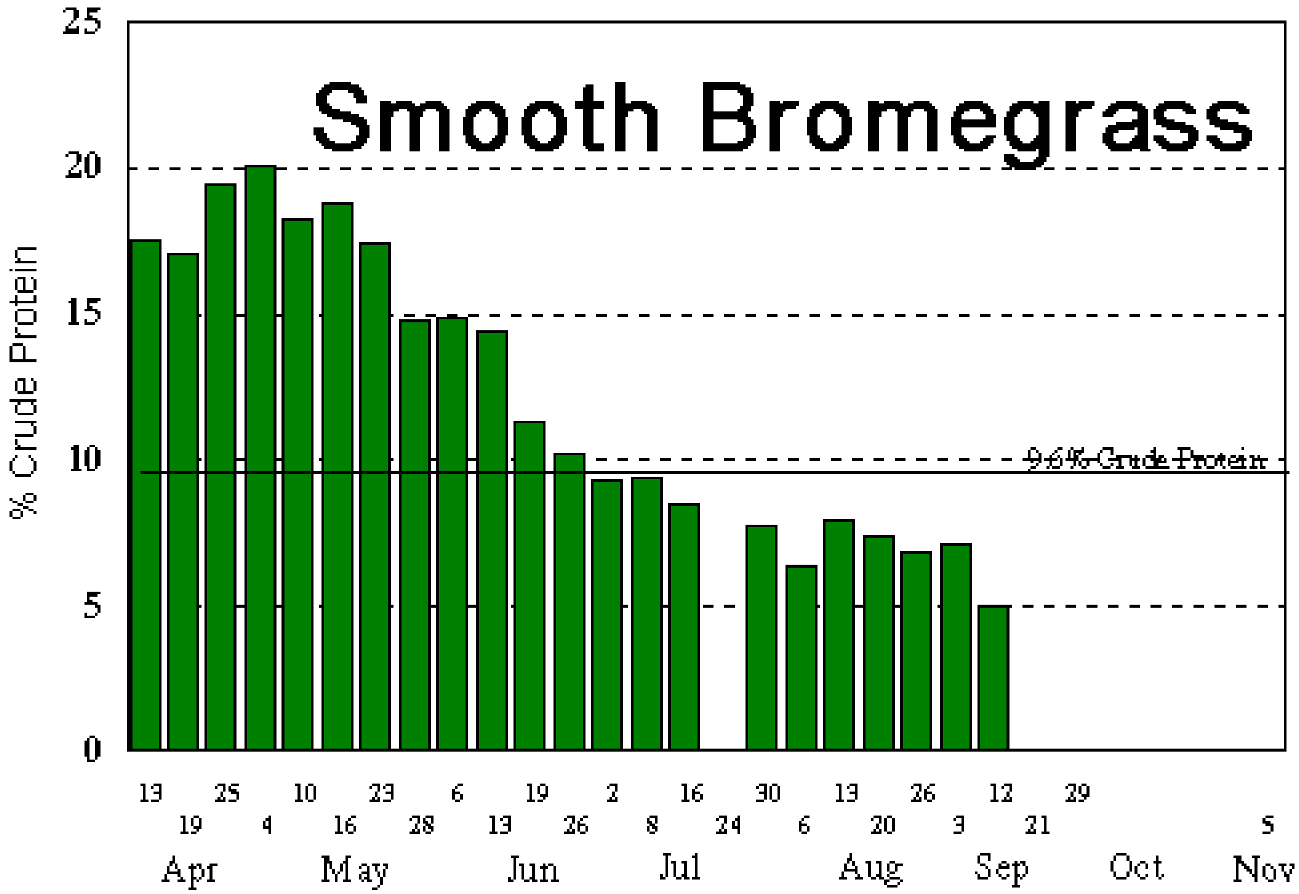


Fig 3. Mean percent crude protein of smooth bromegrass cut for hay at flowering stage in mid June in western North Dakota, data from Whitman et al. 1951.

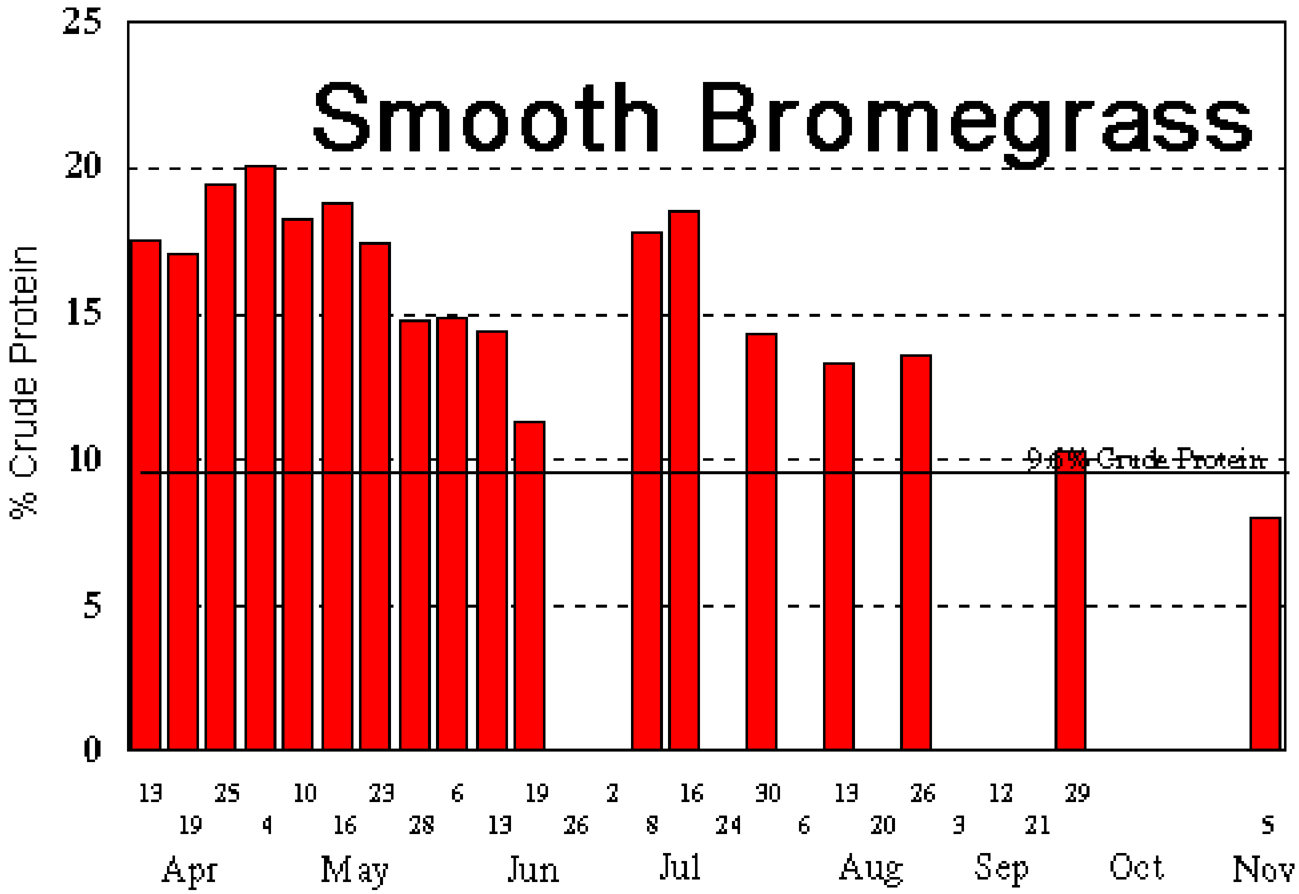


Fig 4. Mean percent crude protein of ungrazed native range upland sedges in western North Dakota, data from Whitman et al. 1951.

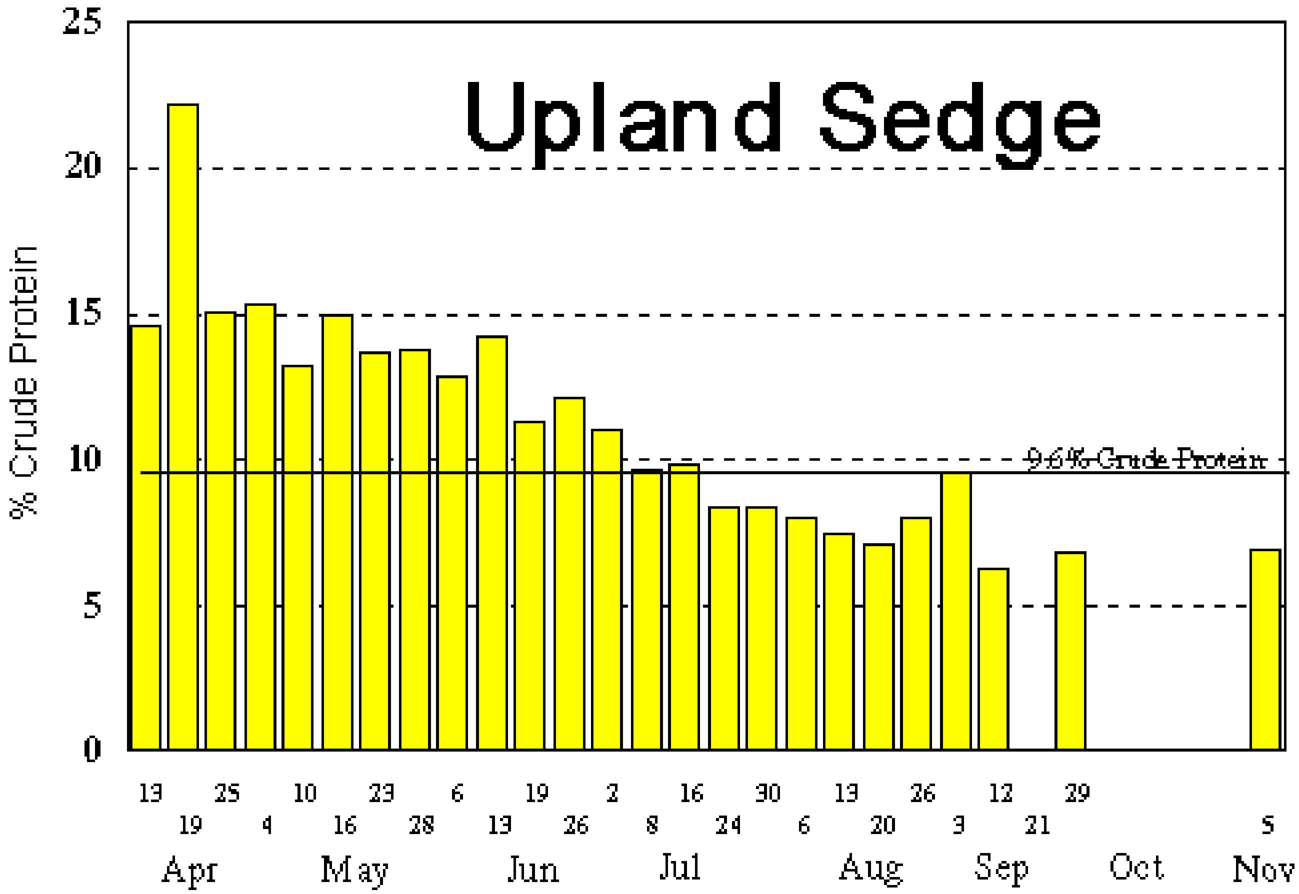


Fig 5. Mean percent crude protein of ungrazed native range cool season grasses in western North Dakota, data from Whitman et al. 1951.

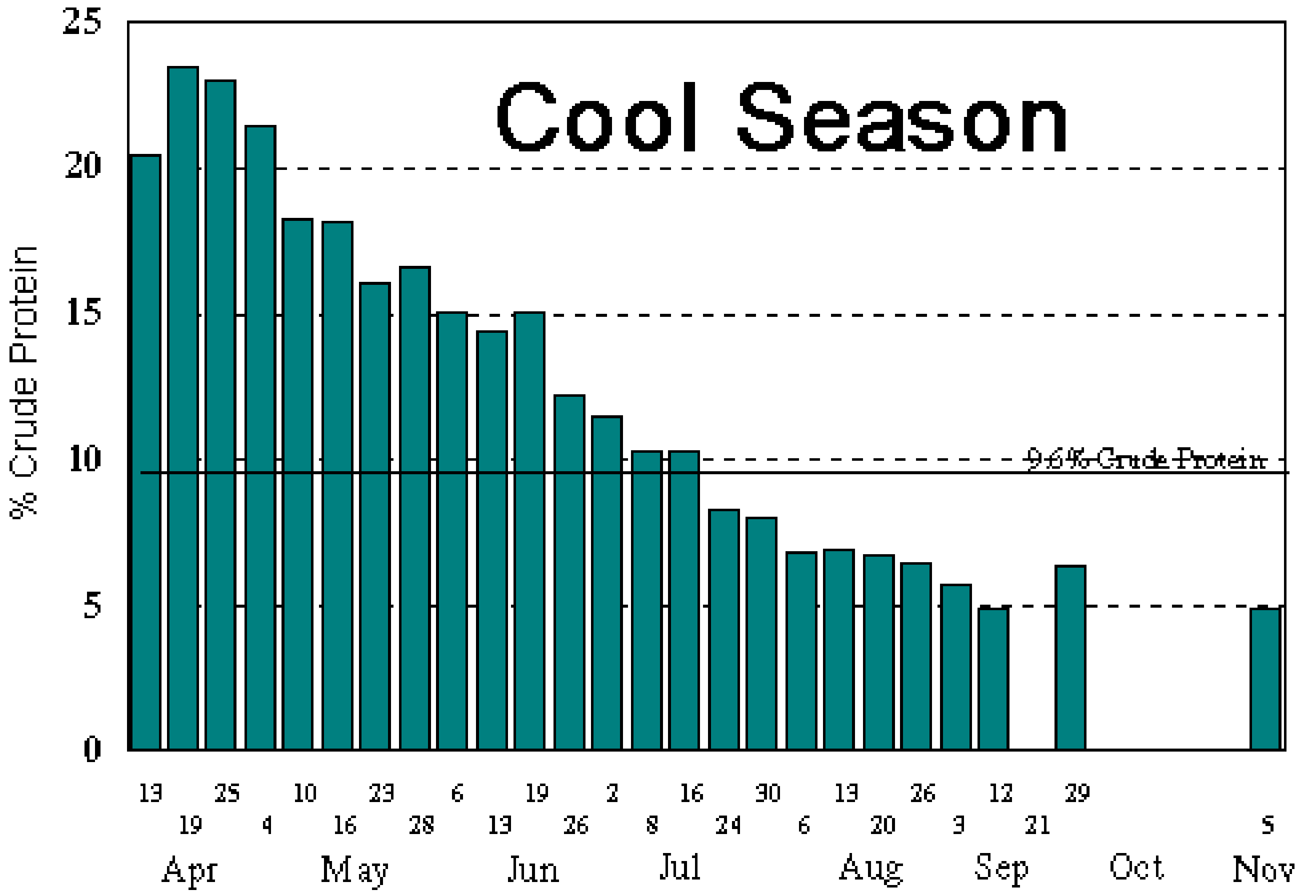


Fig 6. Mean percent crude protein of grazed Kentucky bluegrass in western North Dakota, data from Whitman et al. 1951.

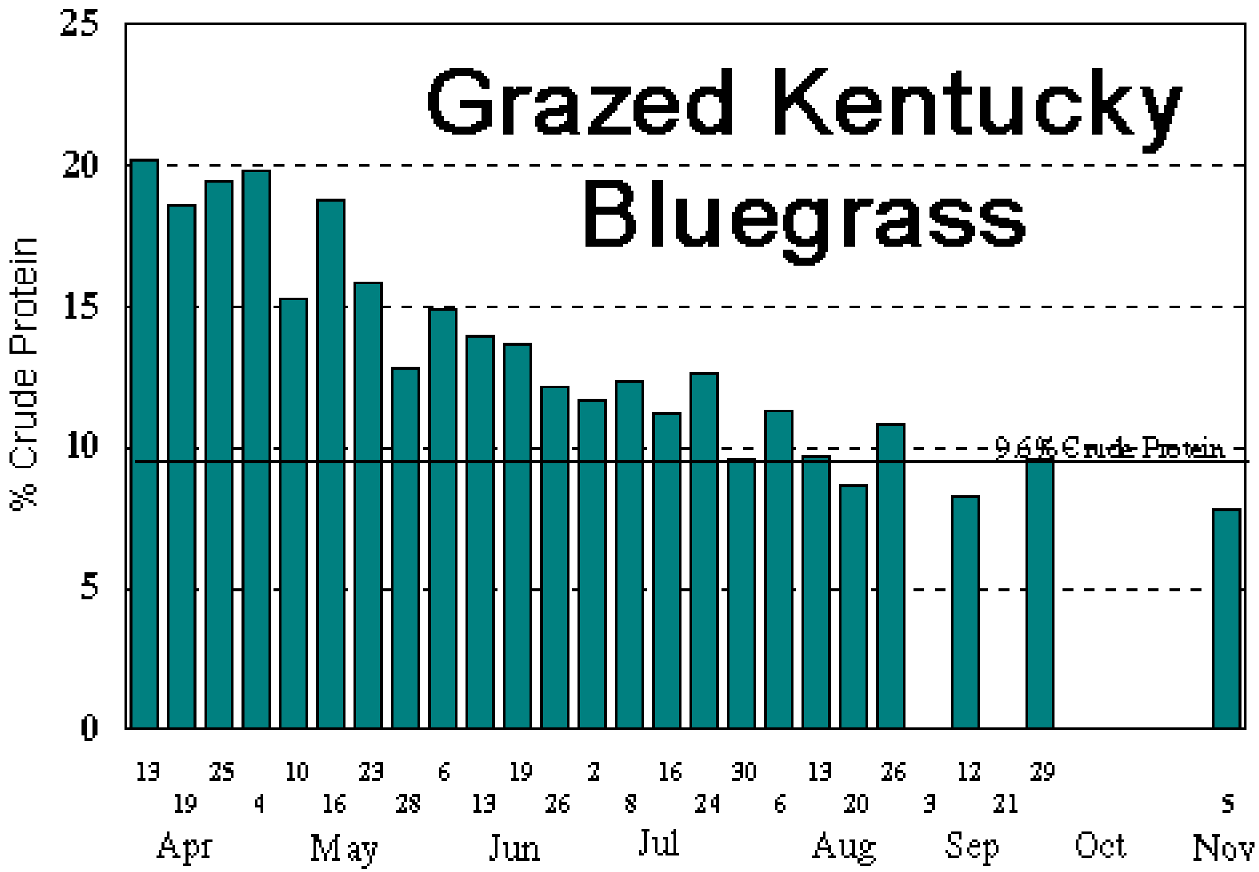
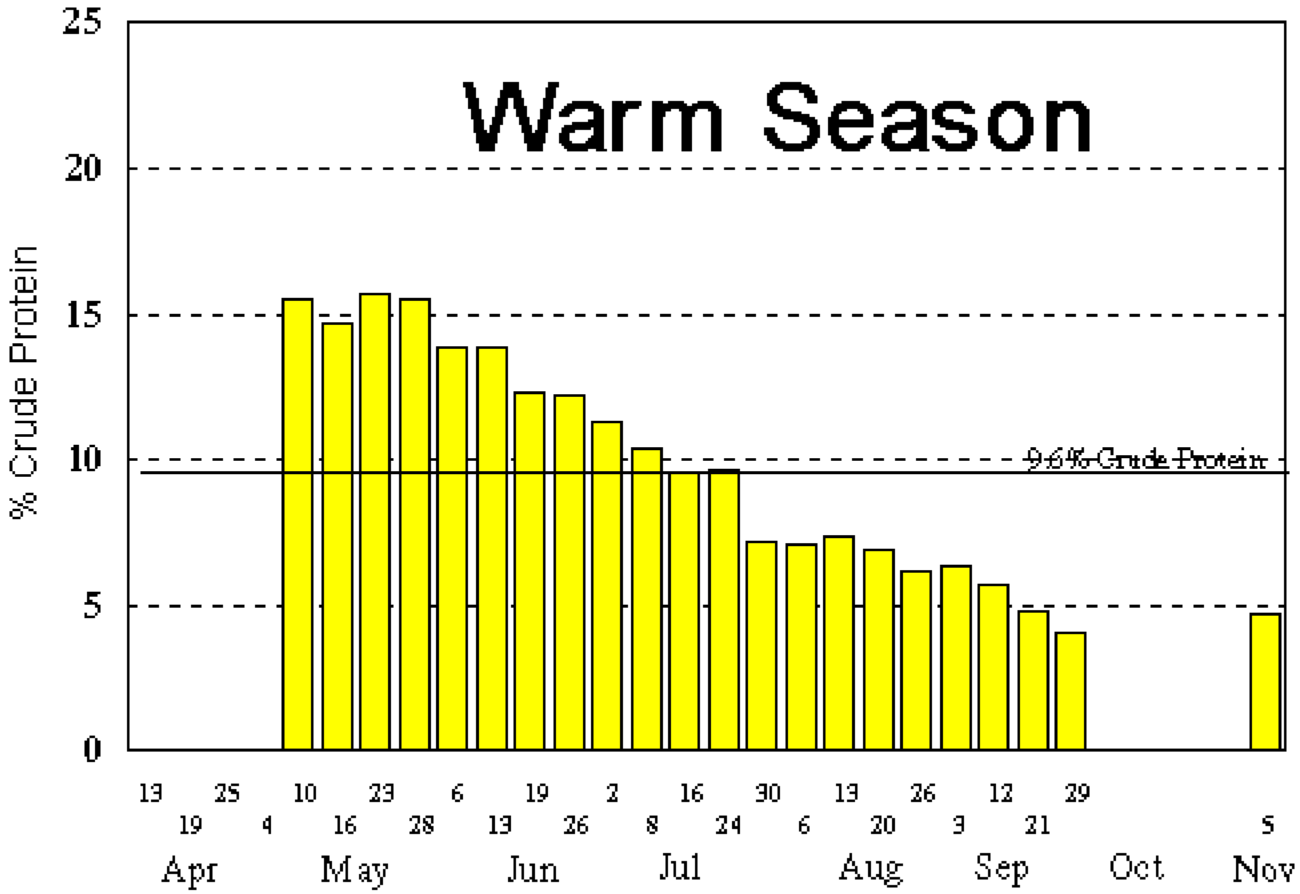


Fig 7. Mean percent crude protein of ungrazed native range warm season grasses in western North Dakota, data from Whitman et al. 1951.



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