Seasonal Yield and Chemical Composition of Crested Wheatgrass in Southeastern Wyoming

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Highlight: *Herbage yields, crude protein levels, and mineral concentrations of crested wheatgrass were influenced by phenological development and distribution of spring precipitation at the Archer Substation near Cheyenne, Wyo. Crude protein levels and mineral concentrations in the crested wheatgrass declined with plant maturity. Amount and distribution of the precipitation enhanced or retarded phenological development. Calcium uptake per acre by the crested wheatgrass was greater during a wet spring, but calcium concentration per unit of dry matter was higher during a dry spring.*

Crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) has been the introduced grass used most widely for seeding dryland for hay and pastures in the Great Plains.

Cook and Harris (1952) stated that palatability of crested wheatgrass for both cattle and sheep declined markedly as the plant matured; however, greater animal selectivity for the more tender parts of crested wheatgrass prevented establishment of a definite trend with maturity. Hyder and Sneva (1959) showed that early growth of crested wheatgrass was characterized by abundant leafiness and a delay in stem elongation, which allowed accumulation of carbohydrates. Patton and Gieseker (1942) found that the concentrations of lignin and cellulose in crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) increased markedly from mid-May to early September. The lignin was indigestible, and as it increased, the availability of other constituents of the herbage decreased.

Soil properties directly and indirectly influence the rate and amount of soil water and nutrients extracted by the plants. Cook (1959) found that site influenced the chemical composition of crested wheatgrass, intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.), and tall wheatgrass (*Agropyron elongatum* (Host) Beauv.).

Chemical analysis of forage crops can be used to estimate the quality and suitability for livestock feed. Sullivan (1962) stated, "...the problem of the evaluation of forage by chemical analysis is a long way from being solved and though progress has been made, contradictory opinions are to be found in the literature." Although chemical analysis does not provide an accurate evaluation of forage quality, it does give a reliable estimate at less cost than the standard evaluation methods of grazing animal or digestion trials.

The purpose of this study was to determine seasonal yields, percentage crude protein, and mineral content of crested wheatgrass as related to climate and plant maturity.

Study Area and Procedure

The Archer substation is about 10 miles east of Cheyenne, Wyo., at an elevation of about 6,100 ft. The study area was seeded in 1943 with crested wheatgrass, alfalfa (*Medicago sativa* L.) and yellow blossom sweet clover (*Melilotus officinalis* (L.) Lam.). Until 1954, the herbage was harvested for hay, except for 2 years when it was grazed by dairy cows. From 1954 through 1964, sheep grazed the stand during April and May.

The soil on the experimental area is Ascalon fine sandy loam, a member of the fine loamy, mixed mesic family of the Aridic Argiustolls formed by fluvial outwash.

Three subplots, 4 ft^2 (14-5/16 × 40-1/4 inches) each, were randomly selected in each of four replicated plots (100 × 272 ft) on each harvest date. All herbage in the subplots was clipped at ground level, and all material except current growth of crested wheatgrass was discarded. Crested wheatgrass herbage was air dried, weighed, and yields expressed in pounds/acre. Five clippings were made each year in 1965, 1967, and 1969 at 2-week intervals from late April through June (Table 1).

The plant material was ground in a Wiley mill (with stainless steel chamber and blades) until it passed 40-mesh openings. Plant material (2g) was digested with nitric (30 ml distilled) plus perchloric (10 ml) of a 4:1 perchloric sulphuric acid mixture; calcium and potassium were determined by atomic absorption spectrophotometry. Crude protein was determined (Agricultural Biochemistry Division, University of Wyoming) as total nitrogen (to include nitrate) × 6.25.

Table 1. Harvest dates and phenological stages of growth of crested wheatgrass for 3 years, Archer Substation, Wyoming.

Year	Early vegetative Stage 1	Late vegetative Stage 2	Boot (immature) Stage 3	Seed head emerged Stage 4	Early bloom full bloom Stage 5
1965	April 29	May 13	May 27	June 11	June 28
1967	April 27	May 8	May 22	June 6	June 22
1969	April 22	May 7	May 22	June 5	June 18

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The research is a contribution from Agricultural Research Service, U.S. Dep. Agr., in cooperation with the Wyoming Agricultural Experiment Station. JA 669.

Manuscript received April 11, 1974.

Phosphorous was determined by the vanadate-molybdate-yellow method described by Chapman and Pratt (1961).

Data on herbage yield, crude protein, and mineral concentration of the crested wheatgrass were analyzed by analysis of variance, and Duncan's Multiple Range Test for significant differences was applied at the 5% probability level. Correlations between herbage yields and crude protein, and the mineral constituents were determined.

Results and Discussion

Herbage Yields

It is generally assumed that soil and air temperatures, and amount and distribution of precipitation, influence herbage yields in the early spring. Cheyenne air and soil temperatures were low before the first harvest date, and precipitation was erratic. Usually, as the season progresses, soil and air temperatures increase; then precipitation and plant nutrients become limiting for herbage production.

Herbage yields varied among years for the five harvest dates. During April 1965, only 0.22 inch of rain fell, and from May 1 to 13, 0.53 inch of precipitation was received. Thus, for the first three harvest dates in 1965 herbage yields were low. Favorable precipitation during April, May, and June 1967 was reflected in the high herbage yields for all harvest dates (Table 2). The crested wheatgrass responded to the above-average precipitation during the first two harvest dates of 1969, but precipitation amounted to only 0.44 inch between the second and fourth harvest dates, and crested wheatgrass growth nearly stopped between the third and fifth harvests. Most precipitation was received between the fourth and fifth harvest dates after the crested wheatgrass had attained most of its growth. Thus precipitation was poorly distributed in 2 of the 3 years. Herbage yields differed significantly between years for the first, second, and fifth harvests. Significant differences in mean herbage yields among harvest dates are shown in Table 3. A significant year × harvest date interaction indicated that these two variables are not independent of each other in determining herbage yields. Correlation coefficients of element concentration with herbage yields showed that only calcium was significantly correlated $P > 0.05$. The correlation was negative, $r = -0.70$, showing that calcium concentration declined in the plant tissue as herbage yield increased.

Crude Protein and Mineral Concentration

Crude protein in the harvested plant material ranged from 9.8% to 27.9% among harvest dates (Table 3). The average percent crude protein declined significantly with each successive harvest date; however, the level in the crested wheatgrass during the five harvest dates was sufficient for most classes of sheep and beef cattle (National Research Council, 1968, 1970). The interaction of years × harvest dates on

Table 2. Annual and April, May, and June precipitation (inches) for the 1965-69 period, and the 49-year average at the Archer Substation, Wyoming.

Year	Annual	April, May, June
1965	16.39	8.58
1966	10.41	3.10
1967	16.54	9.93
1968	15.85	9.49
1969	13.98	5.74
5-year average	14.63	7.37
49-year average	14.67	6.65

Table 3. Crude protein, calcium, phosphorous, and potassium concentrations (%) in crested wheatgrass for five phenological stages of growth, and harvest dates for 3 years, Archer Substation, Wyoming.

Year and constituent	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Year mean
Crude protein						
1965	27.9^{a}[1]	23.7^{a}	19.9^{a}	14.7^{a}	11.5^{a}	19.5^{a}
1967	20.3^{b}	18.8^{b}	15.1^{b}	12.6^{ab}	9.9^{a}	15.3^{b}
1969	21.9^{b}	17.0^{b}	13.1^{b}	10.8^{b}	9.8^{a}	14.5^{b}
Average	23.3^{a}	19.8^{b}	16.0^{c}	12.7^{d}	10.4^{e}	
Calcium						
1965	.46^{a}	.36^{a}	.35^{a}	.31^{a}	.22^{a}	.34^{a}
1967	.29^{c}	.30^{b}	.26^{b}	.28^{a}	.20^{a}	.27^{b}
1969	.37^{b}	.38^{a}	.30^{ab}	.28^{a}	.26^{a}	.32^{a}
Average	.37^{a}	.35^{ab}	.31^{c}	.29^{c}	.23^{d}	
Phosphorous						
1965	.26^{a}	.21^{a}	.24^{c}	.23^{a}	.21^{a}	.23^{a}
1967	.22^{a}	.22^{a}	.22^{a}	.23^{a}	.18^{b}	.21^{a}
1969	.29^{a}	.25^{a}	.23^{a}	.20^{a}	.17^{b}	.23^{a}
Average	.26^{a}	.22^{b}	.23^{b}	.22^{b}	.19^{c}	
Potassium						
1965	2.51^{a}	2.27^{a}	2.00^{a}	1.93^{a}	1.54^{a}	2.05^{a}
1967	1.61^{c}	1.70^{b}	1.68^{a}	1.80^{a}	1.41^{a}	1.64^{b}
1969	2.10^{b}	1.87^{b}	1.58^{a}	1.63^{a}	1.09^{b}	1.66^{b}
Average	2.07^{a}	1.95^{b}	1.76^{d}	1.79^{c}	1.35^{e}	

[1] Numbers with the same letter are not significantly different at the 5% level.

percent crude protein was significant, as expected, because the crude protein declined with maturity.

The Atlas of Nutritional Data on United States and Canadian Feeds, published by the National Academy of Sciences (1971) shows nutritional values for crested wheatgrass. They are shown for six stages of growth ranging from immature to mature, but the species name is lacking. Table 1 attempts to show the phenology of the crested wheatgrass for the five harvest dates used in this study. Phenology of the crested wheatgrass was not determined at the time of harvest, and since the stage of growth varies with years, it was difficult to put a specific stage of growth for the last two harvest dates. Thus it was assumed that the immature stage of growth is comparable to the third harvest date or the boot stage reported here, and early bloom to full bloom is similar to the fifth harvest date. The average crude protein of the crested wheatgrass at the immature stage was reported to be 19.2% (National Academy of Sciences, 1971), and an average of 16% was obtained for the grass from the Archer Substation. At the boot or immature stage of growth the crude protein varied from 13.1% to 19.9% indicating the phenological development varied with years. At the fifth harvest date or early bloom to full bloom growth stage the crude protein was reported as 15.5% for early bloom and 8.7% for full bloom or an average of 12.4%. At the Archer Substation, crude protein of the grass varied from 9.8% to 11.5% for an average of 10.4%, thus indicating that the crested wheatgrass at the Archer Substation may have been harvested at mid to full bloom. Overall, the crude protein values expected and obtained were somewhat comparable for these two stages of growth.

Calcium and potassium concentrations of the forage varied significantly with years, but phosphorous did not (Table 3). Apparently, changes in weather did not significantly affect the phosphorous concentration of crested wheatgrass at the Archer Substation. Amounts of the three macronutrients differed significantly among harvest dates, with the amounts being lowest at the fifth harvest and highest at the first harvest.

Sheep require between 0.22% and 0.34% calcium (National Research Council, 1968). For beef, high energy finishing ration should contain at least 0.22% calcium, and all other rations at least 0.18% (National Research Council, 1970). The calcium concentration of the crested wheatgrass herbage was more than adequate at all harvest dates for beef cattle, but low for sheep in 2 out of the 3 years on the fifth harvest date.

At the third harvest date, the immature or boot stage of growth, the 0.31% average calcium concentration in the crested wheatgrass at the Archer Substation was 26% less than the 0.42% reported in the Atlas of Nutritional Data on United States and Canadian Feeds. Calcium concentrations for the early bloom and full bloom stage of growth was reported at 0.32% and 0.26%, respectively, or an average of 0.24% in the Atlas. At the Archer Substation, calcium concentration averaged 0.23% or nearly the same for this stage of growth.

The phosphorous concentration of the herbage declined significantly with maturity, although there were no significant differences in phosphorous concentrations of the herbage between the second and fourth harvests. Phosphorous requirement for sheep ranges from 0.16% to 0.21%, but "... forage containing below 0.16% phosphorous is usually considered deficient for ewes during gestation, and 0.20% is borderline during lactation." (National Research Council, 1968). The phosphorous requirement for beef cattle is reported to be 0.16% for dry, pregnant, mature cows (National Research Council, 1970).

Phosphorous concentrations in the crested wheatgrass at the third harvest date or immature stage of growth averaged 0.23% at the Archer Substation; the Atlas of Nutritional Data on United States and Canadian Feeds shows the phosphorous concentration for that stage at 0.26%. Phosphorous values shown in the Atlas for the early bloom and full bloom stages of growth were 0.27% and 0.16%, respectively; at the Archer Substation, phosphorous concentrations averaged 0.19%.

Potassium concentrations of the crested wheatgrass herbage ranged from a high of 2.51% to a low of 1.09%. The highest concentrations of potassium was associated with the lowest forage yield at the first harvest date. Potassium concentration declined significantly with maturity. Means for 1967 and 1969 did not differ, indicating that the concentration of potassium may not be influenced by a wet or a dry spring. The NRC has not established a minimum potassium requirement for sheep, but suggests 0.6% to 0.8% for growing and finishing steers.

Crude protein and cumulative mineral concentrations of the crested wheatgrass herbage in pounds per acre are shown in Table 4. The minerals increased between the first and fourth harvest date, then remained constant between the fourth and fifth harvest date probably as a result of plant maturation. Minerals and crude protein accounted for 26% of the average herbage yield on the first harvest date, but for only 12% on the fifth harvest date. Thus lignin, cellulose, and other constituents accounted for 88% of the total herbage by the fifth harvest date.

Table 4. Average cumulative crude protein and minerals in pounds per acre for five phenological stages of growth and harvest dates, Archer Substation, Wyoming.[1]

Measurement	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Herbage yields[2]	162.0^{d}	235.0^{d}	372.0^{c}	605.0^{b}	801.0^{a} [3]
Crude protein	37.7	46.5	59.5	76.8	83.3
Calcium	.6	.8	1.1	1.7	1.8
Phosphorous	.4	.5	.9	1.3	1.5
Potassium	3.3	4.6	6.5	10.8	10.8
Total crude protein and minerals	42.0	52.4	68.0	90.6	97.4

[1] Average of 3 years.
[2] Air dried plant material average for 3 years.
[3] Means with same letter are not significant at the 5% level.

Phenological development of the crested wheatgrass was influenced by precipitation, and minerals decreased proportionately with plant maturity. Mineral concentration in the herbage varied inversely with yields. Above-average April-May-June precipitation during 1967 resulted in more herbage and a greater uptake of calcium per acre, but the concentration of calcium was higher per unit of dry matter during the dry spring of 1969. The uptake of phosphorous and potassium per acre was greater per unit of dry matter during a wet spring (1967) than a dry spring (1969), except for the first two harvest dates. Crude protein and levels of macronutrients declined with plant maturity. Crested wheatgrass at the Archer Substation should have crude protein and macronutrient levels similar to those in crested wheatgrass grown in other areas at comparable stages of growth.

From a nutritional standpoint grazing of crested wheatgrass in southeastern Wyoming should be between the immature and full bloom stage as the minerals and crude protein decline rapidly with plant maturity. When used for hay, crested wheatgrass should be harvested no later than the full bloom stage of growth for best combination of yield, protein, and mineral content.

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