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Morphological and Physiological Factors Affecting the Grazing Management of Crested Wheatgrass[1]

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CRESTED wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) is an introduced perennial bunchgrass that has become a favorite for seeding semiarid range lands because (a) successful seedings are more common with it than with many other adapted species, (b) it is well adapted to semiarid environments and is strongly competitive when established, (c) it produces palatable and nutritious spring feed, and (d) it withstands heavy spring grazing. The fourth point is, perhaps, most important. Crested wheatgrass seedings fill a critical need when used for spring grazing to permit a delay in turnout on native forage species that are less tolerant of spring grazing. In that way, seedings contribute to improved grazing management of integrated rangelands.

An important difficulty with crested wheatgrass results from the growth of stiff culms that become unpalatable and of poor nutritive quality. The stems do not break down over winter, but remain standing and interfere with subsequent grazing. More information is needed about both desirable and undesirable characteristics to permit more effective use of this species.

Research on seasonal patterns of growth activities and effects of defoliating crested wheatgrass in different seasons was initiated at the Squaw Butte Experiment Station in 1955. Ten related experiments were completed over a period of 6 years. This paper reviews and illustrates the seasonal growth patterns of herbage and roots and the effects of clipping at different seasons in relation to seasonal growth patterns. Finally, the results are translated to theoretical pasturing practices in which the good qualities of crested wheatgrass are accentuated and the bad ones minimized. Detailed procedures and results by individual experiments are available elsewhere.[3]

MATERIALS AND METHODS

Vegetation, Soils, and Weather

This work was done on Squaw Butte Experimental Range which is located 42 miles west of Burns, Oregon, at 4,600 feet above sea level. The sites chosen for the experimental trials are examples of the *Artemisia tridentata* / *Agropyron spicatum* habitat type[4] which occurs on residual and alluvial soils developed from basalt and rhyolite parent materials. The soils involved in the crested-wheatgrass experiments are examples of Eckert's[4] uncorrelated series 7 where surface colors vary from grayish brown to dark grayish brown. The textures vary from loam in the A horizon to sandy clay loam in the B. A platy structure is found in the A horizon while the primary structural units in the B are moderate prisms breaking into subangular blocks. These soils are nonsaline throughout and vary in pH from 6.4 to 7.0, except in calcium carbonate pans found on some alluvial fans where the pH is about 8.0. The A_1 contains 2.0 to 2.2% organic matter, but the surface 6 inches usually contains less than 1%. The moisture content at tensions of 1/3 and 15 atmospheres is 17 to 20 and 8 to 11%, respectively, in composite samples from the surface 6 inches of soil.

Average annual precipitation was 11.8 inches for the 20 years 1938 to 1957. Crop-year (September 1–June 30) precipitation amounts were 52, 127, 116, 143, 54, and 56% as much as the 20-year median amount in 1955 to 1960 inclusive, respectively. Temperatures below 32° F. have been recorded in each month, but the average period with temperatures exceeding 32° is about 50 days.

Field-plot Methods

Seasonal patterns of growth and clipping effects were investigated on established stands of standard crested wheatgrass seeded in 1951 to 1956. Randomized-block and split-plot experiments in 4 to 6 replications were established for separate studies. Individual plots were clipped once in the growing season and again in August or early September when the herbage was cured by summer drouth. Various row spacings and nitrogen-fertilization rates were included in some experiments. Physiological and morphological responses to nitrogen fertilization are published elsewhere (5). Data collected at initial clipping times were evaluated for seasonal growth characteristics, and those collected after initial harvests were evaluated for clipping effects on seasonal growth patterns.

Herbage Evaluations

Herbage yields were obtained by hand clipping at ground level, weighing complete fresh samples, drying in a forced-air electric oven at 70° C., and weighing dry samples. Yields are given in pounds per acre, oven dry. Seasonal growth curves are represented by yields from initial clippings, but total yields include initial and final harvests. Herbage-yield series were obtained in 1955 to 1959, inclusive. New plots were established each year to prevent the accumulation of clipping effects.

Oven-dried herbage samples were prepared for chemical determinations by grinding them in a Wiley mill to pass a 20-mesh screen and sealing in glass jars. Crude protein, phosphorus, potassium, and calcium concentrations were determined (5). The crude-protein data reported in this paper were obtained in 1955 to 1959, inclusive. Seasonal trends in the nitrogen content of fresh herbage and roots were determined in 1958 to consider nitrogen translocation from maturing herbage. The nitrogen contents of fresh samples were determined by a standard Kjeldahl procedure. Selenized granules catalized digestion reactions. Nitrogen contents were expressed in percent of herbage and root dry matter.

The morphological development of stems was described at about biweekly intervals in 1959 and 1960. Five or 6 plants were excavated each time, washed, divided into separate stems, and described with reference to number of leaves, lengths of culm internodes, elevations of heads and shoot apices, and the development of axillary buds and tillers. Representative plants at collection times in 1960 were frozen for subsequent simultaneous descriptions to verify seasonal observations. Vegetative and reproductive stems of mature plants were counted to determine stem ratios. This division of stems was complicated by the occurrence of aborted reproductive stems, which often had to be split for positive identification. Shoot apices were isolated for observation by techniques described by Sharman (6).

Root Evaluations

A preliminary investigation of root growth in the field was made with a single soil-pit window in 1956, and more detailed studies were made with 35 windows in 1959 and 1960. The latter experiment included 7 dates of herbage removal in each of 5

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[3] Hyder, D. N. Growth characteristics of crested wheatgrass, *Agroypron desertorum* (Fisch.) Schult., in the big sagebrush-bluebunch wheatgrass province of southeastern Oregon. Ph.D. thesis. Oregon State University, Corvallis. 1961. (Abstract: Dissertation Abstracts, Vol. XXII, No. 4, 1961.)

[4] Eckert, Richard Edgar, Jr. Vegetation-soil relationships in some *Artemisia* types in northern Harney and Lake Counties, Oregon. Ph.D. Thesis, Oregon State University, Corvallis. 1957.

randomized blocks. Individual plots 8 rows wide by 12 feet long were located on an established stand of crested wheatgrass seeded in 1951 by drilling in rows spaced 12 inches apart and running east to west. Soil pits were dug with a wall 5 inches from the north row of each plot, and wooden-sash windows with 18- by 24-inch, double-strength glass panes were staked to the pit walls. The windows were placed with the 18-inch measure near vertical, but sloping from top to bottom 2 inches toward the grass row. A space 1 to 2 inches wide between the glass and soil wall was filled with screened surface soil. The pits were filled with straw and covered with corrugated-iron sheets during the winter to minimize freezing and window breakage. During the growing season, the windows were kept covered with aluminum insulation sheets to minimize temperature and light effects. Roots appearing in the windows were measured at about weekly intervals in 1959 and 1960 growing seasons. On each measurement day the roots were marked by tracing on the glass with a felt ink pen. Thus, only new growth increments were measured. Herbage yields were taken in 1959 by hand clipping on April 21, May 6, June 8, June 22, July 14, and unclipped-check. Regrowth yields were harvested August 3. Root elongation prior to initial herbage clipping represents the normal growth curve, and elongation after initial harvests represents deviations due to clipping. Root-growth measurements were continued in 1960 with a uniform harvest of herbage on May 13.

Root samples were collected for seasonal trends in the concentration of total carbohydrates in 1956 and 1957 (4), and for autumn-storage concentrations in 1955, 1956, and 1957 after herbage removal at different times. Five or 6 clumps per plot were excavated to a depth of about 8 inches at a distance 6 inches from the crowns after clipping the herbage at ground level. Roots with stem bases were washed from the sods, dried at 90° C., ground in a Wiley mill, and sealed in glass jars. Total-carbohydrate concentrations were determined by the Shaffer and Hartmann modification of the Munson and Walker method (2, p. 836). Total-carbohydrate concentrations are given as glucose equivalents in percentage of oven dry matter.

RESULTS

Seasonal Herbage-growth Patterns

Herbage-growth curve—Growth began about April 1 but was slow until May. By the first of May leaf height was about 6 inches, the dry-matter yield about 200 pounds per acre, and the growth increment about 15 pounds per acre per day. Without grazing or clipping, the growth rate increased during May, reached a maximum about June 1, and terminated by July. Figure 1 shows the fully expressed growth curve for 1957, when precipitation was above average, and yield points in other years to show variability. Yields and the duration of active growth depended on the amount and seasonal distribution of moisture. Hay yields averaged about 900 pounds per acre and ranged from 350 to 2,000 pounds.

Herbage dry matter—Herbage dry-matter contents increased gradually from about 28% in early May to about 74% in late August. Dry-matter percentages were highly correlated (r = 0.93) with number of days after April 30 and were very near 50% during anthesis each year. Physiological activities involving translocation appeared to terminate by the time herbage dry-matter contents reached 70%.

Herbage crude protein and minerals—The crude-protein content of herbage dropped continuously and rapidly during the growing season. By late June, the content was down to about 6% and decreased slowly thereafter to about 3% in cured herbage. The leaves cured to about 5% and culm internodes to about 1.5%. Crude-protein yields, however, usually reached maximum in early June and decreased rapidly in later stages of growth (Figure 2).

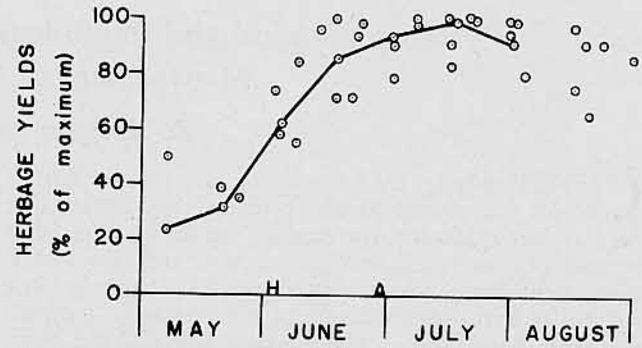

Figure 1—The herbage growth curve in 1957 with yield points in 4 other years indicating yearly variability. H = heading, A = anthesis.

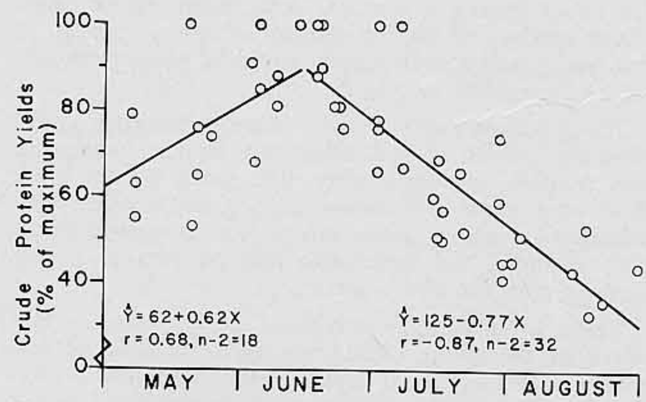

Figure 2—Crude-protein yields usually reached maximum in early-June and decreased rapidly in later stages of growth. Y = crude-protein yield in percent of maximum, X = number of days after April 30.

Similar trends were noted for phosphorus and potassium concentrations and yields (5). Therefore, crested wheatgrass provides good quality forage from late April until late June, but grazing only in June harvests maximum amounts of nutrients. The decline in crude-protein yields continued throughout the summer and by September about 60% of the crude protein had been lost from the herbage. In the curing period, increases in the concentration of crude protein in the roots was significantly (1% level) correlated (r = 0.57) with decreases in the herbage.

Reproductive stems—The reproductive stems of crested wheatgrass grew from buds produced in a previous year in the leaf axils at underground culm nodes. Total culm length was about 1 inch on May 1 and the lowermost internode was essentially at a maximum length of about ½ inch. By mid-May individual stems usually had 5 leaf blades fully exposed, the first 2 internodes fully elongated, and heads about 1 inch long. With 5 leaf blades exposed, the stems had produced nearly a maximum of leaf area. This development to maximum leaf area promoted maximum growth rates (Figure 1). All active culm intercalary meristems were above the soil surface when the first 2 internodes were mature and 5 leaf blades fully exposed. The heads emerged from the uppermost leaf sheath about June 1, and the spikelets were in anthesis in late June and early July.

Mature reproductive culms had 5 to 7 internodes and leaves. The lowermost internode usually was shorter than

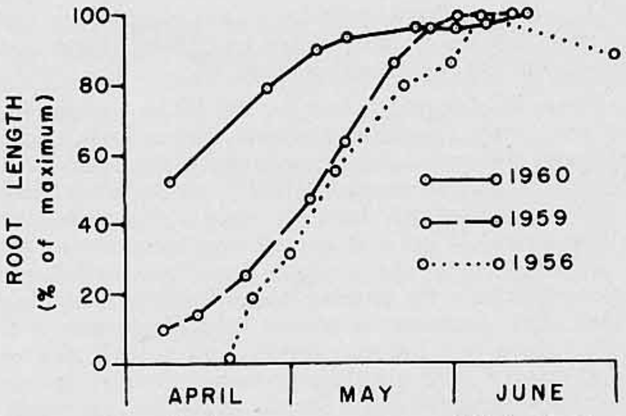

Figure 3—Crested wheatgrass roots grew rapidly in April and early May.

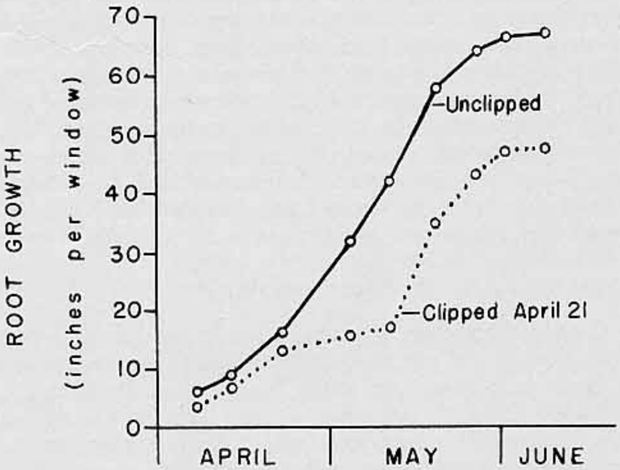

Figure 4—Herbage removal by clipping April 21, 1959, depressed root growth.

½ inch, and frequently the second internode also was very short. The short internodes became enlarged toward the base, lived 2 years or more, and supported new stems from axillary buds. The uppermost internode was the last to become fully elongated. Its length was related to the duration of available soil moisture, but was often equal to the remainder of the culm. Culm growth stopped at or before anthesis and all above-ground tissues cured rapidly after anthesis even when available soil moisture was maintained by irrigation.

Aborted reproductive stems, in which the heads and upper internodes had died, were fairly common. When such injury occurred at relatively early stages of culm elongation the stems lost dominance over axillary buds. Subsequently, slender stems or tillers grew from buds in the lower leaf axils. Tillers were found infrequently on uninjured stems.

Vegetative stems—The vegetative stems of crested wheatgrass grew from axillary buds of old stem bases and produced culms. Internode lengths were the same as for reproductive stems up to the third node, and the short basal internodes lived 2 years or more. Higher internodes usually were progressively shorter than the third. The most fully developed vegetative stems had 10 to 12 internodes and leaves. Vegetative culms were more slender than reproductive ones, especially in the upper parts, and were distinguished by the presence of immature upper leaf blades and shoot apices with 3 or 4 leaf-bud ridges. Being indeterminate, the vegetative stems could grow indefinitely under favorable conditions, but in this test they always died during the dry, hot summers. Vegetative stems varied greatly in length and number of leaves, but usually were much shorter than reproductive stems.

Stem ratios—Most of the herbage weight was composed of reproductive stems, but stem ratios varied greatly. The percentage of reproductive stems increased from 24 to 69% in stands seeded in rows spaced 6 to 36 inches, respectively. With less competition, nitrogen fertilization (5), or more favorable growing conditions, a higher proportion of growing points differentiated to reproductive status. Crested wheatgrass remained almost strictly vegetative on some high-elevation sites.

Seasonal Root-growth Patterns

Root growth preceded herbage growth and appeared to terminate about June 1 (Figure 3). Roots were measured as they appeared and elongated behind soil-pit windows placed in the field. Since the windows were set 1 to 2 inches from the soil-pit walls and the intervening spaces filled with screened surface soil, the roots began growing some time before their appearance behind the windows. Of the 3 root-growth patterns included in Figure 3 the one for 1960 probably represents a more accurate growth curve because the roots measured were, in part, continuations from roots that appeared in 1959. Crested wheatgrass roots exhibited maximum elongation rates in late April and early May, and growth subsided in May as herbage-growth activity increased.

Effects of Clipping at Different Seasons

Root-growth depression—After herbage removal on April 21, 1959, root growth was depressed for about 20 days, but resumed rapidly in late May and terminated about June 1 (Figure 4). The growth of roots of unclipped plants is included for comparison. Grasses clipped once on April 21 produced about 65% as much root length as those not clipped. Herbage removal on May 6 and later dates did not result in significant root-growth depression, and those data are omitted from Figure 4. Root-elongation activity was subsiding and carbohydrate concentrations (4) were relatively high by mid-May, when herbage removal failed to cause even slight depressions in root growth.

Carbohydrate storage—Underground parts left in place after herbage clipping were sampled for carbohydrate concentrations in September. These autumn-storage concentrations are plotted over clipping dates to illustrate clipping effects (Figure 5). Seasonal trends in carbohydrate concentrations are published elsewhere (4). The lowest autumn-storage concentrations of carbohydrates resulted from clipping in June. This pattern of clipping effects appeared to be related to a seasonal decrease in carbohydrates in June (4) and to the lack of regrowth opportunity after those clippings. Large clipping effects appeared in 1955, when precipitation was much below normal, and slight (if any) effects appeared in 1956 and 1957, when precipitation was much above normal.

Herbage removal effectively limited root growth and carbohydrate accumulation when clipping was done in late

April and mid-June, respectively. However, herbage removal in May was not very effective in limiting either root growth or carbohydrate storage.

Herbage yields—Among total herbage yields the lowest amounts resulted from clipping about mid-May (Figure 6). Extending the lines in Figure 6 to earlier dates would indicate that clipping about April 1 would not have decreased total herbage yields. This extension of the lines is reasonable because growth was just beginning on April 1. Herbage-yield reductions were larger in a wet year (1957) than in a dry one (1959), because growth stopped soon after mid-May in dry years.

Herbage removal reduced total photosynthetic gains and this reduction appeared in less root elongation, less herbage yield, and less carbohydrate storage in a chronological sequence. Timing herbage removal to cause a large reduction in herbage yields appeared to minimize the effects on underground parts, because root growth was nearing completion, carbohydrate concentrations in underground parts were relatively high (4), and large yield reductions involved a sacrifice in culm elongation and seed production. Energy requirements for culm elongation and seed production apparently were about equal to the energy that could be accumulated by photosynthesis after mid-May.

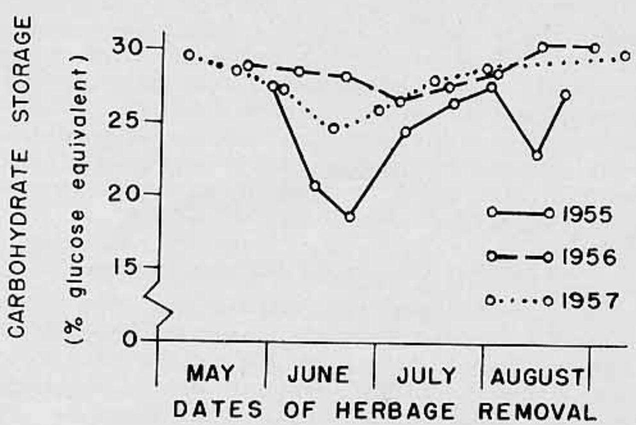

Figure 5—Herbage removal by clipping in June depressed autumn-storage concentrations of carbohydrates.

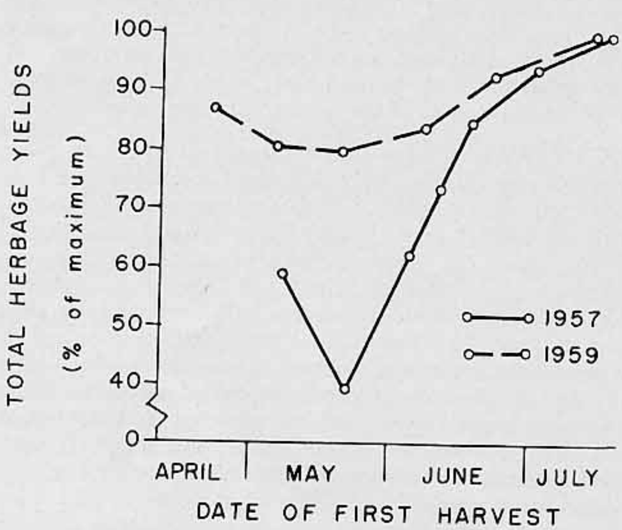

Figure 6—Herbage removal by clipping in May depressed total herbage yields for the season.

Additional considerations involve stem morphology and the induction of growth in axillary buds, from whence new growth and leaf tissue must originate.

Regrowth—Clipping before five leaf blades are exposed, but when stem elongation has barely begun, will remove the leaves without interrupting subsequent stem elongation. A reproductive tiller exposed to this treatment will produce a spike on a leafless culm (3), while a vegetative tiller will be devoid of leaves at the first 4 or 5 nodes.

A short delay in time of clipping, or clipping at a lower level will remove the growing tissues from the elongating culms. This treatment terminates stem dominance over axillary buds and initiates growth of a second crop of tillers. About 90% of these second-crop tillers remain vegetative. In southeastern Oregon this effect can usually be accomplished by a close grazing in approximately mid-May.

Plots in one experiment were clipped in May to promote tiller-type regrowth in four consecutive years. The yields of second-crop stems taken about August 1 ranged from 529 pounds per acre in 1957, when precipitation was 16% above average, to zero in 1959, when precipitation was 46% below average. In 1960, when precipitation was 14% below average, the second crop yield was 205 pounds per acre. Crude-protein contents averaged 6.6% in cured second-crop herbage. These four years of clipping maintained high plant vigor in all years.

DISCUSSION

Crested wheatgrass is somewhat undesirable as a pasture grass because the percentage of reproductive stems usually is large and vegetative stems have culms. Branson (1) described these characteristics as relatively undesirable in other species. However, tolerance of heavy spring grazing derives from early root-growth activity, early accumulation of leaf tissue, and early accumulation of carbohydrates in the underground parts (4). These desirable physiological characteristics can be used to advantage when crested wheatgrass seedings provide spring grazing and permit delayed grazing on native species that are less tolerant of early grazing.

A primary undesirable feature results from the growth of stiff culms that become unpalatable and interfere with subsequent grazing. Practicing spring grazing without attention to stem morpholgy can intensify this problem because leafless culms are less palatable and nutritious than fully-developed, leafy ones. At best, full-grown crested wheatgrass is unpalatable to cattle unless vegetative stems predominate. The desirable characteristics of crested wheatgrass can probably be used to advantage, and the undesirable characteristic of stemminess minimized, by grazing to produce either one or two crops of stems in a single season. With favorable growing conditions, a palatable and desirable forage can even be produced for late-summer or fall grazing.

At the study location in Oregon, one-crop management would involve grazing from about May 20–25, when the heads are in the boot, until about July 1, when the spikelets are in anthesis. An average stocking rate would be about 1 to 2 acres per cow. One-crop grazing would be expected to (a) permit maximum root growth, (b) harvest maximum amounts of dry matter, crude protein, phosphorus, and potassium, and (c) depress autumn-storage concentrations of carbohydrates in the underground parts

—more in dry years than wet ones. Nitrogen fertilization would facilitate one-crop grazing by increasing herbage and nutrient yields and carbohydrate-storage concentrations (5).

Two-crop management would require grazing beginning about May 1, when the leaves are 6 inches high, and the adjustment of stocking rate to achieve very close grazing about May 20–25, when the heads are in the boot. An average stocking rate would be about 3 to 4 acres per cow. A second crop of stems would initiate growth after May 20–25. Second-crop herbage could be grazed as needed in late summer or fall, but should not be grazed until fully cured. Its leafy growth and favorable crude-protein content make it very palatable to cattle and fairly nutritious, considering the lack of green forage in late summer. In dry seasons there would be but little or no second-crop herbage; however, a lack of herbage in the summer seems more desirable and less detrimental to the plants than the growth of leafless culms, as can result from lighter grazing in May. Two-crop grazing would be expected to (a) depress root growth slightly, (b) harvest a maximum of earliest feed, (c) reduce total herbage production, (d) permit high storage concentrations of carbohydrates, and (e) provide some palatable late-summer or fall forage. It is concluded elsewhere (5) that nitrogen fertilization should not be employed prior to two-crop grazing, or to facilitate earlier grazing and higher early-spring stocking rates, because of greater spring carbohydrate mobilization and lower yield returns than when employed prior to late-spring grazing.

For a longer grazing season, crested wheatgrass could be grazed continuously from the time leaves are 6 inches high (earlier grazing can depress root growth severely) until anthesis, but a rotation combination of 2-crop and 1-crop grazing might be more advantageous. With, for example, 3 pastures of equal size, 2 of them grazed in May for 2-crop production would carry about as many animals as 1 of them would carry in June under 1-crop grazing. Although a given pasture might be grazed for either 1 or 2 crops on a reasonably permanent basis, a rotation plan among years, as illustrated below, might facilitate better management and higher production.

Year	*Pasture A*	*Pasture B*	*Pasture C*
1	1 crop	2 crops	2 crops
2	2 crops	1 crop	2 crops
3	2 crops	2 crops	1 crop

These schedules are suggested on a theoretical basis for the grazing management of crested wheatgrass. It remains to be seen where and to what extent these schedules can be realized on a practical basis or whether cultural practices such as fertilization and limited irrigation will be needed to facilitate them.

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