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The autecology of Crested wheatgrass, *Agropyron cristatum*, is one of the prairie plant species included in a long ecological study conducted at the NDSU Dickinson Research Extension Center during 67 growing seasons from 1946 to 2012 that quantitatively describes the changes in growth and development during the annual growing season life history and the changes in abundance through time as affected by management treatments for the intended purpose of the development and establishment of scientific standards for proper management of native rangelands of the Northern Plains. The introduction to this study can be found in report DREC 16-1093 (Manske 2016).

Crested wheatgrass, *Agropyron cristatum* (L.) Gaertn., is a member of the grass family, Poaceae, tribe, Triticeae, and is a long lived perennial, monocot, cool-season, mid grass, that is highly drought tolerant and winter hardy. Crested wheatgrass was introduced into the United States in 1906 and into Canada in 1915 from Eurasia and was naturalized in the Northern Plains. Numerous accessions of plant material originating from Turkey, Iran, Kazakhstan, central Asia, western and southwestern Siberia, and the steppe region of European Russia have been brought to North America. A total of three recognized species were introduced: Crested wheatgrass, *Agropyron cristatum* (L.) Gaertn., (Fairway type); Desert wheatgrass, *Agropyron desertorum* (Fisch. Ex Link) Schultes, (Nordan type and MT Standard type); and Siberian wheatgrass, *Agropyron fragile* (Roth) Candargy, (Siberian type). Even though each species maintained as isolated plant material has distinct characteristics, specific identification of nonsecluded individual plants is difficult because the morphological variation has developed into a continuum as a result of the extensive intercrossing that has occurred since the 1930's. The separation of this resultant mixture of plants into more than one taxon has proven to be impractical. A taxonomic description of most of this material would be more similar to *Agropyron cristatum*. The first North Dakota record is Stevens 1961. Early aerial growth consists of basal leaves from crown and rhizome tiller buds. Basal leaf blades are 10-20 cm (4-8 in) long, 5-10 mm wide, tapering to a point. Leaves roll inward when dry. The split sheath has overlapping margins that open towards the top. The distinct collar is divided. The membranous ligule is 1-2 mm long with a cut like fringed edge. The small auricles are slender, clasping, and clawlike. The rhizomes are traditionally described as short and the plants are categorized as bunches (caespitose), however, the number and length of the rhizomes and the relative quantities of crown tillers and the rhizomes tillers is determined by the timing of the partial defoliation management and having sufficient quantities of viable green leaf area remaining at end of the treatment. Partial defoliation prior to flowering stimulates the number and length of the rhizomes and increases the quantity of rhizome tillers. Partial defoliation following flowering inhibits rhizome development and decreases the quantity of rhizome tillers. The extensive root system has tough main roots arising from stem crowns and rhizome nodes growing vertically downward producing numerous fine branches forming a dense mass in the top 1 m (3.3 ft) of soil. Several long main roots descend to depths of 2.4 m (8 ft) in loose soil. Regeneration is primarily asexual propagation by crown and rhizome tiller buds. Viable seed production is high and seedlings are vigorous, however, seedlings are successful only when competition from established plants is nonexistent. The numerous flower stalks are erect, slender, 30-80 cm (12-32 in) tall, and hairless. Inflorescence is a flattened dense spike, 5-10 cm (2-4 in) long, that has closely spaced overlapping, laterally compressed spikelets of 3 to 8 florets in two opposite rows with one spikelet per node. Flower period is from late May to mid June. Aerial parts are palatable and nutritious during May. Stocking rates greater than proper for native rangeland can be used during early to late May. Fire top kills aerial parts and kills deeply into the crown when soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reduction in biomass production and tiller density. This summary information on growth development and regeneration of Crested wheatgrass was based on works of Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains

Flora Association 1986, Zlatnik 1999a and b, Ogle 2006 a and b, Larson and Johnson 2007, Stubbendieck et al. 2011, and Ogle et al. 2013.

Procedures

The 1946-1947 Study

Grass and upland sedge species samples to determine crude protein and phosphorus content were collected weekly during the growing seasons of 1946 and 1947 from two seeded domesticated grasslands and a native rangeland pasture at the Dickinson Research Extension Center located at Dickinson in western North Dakota. Current year's growth of lead tillers of each species was included in the sample; previous year's growth was separated and discarded. Ungrazed samples were collected for each species except for Kentucky bluegrass, which only grew along a watercourse where almost all of the plants had been grazed and remained in an immature vegetative stage, however, a small number of plants escaped grazing and developed normally providing the phenological development data. Crude protein (N X 6.25) content was determined by the procedure outlined in the Official and Tentative Methods of Analysis (A.O.A.C. 1945). Phosphorus content was determined by the method outlined by Bolin and Stamberg (1944). Data were reported as percent of oven-dried weight.

Plant condition by stage of plant development and growth habit was collected for each species on sample dates. These data are reported as phenological growth stage in the current report. The grass nutritional quality and phenological growth data were published in Whitman et al. 1951.

The 1955-1963 Study

Crested wheatgrass was known to start growth earlier in the spring than native rangeland, however, it was not known how or when to best use crested wheatgrass pastures. Dr. W.C. Whitman conducted a trial to evaluate crested wheatgrass as a spring pasture. The trial compared steer weight performance and herbage biomass production on two replicated pastures of 8 acres each of crested wheatgrass alone, crested wheatgrass with alfalfa, and crested wheatgrass fertilized with 50 lbs N/ac in early spring. The mean stocking rates were 1.00 ac/AUME on the crested wheatgrass alone, 0.75 ac/AUME on the crested wheatgrass with alfalfa, and 0.72 ac/AUME on the fertilized crested wheatgrass pastures.

The 1972-1982 Study

A 3-pasture, repeat seasonal grazing system was designed by Dr. W.C. Whitman that compared unfertilized and fertilized systems. Yearling steers grazed the systems during 1972 to 1976 (Nyren et al. 1983) and cow-calf pairs grazed the systems during 1978 to 1982 (Manske et al. 1984). Crested wheatgrass pastures were used during spring, native rangeland pastures were used during summer, and Russian wildrye pastures were used during late summer and/or fall. Livestock were weighed on and off each pasture type and at 28 day intervals when pastures were grazed longer than a month. Herbage samples were clipped prior to and shortly after being grazed using 0.76 X 1.5 meter frames inside and outside the exclosure cages distributed at a rate of one cage per every 0.75 acres of pasture.

The 1985-1986 Study

Crested wheatgrass has been a very beneficial and desirable introduced grass used as spring pasture or for hay production. It has been relatively easy to seed with usually good success. It has been used to revegetate small parcels of old fields, and abused and eroded areas that end up to be surrounded by a different type of vegetation creating difficulties in management. The characteristics that give crested wheatgrass its high success rate, also give it the ability to invade spaces that it is not desired. As beneficial as crested wheatgrass is, some plants are growing where it is not wanted. A technique was needed that would eliminate the unwanted crested wheatgrass plants, leave the desirable plants, and with no disturbance to the soil.

A small plot pilot study was conducted during 1985 and 1986 to evaluate chemical herbicide application in early spring. The two chemicals tested were Bromacil (Hi Var by Dupont) and Glyphosate (Roundup by Monsanto). The bromacil was applied at 0.75, 1.5, and 3.0 lbs ai per acre rates on 15 April and 15 May 1985, and the glyphosate was applied at 1.0 lbs ai per acre rate on 15 April 1985. Each treatment plus a control of no treatment had two replications. Quantitative species composition change data were collected by the ten pin point frame method monthly during June, July, and August each growing season to follow the effects of the chemical herbicide treatments.

The 1983-1994 Study

Crested wheatgrass pastures fertilized with 50 lbs N/ac applied at least one month prior to the start of grazing were evaluated as spring (May) complementary pastures included in a system with native rangeland pastures used during summer and altai wildrye pastures used during fall. The system was replicated two times.

Plant species basal cover was determined by the ten-pin point frame method (Cook and Stubbendieck 1986) with 2000 points collected along transect lines at each replicated vegetation sample site that had ungrazed and grazed paired plots. Aboveground herbage biomass was collected from replicated ungrazed and grazed paired plots by the standard clipping method (Cook and Stubbendieck 1986) monthly from April through September. The herbage material from five 0.25 m^2 quadrats (frames) at each sample site was sorted in the field by biotype categories: domesticated grasses, cool season grasses, warm season grasses, sedges, forbs, standing dead, and litter. The herbage of each biotype category from each frame was placed in labeled paper bags of known weight, oven dried at 140° F (60° C), and weighed. Cow and calf weight performance was determined by individual animal live weight collected on and off each pasture type.

The 1995-2005 Study

Crested wheatgrass used as spring (May) complementary pasture included in a system with native rangeland pastures used during summer and altai wildrye pastures used during fall were evaluated as a 1 pasture treatment and as a 2 pasture switchback treatment. The one pasture of crested wheatgrass spring grazed during May was designed with two replicated pastures each of 15 acres grazed for 28 to 30 days, stocked at 2.33 acres per cow-calf pair per month. The two pasture switchback of crested wheatgrass spring grazed during May was designed with two replicated pastures with 26.5 acres split in half, creating, two two pasture switchback systems with each half pasture grazed two periods of 7 or 8 days for a total of 15 or 16 days on each during 30 or 31 days in May, stocked at 1.05 acres per cow-calf pair per month during the early portion of the study. As the study progressed, greater land area was given to each cow-calf pair reaching 1.31 acres per pair per month. The later management was simplified by grazing 28 days during May with each half pasture grazed for two 7 day periods, thus the pasture switch was always made during the same day of the week i.e. on each Monday morning at 8:00 a.m.. The half pasture grazed first one year would be grazed second the next year.

The plant species basal cover, aboveground herbage biomass, and cow and calf weight performance data were collected by the same methods used during the 1983-1994 study.

Results

Crested wheatgrass starts early leaf greenup in mid April (table 1). The crested wheatgrass tillers have three and a half new leaves around 22 April which is four to five weeks earlier than native cool season grasses. These early new leaves are highly nutritious forage, however, the available herbage weight is insufficient for grazing until 1 May. Early boot stage occurs in mid May and the first stalks with flowers occurs around 28 May (tables 1 and 2). Most of the lead tillers reach the flower stage during the following 10 to 14 days. The late flowering lead tillers should flower by 10 June (table 2). Seed development occurs after the flower stage and seeds reach maturity during the following 5 to 8 weeks (table 1) (Whitman et al. 1951, Manske 1999b).

The nutritional quality of ungrazed lead tillers of crested wheatgrass changes with the tillers' phenological development (table 1). Early season growth stages are high in crude protein and water. The early vegetative leaf stages contain levels of crude protein above 15% during early to mid May. As seed stalks begin to develop in mid May, crude protein levels begin to decrease. At the flower stage, lead tillers contain 13.5% crude protein. The flower stage is when the greatest weight of crude protein per acre occurs. After the flower stage, crude protein levels remain above 9.6% until late June (tables 1 and 3, figure 1). As the ungrazed lead tillers mature, the fiber content increases and percent crude protein, water, and digestibility decrease. By early July, crude protein levels drop below 7.8% and below 6.2% in early August (table 1, figure 1). Phosphorus levels drop below 0.18% in late July (tables 1 and 3). The patterns of change in nutritional quality are similar from year to year because tiller phenological development is regulated primarily by photoperiod (changes in the length of daylight). Slight variations in nutritional quality result from annual variations in temperature, evaporation, and water stress. Nutritional quality can also be slightly altered by changes in rates of tiller growth and plant senescence. Growth rates are affected by the level of photosynthetic activity, which is affected by air and soil temperature, cloud cover, and availability of hydrogen (from water) for carbohydrate synthesis. Senescence rates increase with high temperatures, precipitation deficiency, and water stress (Whitman et al. 1951, Manske 1999b).

Crested wheatgrass had been introduced into North America during the early portion of the 20th Century and many grass scientists had known of the beneficial potential that crested wheatgrass had, however, little practical use was made of crested wheatgrass before the late 1930's and early 1940's when it was used to revegetate millions of acres of abandoned cropland that had been turned over with steel moldboard plows in order to fulfill the compliance requirements of the Homestead Acts of the United States and Canada. In spite of the time period crested wheatgrass had been growing in North America, not much was known on how to best graze crested wheatgrass pastures.

The spring pasture trial of 1955 to 1963 was the first scientifically designed research project conducted in western North Dakota to answer questions on how to best graze crested wheatgrass pastures. This study revealed several practices not to do along with pointing the direction for future research.

The replicated research pastures were seeded with crested wheatgrass in 1953 and two pastures were overseeded with alfalfa in 1954 resulting in excellent stands of both grass and alfalfa. The fences were constructed in 1954 and ten movable 4' X 4' exclosure cages were uniformally placed in each pasture. Twenty eight yearling Hereford steers that had starting weights around 500 pounds were selected each spring (Whitman 1963). During this era, herbage samples for pasture studies were cut at a two inch height. The reported herbage weights were the quantity of herbage above 2 inches.

The stocking rates of 1.00 ac/AUME on the crested wheatgrass alone, 0.75 ac/AUME on the crested wheatgrass with alfalfa, and 0.72 ac/AUME on the fertilized crested wheatgrass pastures were much too heavy. The forage utilization was 80.4% on the crested wheatgrass alone, 80.7% on the crested wheatgrass with alfalfa, and 72.6% on the fertilized crested wheatgrass pastures. The remaining forage left on the ground was 177.6 lbs/ac on the crested wheatgrass alone, 227.9 lbs/ac on the crested wheatgrass with alfalfa, and 329.0 lbs/ac on the fertilized crested wheatgrass pastures. These plants did not have enough residual leaf area to fully recover during the remaining months of the growing season. Heavy use and low residual leaf biomass causes a substantial delay of growth the following spring. During 1955, the steers on the crested wheatgrass alone pastures were short of forage for the last 15 days of the trial. Their daily gains dropped to 1.44 lbs and their total weight gain was only 73.5 pounds per head. This treatment had one less animal for the duration of the study.

The heavy forage utilization on the crested wheatgrass with alfalfa treatment, reduced and nearly eliminated the alfalfa in 5 years. During the entire study no bloat was experienced on the crested wheatgrass with alfalfa treatment, however, some subclinical effects occurred. During the early years, the diet on pasture 2 was measured to be 60% alfalfa and 40% grass. These animals gained 97.1 lbs/head, 1.90 lbs/day and 85.0 lbs/acre. While the diet on the other replication, pasture 4, was measured to be 30% alfalfa and 70% grass. These animals gained 113.6 lbs/head, 2.23 lbs/day, and 99.4 lbs/acre, which was 17% better than the animals that eat a diet with 60% alfalfa.

After the first two years, there was little difference in individual animal performance on the crested wheatgrass alone and crested wheatgrass with alfalfa treatments. The gain per head and gain per day was greater on the crested wheatgrass alone during 1957, 1959, 1961, and 1962 and was nearly similar for the mean of nine years (table 4).

Crested wheatgrass alone has adequate crude protein content during the month of May for steers and cow-calf pairs and there are no subclinical detrimental side effects. Alfalfa has double the water use requirements per pound of dry matter herbage production than grasses. This high water use causes depleted soil water levels to an average of 35% below ambient soil water in a 5 foot radius around each alfalfa plant resulting in water stress conditions in the adjacent grass plants and, subsequently, further reducing grass herbage production (Manske 2005).

Four years of heavy utilization on one of the pastures of crested wheatgrass alone caused major stand degradation, so 50 lbs N/ac was applied each spring starting in 1959. During the five years of fertilization, the steer gains were 148.4 lbs/head, 2.50 lbs/day, and 141.8 lbs/acre. During the same five year period, the steer gains on the crested wheatgrass with alfalfa were 134.0 lbs/head, 2.26 lbs/day, and 133.8 lbs/acre. The fertilized crested wheatgrass produced 11% greater gains per head and per day and 6% greater gains per acre than the crested wheatgrass with alfalfa. During the same five year period, the steer gains on the crested wheatgrass alone were 143.8 lbs/head, 2.45 lbs/day, and 109.6 lbs/acre. The fertilized crested wheatgrass produced 3% greater gains per head, 2% greater gains per day, and 29.4% greater gains per acre than the unfertilized crested wheatgrass alone treatment. The fertilized crested wheatgrass treatment had the additional production cost of the annual application of the fertilizer. The lower gains per acre on crested wheatgrass alone treatment was directly caused by low herbage biomass production which was caused by the extremely heavy stocking rate prolonged for nearly two months extending into early July which should be fixable.

The follow up study that used crested wheatgrass in spring and Russian wildrye in fall as a system with native rangeland grazed in summer was conducted duirng 1972 to 1976. This study doubled the land acreage of crested wheatgrass for the unfertilized treatment, reduced the grazing period 2 days and greatly reduced the percent forage utilization allowed leaving 975 lbs/ac of grass on the unfertilized treatment and 1191 lbs/ac of grass on the fertilized treatment each growing season.

The fertilized crested wheatgrass produced a peak herbage biomass 42% greater than that on the unfertilized treatment. These steers required 18 or 19 lbs of forage per day, so both treatments had sufficient available forage (table 5). The steers on the unfertilized treatment utilized 54% of the forage and the steers on the fertilized treatment utilized 61% of the forage, both still greater than the desired 50% utilization. The individual animal steer gains on the unfertilized treatment were 18% greater gain per head and gain per day than the steer gains on the fertilized treatment even though they had 42% greater peak forage available. The problem was that the fertilized crested wheatgrass sychronized the tiller growth to increase and occur at an earlier but shorter time span resulting in the greater peak biomass which also increased the rate of senescence to also occur earlier which greatly reduced the length of time that the forage had an adequate quantity of crude protein. Thus the steers on the fertilized treatment had a greater number of grazing days on forage that was below their crude protein requirements than the steers on the unfertilized treatment. The steers on the fertilized treatment did produce 68% greater pounds of beef per acre than the steers on the unfertilized treatment (table 6). However, that weight gain per acre should have been double that on the unfertilized treatment if the steers on the fertilized treatment would have had adequate forage quality. The length of the grazing period on both crested wheatgrass treatments was too long, with grazing forage below animal nutritional requirements.

The same pasture system grazed by steers during 1972 to 1976 were grazed by cow-calf pairs during 1978 to 1982. The drought conditions of 1980 had a 26.5% reduction in growing season precipitation with grasses in water stress conditions during April, May, and July resulting in a 65% reduction in the quantity of grass production.

The 1978-1982 study increased the land area per AUM, and shortened the length of grazing period on crested wheatgrass. However, reduction in the number of days was removed from the wrong end of the grazing period, the early May portion, not from the June portion. The high percent utilization was continued with 698 lbs/ac of grass remaining on the unfertilized treatment and 1510 lbs/ac of grass remaining on the fertilized treatment. The cows required around 26 pounds of forage per day and adequate quantities of forage were available on both treatments (table 7).

The calves (half heifers, half steers) on the fertilized crested wheatgrass had greater weight gains with 37% greater gain per head, 14% greater gain per day, and 179% greater gain per acre than the calves on the unfertilized crested wheatgrass. The cows on the fertilized crested wheatgrass had greater weight gains with 48% greater gain per head, 22% greater gain per day, and 193% greater gain per acre than the cows on the unfertilized crested wheatgrass (table 8). However, the cow and calf weight performance on both crested wheatgrass treatments did not produce at their biological potential because they grazed crested wheatgrass during a period that the grass had 12% crude protein from mid May to mid June rather than graze during the period of early May to late May when the grass has 17% crude protein. Also the calves were less than a month old when the grazing period started. Calves less than a month old cannot gain much more than 1.25 pounds per day no mater how much milk the cow produces.

Crested wheatgrass sometimes grows where it is not wanted. These areas usually have soils that should not be bare for any extended time and often there is an understory of desirable grasses. A study that attempted to remove the crested wheatgrass, leave the desirable grass and not disturb the soil was conducted during 1985 to 1986. A powerful herbicide, bromacil was tested at three rates and two application dates compared to a standard application of glyphosate and a control of no treatment. The high rate of 3.0 lbs ai/ac of bromacil almost reduced all of the crested wheatgrass plants in one application (table 9). However, 6% of the crested wheatgrass plants survived and two growing seasons later these treatment plots could not be identified; the crested wheatgrass had returned. The bromacil also greatly reduced or totally killed the native cool season grasses and forbs causing the quantity of bare ground to increase. Unexpectedly, native warm season grasses increased as a result of increased sunlight reaching these shorter grasses (table 9).

Glyphosate applied at 1.0 lb ai/ac decreased crested wheatgrass a little more than bromacil applied at 1.5 lb ai/ac. Glyphosate decreased the forbs less, increased the native cool season grasses slightly, increased the native warm season grasses greatly, and decreased the bare soil area (table 9). Glyphosate did not and could not eliminate perennial grass in one application.

An interesting pattern of the crested wheatgrass basal cover emerges from the data set. The basal cover decreases within the first or second month after early spring herbicide application. The plants have a period of partial recovery and basal cover increases during the remainder of the growing season. Tiller mortality during the winter is greater than nontreated plots. During the second growing season, the plants have a second period of partial recovery and basal cover increases again (table 9). Interpretation of this information suggests that additional applications of the herbicide during late summer of the first growing season and again during early spring of the second season would counter the partial recovery periods and would be essential to reduce perennial grasses with herbicides.

The grazing management research was moved to the DREC ranch west of Manning, ND in 1983. The previous knowledge gained was incorporated into the newly designed complementary system that used crested wheatgrass during May and used Altai wildrye during fall added to the native rangeland managed with twice-over grazing and used during summer. The crested wheatgrass treatment had 2 replicated pastures grazed from early May to early June and were fertilized with 50 lbs N/ac at least one month before the start of grazing. The land area per AUM remained about the same, a goal of leaving at least 500 lbs/ac residual herbage was attempted, and the main change was starting grazing in early May and moving off during the first days of June (table 10). The change in the dates of the grazing period more closely matched the herbage production curve and the available nutritional quality curve of crested wheatgrass (table 1 and figure 1).

The 5 year period of 1988 to 1992 had low growing season precipitation of 68% of the long term mean with five months of water stress during 1988 and an annual average of 2.6 months of water stress during 1989 to 1992. The number of days grazed were reduced during this low precipitation period. When normal rates of precipitation returned, the basal cover quickly improved (table 11), however, the total herbage biomass produced was slow to fully recover (table 12). During the twelve years of the study, the cow and calf gain per day was increased from previous studies. The gain per head and gain per acre were very good for the few number of days grazed (table 13). The return/acre after the fertilizer costs were paid were 215% greater on fertilized crested wheatgrass May pastures than that on unfertilized crested wheatgrass May pastures when both treatments had one month old calves on 1 May (Manske 2014). Fertilization of crested wheatgrass pastures can work biologically and economically if 50 lbs N/ac are applied one month before the start of grazing; it takes that long of a time period for that treatment to be effective. The calves need to be one month old at the start of grazing period; calves less than one month old cannot gain much more than 1.25 lbs/day. If the calves are not going to be one month old on 1 May, leave the crested wheatgrass May pastures unfertilized. Do not fertilize one year and not fertilize the next year. Make long term plans to produce one month old calves on 1 May and fertilize or produce less than one month old calves and do not fertilize.

The annual fertilizer costs can appear to be an extra burden to livestock producers who do not know how much calf and cow weight gain occurs on different pasture treatments. And during years of high fertilizer costs, the fertilizer bill is some of the first items dropped. There was a need to find a way to increase plant density and herbage biomass production without fertilization.

The 1995-2005 study compared one pasture of crested wheatgrass grazed in spring during May for 30 to 28 days at a stocking rate of 2.33 ac/AUM (table 14) with two pastures of crested wheatgrass grazed as a switchback every 7 or 8 days in spring during May for 32 to 28 days at a stocking rate of 1.21 ac/AUM (table 14). Both treatments were replicated two times.

During the eleven years of the study, the one pasture treatment left a mean domesticated grass lead tiller residual of 797.13 lbs/ac after the May grazing period. The mean secondary tiller growth by July was 384.83 lbs/ac (table 18). The basal cover was maintained at 18.6% (table 16). The cow gains were 61.8 lbs/head, 2.16 lbs/day, and 72.7 lbs/acre and calf gains were 72.7 lbs/head, 2.58 lbs/day, and 32.9 lbs/acre (table 19).

The two pasture switchback treatment left a mean domesticated grass tiller residual of 1038.97 lbs/ac after the May grazing period (table 17), 30.3% greater than that on the one pasture treatment. The mean secondary tiller growth by July was 757.62 lbs/ac (table 17), 96.9% greater than that on the one pasture treatment. The basal cover was maintained at 22.1% (table 15), 18.8% greater than that on the one pasture treatment. The cow gains were 76.7 lbs/head, 2.66 lbs/day, and 66.39 lbs/acre (table 19), 24.1%, 23.1%, and 138.6% greater, respectively, than cow gains on the one pasture treatment. The calf gains were 76.08 lbs/head, 2.62 lbs/day, and 66.03 lbs/acre (table 19), 4.6%, 1.6%, and 100.9% greater, respectively, than calf gains on the one pasture treatment.

Crested wheatgrass meadows are excellent spring pastures during May. Crested wheatgrass is physiologically ready for grazing in early May. The three and a half new leaf stage are produced around 22 April, however, the leaf weight is not great enough to start grazing during late April. It is important to wait until 1 May when the herbage biomass quantity is sufficient for grazing. The ability to start grazing a month ahead of the proper grazing start date on native rangeland (1 June) is the primary biological advantage of crested wheatgrass pastures and their priority use should be grazing during May as spring complementary pastures in conjunction with summer grazing native rangeland rotation systems.

The stocking rate for grazing crested wheatgrass during May can be relatively heavy because of the similar lead tiller rapid growth during the early portion of the growing season.

The one spring pasture treatment in very good condition was stocked at 2.33 acre/AUM. The two spring pasture switchback system in excellent condition was stocked too heavy at 1.05 acres/AUM for three years then reduced to better rates at 1.25 acres/AUM and then to 1.30 acres/AUM during the following years. A high stocking rate can be repeated annually on spring complementary crested wheatgrass pastures when the grazing occurs during the period that the quantity of herbage biomass is increasing towards the peak level which occurs during late May. Vegetative tillers on a healthy dense stand of crested wheatgrass can produce 300 pounds of herbage biomass per acre per day until the lead tillers reach the flower stage starting around 28 May and lasting to about 10 June. This level of production can be maintained year after year if the stubble left after grazing at the end of May is greater than three inches tall and weighs between 500 lbs and 1000 lbs/ac and the pasture is not used again until next spring. Heavy use of crested wheatgrass plants one time during May require the remainder of the growing season to recover biologically.

The two pasture switchback spring grazing system activated all of the internal compensatory physiological processes and vegetative tiller growth processes yielding greater domesticated grass live plant biomass production, greater domesticated grass basal cover, and greater development of secondary tillers and fall tillers resulting in greater cow and calf weight gains with greater gain per head, gain per day, and gain per acre than the vegetative growth and annual weight performance on the one pasture spring (May) grazing treatment.

Cutting crested wheatgrass hay during mid to late July to maximize the dry matter yield causes problems that decrease herbage production and plant basal cover. Cutting the lead tillers after they have flowered and started to develop seeds prevents activation of the compensatory physiological processes and the vegetative reproduction by tillering processes. Removal of greater than 50% of the leaf material from mature lead tillers results in insufficient leaf area retained on the tiller for even partial foliage recovery using current photosynthetic assimilates. Tillers with 50% or more of the aboveground leaf material removed reduce root growth, root respiration, and root nutrient absorption (Crider 1955). Root mortality and decomposition begin within 2 days of haying mature tillers (Oswalt et al. 1959). Mature tillers must depend upon stored carbohydrates for replacement leaf growth (Briske and Richards 1995). Grass plants have low quantities of stored carbohydrates from spring to mid August. There is a high biological cost to the tiller when the photosynthetic system needs to be replaced from stored carbohydrates. This implied reduction in efficiency results in reduced root growth, decreased tiller development, and low growth rates causing decreased tiller numbers, reduced total basal cover, and reduced quantities of herbage biomass produced (Coyne et al. 1995) and promotes the development of widely spaced wolf plants. Repeated late season haying of crested wheatgrass progressively reduces the quantities of stored carbohydrates. Which is the principal cause of hayfield plant reduction.

Late cut mature crested wheatgrass hay has low crude protein content of around 6.4%. The nutrient content of late cut mature hay meets the dietary requirements of range cows only during the dry gestation production period. This is the only range cow production period that late cut mature hay has lower costs, by a few cents, than crested wheatgrass cut at the boot stage during mid May to early June (16 May to 10 June). Cutting crested wheatgrass hay at the boot stage reduces the dry matter yield by 300 lbs/ac (19%) and increases the crude protein yield by 87 lbs/ac (85%) (table 20). The forage feed costs per day from feeding late cut mature crested wheatgrass to range cows during the third trimester and early lactation production periods was 16% greater and 50% greater, respectively, compared to the feed costs per day from feeding early cut hay at the boot stage. Feeding early cut boot stage hay has lower forage feed costs because the greater crude protein yield per acre reduces the crude protein cost per pound and thus reducing the feed cost per day (table 20) (Manske 2014).

The middle period of cutting crested wheatgrass hay during mid to late June did not improve herbage biomass production or tiller basal cover after six years of treatment. Cutting crested wheatgrass hay early between the boot stage and the flower stage captures greater weight of crude protein per acre (thus greater wealth per acre) and activates the vegetative reproduction by tillering processes that increases tiller density and promotes development of rhizome tillers that fill in the spaces between bunches.

Crested wheatgrass meadows can be used one time per year without detrimental effects as spring (May) pastures or as early cut boot stage hayfields. The pasture use and hayfield use can be rotated every three to five years.

Unfortunately, double heavy use of crested wheatgrass causes biological degradation. Even though this is a fact long-known, many crested wheatgrass pastures have two heavy uses per growing season with intense grazing occurring during the spring and fall. Some crested wheatgrass meadows are grazed in the spring and hayed during the summer, and others are hayed during the summer and grazed in the fall. Crested wheatgrass plants are hardy but they do not fully recover from two heavy uses during one growing season. Numerous biological problems develop in crested wheatgrass plants that are used heavy two times each year. Double heavy use decreases plant health with accompanying decreases in herbage production and plant basal cover. Repeated double heavy use results in a depauperated stand that can have greater than 50% bareground, while a properly managed stand with one use per year would be healthy and productive and would have no more than about 6% or 12% bareground.

Crested wheatgrass stands persist after several years of heavy use as widely spaced large bunches or widely spaced single tillers and small bunches. The growth characteristics of open canopy provide favorable habitat for several pest grasshopper species (Onsager 2000). The majority of grasshopper “hot spots” in the Northern Plains are found on double used or poorly used crested wheatgrass hayfields and pastures. Management of crested wheatgrass favorable for livestock production and unfavorable for pest grasshopper production needs to be implemented.

Double use of crested wheatgrass meadows that removes most of the standing dead vegetation has the potential to cause serious mineral deficiencies in the grazing cows blood. Mature lactating cows can develop milk fever or grass tetany while grazing lush spring crested wheatgrass vegetation that contains little standing dead grass. Milk fever is caused by a blood deficiency of calcium (Ca) and grass tetany is caused by a blood deficiency of magnesium (Mg). Crested wheatgrass herbage, however, is rarely deficient in calcium or magnesium during the growing season. A cows blood serum deficiency of calcium or magnesium is not caused by consuming crested wheatgrass forage deficient in these minerals. Absorption of most minerals is by passive diffusion across the intestinal wall; some calcium is transported with a protein carrier. Only about half of the ingested minerals are absorbed through the intestinal wall into the cows blood system under normal conditions. During the early spring, the rate of forage passage through the cows digestive tract is accelerated when lush vegetation high in water and crude protein is consumed; greatly reducing the quantity of dietary minerals absorbed through the intestinal wall and potentially resulting in deficiencies of calcium or magnesium in the cows blood. Cattle grazing crested wheatgrass pastures containing sufficient amounts of dry standing carryover residual vegetation can maintain normal slow rates of forage passage through the digestive tract and normal rates of mineral absorption; which in effect, prevents the occurrence of mineral deficiencies in the blood and thus preventing the development of milk fever or grass tetany in cows grazing crested wheatgrass spring (May) complementary pastures.

Discussion

Crested wheatgrass, *Agropyron cristatum*, is an introduced cool season, mid grass, monocot, of the grass family that is drought tolerant and winter hardy. Early aerial growth consists of basal leaves from crown and rhizome tiller buds. The relative quantities of crown tillers and rhizome tillers is determined by the timing of partial defoliation management. Partial defoliation prior to flowering stimulates the number and length of the rhizomes and increases the quantity of rhizome tillers. Partial defoliation following flowering inhibits rhizome development and decreases the quantity of rhizome tillers and increases the quantity of crown tillers forming large bunches (Caespitose). Almost all grass tillers live for two growing seasons, first as a vegetative tiller and second as a reproductive lead tiller. The lead tillers produce almost all of the herbage weight during May and early June, vegetative tillers produce the additional herbage weight during late June, July, and August. Fall vegetative tillers produce the additional herbage weight after mid August and during September and early October. The quantity of vegetative tillers and fall tillers during that growing season depends on the quantity of leaf area remaining at the end of the grazing period at the end of May. These vegetative tillers are how the plants maintain the basal cover and next seasons herbage biomass quantity. Utilization of greater than 50% of the aboveground herbage biomass is detrimental to the productivity of the stand. Crested wheatgrass is best used as a spring (May) complementary pasture. Fertilization with 50 lbs N/ac at least one month prior to grazing start on 1 May can work biologically and economically if the calves are one month old on 1 May and grazing is stopped late May or a couple of days in early June, leaving 500 lbs to 1000 lbs of residual herbage weight per acre.

High animal weight gain per day can be achieved without fertilizer by use of a 2 pasture switchback treatment where each of the two pastures are grazed for two periods of 7 to 8 days during May for a total of 28 to 32 days. The calves need to be one month old on 1 May at the start of the grazing period and at least 500 lbs to 1000 lbs of residual herbage weight per acre must remain after grazing; the more the better.

Hayfields of crested wheatgrass can maintain basal cover and herbage biomass production when cut between the boot stage and the full flower stage, 16 May to 10 June, and capture greater weight of crude protein per acre and reduce forage feed costs because of the higher nutrient content.

Crested wheatgrass plants are hardy but cannot fully recover from double heavy use during one growing season. The stand deteriorates with great reductions in basal cover and herbage production. Poorly managed crested wheatgrass hayfields and pastures are the primary “Hotspot” source of pestiferous grasshopper outbreaks in the Northern Plains.

Crested wheatgrass is a beneficial introduced grass when managed properly. Crested wheatgrass is a valuable asset on the Northern Plains Grass Prairie.

Acknowledgment

I am grateful to Sheri Schneider for assistance in the production of this manuscript and development of the tables and the figure.

Table 1. Agropyron cristatum, Crested wheatgrass, weekly percent crude protein, percent phosphorus, and phenological growth stages of ungrazed lead tillers in western North Dakota, 1946-1947.

Sample Date	Crude Protein %	Phosphorus %	Phenological Growth Satges
Apr 1			
13	15.5	0.256	Early leaf greenup
19	17.1	0.315	
25	16.2	0.313	
May 4	19.0	0.310	Active leaf growth
10	21.0	0.284	
16	16.2	0.255	Flower stalk developing
23	14.5	0.245	
28	13.5	0.247	Flowering (Anthesis)
Jun 6	12.1	0.232	Seed developing
13	11.5	0.255	
19	10.6	0.225	
26	9.7	0.232	
Jul 2	8.6	0.212	Seed maturing
8	7.5	0.191	
16	7.5	0.181	Seed mature
24	6.4	0.178	Drying
30	6.4	0.183	Drying
Aug 6	5.9	0.148	Drying
13	5.8	0.142	
20	5.8	0.151	
26	5.8	0.147	
Sep 3	4.5	0.148	
12	4.0	0.122	
21	-	-	
29	4.7	0.084	
Oct			
Nov 5	4.2	0.090	Drying

Data from Whitman et al. 1951.

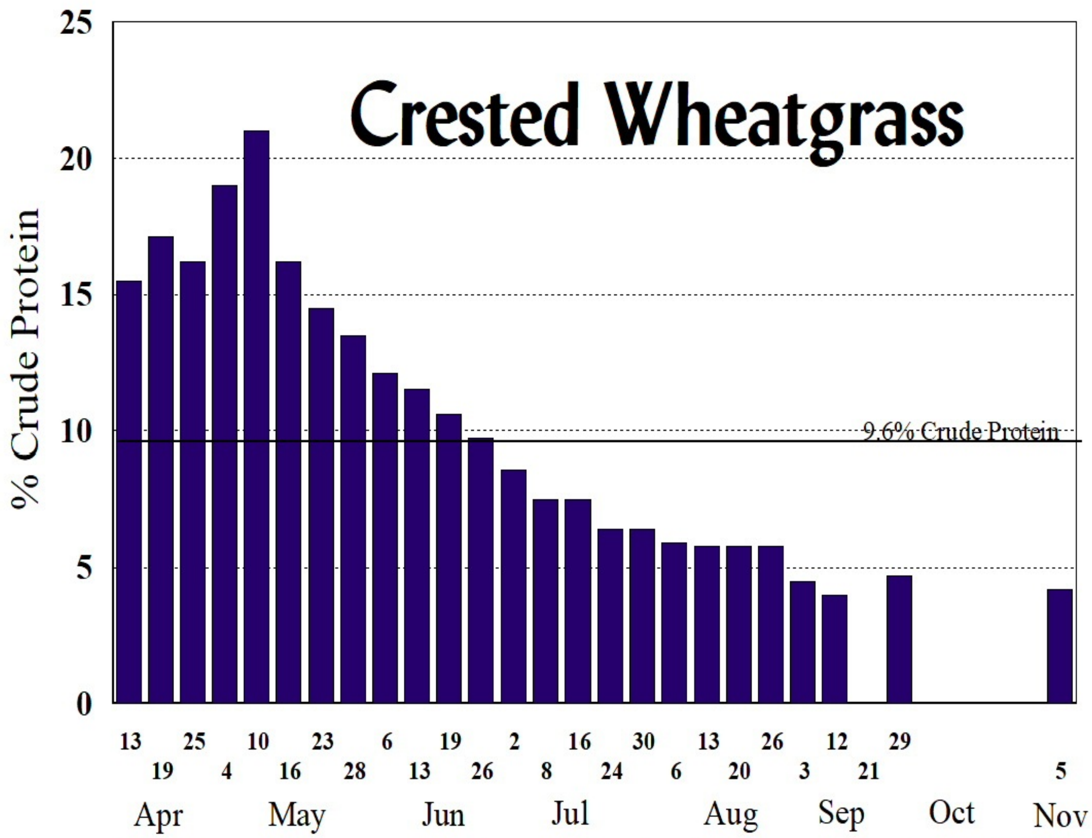

Fig 1. Mean percent crude protein of ungrazed crested wheatgrass in western North Dakota, data from Whitman et al. 1951.

Table 2. First flower and flower period of Agropyron cristatum, Crested wheatgrass.

	Apr	May	Jun	Jul	Aug	Sep
First Flower						
Mean		28				
Flower Period		X	XX			

First Flower data from Whitman et al. 1951.

Table 3. Intake nutrient requirements as percent of dry matter for range cows with average milk production.

	Dry Gestation	3rd Trimester	Early Lactation	Lactation (Spring, Summer, Fall)
1000 lb cows				
Dry matter (lbs)	21	21	24	24
Crude protein (%)	6.2	7.8	10.5	9.6
Phosphorus (%)	0.11	0.15	0.20	0.18
1200 lb cows				
Dry matter (lbs)	24	24	27	27
Crude protein (%)	6.2	7.8	10.1	9.3
Phosphorus (%)	0.12	0.16	0.19	0.18
1400 lb cows				
Dry matter (lbs)	27	27	30	30
Crude protein (%)	6.2	7.9	9.8	9.0
Phosphorus (%)	0.12	0.17	0.19	0.18

Data from NRC 1996.

Table 4. Spring pasture trial, crested wheatgrass alone, with alfalfa, and fertilized, grazed by steers at 633 lbs from early May to early July, 1955-1963.

	Year	# Days	# Months	# Head	Gain per Head, lbs	Gain per Day, lbs	Gain per Acre, lbs	Herbage lbs/ac
Crested wheatgrass								
8 ac	1955	51	1.67	7	74	1.44	64.3	962
	1956	45	1.48	6	81	1.79	60.3	743
	1957	60	1.97	6	144	2.40	107.7	1046
	1958	63	2.07	6	127	2.02	95.3	902
	1959	52	1.70	6	142	2.73	106.5	940
	1960	73	2.39	6	135	1.85	101.3	981
	1961	48	1.57	6	111	2.31	83.1	852
	1962	67	2.20	6	171	2.55	128.8	1291
	1963	57	1.87	6	160	2.81	119.7	1867
Mean		57	1.88	6	127.2	2.21	96.3	1065
Crested wheatgrass								
with alfalfa	1955	51	1.67	7	106	2.06	92.2	1429
8 ac	1956	45	1.48	8	96	2.14	96.3	1020
	1957	60	1.97	8	141	2.35	158.1	1415
	1958	63	2.07	8	132	2.10	132.0	1102
	1959	52	1.70	8	113	2.17	112.5	1110
	1960	73	2.39	8	137	1.87	137.0	1200
	1961	48	1.57	8	94	1.96	94.0	885
	1962	67	2.20	8	153	2.28	153.1	1469
	1963	57	1.87	8	173	3.03	172.5	2557
Mean		57	1.88	8	127.2	2.22	127.5	1354
Crested wheatgrass								
+ 50 lbs N/ac	1959	52	1.70	6	133	2.56	99.8	1153
8 ac	1960	72	2.39	8	165	2.26	165.0	1476
	1961	48	1.57	8	107	2.23	106.9	884
	1962	67	2.20	8	182	2.72	182.5	2882
	1963	57	1.87	8	155	2.72	155.0	4950
Mean		59	1.95	8	148.4	2.50	141.8	2269

Data from Whitman 1963.

Table 5. Steer stocking rate and forage utilization on unfertilized and fertilized spring crested wheatgrass pastures, 1972-1976.

Crested wheatgrass	# Days Grazed	# Months Grazed	# Head	# AUME 0.745	# ac/AUME	Forage Produced lbs/ac	Forage Utilized lbs/ac	Utilization %	Forage per Steer lbs/d
Unfertilized 16 ac									
1972	56	1.84	10	13.7	1.17	2216	798	36	22.8
1973	56	1.84	12	16.4	0.97	1637	966	59	23.0
1974	55	1.80	12	16.1	0.99	1950	897	46	21.7
1975	56	1.84	13	17.8	0.90	2213	1505	68	33.1
1976	53	1.74	13	16.9	0.95	2564	1538	60	35.7
Mean	55	1.81	12	16.2	1.00	2116	1141	53.8	27.3
Fertilized 8 ac									
1972	56	1.84	10	13.7	0.58	4168	1792	43	25.6
1973	56	1.84	12	16.4	0.49	1988	1352	68	16.1
1974	55	1.80	12	16.1	0.50	2365	1372	58	16.6
1975	56	1.84	13	17.8	0.45	3611	2744	76	30.2
1976	53	1.74	13	16.9	0.47	2849	1766	62	20.5
Mean	55	1.81	12	16.2	0.50	2996	1805	61.4	21.8

Data from Nyren et al. 1983.

Table 6. Steer weight performance on spring crested wheatgrass pastures, unfertilized and fertilized with 50 lbs N/ac, 1972-1976.

Crested wheatgrass	Dates Grazed	# Days	# Head	Gain per Head, lbs	Gain per Day, lbs	Gain per Acre, lbs
Unfertilized 16 ac						
1972	12 May-7 Jul	56	10	125.0	2.23	78.1
1973	26 Apr-21 Jun	56	12	92.9	1.65	69.7
1974	1 May-21 Jun	55	12	94.9	1.72	71.2
1975	13 May-8 Jul	56	13	65.7	1.17	53.4
1976	6 May-28 Jun	53	13	75.3	1.41	61.2
Mean	5 May-29 Jun	55	12	90.8	1.64	66.7
Fertilized 8 ac						
1972	12 May-7 Jul	56	10	118.1	2.12	147.6
1973	26 Apr-21 Jun	56	12	73.7	1.32	110.6
1974	1 May-21 Jun	55	12	79.1	1.43	118.7
1975	13 May-8 Jul	56	13	70.8	1.26	114.9
1976	6 May-28 Jun	53	13	42.6	0.79	69.3
Mean	5 May-29 Jun	55	12	76.9	1.38	112.2

Data from Nyren et al. 1983.

Table 7. Cow-calf stocking rate and forage utilization on spring crested wheatgrass unfertilized and fertilized pastures, 1978-1982.

Crested wheatgrass	# Days	# Months	# Head	# AUM	# ac/AUM	Forage Produced lbs/ac	Forage Utilized lbs/ac	Utilization %	Forage per Cow-calf lbs/d
Unfertilized 16 ac									
1978	28	0.92	10	9.2	1.74	2030	1068	53	61.0
1979	31	1.02	10	10.2	1.57	1675	1174	70	60.6
1981	33	1.08	8	8.6	1.85	1649	1014	61	61.5
1982	32	1.05	10	10.5	1.52	1739	1046	60	52.3
Mean	31	1.02	9.5	9.6	1.67	1773.3	1075.5	61	58.9
Fertilized 8 ac									
1978	56	1.84	10	18.4	0.43	5060	3426	68	48.9
1979	31	1.02	10	10.2	0.78	2243	1713	76	44.2
1981	33	1.08	8	8.6	0.93	3589	1742	67	52.8
1982	32	1.05	10	10.5	0.76	3862	1835	48	45.9
Mean	38	1.25	9.5	11.9	0.73	3688.5	2179.0	65	48.0

Data from Manske et al. 1984.

Table 8. Cow and calf weight performance on spring crested wheatgrass unfertilized and fertilized pastures, 1978-1982

Crested wheatgrass	Dates Grazed	# Days	# Head	Initial wt, lbs	Final wt, lbs	Gain per Head, lbs	Gain per Day, lbs	Gain per Acre, lbs
Calf								
Unfertilized 16 ac								
1978	22 May-19 Jun	28	10	180	228	48	1.7	30
1979	22 May-22 Jun	31	10	160	218	58	1.9	36
1981	21 May-23 Jun	33	8	155	224	69	2.1	34
1982	20 May-21 Jun	32	10	137.5	200.5	63	1.97	39.4
Mean	21 May-21 Jun	31	9.5	158.1	217.6	59.5	1.92	34.9
Fertilized 8 ac								
1978	15 May-10 Jul	56	10	152	255	103	1.8	129
1979	22 May-22 Jun	31	10	171	252	81	2.6	101
1981	15 May-16 Jun	33	8	148	221	73	2.2	73
1982	20 May-21 Jun	32	10	139.5	208.5	69	2.16	86.3
Mean	18 May-25 Jun	38	9.5	152.6	234.1	81.5	2.19	97.3
Cow								
Unfertilized 16 ac								
1978	22 May-19 Jun	28	10	990	1044	55	2.0	34
1979	22 May-22 Jun	31	10	970	1038	67	2.2	42
1981	21 May-23 Jun	33	8	1138	1148	10	0.3	5
1982	20 May-21 Jun	32	10	897.0	1004.0	107	3.35	66.9
Mean	21 May-21 Jun	31	9.5	998.8	1058.5	59.8	1.96	37.0
Fertilized 8 ac								
1978	15 May-10 Jul	56	10	958	1066	108	1.9	135
1979	22 May-22 Jun	31	10	976	1064	88	2.8	110
1981	15 May-16 Jun	33	8	1010	1042	32	1.0	32
1982	20 May-21 Jun	32	10	893.5	1018.5	125	3.91	156.3
Mean	18 May-25 Jun	38	9.5	959.4	1047.6	88.3	2.40	108.3

Data from Manske et al. 1984.

Table 9. Reduction of crested wheatgrass by herbicide trial, percent basal cover, 1985-1986.

	Control	Bromacil ai/ac						Glyphosate ai/ac
		15 Apr			15 May			15 Apr
Point Frame Dates and % Difference		0.75	1.5	3.0	0.75	1.5	3.0	1.0
Crested wheatgrass								
17 Jun 85	14.40	9.10	9.40	12.70	12.30	11.40	6.50	9.00
16 Aug 85	16.00	14.20	12.60	5.60	13.90	14.40	13.40	12.90
11 Jun 86	7.80	6.40	4.20	0.40	5.90	3.70	0.20	5.80
7 Aug 86	7.70	7.00	6.50	0.90	7.00	7.80	2.20	6.00
% Difference	-46.5	-51.4	-54.9	-93.8	-51.4	-45.8	-84.7	-58.3
Cool Season								
17 Jun 85	1.40	0.00	1.40	1.00	1.10	0.00	0.00	0.40
16 Aug 85	0.30	0.70	0.30	0.10	0.70	0.20	0.80	0.60
11 Jun 86	0.30	0.30	0.30	0.00	0.50	0.20	0.10	0.50
7 Aug 86	1.40	2.30	0.00	0.00	0.70	0.20	0.00	1.50
% Difference	0.0	64.3	-100.0	-100.0	-50.0	-85.7	-100.0	7.1
Warm Season								
17 Jun 85	4.10	3.10	5.40	6.30	4.50	6.10	5.00	7.90
16 Aug 85	7.80	5.80	8.00	6.20	8.80	7.50	8.00	13.50
11 Jun 86	2.60	4.20	3.80	4.90	4.20	2.70	2.90	5.20
7 Aug 86	5.00	5.20	7.00	9.50	10.60	8.10	7.10	8.10
% Difference	22.0	26.8	70.7	131.7	158.5	97.6	73.2	97.6
Forbs								
17 Jun 85	0.90	0.60	0.40	0.20	0.70	0.40	0.60	0.50
16 Aug 85	1.30	0.80	0.10	0.00	0.30	0.60	0.00	1.50
11 Jun 86	1.10	0.50	0.40	0.40	0.20	0.20	0.10	0.80
7 Aug 86	1.70	0.30	0.40	0.30	0.30	0.00	0.00	0.70
% Difference	70.0	-70.0	-60.0	-70.0	-70.0	-100.0	-100.0	-30.0
Bare Soil								
1985	24.97	10.00	24.17	25.53	29.57	20.93	20.23	14.67
1986	9.27	6.47	11.83	24.30	11.00	13.57	15.17	9.33
Mean	17.12	8.23	18.00	24.92	20.28	17.25	17.70	12.00
% Difference	-	-51.9	5.1	4.6	18.5	0.8	3.4	-30.0

Table 10. Crested wheatgrass spring (May) complementary pasture fertilized with 50 lbs N/ac, stocking rates, 1983-1994.

1 Pasture, 13 ac Fertilized 50 lbs N/ac	Grazing Period	# Days	# Months	# Head	AUM's	ac/AUM
1983-1987	9 May-2 Jun	24	0.79	25	19.67	0.70
1988-1990	21 May-3 Jun	13	0.43	25	10.66	1.22
1991-1994	9 May-2 Jun	24	0.79	22	17.31	0.75
1983-1994	12 May-2 Jun	21	0.70	24	16.52	0.85

Table 11. Crested wheatgrass spring (May) complementary pasture fertilized with 50 lbs N/ac, ungrazed and grazed basal cover, 1983-1994.

		Ungrazed			Grazed	
1 Pasture, 13 ac Fertilized 50 lbs N/ac	CW 1	CW 2	Mean	CW 1	CW 2	Mean
1983-1987	23.90	24.03	23.97	21.91	21.04	21.47
1988-1990	19.87	23.57	21.72	16.84	21.28	19.06
1991-1994	36.32	35.04	35.68	35.37	29.05	32.21
1983-1994	26.70	27.55	27.12	24.71	23.79	24.25

Table 12. Crested wheatgrass spring (May) complementary pasture fertilized with 50 lbs N/ac, mean monthly ungrazed and grazed herbage biomass (lbs/ac), 1983-1994.

1 Pasture, 13 ac Fertilized 50 lbs N/ac	Apr	May	Jun	Jul	Aug	Sep
1983-1987						
Ungrazed	1219.88	1784.76	2225.88	2386.50	2496.17	1754.12
Grazed		619.38	858.17	984.93	1168.39	876.44
1988-1990						
Ungrazed	1069.14	1206.88	1568.48	1466.30	1317.93	965.37
Grazed		484.51	549.59	674.06	700.45	394.78
1991-1994						
Ungrazed	1023.42	1076.05	1946.47	2275.80	2198.68	1705.86
Grazed		418.48	721.06	1348.86	1391.75	561.19
1983-1994						
Ungrazed	1125.19	1433.87	2004.75	2105.35	2033.45	1514.97
Grazed		518.65	752.21	964.46	1062.04	637.81

Table 13. Crested wheatgrass spring (May) complementary pasture fertilized with 50 lbs N/ac, cow and calf weight performance, 1983-1994.

		Cow			Calf	
1 Pasture, 13 ac Fertilized 50 lbs N/ac	Weight Gain lbs	Gain per Day lbs	Gain per Acre lbs	Weight Gain lbs	Gain per Day lbs	Gain per Acre lbs
1983-1987	62.52	2.76	117.22	47.60	2.04	90.10
1988-1990	35.67	2.62	69.09	31.57	2.36	60.71
1991-1994	54.41	2.33	92.11	57.07	2.38	96.92
1983-1994	53.10	2.58	96.82	46.75	2.26	85.02

Table 14. Crested wheatgrass spring (May) complementary pasture comparing 2 pasture switchback with 1 pasture, stocking rates, 1995-2005.

Crested wheatgrass	Grazing Period	# Days	# Months	# Head	AUM's	ac/AUM
2 Pasture Switchback 26.5 ac						
1995-1997	2 May-3 Jun	32	1.05	24	25.18	1.05
1998-2001	4 May-1 Jun	28	0.92	23	21.12	1.26
2002-2005	4 May-1 Jun	28	0.92	22	20.20	1.31
1995-2005	3 May-1 Jun	29	0.95	23	21.87	1.21
1 Pasture, 15 ac						
1995-1997	4 May-3 Jun	30	0.98	7	6.89	2.18
1998-2001	4 May-1 Jun	28	0.92	7	6.43	2.33
2002-2005	4 May-1 Jun	28	0.92	7	6.43	2.33
1995-2005	4 May-1 Jun	28	0.92	7	6.43	2.33

Table 15. Crested wheatgrass spring (May) complementary pasture comparing 2 pasture switchback with 1 pasture, grazed basal cover, 1995-2005.

	Grazed		
2 Pasture 26.5 ac Switchback	CW 1-3	CW 2-4	Mean
1995-1997	21.33	18.35	19.84
1998-2001	18.55	19.99	19.27
2002-2005	25.19	29.01	27.10
1995-2005	21.69	22.45	22.07

Table 16. Crested wheatgrass spring (May) complementary pasture comparing 2 pasture switchback with 1 pasture, grazed basal cover, 1995-2005.

	Grazed			
1 Pasture 15 ac	CW 5	CW 6	CW 13	Mean
1995-1997	25.65	26.10	12.33	21.36
1998-2001	15.46	16.03	12.08	14.40
2002-2005	20.22	21.52	12.58	20.15
1995-2005	20.44	21.22	12.33	18.64

Table 17. Crested wheatgrass spring (May) complementary pasture comparing 2 pasture switchback with 1 pasture, mean monthly ungrazed and grazed herbage biomass (lbs/ac), 1995-2005.

Crested wheatgrass	Apr	May	Jun	Jul	Aug	Sep
2 Pasture, Switchback, 26.5 ac						
1995-1997						
Ungrazed	845.97	1652.54	1692.04	2010.26	2195.99	2736.03
Grazed		542.23	684.53	1107.18	1025.37	1298.99
1998-2001						
Ungrazed	1593.04	2811.36	3623.75	4159.88	3644.77	3339.07
Grazed		1148.79	1581.13	2323.64	2159.29	1940.78
2002-2005						
Ungrazed	1289.46	1926.11	2924.92	2775.76	2761.14	2300.32
Grazed		1177.53	1750.23	1786.61	1874.19	1818.66
1995-2005						
Ungrazed	1330.38	2182.50	2829.06	2570.67	2945.05	2802.96
Grazed		1038.97	1362.88	1796.59	1733.59	1763.57

Table 18. Crested wheatgrass spring (May) complementary pasture comparing 2 pasture switchback with 1 pasture, mean monthly ungrazed and grazed herbage biomass (lbs/ac), 1995-2005.

Crested wheatgrass	Apr	May	Jun	Jul	Aug	Sep
1 Pasture, 15 ac						
1995-1997						
Ungrazed	627.40					
Grazed		777.68	1040.18	864.23	790.41	876.54
1998-2001						
Ungrazed	969.21					
Grazed		808.67	978.91	1337.48	1251.48	1091.25
2002-2005						
Ungrazed	545.94	1260.70	1265.75	2001.65	1769.43	1992.73
Grazed		795.32	1055.53	1185.30	1109.32	982.76
1995-2005						
Ungrazed	752.16					
Grazed		797.13	1018.07	1181.96	1101.63	1019.18

Table 19. Crested wheatgrass spring (May) complementary pasture comparing 2 pasture switchback with 1 pasture, cow and calf weight performance, 1995-2005.

	Cow			Calf		
Crested wheatgrass	Weight Gain lbs	Gain per Day lbs	Gain per Acre lbs	Weight Gain lbs	Gain per Day lbs	Gain per Acre lbs
2 Pasture Switchback, 26.5 ac						
1995-1997	61.38	1.91	55.59	80.51	2.50	72.92
1998-2001	90.79	3.25	78.98	75.28	2.69	66.04
2002-2005	74.13	2.65	61.91	73.56	2.63	60.85
1995-2005	76.71	2.66	66.39	76.08	2.62	66.03
1 Pasture, 15 ac						
1995-1997	29.80	0.83	13.91	72.03	2.43	33.61
1998-2001	71.14	2.54	33.20	73.70	2.63	34.40
2002-2005	76.50	2.79	32.90	72.29	2.64	30.79
1995-2005	61.81	2.16	27.83	72.73	2.58	32.87

Table 20. Forage dry matter biomass and crude protein yield and costs for crested wheatgrass hay cut at two growth stages.

	Costs/acre								
	Land Rent	Custom Work	Baling Costs	Production Costs $/ac	Forage Biomass Yield lb/ac	Forage Biomass Costs $/ton	Crude Protein %	Crude Protein Yield lb/ac	Crude Protein Costs $/lb
Crested Wheatgrass									
Mature	14.22	5.31	8.58	28.11	1600	34.80	6.4	102	0.28
Boot stage	14.22	5.31	6.97	26.50	1300	40.80	14.5	189	0.14

Data from Manske 2014.

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