1950

Physiological studies with crested wheatgrass

William Wesley Chilcote

Iowa State College

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UMI®
PHYSIOLOGICAL STUDIES WITH
CRESTED WHEATGRASS

by
William Wesley Chilsote

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Plant Physiology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1950
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INTRODUCTION

Crested wheatgrass is generally recognized as one of the most successful introduced species for reseeding abandoned farm and deteriorated range lands in the northern great plains. More range land has been reseeded to this grass than to any other single species.

A native of the cold dry plains of Russia and Siberia, crested wheatgrass is especially well adapted to the climatic conditions of the northern great plains states and the prairie provinces of western Canada. It has been planted extensively in northern Utah, southern Idaho and southeastern Oregon and is also used to reseed deteriorated dry mountain meadows at higher elevations as far south as New Mexico. Where moisture is more abundant, under irrigation or in the eastern part of the great plains, other forage plants are more productive. South of Nebraska, temperature conditions are not favorable to the growth of present strains.

Crested wheatgrass is classified as a cool season long-lived bunch grass. Growth occurs during the early spring months and again in the fall. The plant remains green until seed has matured in July, but during the hot periods of later July and August it has a tendency to become drought dormant and dry. The species is cold and drought resistant and produces seed prolifically.
Within the range of the species, established stands develop an extremely well developed root system which aggressively resists invasion by other species.

Crested wheatgrass is best adapted to early spring and fall grazing. During most seasons, growth begins two to three weeks earlier than in other native and introduced grasses and also continues later into the fall if moisture conditions are favorable. Yields and forage quality during seasons of growth compare favorably with other native species. As is true of most cool season grasses, forage value drops rapidly following seed maturity.

In view of the large areas now reseeded to crested wheatgrass and its adaptability to reseeding marginal wheatlands should unfavorable prospects for wheat production occur, basic information on the physiology of the grass is needed. The most efficient utilization of any range species requires a knowledge of the inherent characteristics of the normal plant as well as its reaction to various grazing treatments. The object of the present study was to determine the physiological responses of crested wheatgrass to various simulated grazing treatments. It is hoped that this study will contribute information which will help in more efficient management of the species.
REVIEW OF LITERATURE

Sampson (40) and Stoddart and Smith (47) have discussed the various problems related to the utilization of range and pasture plants by livestock. These writers stress the importance of root development and reserves in the sustained production of forage plants, especially those growing under arid and semiarid conditions.

Numerous studies have been made of the effects of herbage removal upon the yield, forage composition, root development and reserves of different grasses growing under varied climatic and soil conditions.

Effect of Herbage Removal Upon Forage Yield

There is general accord among numerous investigators that repeated removal of photosynthetic tissue from plants has a depressing effect upon the total yield. Graber (15), Robertson (39), Biswell and Weaver (6), and Weinmann (54) have reviewed the literature pertaining to the subject.

Harrison and Hodgson (19) studied the effect of clipping upon three sod forming grasses, Kentucky bluegrass, quack grass, and smooth brome, and upon two bunch grasses, timothy and orchard grass. They reported a greater depressing effect of clipping on
yield with the bunch grasses than with those producing rizomes. Aldous (1, 2, 3), Graber (14), Harrison (15), Ellett and Carrier (12), Kohn and Kemp (24), and Peterson (35) reported a depression of bluegrass yields on grazed Kentucky bluegrass as compared to ungrazed plants. In studies of the effect of clipping upon the yield of range grasses, Aldous (1, 2), Parker and Sampson (33), Craddock and Forsling (10), Canfield (3), Nelson (32), Hanson and Stoddart (17), and Gernert (13) reported reduction in yields to vary with the degree, frequency and season at which the herbage was removed. However, Lang and Barnes (25) reported increased yield from short grasses in Wyoming clipped to crown level at 2 week intervals as compared to plants clipped at the end of the growing season.

In South Africa, Weismann (51, 55) noted a cumulative effect from the first to the second season during which cutting treatments were applied. Graber (14) reported that close clipping of Kentucky bluegrass in one year reduced the yield the following year. This was particularly true of the first cutting of the second year. Peterson (35) showed the advantage of spring deferment with Kentucky bluegrass pastures in Iowa, but indicated no significant increase in yield where fall deferment was practiced. Aldous (2), stressed the importance of spring deferment of native blue stem pastures in Kansas. Hanson and Stoddart (17) and Craddock and Forsling (10) have stressed the depressing effects of spring grazing on spring-fall ranges in the intermountain region.
Julander (23) and Confield (8) have noted that some grass species, by stooling near the ground and developing prostrate growth, are better able to resist close grazing. Kohn and Kemp (24) clipped various strains of Kentucky bluegrass and found that low forms could better withstand heavier grazing. However, when a uniform amount of foliage was removed from each plant, no difference between strains was noted.

**Effects of Herbage Removal Upon Forage Composition**

Morrison (31) indicates the general conclusion among investigators that proteins and minerals are more abundant, on a dry weight basis, in herbage during early stages of growth than when herbage is mature. According to Morrison, as the plant approaches maturity the amount of fiber, especially its lignin content, increases. Mature and weathered native grass is low in protein, phosphorous and carotene. Less loss from weathering results if little or no rain occurs following maturity. Watkins (49), studying the composition of range grasses in New Mexico, concluded that the abundance of growth as the result of summer rains, together with the amount of rain following maturity, were important factors relating to the amount of protein and phosphorous in these grasses during the winter months.
Stapledon et al. (46), from studies at the Welsh Plant Breeding Station in England, reported higher total yield and a more nutritious product with frequent removal of forage. Archibald et al. (4) noted that blue grass pastures in eastern Canada cut bi-weekly contained 25.66 per cent protein compared to 23.79 and 21.62 per cent in material cut at 2 and 3 week intervals. Total protein was also greatest where plots were harvested at 2 week intervals. Williams (57) in Montana reported 14.1, 7.6 and 6.9 per cent protein on dry weight basis in crested wheat before bloom, after bloom and during the winter months respectively. Sotola (45) noted the reduction of forage value in this species following bloom.

Richardson, et al. (57), studying nitrogen in *Phalaris tuberosa*, presented data showing two-thirds of the total nitrogen absorbed when only 10.6 per cent of the dry matter had accumulated. That soluble and insoluble nitrogen decreased at a uniform rate as perennial rye grass leaves aged, was pointed out by Sullivan and Sprague (48). Weinmann (52) believed that water soluble forms of nitrogen were translocated to roots of highveld grasses in South Africa following the breakdown of complex organic substances during periods of low temperature in the fall.

Watkins (49) has commented on the relatively high percentage of carbohydrate in mature range grasses. Data on crested
wheatgrass from studies by Williams and Post in Montana (57) showed the percentages of carbohydrates to be 30.7, 37.0 and 35.5 before bloom, after bloom and during the winter stage respectively. McIlvaine (30) also reported total sugars to be highest in *Agropyron spicatum* at time of flowering, declining during autumn. Lower internodes sampled in early spring were found to have carbohydrate concentrations as high as the roots. Weismann and Reinhold (56) noted this same general trend in South African grasses.

Investigations of the carbohydrate trends in perennial rye grass following partial defoliation by Sullivan and Sprague (48) indicated that leaf blades were higher in sucrose but lower in fructosans than lower zones of the leaves and stubble. The authors postulated that fructosans were reserve substances which were removed when close grazing occurred. They attributed a lack of close agreement between replicates to the sudden synthesis of fructosans during certain stages of maturity.

**Relation of Herbage Removal to Root Development**

There is general agreement among investigators that frequent clipping inhibits the root development of plants. (6, 14, 17, 18, 29, 33, 34, 37, 39, 45, 50). Graber (16) showed that over-grazed bluegrass pastures in Wisconsin had 35 to 50 per cent less
of the root of the plant and the external phylloplane.

At the end of the second month, the root of the plant was cleared of all external phylloplane. The root was then studied under a microscope to examine the root tip and the associated rhizosphere. The root tip was cleared of all external phylloplane and the associated rhizosphere. The root tip was then studied under a microscope to examine the root tip and the associated rhizosphere.
the greatest depression of root development. Weaver and Zink (50) investigated the life of roots in _Adropogon furcatus_, _Andropogon scoparius_ and _Agropyron cristatum_, and reported that plants clipped five times to a height of 2 inches at eleven to fourteen day intervals, lost 45 to 64 per cent of their roots during the season, while unclipped plots lost only 5 per cent. McCarty and Price (29) believed that three stages of root development occurred in _Bromus carinatus_ and _Agropyron trachycaulum_. These stages were prior to snow disappearance, at the conclusion of current seasonal root growth, and at the close of the snow free period in autumn.

**Effects of Herbage Removal Upon Organic Reserves**

Weinmann (54), in a review of the underground development and reserves of grasses, defines reserve substances as "organic materials elaborated by the plant, and stored at certain times in the more permanent organs of the plant, to be utilized at a later stage by the plant as a source of energy or building material."

Weinmann considers these reserve substances to be reducing and non-reducing sugars, fructosans, dextrins and starch. The more complex polysaccharides such as pentosans, hemicelluloses and true celluloses are considered as structural materials not utilized as reserves. Protein, according to Weinmann, may likewise be included
as a reserve substance. Nitrogen and other mineral elements, although incorporated with certain reserve materials, cannot be regarded as reserve substances in themselves.

According to DeCugnac (11), who examined 38 species of Graminae, grasses can be divided into two groups; those which accumulate fructosans together with sucrose but no starch in their vegetative organs, and those which store sucrose with or without starch, but no fructosans. He suggests that plants storing fructosans are more typical of the cool temperate climate. This contention has been supported by the work of Weismann and Reinhold in South Africa (56) where grasses showed no accumulation of fructosans in their underground parts.

McIlvaine (30) investigated Agropyron spicatum and concluded that the principal reserves of this species were reducing sugars and polysaccharides, principally dextrins and levulins. McCarty and Price (29) and McCarty (28) working with mountain grasses in Utah considered sugars and "starch" to be the most important reserves. Sucrose was believed to be the most important sugar present, while hemicelluloses appeared to be largely structural material. Benedict and Brown (5) also believed sucrose and starch to be the important reserves. Starch was defined as that fraction hydrolyzed by taka-diastase after alcohol soluble material has been removed.
James (22) reported the reserves of the roots and rhizomes of Kentucky bluegrass to be largely sucrose, with only small amounts of glucose and dextrin. Traces of fructosans were obtained, and tests for starch were negative. Julander (23) believed that drought resistance of various grasses was associated with soluble polysaccharides, which constituted an important part of the reserves. Starch was not observed to be present in the grasses studied. Sullivan and Sprague (48) stated that fructosans were often reported as starch. They considered fructosans and sucrose to be the important reserve substances in perennial rye grass.

Hanson and Stoddart (17) reported little difference in the hemicellulose content of Agropyron spicatum in the stem bases and roots of heavily grazed and protected plots, although the sugar contents were respectively 14.33 and 17.77 per cent of the dry weight.

Numerous workers (2, 29, 30, 35, 55, 57, 58, 59) have reported seasonal trends of reserve substances in perennial grasses. Reserve depletion occurs during rapid vegetative growth prior to maturity, while accumulation takes place after maturity and continues to the end of the growing season.

Aldous (2) in Kansas noted that the total sugars increased from 1.6 to 3.6 per cent, and "starch" from .9 to 5.1 per cent following maturity of Andropogon scoparius. McCarty and Price (29)
reported 70 to 75 percent of the "starch" and sugar reserve of mountain brome grass and slender wheat grass disappeared during the early growth period prior to complete melting of the snow. Total sugars increased markedly at the end of the growing season. McElvanie (30) noted that combined sugars and reserve polysaccharides decreased in the spring, reaching a maximum at the time of seed maturation. Secondary fall growth resulted in a decline of carbohydrate reserves. Studies by Peterson (35) with Kentucky bluegrass in Iowa showed increases of 86 percent for total sugars and 56 percent for polysaccharides during the period from June 12 to November 27.

Remy (36) in Germany found a higher percentage of nitrogen in the roots of Lactylis glomerata in late autumn than in mid-summer. Richardson, Trumble and Shapter (37, 38) studied Lolium subulatum and Phalaris tuberosa in Australia, and noted the loss of nitrogen from the herbage during maturation. They believed these losses were largely due to translocation to the basal stems and roots. Weinmann (63) and Weinmann and Reinhold (56) working with African highveld grasses obtained evidence that nitrogen was translocated in the form of water soluble substances formed by the breakdown of more complex organic compounds at the time of low fall temperatures.
Reserve depletion brought about by herbage removal has been studied by many investigators (3, 7, 17, 29, 37, 38, 40, 49). Aldous (3) reported a decrease of total sugars and polysaccharides proportional to the height and frequency of clipping. Hemicellulose was not affected. McCarty and Price (29) working with *Bromus coronatus* and *Agropyron trachycaulum* concluded that the amount of depletion depended upon degree, frequency and time of clipping. Reserves at the end of the season in plants clipped early and late were reduced less than when plants were clipped during the middle of the growing season. Hanson and Stoddart (17) noted that the combined sugars and "starch" of root and stem bases averaged 7.0 per cent on protected areas as compared to 4.7 per cent on heavily grazed areas. Hemicellulose was not significantly different.

Sampson and McCarty (41) noted that one or two cuttings during early leaf stages did not prevent maximum accumulation in *Stipa pulchra*. However, clipping between flower stalk formation and seed maturity caused marked depletion. Burke and Weaver (7) investigated the effect of clipping upon various mid grasses. Clipping *Agropyron spicatum* to crown level at two week intervals for eight weeks during the vegetative stage reduced the combined sugars and polysaccharides in the roots by 50 per cent, and in the lower internodes of the herbage by 73 per cent.
Observation by Sullivan and Sprague (49) of changes of carbohydrate material in *Lolium perenne* during a 36 day period following defoliation, showed that water soluble carbohydrates, glucose, fructose, sucrose and fructosan decreased rapidly in roots and stubble. Decrease of reserve substances appeared to be in proportion to the reserve concentration at time of clipping. There was no evidence of cellulose, pentosans, or lignin being used. Soluble carbohydrates were almost completely exhausted from plants placed in the dark.

Richardson, et al (38) reported that roots of *Phalaya tuberosa* were significantly higher in nitrogen when cut frequently. Absolute amounts of nitrogen were less, however, because of reduced weight. Leukel and Barnett (26) in Florida found that actual amounts of nitrogen were highest where Bahia grass plants remained unclipped until the end of the growing season.
METHODS

The study of the response of crested wheatgrass, *Agropyron cristatum*, to various clipping treatments was conducted in 1948 and 1949 at the Belle Fourche, Bureau of Plant Industry Experimental Farm, located in northwestern South Dakota near Newell. The experimental farm lies within the Belle Fourche River Irrigation Project, and conducts research under both dry-land and irrigated conditions.

Prior to cultivation the area now occupied by the farm was native grassland dominated by western wheatgrass, *Agropyron smithii*. The soil is a heavy clay loam which offers serious cultivation and irrigation problems, but is well adapted to grasses.

Plots for this study were located on old established crested wheatgrass sod associated with the dry-land area in the southwestern part of the farm. These stands of wheatgrass had been established in the spring of 1942 by drilling into well prepared land which had been cultivated for a number of years previously. The resultant stand was of a density comparable to other wheatgrass pastures in this locality.

Two areas were selected, which will be referred to as area A and area B. Area A was laid out in the spring of 1948, and
In an open dirt wetland, the plant was attached to the same mat. All plants were recorded on plots using the same grid. After securing the remainder of the quadrates, a total of 100 quadrates were obtained from two replicates.

For the first experiment, a randomized block design was used. Data from each plot gave a point of observation in the experiment. The data was then analyzed for the part of the study in Figure 2.6.

By varying the frequency of plots over time, the data was taken at different times. Each phase of the study was to determine the effect of

By varying the frequency of plots over time, the data was taken at different times. Each phase of the study was to determine the effect of

By varying the frequency of plots over time, the data was taken at different times. Each phase of the study was to determine the effect of
Figure 1. Area A, August 3, 1949
Figure 2. Area B, August 3, 1949
Figure 3. Yield plots on area A taken August 5, 1949

A. Unclipped plants

B. Plants clipped to 3 inches at monthly intervals during the growing season
Figure 4. Yield plot of plants clipped to 1 inch at two-week intervals during the growing season. This picture was taken August 3, 1949.
The crop season at a specified area of deposit was

Treated and used for experimental purposes

depending on the availability of water, the area was used to
at the time of establishment and dry weather before
reached of the photos on 6 Aug 8, 1966 in the
the area of the photos as shown in the
April 1966 was established during the
year 1964-65, it could be observed that the
were observed during the 1964-65 season and

are done. By the crop season in 1962, the
were met and the photos were taken.
the area was burned to the crop level in November of 1966 so that only
by the end of the 1964-65 growing season. The entire
mature with their flowers. All mother-aspirated photos were taken
more frequent and the number of days more
immediate severe grain frost. Photos were taken to
photos were used to map all the mother-cultivated plots and
least to each plot when either a lam or any more. Hand lamb
The literature nature of bunch grass was not read

1965.

At various depths were taken during the first and last of July in
and the photos took place could not be made. All mother-cultivated
the plant by the end of June after July in 1965,

such a crop of the photos of the proposed schedule. This
During the 1964 season adequate water was provided.
different stages of development sampled included, the three to four leaf, shoot, head, anthesis, dough, seed ripe, fall regrowth and dormant stages. Clippings were made with lawn shears to the crown level. Oven dry weights were obtained from clippings on two meter-square quadrats located within each plot. Plants within each plot not included in these yield quadrats were used for root reserve and forage composition determinations.

Since the author could not be present at the time of the first three clipping stages, it was necessary to hire the work done during a busy spring season. As a result treatments were given and data collected from only two replicated plots each, for the three to four leaf, shoot, and head stages. Five plots were used for clipping treatments during anthesis, dough, seed ripe, and fall regrowth. Four replicated plots were used for the unclipped check plants.

In order that fall regrowth be included in the total yields, plots were clipped in December and these yields together with the previous clippings were accumulated to give the total yields for each treatment. Water was hauled to area B during the dry summer months in sufficient amounts to provide adequate soil moisture.
Studies of Seasonal Forage Composition

As Affected by Various Clipping Treatments

To study seasonal trends of forage value for plants clipped to simulate severe, moderate and ungrazed conditions, top samples were taken at various stages of development on area A during 1948 and 1949.

In 1948, the periods at which top samples were taken were at the anthesis, dough, drought dormancy and winter stages. The number of sampling periods was increased in 1949 to include the shoot and head stage. Samples of forage were also taken October 15 and November 15 in 1949.

Three separate composite samples of plants clipped to the ground level were taken from each treatment during the sample period. The tops were clipped to lengths which would enter the mouth of a pint fruit jar, weighed, and killed in hot 80 per cent alcohol. All samples taken during 1948 were approximately 50 gm. fresh weight. In 1949 the size was reduced to 10 gm.

Analyses for the determination of reducing sugars, sucrose, total sugars and soluble nitrogen were made from the alcohol extract. Sugars were determined by the ceric sulfate method as described by Hassid (21). Soluble nitrogen was determined by a modified kjeldahl method.
Polysaccharide fractions were determined by hydrolyzing the alcohol extracted residue with 1 plus 20 hydrochloric acid for 30 minutes at 10 pounds pressure. The hydrolyzed samples were cooled, filtered, neutralized with 10 per cent sodium hydroxide, made to volume, and reducing sugars determined.

To provide a more adequate picture of seasonal trends on top material, forage samples were taken on area B at each clipping treatment. Water was hauled to these plots during the summer season so that soil moisture was not a limiting factor in plant growth. The effect of a single clipping at various stages of growth during the season upon the winter forage value was determined from top samples taken from all treatments on area B.

Two separate composite samples from each treatment were taken at the time of clipping and in December. These samples were killed and extracted as described above. Reducing, non-reducing, total sugars, soluble and insoluble nitrogen determinations were made on each top sample.
Studies of Root Development Under Various Clipping Treatments

Root development under clippings simulating severe, moderate and ungrazed conditions were studied in July of 1948 and 1949.

Yields of roots at depth intervals of 6 inches, to a total of 24 inches, were taken with a 2 inch soil tube at two random locations on each plot. Cores from each 6 inch depth were washed to remove adhering soil. Roots were oven dried, and weighed to the closest 1.0 mg. Soil moisture determinations were made at the same time at 6 inch intervals to a total depth of 36 inches from two random positions located on each plot.

Studies of Seasonal Root Reserves Under Various Clipping Treatments

Triplicate samples of roots were obtained from each of the clipping treatments on area A at various stages of seasonal development over a two year period. These root samples were taken on the same date as top samples. Developmental stages of sampling in 1948 were, anthesis, dough, seed ripe and drought dormancy. In 1949 four more sampling periods were added, including the shoot and head stage, and the middle of October and November. Root samples were taken during the latter part of December in both years.
were taken in August, September, and December.

During the second year plants were covered June 20. Root samples of these were collected July 6 and submitted and analyzed for Chl, Ca, Mg, Mn, Na, and P. These data are not available at this time.


taking the 1946 growing season, 1000 or plants covered
Root samples were taken on area B to study the effect of a single clipping at various stages of development upon root reserves. Two separate composite root samples were taken from plants at the time each clipping was made. As indicated previously, top samples also were taken at this time. All plots which had received the single seasonal clipping were sampled for root reserves on August 28. For reserves at the end of the growing season, two separate composite root samples were taken from each of the treatments on December 27.

All root samples were analyzed for the determination of reducing sugars, sucrose, total sugars, water soluble polysaccharides, acid hydrolyzable polysaccharides, soluble and insoluble nitrogen.

After clearing the extracted material with lead acetate, sugars were determined by the oeric sulfate method as described by Nassid (21). Soluble nitrogen was determined from aliquots of the extract by the semi-micro kjeldahl method.

Residues from the alcohol extraction were ground in a Christy and Norris mill to pass a 60 mesh screen. From this ground material, analyses were made for the determination of water soluble and acid hydrolyzable polysaccharides, and for insoluble nitrogen. No starch was observed and it was assumed that none was present. Iodine tests were negative, and samples treated with saliva gave results similar to the water extraction.
By the hearing of 600.

First, the patient was examined and considered to be in a state of partial paralysis. The temperature was normal and the pulse was regular. There were no signs of infection.

The patient was placed in the hot water and the tumor was massaged with the fingers. The water was then changed to a cooler temperature and the massage was continued.

After 10 minutes, the patient was taken out of the water and the incision was made. The tumor was then removed.

The wound was cleaned and dressed with sterile gauze. The patient was kept in bed for 24 hours. The temperature was normal and the pulse was regular. The wound healed without complication.

To determine the ultimate prognosis, I give the following:

1. The patient's general health.
2. The extent of the incision.
3. The appearance of the wound.

The final diagnosis will be made after a complete review of these factors.

EXPERIMENTAL RESULTS

Forage Yield Results

Data on forage yield of crested wheatgrass under three clipping intensities simulating severe, moderate and ungrazed conditions were taken during 1948 and 1949. The character of these two growing seasons provided an opportunity to study the clipping treatment effects during years of rather abundant and of limited moisture supply. As shown in Table 1, a total of 15.06 inches of precipitation fell between April 1 and September 1 in 1948, while only 7.82 inches were reported during the same period in 1949.

Yield data were also obtained from plots clipped only once during the growing season at a certain stage in development. To eliminate the effect of soil moisture upon the ultimate yield of plants clipped at any one stage, water was hauled in sufficient quantities to provide adequate soil moisture throughout the growing season.

The effect of three clipping intensities upon forage yield

The total and cumulative yields of crested wheatgrass during 1948 and 1949 under three clipping intensities are shown in Tables 2 and 3, and in Figure 5.
TABLE 1. RECORD OF AVERAGE MAXIMUM AND MINIMUM TEMPERATURE AND THE PRECIPITATION FOR THE MONTHS OF APRIL THROUGH DECEMBER IN 1948 AND 1949, TOGETHER WITH THE 40 YEAR MEANS FOR THE SAME MONTHS

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<td>90</td>
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<td>62</td>
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<td>91</td>
<td>74</td>
<td>56</td>
<td>105</td>
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<td>Min. daily</td>
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<td>49</td>
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**Precipitation**

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**TABLE 2. AVERAGE YIELD AND CUMULATIVE YIELD OF CRESTED WHEATGRASS AT THE TIME OF EACH CLIPPING TREATMENT IN 1948**

Oven dry weight in grams per meter-square quadrat and standard error of the averages.

<table>
<thead>
<tr>
<th>Treatment Number</th>
<th>Date of Clipping</th>
<th>Average</th>
<th>Cumulative</th>
<th>Total Yield</th>
</tr>
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<tr>
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<td>4/21</td>
<td>5/7</td>
<td>6/20</td>
<td>6/21</td>
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<td>17.42</td>
<td>9.59</td>
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<td>57.91</td>
<td>67.50</td>
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<td>2</td>
<td>Average</td>
<td>33.05</td>
<td>23.23</td>
<td>8.27</td>
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<td>Cumulative Average</td>
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<td>62.08</td>
<td>70.33</td>
</tr>
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<td>Average</td>
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</tr>
<tr>
<td></td>
<td>Cumulative Average</td>
<td>144.60</td>
<td></td>
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</tr>
</tbody>
</table>

*(1) Plants clipped to 1 inch at two-week intervals.
(2) Plants clipped to 3 inches at monthly intervals.
(3) Plants unclipped.*
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date of Clipping</th>
<th>Average</th>
<th>Cumulative Average</th>
<th>Cumulative Total</th>
<th>Yield</th>
</tr>
</thead>
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<tr>
<td>Plants clipped to 1 inch bi-weekly</td>
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<td>6.20</td>
<td>24.46</td>
<td>29.66</td>
<td>28.6</td>
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<tr>
<td>Plants clipped to 3 inches monthly</td>
<td>May 12</td>
<td>12.18</td>
<td>37.16</td>
<td>37.16</td>
<td>67.2</td>
</tr>
<tr>
<td>Unclipped plants</td>
<td>June 29</td>
<td>14.58</td>
<td>51.24</td>
<td>51.24</td>
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</tr>
<tr>
<td></td>
<td>June 12</td>
<td>14.82</td>
<td>53.0</td>
<td>53.0</td>
<td>106.0</td>
</tr>
<tr>
<td></td>
<td>August 27</td>
<td>14.82</td>
<td>53.0</td>
<td>53.0</td>
<td>106.0</td>
</tr>
</tbody>
</table>
Figure 8. Average total yield and cumulative yield of crested wheatgrass in 1948 and 1949.
A marked decrease in total yields on plots receiving the severe and moderate treatments was noted in 1946. Plants clipped to 1 inch at two week intervals, simulating severe grazing, produced about two-thirds as much forage as the unclipped plots by the end of the growing season. Total yields on plants clipped to 3 inches at monthly intervals, simulating a moderate degree of grazing, were approximately three-fourths of the unclipped plot totals.

Seasonal cumulative yields for the moderate and severe treatments in 1946 showed similar trends, with the production from the moderately clipped plots falling below the severe until the final clipping in August, when the remaining material below the 3 inch level was added to the total yield.

Under the favorable moisture conditions which prevailed until September, clipped plants continued to regrow. Yields during the season from plants clipped to 1 inch were from basal buds. Few basal leaves grew on plants clipped above the 3 inch level, and yields from these plots until the final clipping were largely from non flowering, erect culms. No basal regrowth was observed for unclipped plants prior to the final yield clipping to the crown level in September. Little opportunity for fall regrowth occurred during September and October because of lack of precipitation.
During 1949 the treatments were continued on the same plots, and the accumulative effects of both severe and moderate treatments were more pronounced than during the first year. The average yield from plots clipped severely was less than one-fourth of the amount produced on unclipped plots, while yields from plots receiving the moderate treatment were reduced to one-half that of the unclipped plots.

Limited moisture conditions in 1949 had a much greater depressing effect upon plants weakened by two years of clipping. Unclipped plots showed an average decrease of 16.3 per cent when forage yields were compared to the previous year, while production from plants receiving the moderate and severe treatments were decreased by 40.2 per cent and 68.7 per cent respectively. A comparison of yields from moderately and severely clipped plots in 1948 and 1949 at similar dates in May, June and August, showed a depression of 56, 41 and 40 per cent respectively. Reduction in yields for similar periods on severely clipped plots were 80, 67 and 69 per cent. Marked drought dormancy conditions had occurred by the latter part of July on all treatments and continued until September. Precipitation during September and October provided conditions for fall regrowth, which appeared to be more abundant on the unclipped and moderately treated plots. This regrowth was not included in the final yield summations for 1949.
The effect of clipping at various stages of development upon yields

Possible relationships between the development stage of crested wheatgrass plants at the time of clipping and the total yield at the end of the growing season are shown in Table 4. Plants were clipped to the crown level at the various stages indicated. Average yields from meter-square quadrats at the time of the single clipping treatment during the growing season plus a post season clipping in December were added to give the total average yields for each plot sampled.

Discounting variabilities, it is possible that the decline in average yields from quadrats clipped following the dough stage was due to seed shattering, foliage consuming insects, or breakage and blowing of dried leaves and culms.

Although the data are limited there is some indication of depressing effects in yields due to clipping once during the growing season at stages prior to anthesis. The highest average total yield occurred on plots clipped during the dough stage.

With adequate moisture supplied, all plants produced new basal growth within a week’s time after the earlier clipping treatments. It was noted, however, that those plants which had progressed through seed production stages produced little or no new basal growth
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date and Stage of Development</th>
<th>3-4 Leaf</th>
<th>Shoot</th>
<th>Head</th>
<th>Anthesis</th>
<th>Dough</th>
<th>Ripe</th>
<th>Dormancy</th>
<th>End of Season</th>
<th>Total</th>
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<tr>
<td>Clipped once during 3-4</td>
<td>April 30</td>
<td>21.9</td>
<td>46.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clipped once during shoot</td>
<td>May 10</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clipped once during ripe stage</td>
<td>August 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Clipped once during seed</td>
<td>Sept. 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clipped once during dormancy</td>
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<td>Average cumulative yield</td>
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<td>36.9</td>
<td>60.4</td>
<td>101.8</td>
<td>109.4</td>
<td>104.0</td>
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<td>97.6</td>
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TABLE 4. AVERAGE YIELD OF CRESTED WHEATGRASS CLIPPED ONCE AT A SPECIFIC STAGE OF DEVELOPMENT, AND AT THE END OF THE GROWING SEASON IN 1949

Oven dry weight in grams per meter-square quadrat, and standard error of the averages.
until the cooler temperatures of early September. This failure was one of the factors contributing to the reduced total yield of plants clipped after the dough stage.

Forage Composition

Seasonal trends in the forage composition of unclipped crested wheatgrass

Forage samples from undisturbed crested wheatgrass were taken at various stages of development from plants growing under dry land and irrigation in 1949, and during a season of relatively abundant moisture in 1948.

Fractions determined included reducing and non-reducing sugars, total acid hydrolysable material, alcohol soluble and insoluble nitrogen. Determinations for acid hydrolysable material were not made on samples from irrigated plots. No values for soluble nitrogen were obtained for samples taken in 1949, or for forage produced under irrigated conditions. The hydrolysis treatment of 10 pounds pressure for 30 minutes in 1 plus 20 hydrochloric acid was selected for total acid hydrolysable determinations. Preliminary tests of various degrees of hydrolysis showed a progressive increase in reducing sugar values from the mild to the stronger treatments (Table 5).
TABLE 5. REDUCING SUGAR DETERMINATIONS FROM ONE SAMPLE OF TOP MATERIAL AT FOUR LEVELS OF HYDROLYSIS

Milligrams of reducing sugar recovered per 100 mg. oven dry weight of top material

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<th>Replication</th>
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<th>1+100 HCl, steamed</th>
<th>1+100 HCl, at 10 lbs. pressure</th>
<th>1+20 HCl, steamed</th>
<th>1+20 HCl, at 10 lbs. pressure</th>
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<td>35.56</td>
<td>45.12</td>
<td>47.06</td>
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<td>3</td>
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<td>28.36</td>
<td>36.79</td>
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<td>25.12</td>
<td>34.11</td>
<td>42.79</td>
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</table>
Forage composition determinations for unclipped plants appear in Tables 6 and 7. Trends for various fractions are shown in Figures 6 and 7. During the growing season of 1948, total sugars increased from anthesis to drought dormancy, with December values slightly below the drought dormancy determination. For the stages sampled, reducing sugars increased from the dough stage to December while sucrose showed a decrease during the same period. A more complete series of stages under irrigation indicated a decrease in total sugars during the head stage and during September when regrowth occurred. However, the same general trends were in evidence, with highest total sugar values occurring during the dough and seed ripe stages.

Similar relationships between reducing sugars and sucrose were evident in the two years, with a downward trend in sucrose and an upward trend in reducing sugars following maturity. Under the dry conditions prevailing in 1949, upward trends similar to those of 1948 occurred in total sugars to the dough stage. However, both reducing sugars and sucrose decreased from dough to seed ripe. Following seed ripening a net downward trend in sucrose with an increase in reducing sugars indicated a pattern similar to plants grown under more favorable moisture conditions.

Total acid hydrolyzable material determined from the alcohol extracted residue gave extremely large values, ranging to
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<th>% Protein on Dry Wt.</th>
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<td>Protein</td>
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<td>Dry Matter</td>
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</tr>
<tr>
<td>6.0%</td>
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<td>2.7</td>
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<tr>
<td>4.0%</td>
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<tr>
<td>6.0%</td>
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<td>1.9</td>
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<td>8.0%</td>
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<td>2.0</td>
<td>2.0%</td>
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<td></td>
</tr>
</tbody>
</table>

*Average of 2 composite samples in milligrams per 100 g. Fresh weight.
Figure 6. Seasonal trends in the top composition of unclipped crested wheatgrass in 1949 and 1949. (Acid hydrolysable polymaccharides in 10,000 mg.)
Figure 7. Seasonal trends in the dry composition of crested wheat grass under irrigation.

1000 MILLIGRAMS
32 per cent on a fresh weight basis, during drought dormancy when much dry material was included in the sample. In 1948, a season of relatively abundant moisture, the hydrolyzable fraction for the stages analyzed increased from anthesis to December. During the drier growing season of 1949 a similar upward trend occurred to seed ripe, after which a decline to December was noted.

Stages sampled under irrigated conditions showed a progressive decline in the percentage of protein on the dry weight basis as the season progressed. Protein percentages ranged from 17.3 per cent during the three to four leaf stage, to 3.2 per cent in December. Similar trends for protein occurred in plants growing under all three conditions. Absolute amounts of insoluble nitrogen showed an increase at seed ripe over the anthesis and dough stage determinations. Nitrogen values decreased rapidly following drought dormancy. Soluble nitrogen was highest during the early stages of development, decreasing to a low at the dough stage, and increasing following maturity, indicating the mobilization of this form during the seed formation stage.

Total sugars for both the 3 inch and 1 inch clippings showed a general increase during the growing season (Tables 8 and 9 and Figures 8 and 9). Unclipped plants in both seasons reached a peak in total sugars during the dough stage, while clipped plants
<table>
<thead>
<tr>
<th>Stage and Date Sampled</th>
<th>Red. Sugar</th>
<th>Sucrose</th>
<th>Total Sugar</th>
<th>Total Acid Hydrolyzable</th>
<th>Soluble</th>
<th>Insoluble</th>
<th>Total Nitrogen</th>
<th>% Protein on Dry Weight</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1042</td>
<td>3046</td>
<td>4092</td>
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<tr>
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<td>4620</td>
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<td>51,320</td>
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<td>7.04</td>
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<td>263.8</td>
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<tr>
<td><strong>Anthropus</strong></td>
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<td>6/29/49</td>
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<td></td>
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<td></td>
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<tr>
<td>7/7/49</td>
<td>2000</td>
<td>3250</td>
<td>5250</td>
<td>22,153</td>
<td>164.5</td>
<td>759.3</td>
<td>904.3</td>
<td>10.6</td>
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<td>8/1/49</td>
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<td>4100</td>
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<td>612.1</td>
<td>773.1</td>
<td>5.75</td>
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<td></td>
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</tr>
<tr>
<td>9/23/49</td>
<td>1374</td>
<td>4700</td>
<td>6074</td>
<td>50,150</td>
<td>170.3</td>
<td>744.1</td>
<td>914.4</td>
<td>7.35</td>
</tr>
<tr>
<td><strong>Winter</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/29/49</td>
<td>2500</td>
<td>5000</td>
<td>7500</td>
<td>30,226</td>
<td>182.0</td>
<td>1223.0</td>
<td>1405.0</td>
<td>12.8</td>
</tr>
</tbody>
</table>
The weather was poor for November, December, and January, with abundant rainfall, and December was the only month in which the weather was consistently suitable for the production of the crop. The rainfall was sufficient to ensure a good harvest, and the temperature was moderate, which resulted in a good yield of the crop. The total rainfall for the month was increased during the season and contributed to the good harvest. The total rainfall for the month was increased during the season and contributed to the good harvest.
Figure 10. Comparisons in the seasonal trends of total sugars and total nitrogen in the tops of unclipped, moderate and severely clipped crested wheatgrass in 1948 and 1949.
degree of protein digestion would appear to be dependent upon temperature, rainfall and the protection offered by snow.

Samples from grazed and ungrazed crested wheatgrass plants in adjacent pastures in December, showed top composition comparable to the plots on area A. Ungrazed plants were lower in total sugars and nitrogen than plants which had been grazed moderately.

Crested wheatgrass plots on area B, which received one clipping during the growing season at a specific stage of development, were sampled December 22. The results of determinations for carbohydrate fractions are shown in Table 10. Total carbohydrates were lowest in the three to four leaf and shoot stages. Plants clipped in September also contained a small amount of total carbohydrates. Highest values occurred for plants clipped during seed ripe, and for unclipped plants. There appears to be some agreement between the total carbohydrates for three to four leaf plants and their reduced root reserves and total yield.

Root Development in Relation to Clipping Intensities

Samples of crested wheatgrass roots were taken from all plots on area A in July of 1948 and 1949. A 2 inch soil tube was used to obtain samples containing approximately 18.84 cubic inches of soil and roots from each 6-inch depth interval to a total depth of 24 inches. Two sample locations on each of six replicated plots
<table>
<thead>
<tr>
<th>Species</th>
<th>Stage</th>
<th>Treatment</th>
<th>Repetition</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Norw.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**100 lb. of Furon per acre**

Average weight of two consecutive samples in milligrams per acre.
not appear to a marked extent

depth under the treatment observed by several workers, which
the tendency for a greater decrease in root weight when
moderate to high nitrogen for the untopped plants. However,
dercrease of roots at the 16 to 24 inch layer for the several
in 1944 there was some evidence of a greater percentage

14.6 and 22.6 per cent respectively

moderate and severe "A" type root disorders of
per cent over the previous year. Similar conditions between
average root weights of untopped plants in 1943 and 1945.
Under these conditions the "A" type predicted during 1946.

These are measures of dead roots making up the total

showed a marked increase in the untopped plants over the 2 hours at monotony. Apparently the same amounts of the
are all root yields from the untopped plants as the same amounts of the
rattled off the plant. These were 100 per cent in 1946 or 1943 or the 24 inch layer or pools

results of this study are shown in Table II and Figure II.

Only

Gardens and this procedure in root samples with deep decay conductors. He
random samples were taken and between bunch names at two places.

Gardens. Because of the small diameters of the green decay
Gave a total of three samples at each depth interval for each
TABLE 11. AVERAGE WEIGHT OF ROOTS IN 1948 AND 1949 FROM SIX INCH DEPTH INTERVALS TAKEN FROM CRESTED WHEATGRASS PLOTS SUBJECTED TO THREE INTENSITIES OF CLIPPING

Oven dry weight in milligrams per soil tube core 2 inches in diameter and 6 inches long (18.84 cubic inches) and standard error of the averages

<table>
<thead>
<tr>
<th>Depth Interval in Inches</th>
<th>Plants clipped to 1 inch</th>
<th>Plants clipped to 3 inches</th>
<th>Unclipped plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave.</td>
<td>%</td>
<td>Ave.</td>
</tr>
<tr>
<td>0-6</td>
<td>447</td>
<td>52</td>
<td>546</td>
</tr>
<tr>
<td></td>
<td>±50</td>
<td>±66</td>
<td>±60</td>
</tr>
<tr>
<td>6-12</td>
<td>223</td>
<td>25</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>±45</td>
<td>±15</td>
<td>±18</td>
</tr>
<tr>
<td>12-18</td>
<td>170</td>
<td>19</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>±50</td>
<td>±8</td>
<td>±33</td>
</tr>
<tr>
<td>18-24</td>
<td>40</td>
<td>4</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>±11</td>
<td>±17</td>
<td>±13</td>
</tr>
<tr>
<td>Total</td>
<td>880</td>
<td>100</td>
<td>617</td>
</tr>
</tbody>
</table>

*Percent of total roots.
Figure 11. Average weight of roots for 6-inch depth intervals on crested wheatgrass plots subjected to three intensities of clipping in 1949 and 1960.
Root samples taken in 1949 show a reversed tendency. A smaller percentage of total root weights occurred at lower levels for the unclipped plants than for plants clipped during the growing season. This tendency was accentuated by the large increase in roots of the unclipped plants at the 0-6 inch zones in 1949. Moisture supply at the various soil levels may explain these differences. Soil moisture data taken at the time of sampling (Table 12 and Figure 12) showed a somewhat greater moisture percentage at deeper soil levels under the severely clipped plants. This soil moisture condition may have made it possible for roots of closely clipped plants which were at deeper levels to compete successfully with roots nearer the surface, regardless of the relative distance from the carbohydrate source.

Root Reserves

Seasonal trends in root reserves of unclipped plants

Root samples from unclipped plots of crested wheatgrass were taken at various stages of development in 1948 and 1949 to determine the seasonal trends of the various reserve fractions. Reserves were examined under three growing conditions. On area A the growing seasons of 1948 and 1949 gave a comparison of relatively wet and dry years. Root samples from unclipped plants on area B gave results for plants grown under irrigation. For
TABLE 12. AVERAGE SOIL MOISTURE DETERMINATIONS TAKEN JULY 26, 1946
ON CRESTED WHEATGRASS PLOTS RECEIVING 3 LEVELS OF CLIPPING

Average of 2 samples from each depth
from each of 2 replicated plots

<table>
<thead>
<tr>
<th>Replicate</th>
<th>Plot Number</th>
<th>No. of Samples</th>
<th>Depth Intervals in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipped to</td>
<td>11</td>
<td>2</td>
<td>0-6 12-18 24-30 30-36</td>
</tr>
<tr>
<td>1st bi-weekly</td>
<td>16</td>
<td>2</td>
<td>10.00 11.42 14.77 17.30 21.59 22.14</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>19.44 24.89 28.95 33.35 45.29 45.14</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>8.22 12.44 14.47 16.67 21.64 21.57</td>
</tr>
</tbody>
</table>

| Clipped to | 5            | 2              | 0-6 12-18 24-30 30-36     |
| 3rd monthly | 10           | 2              | 7.25 13.13 14.13 15.09 16.46 19.05 |
| Total      |              |                | 14.26 25.06 27.18 28.30 31.46 37.71 |
| Average    |              |                | 7.13 14.54 13.59 14.16 15.73 15.85 |

| Unclipped  | 4            | 2              | 0-6 12-18 24-30 30-36     |
| Total      |              |                | 18.90 25.76 27.44 28.56 31.23 39.85 |
| Average    |              |                | 9.45 12.88 13.72 14.18 15.61 19.77 |
Figure 12. Soil moisture determinations for 6 inch depth intervals taken July 26, 1949 on crested wheatgrass plots subjected to three intensities of clipping.
unirrigated and unclipped plants, total sugars in general showed an increase from spring to fall with temporary decreases during the dough stage (Tables 13 and 14 and Figures 13 and 14). In 1948 total sugars dropped from 449 mg. at anthesis to 332 mg. during the dough stage, and increased to 596 mg. at drought dormancy. In the following year total sugars dropped from 542 mg. at anthesis to 400 mg. at the dough stage, with 304 mg. determined at drought dormancy. Another period of depression occurred during fall regrowth in 1949. Samples were not taken at this period in the previous year. Total sugars for unclipped, irrigated plants showed a general increase to anthesis, then a consistent downward trend to the end of the growing season. Highest total sugars were obtained from December samples.

Reducing sugars and sucrose followed approximately similar trends, with the exception of the period between November and December, when a decrease in sucrose and an increase in reducing sugars were observed (Figures 13 and 14). The relation of sucrose to reducing sugars reflects periods of growth activity. In unirrigated plants, sucrose was consistently higher following maturity and during limited moisture conditions. Reducing sugars were relatively higher during periods of active growth, which occurred on plants clipped prior to the dough stage in both years. In 1949 sucrose dropped below the reducing sugar level during fall regrowth.
<table>
<thead>
<tr>
<th>Date of Sampling</th>
<th>Aver. % Dry Wt.</th>
<th>Sugars</th>
<th>Polysaccharides</th>
<th>Acid</th>
<th>Total Soluble Insoluble</th>
<th>Total</th>
<th>Insoluble Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6/26/49</td>
<td>31.56</td>
<td>260</td>
<td>169</td>
<td>449</td>
<td>2224</td>
<td>8,810</td>
<td>12,039 316</td>
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<tr>
<td>Dough</td>
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</tr>
<tr>
<td>7/14/49</td>
<td>34.90</td>
<td>219</td>
<td>163</td>
<td>352</td>
<td>713</td>
<td>8,216</td>
<td>8,932 26.5</td>
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<td>261</td>
<td>296</td>
<td>596</td>
<td>1667</td>
<td>9,880</td>
<td>11,547 17.17</td>
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<td>480</td>
<td>360</td>
<td>362</td>
<td>5,589</td>
<td>8,746 28.4</td>
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<td>542</td>
<td>1281</td>
<td>10,281</td>
<td>11,562 -</td>
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<td>178</td>
<td>400</td>
<td>848</td>
<td>4,192</td>
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<td>529</td>
<td>904</td>
<td>1001</td>
<td>8,220</td>
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<td>1359</td>
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<td>14,308</td>
<td>15,412 39</td>
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<td>10/17/49</td>
<td>51.1</td>
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<td>365</td>
<td>775</td>
<td>578</td>
<td>14,866</td>
<td>15,244 34.4</td>
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<td></td>
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<tr>
<td>11/20/49</td>
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<td>385</td>
<td>1497</td>
<td>1372</td>
<td>984</td>
<td>14,453</td>
<td>15,438 29.6</td>
</tr>
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<td></td>
<td></td>
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</tr>
<tr>
<td>12/29/49</td>
<td>39.1</td>
<td>635</td>
<td>870</td>
<td>1405</td>
<td>425</td>
<td>14,117</td>
<td>14,543 34.9</td>
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</table>
TABLE 14. SEASONAL TRENDS IN ROOT COMPOSITION OF UNGRAZED CRESTED WHEATGRASS UNDER IRRIGATION DURING THE GROWING SEASON IN 1949

Averages of two composite sample determinations in milligrams per 100 grams of green weight

<table>
<thead>
<tr>
<th>Date of Sampling</th>
<th>Dry Wt.</th>
<th>Reducing Sugars</th>
<th>Sucrose</th>
<th>Total Soluble</th>
<th>Hydrolysable</th>
<th>Total Soluble</th>
<th>Insoluble</th>
<th>Total</th>
<th>Carbohydrates</th>
<th>Polysaccharides</th>
<th>Acid</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-6 leaf</td>
<td>26.78</td>
<td>325</td>
<td>264</td>
<td>639</td>
<td>436</td>
<td>8,760</td>
<td>10,184</td>
<td>15.9</td>
<td>294</td>
<td>309.8</td>
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<td></td>
</tr>
<tr>
<td>5/2/49</td>
<td>325</td>
<td>264</td>
<td>639</td>
<td>436</td>
<td>8,760</td>
<td>10,184</td>
<td>15.9</td>
<td>294</td>
<td>309.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoot</td>
<td>22.30</td>
<td>299</td>
<td>751</td>
<td>413</td>
<td>9,294</td>
<td>8,666</td>
<td>26.4</td>
<td>159</td>
<td>185.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/19/49</td>
<td>47.8</td>
<td>467</td>
<td>977</td>
<td>1800</td>
<td>12,597</td>
<td>14,097</td>
<td>35.6</td>
<td>254</td>
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<td>495</td>
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<td>678</td>
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<td>323</td>
<td>748</td>
<td>569</td>
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<td>425</td>
<td>323</td>
<td>748</td>
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<td>10,573</td>
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<td>255</td>
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<tr>
<td>Drought</td>
<td>39.1</td>
<td>363</td>
<td>246</td>
<td>600</td>
<td>415</td>
<td>13,986</td>
<td>13,948</td>
<td>54</td>
<td>284</td>
<td>333</td>
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<tr>
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<td>363</td>
<td>246</td>
<td>600</td>
<td>415</td>
<td>13,986</td>
<td>13,948</td>
<td>54</td>
<td>284</td>
<td>333</td>
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<tr>
<td>December</td>
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<td>515</td>
<td>1097</td>
<td>1602</td>
<td>439</td>
<td>11,641</td>
<td>11,728</td>
<td>25.4</td>
<td>240</td>
<td>265.9</td>
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</table>
Figure 13. Seasonal trends in the root composition of unclipped crested wheatgrass in 1945 and 1946. (Acid hydrolyzable polysaccharides in 1,000 mg.)
Figure 14. Seasonal trends in the root composition of unlimed crested wheatgrass grown under irrigation. (Acid hydrolyzable polysaccharides in 1,000 mg.)
Under irrigated conditions, reducing sugars were generally higher throughout the season. Although little regrowth occurred on mature, irrigated plants until cooler temperatures in September, sucrose remained low, suggesting little conversion to this storage form. Increased root growth during this period may have occurred. From the above observation, it appeared that sucrose was one of the first reserves stored and utilized.

Water soluble polysaccharides showed seasonal trends which were similar to the sugars (Tables 13 and 14 and Figures 13 and 14). An exception, however, occurred between drought dormancy and December on unsprayed plots. While sugars showed a net increase, a marked decrease was noted for this fraction. Water soluble polysaccharides determined by mild hydrolysis appeared to be an important part of the root reserves of crested wheatgrass. The high peak for this carbohydrate at drought dormancy in 1948 was 1,567 mg. and 1,304 mg. in 1949, while sucrose values for similar periods were 226 and 1,033 mg., respectively. Although trends are similar for the two years, water soluble polysaccharides fluctuated more widely in 1948 than in 1949, being higher at anthesis and lower at the dough and winter stages during the first year of sampling. Under irrigation the greatest amounts of water soluble polysaccharides were found at the head stage. A relatively high level was also shown at anthesis, with a gradual decline paralleling the sugars as the season progressed.
In 1944, there was a decrease in the number of cases. However, there was an increase in the number of deaths. This decrease in cases was most likely due to a decrease in the spread of the disease. It is also possible that there was an increase in the treatment and diagnosis of the disease, leading to a decrease in the number of fatalities. The overall trend was a decrease in the spread of the disease.
stages. Insoluble nitrogen comprised the bulk of the total nitrogen values. In general, both fractions followed similar trends during the season with the exception of the winter sampling when soluble nitrogen increased while insoluble decreased.

**The effect of clipping upon seasonal trends in root reserves**

Roots from plants clipped to 3 inches at monthly intervals, and to 1 inch bi-weekly were sampled in 1948 and 1949 at dates corresponding to the various stages of development in unclipped plants.

For plants receiving the moderate clipping treatment, total sugars followed the trend noted in unclipped plants with a general increase in total sugars from anthesis to the end of the growing season (Table 16 and Figures 13 and 15). Reducing sugars ranged higher than sucrose at all times with the exception of the November and December samples. Highest values for sugars were at the end of the growing season. In 1949, lowest points for both reducing and non-reducing sugars occurred during fall regrowth in October. Total sugars at the end of the growing season in 1949 were higher than at any other sampling date during the two seasons. Total sugars for the 3 inch clipping were not greatly different from those of adjacent unclipped plots, however, the characteristic depression during the dough stage did not occur in clipped plants not forming heads (Figure 17).
### TABLE 15. SEASONAL TRENDS IN THE ROOT COMPOSITION OF CRESTED WHEATGRASS CLIPPED TO 3 INCHES AT MONTHLY INTERVALS DURING THE GROWING SEASONS OF 1948 AND 1949

Averages of two composite sample determinations in milligrams per 100 grams of green weight

<table>
<thead>
<tr>
<th>Date of Sampling</th>
<th>Carbohydrates</th>
<th></th>
<th>Polysaccharides</th>
<th></th>
<th>Acid</th>
<th></th>
<th>Nitrogen</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Reducing Sugars</td>
<td>Sucrose Total</td>
<td>Soluble Hydrolyzable Total</td>
<td>Soluble Insoluble Total</td>
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<tr>
<td></td>
<td>Ave. % Dry Wt.</td>
<td>Sugars</td>
<td></td>
<td></td>
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<tr>
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</tr>
<tr>
<td>6/25/48</td>
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<td>194</td>
<td>127</td>
<td>321</td>
<td>915</td>
<td>8,729</td>
<td>9,044</td>
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</tr>
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<td></td>
</tr>
<tr>
<td>6/26/49</td>
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<td>204</td>
<td>458</td>
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<td>7,543</td>
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</tr>
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<td><strong>Dough</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>7/7/49</td>
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<td>922</td>
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<td>17,915</td>
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<td>12/29/49</td>
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<td>381</td>
<td>12,057</td>
<td>13,458</td>
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</table>
Figure 15. Seasonal trends in the root composition of crested wheatgrass clipped to 3 inches at monthly intervals during the growing season of 1948 and 1949. (Acid hydrolyzable polysaccharides in 1,000 mg.)
Under the severe clipping treatment, total sugars followed a somewhat different trend (Table 16 and Figure 16). In 1948 sugars were lowest at drought dormancy, showing a small increase in December. A surprising increase in total sugars following fall regrowth in 1949 resulted in November and December values for sugars which were higher than at any previous sampling date in the two years of treatment. Reducing sugars remained lower than sucrose at all dates sampled except at the end of the growing season in 1949. It appeared that fall regrowth in October provided a surprising amount of efficient photosynthetic area, indicating the remarkable ability of this bunch grass to recover after two seasons of severe clipping.

High peaks for water soluble polysaccharides occurred during anthesis, drought dormancy and in November for plants clipped to 3 inches. Decreases occurred in July in both years, possibly reflecting the effect of clipping prior to the date of sampling. Water soluble polysaccharides appeared to increase during dry periods and to decrease during active growth and at the end of the growing season.

Acid hydrolyzable materials were highest during the dough stage in 1948 for both clipping treatments. Highest values for 1949 occurred during October and November for moderately
<table>
<thead>
<tr>
<th>Month</th>
<th>December</th>
<th>November</th>
<th>October</th>
<th>September</th>
<th>August</th>
<th>July</th>
<th>June</th>
<th>May</th>
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<th>March</th>
<th>February</th>
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<td>47^b</td>
<td>42^c</td>
<td>49^d</td>
<td>57.2^e</td>
<td>59.5^f</td>
<td>58.6^g</td>
<td>58.6^h</td>
<td>58.6^i</td>
<td>59.4^j</td>
<td>58.6^k</td>
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<td>281.4^l</td>
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<td>24.0</td>
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</table>

Table 16. Seasonal trends in the root composition of certain wheatgrass cultivars.
Figure 16. Seasonal trends in the root composition of crested wheatgrass clipped to 1 inch at two-week intervals during the growing seasons of 1948 and 1949.
(Acid hydrolyzable polysaccharides in 1,000 mg.)
Figure 17. Comparisons in the seasonal trends of total sugars in the roots of unclipped, moderate and severely clipped crested wheatgrass in 1948 and 1949.
clipped plants, and during drought dormancy for plants clipped to 1 inch. The sudden decrease in acid hydrolysable material in roots of plants clipped to 1 inch suggests utilization of this material during fall regrowth. A similar decrease did not occur during fall regrowth for unclipped plants or plants receiving the 3 inch treatment. Again the wide range of water insoluble polysaccharides included within the fraction hydrolyzed may be an explanation for these differences.

Total nitrogen for plants clipped to 3 inches and to 1 inch showed a progressive increase from anthesis to the end of the growing season. A general decrease in insoluble nitrogen with an increase of soluble nitrogen was noted in December samples. The downward trend in nitrogen at the dough stage in unclipped plants was not marked in clipped plants. Total nitrogen for comparable stages was higher in 1948 and 1949, probably reflecting more favorable moisture conditions during the first year. Plants receiving the severe treatment showed no indication of limited synthesis of insoluble nitrogen because of insufficient carbohydrate levels.

A comparison of total nitrogen in the roots of plants receiving the three clipping treatments is shown in Figure 18. Highest total nitrogen percentages in 1949 occurred in the roots of
plants clipped to 1 inch. Next highest values were determined in plants clipped to 3 inches, while unclipped plants contained the least amount. More favorable moisture, as a result of reduced transpiration from closely clipped plots, together with more nitrogen being available for the fewer and smaller remaining plants on clipped plots, may explain these results.

The effect of one clipping at a specific stage of development upon root reserves

Table 17 contains the results of root reserve determinations taken in December from plants clipped only once during the growing season at a specific stage of development. The limited sampling and the short duration of the experiment did not yield conclusive results. However, there was an indication of lower total carbohydrates in plants clipped at the three to four leaf and shoot stages. Results of both forage yield and composition determinations showed similar evidence. Clipping during the spring season when favorable temperatures and moisture conditions for the cool season grass prevail would be expected to depress the carbohydrate synthesis to a greater extent than later clipping performed under less favorable growing conditions. The short time interval between the fall regrowth clipping and the December sampling may account for the lower carbohydrate level for plants receiving this treatment.
TABLE 17. ROOT COMPOSITION OF CRESTED WHEATGRASS PLANTS CLIPPED ONCE DURING THE GROWING SEASON, SAMPLED DECEMBER 29, 1949

Averages of two composite sample determinations in milligrams per 100 grams of green weight

<table>
<thead>
<tr>
<th>Stage of Clipping Treatment</th>
<th>Reducing Sugars</th>
<th>Sucrose</th>
<th>Total</th>
<th>Soluble</th>
<th>Insoluble</th>
<th>Total</th>
<th>Soluble</th>
<th>Insoluble</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-4 leaf</td>
<td>69.5</td>
<td>831</td>
<td>911</td>
<td>558</td>
<td>10,550</td>
<td>11,138</td>
<td>28.9</td>
<td>231.9</td>
<td>260.5</td>
</tr>
<tr>
<td>Shoot</td>
<td>64</td>
<td>779</td>
<td>843</td>
<td>523</td>
<td>3,696</td>
<td>4,219</td>
<td>32.9</td>
<td>219.5</td>
<td>282.4</td>
</tr>
<tr>
<td>Head</td>
<td>63</td>
<td>940</td>
<td>1003</td>
<td>483</td>
<td>12,467</td>
<td>12,940</td>
<td>31.0</td>
<td>254.2</td>
<td>265.2</td>
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<tr>
<td>Anthesis</td>
<td>61.6</td>
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<td>1094</td>
<td>486</td>
<td>11,392</td>
<td>12,480</td>
<td>28.0</td>
<td>256.7</td>
<td>264.7</td>
</tr>
<tr>
<td>Dough</td>
<td>63.5</td>
<td>828.5</td>
<td>891</td>
<td>560</td>
<td>11,908</td>
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<td>23.5</td>
<td>202.9</td>
<td>225.4</td>
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<td>592</td>
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<td>814</td>
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<td>15,852</td>
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<td>290.3</td>
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<td>1269</td>
<td>11,641</td>
<td>12,309</td>
<td>25.4</td>
<td>240.9</td>
<td>266.3</td>
</tr>
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</table>
Depletion of root reserves in etiolated plants

The results of exhaustion studies are shown in Tables 18 and 19. Plants on three replicated plots for each treatment were covered with light-tight, ventilated boxes. Samples for root composition were taken at the time of covering and subsequent samples were taken following etiolation periods. In 1949, plants were covered on July 14, and uncovered and analyzed approximately six weeks later on September 3. The etiolated plants were still growing at the end of this treatment, indicating that the reserves were not exhausted. Determinations were made of the various carbohydrate and nitrogen fractions at the beginning and end of the etiolation period.

The greatest percentage decrease for sugars was with sucrose, which dropped 69 per cent for plants clipped to 1 inch, from 135 mg. at the time of covering to 62 mg. at the end of the treatment. Total sugars decreased by 15.6, 55.7 and 51.1 per cent for the unclipped, 3 inch and 1 inch clippings respectively (Table 18). Greatest decreases in polysaccharides were in the water soluble fraction and amounted to 64.3 per cent for covered plants which had previously received the 1 inch clipping treatment.

A downward trend also appeared in acid hydrolysable material, except in unclipped plants. It is possible that the
TABLE 16. ROOT COMPOSITION OF CRESTED WHEATGRASS ON JULY 14
AND SEPTEMBER 3, 1948—THE BEGINNING AND END OF
AN ETIOLATION TREATMENT

Averages of two composite sample determinations
in milligrams per 100 grams of green weight

<table>
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<tr>
<th>Fraction</th>
<th>Plants clipped to 3 in. at monthly intervals prior to covering</th>
<th>Plants clipped to 1 in. bi-weekly prior to covering</th>
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<tr>
<td></td>
<td>Plants unclipped prior to covering</td>
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</tr>
<tr>
<td>Reducing sugars</td>
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<td></td>
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<tr>
<td>beginning</td>
<td>219</td>
<td>393</td>
</tr>
<tr>
<td>end</td>
<td>220</td>
<td>159</td>
</tr>
<tr>
<td>% decrease</td>
<td>-</td>
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<td>Sucrose</td>
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<td></td>
</tr>
<tr>
<td>beginning</td>
<td>163</td>
<td>123</td>
</tr>
<tr>
<td>end</td>
<td>110</td>
<td>65</td>
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<tr>
<td>% decrease</td>
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<tr>
<td>beginning</td>
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<td>506</td>
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<tr>
<td>end</td>
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<td>% decrease</td>
<td>15.6</td>
<td>55.7</td>
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<tr>
<td>Soluble Polysaccharides</td>
<td></td>
<td></td>
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<tr>
<td>beginning</td>
<td>713</td>
<td>497</td>
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<tr>
<td>end</td>
<td>546</td>
<td>366</td>
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<tr>
<td>% decrease</td>
<td>23.4</td>
<td>28.3</td>
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<tr>
<td>Acid Hydrolyzable Polysaccharides</td>
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<tr>
<td>beginning</td>
<td>8,216</td>
<td>10,360</td>
</tr>
<tr>
<td>end</td>
<td>10,411</td>
<td>8,571</td>
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<tr>
<td>% difference</td>
<td>+26.7</td>
<td>-17.2</td>
</tr>
<tr>
<td>Total Polysaccharides</td>
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<td></td>
</tr>
<tr>
<td>beginning</td>
<td>9,229</td>
<td>10,857</td>
</tr>
<tr>
<td>end</td>
<td>10,957</td>
<td>9,937</td>
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<tr>
<td>% difference</td>
<td>+22.7</td>
<td>-17.6</td>
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<tr>
<td>Soluble nitrogen</td>
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</tr>
<tr>
<td>beginning</td>
<td>17.1</td>
<td>22.2</td>
</tr>
<tr>
<td>end</td>
<td>17.2</td>
<td>13.1</td>
</tr>
<tr>
<td>% decrease</td>
<td>-</td>
<td>40.5</td>
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<tr>
<td>Insoluble nitrogen</td>
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</tr>
<tr>
<td>beginning</td>
<td>265</td>
<td>292</td>
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<tr>
<td>end</td>
<td>164</td>
<td>162</td>
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<tr>
<td>% decrease</td>
<td>45.6</td>
<td>47.9</td>
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<tr>
<td>Total nitrogen</td>
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<tr>
<td>beginning</td>
<td>300.1</td>
<td>314.1</td>
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<tr>
<td>end</td>
<td>171.2</td>
<td>175.5</td>
</tr>
<tr>
<td>% decrease</td>
<td>42.9</td>
<td>45.2</td>
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<tr>
<td>Temp (°F)</td>
<td>Hydrometer</td>
<td>Refractometer</td>
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<tr>
<td>----------</td>
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<tr>
<td>11.9°F</td>
<td>10.9°F</td>
<td>11.9°F</td>
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<td>10.9°F</td>
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<td>11.9°F</td>
<td>10.9°F</td>
<td>11.9°F</td>
</tr>
</tbody>
</table>

Note: The table above shows the temperature readings from a hydrometer and refractometer. The temperature readings are consistent across all measurements, indicating stable conditions.

**Calculations**

- **Total Sugar:**
  - 1.0% 11.9°F 16.6°B
  - 1.0% 11.9°F 16.6°B
  - 1.0% 11.9°F 16.6°B
  - 1.0% 11.9°F 16.6°B
  - 1.0% 11.9°F 16.6°B
  - 1.0% 11.9°F 16.6°B

**Sugar Extracted**

- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B

**Proportion to Cooper's Standard**

- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B

**Preliminary Tannin Test**

- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B

**Treatment**

- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B

**Detoxifications:**

- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B
- 1.0% 11.9°F 16.6°B

**Footnotes:**

- **September 6**, and December 6, 1949.
- **End of Experiment on August 6, 1949.**
- **On dates of cooperation, June 26, 1949, and Aug. 6, 1949, the**
- **Tannin 1% root composition of Cretaceo-Wheatgrass sampled**
fractions measured under the strong hydrolysis were different to begin with, and that they were more available and less complex under the 3 inch and 1 inch treatments.

Both soluble and insoluble nitrogen decreased, with the greatest decrease in the insoluble nitrogen. Soluble nitrogen remained unchanged for the unclipped treatment, but decreased by 45.58 per cent in clipped plants. It appeared that both soluble and insoluble nitrogen were either lost or utilized under the partial exhaustion treatment, and as has been generally recognized, should be included under root reserves.

Data for similar exhaustion studies in 1949 are shown in Table 19. Plants were covered June 28, three weeks earlier than the previous year. This period corresponded with the anthesis stage of unclipped plants. To determine reserve trends during exhaustion, analyses were made of roots beneath one box from each treatment at each of three dates; August 5, September 6, and December 29. Determinations for the various fractions at the beginning, and subsequent determinations at three dates are shown in Table 19. Since sample boxes were only 1 foot square, and only one replicate was analyzed for each date, considerable variability occurred. The trends would have been more reliable had larger boxes been used, with samples taken from a greater number of plants.
Hydroxydeacetic material decreased with increases in temperature. The decrease was the result of a conversion of the material to an artifact consisting of deodorant and reduced sugar content. Posteriorly, higher reduced sugar values in the stool samples showed the most uniform and consistent results.

September 1, December 1, and the 1st of each month were the most uniform.

Posteriorly, the highest sugar content showed an increase from the 1st to the 15th of each month, with a decrease in the 16th to the 31st. The decrease in total sugar by December was 64.75 and...
DISCUSSION

A major objective of range and pasture management is the greatest sustained yield of high nutrient forage. To attain this objective requires, first, a fundamental knowledge of the growth characteristics of plants allowed to develop undisturbed, and, secondly, an understanding of the effects of grazing at various seasons and intensities upon total yield, forage composition and plant vigor. Barring economic factors which often require compromises to meet livestock programs, correct management is dependent upon information pertinent to the individual forage plant.

This study attempted to investigate the responses of crested wheatgrass to clipping treatments from the standpoint of: (a) total yield and composition of forage, (b) the maintenance of plant vigor as indicated by stand density, root development and root reserves.

Two intensities of clipping, simulating moderate and severe grazing, were used during two consecutive growing seasons. Yields from these treatments were compared with those of the unclipped plants. Compared to undisturbed plants, moderate clipping reduced total yields at the end of the second growing season by 50 per cent and severe clipping by 75 per cent. The growth habit of this bunch grass does not permit it to withstand the close
clipping treatment tolerated in plants capable of a more prostrate growth. Severely clipped plants at the end of the second growing season were reduced markedly in density, to the extent that moisture and erosion problems would soon aggravate the condition. Stand density was maintained under the moderate clipping treatment. Where moisture was not limited, there was some indication that clipping during the shoot stage depressed total yields to the greatest extent. However, protein content and palatability were high at these stages. Higher total yields were obtained from plants clipped at maturity, but reduced palatability offset the yield advantage.

Results show that both protein and sugar contents increased until later in the season in clipped plants, indicating that a grazing system which prevents a large part of the plants from forming heads improves forage composition. High protein in closely clipped plants probably reflects more than the purely physiological reaction of herbage removal upon the plant. Even though total yields were markedly reduced during the second year period, moisture, and possibly nitrogen supply were temporarily greater on closely clipped plots as shown by the greater growth of unclipped plants adjacent to the more severe treatment.

Studies should concentrate upon the spring grazing treatment systems because this grass is most valuable during spring
growth. Fall regrowth does not appear too dependable in this area, and summer grazing is limited through the drought dormancy reactions. The remarkable ability of the plant to regenerate depleted reserves during fall regrowth if moisture is available, suggests that fall defoliation may have a place in stimulating depleted stands.

The relative depth of root penetration and resultant ability to obtain moisture from lower soil levels has been reported as an important factor in the drought resistance of forage grasses. However, deeper subsoil moisture availability under the seasonal rainfall patterns characteristic of the great plains may not be as important a factor as the relative abundance of root reserves.

The weak growth of the closely clipped plants during the early spring months of the second year indicates the importance of an abundant reserve for rapid growth during the cool spring season when crested wheatgrass is most valuable.

Root and top relationships for unclipped plants followed a trend described by previous workers. Root reserves were depleted during the early stages of top growth and were lowest at the dough stage of development. Sampling did not cover the early spring period completely enough to permit conclusions for trends during this period. Carbohydrates were highest in the tops at dough
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The acid hydrolysis used in the analysis gave no indication of what polysaccharide fraction was accumulated or depleted. Total acid hydrolysable materials appeared to fluctuate less in unclipped than in clipped plants, suggesting a more complex and immobile form. A more specific fractionation would have been desirable.

Rapid carbohydrate accumulation from a relatively small amount of leaf area in the fall suggested that photoperiod effects may be present in growth relationships. Since this plant is being used to reseed depleted mountain ranges in western states as far south as New Mexico, and also since flower primordia initiation is an important factor in stand improvement and seed production, studies of photoperiod responses would be valuable.
Summary

- November sugar accumulation resulted from irrigation and
  chemical treatment and in January the base of the soil was
  not deep enough to support photosynthesis in sweet potato
  plants.

- sweet and deepened seed water by
  liming applied in the first week of April.
  those sweet and water soluble photosynthesis in the tops of
  the crop.

- Growth and development of the corn during the most
  favorable period of photosynthesis were
  limited by the soil requirements.

- During the growth of the sweet potato the tops were
  limited to four feet and four leaves from the ground up.

- Irrigated plots of the sweet potato were
  produced per cent as much as untreated plots.

- Stunt growth during the same period produced only
  60 per cent lower than the untreated plants. *Plantae
  morfeo to 1 in 100.

- Results indicate the need for an irrigation in the second year when more 50 per
  5 months at the end of the second year gives better
  results under dry-land conditions. Aceeved photosynthesis plants of the
  sweet potato.
5. Clipped plants were higher in protein than unclipped plants at all stages following anthesis. Plants clipped to 1 inch were higher in protein than plants clipped to 3 inches. Factors other than relative physiological maturity are indicated. Reduced crown density and growth resulted in more available moisture and probably more available soil nitrogen on the closely clipped plots.

6. In July of the second year of clipping, root yields of crested wheatgrass plots clipped to 3 inches were 47 per cent as much as the root yields from unclipped plots, while plants clipped to 1 inch were reduced to 28 per cent as compared to the unclipped plants.

7. Root yield data from plants clipped to various intensities do not indicate a greater reduction at lower levels for closely clipped plants. Data indicate that root growth and survival may depend more upon the location of available soil moisture than upon relative distance of roots from the carbohydrate source.

8. Under dry-land conditions, total sugars in the roots of unclipped plants for stages sampled were lowest during the dough stage and highest following maturity.
9. Data indicated that root reserves were depleted during periods of active vegetative growth, while reserves were accumulated under growing conditions which checked top development most.

10. Reducing sugars increased during active growth and during the dormant winter season, indicating the mobility of this form. Sucrose appeared to be the first form of storage and utilization, followed by water soluble polysaccharides which were more abundant than either of the sugars.

11. Total nitrogen was higher in crested wheatgrass roots during the early spring and post growing seasons. Probably the more abundant moisture conditions and more available carbohydrates during these periods resulted in more root development.

12. Root analysis of etiolated plants indicated that sugars, water soluble polysaccharides, nitrogen, and part of the acid hydrolyzable polysaccharides were utilizable root reserves.

13. The ability of crested wheatgrass to accumulate reserves rapidly during the fall regrowth period of the second year of severe clipping, suggests possible photoperiod responses, and demonstrates the resistance of this species to heavy grazing.
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