The effect of previous cutting on apparent carbohydrate storage and spring growth of perennial grasses with a comparison of methods of determining apparent carbohydrate storage
by Clee S Cooper

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
This study was made to try to devise a simple indirect method whereby the reserves of plants and their effect on subsequent growth could be measured.

Root samples were taken with a soil tube from three varieties of each of three species of grass. These plots had previously been exposed to three different cutting treatments; (1) cut for seed, (2) cut for hay, (3) cut to simulate pasture. In May of the season preceding this study, one-half of each plot was fertilized at the rate of 500 pounds of NH4SO4/acre. Core samples of bromegrass varieties were taken from both fertilized and unfertilised plots.

Samples taken were subjected to the following methods of treatment to determine the apparent carbohydrate storage; (l) Gores washed, placed in nutrient-free sand in paper containers and grown in greenhouse.

(2) Cores washed, placed in nutrient-free sand in paper containers and grown in darkroom.

(3) Cores placed in river sand in clay pots and grown in greenhouse.

(4) Cores placed in river sand in clay pots and grown in darkroom.

Top growth made by the cores under the above methods of treatment was clipped, oven dried, and the yields expressed as grams of dry matter.

On plots from which core samples had been removed, spring clippings were taken, oven dried, and the yields expressed in pounds per acre.

The results of this study exhibited considerable variability.

Yield averages of cores from the seed treatment plots were higher than yield averages of cores from other cutting treatment plots.

A different factor was being measured by spring clippings than that which was being measured by methods.

Nitrogenous fertilisation apparently had little effect on the response of bromegrass varieties to previous cutting treatments.

THE EFFECT OF PREVIOUS CUTTING ON APPARENT CARBOHYDRATE STORAGE AND SPRING GROWTH OF PERENNIAL GRASSES WITH A COMPARISON OF METHODS OF DETERMINING APPARENT CARBOHYDRATE STORAGE

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ABSTRACT

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INTRODUCTION

A number of studies have been conducted on the effect of cutting treatments in relation to the storage of food reserves and the subsequent growth of grasses. As a result of these studies we now know there are differences between species and varieties of a species in their response to previous cutting treatments.

The ability of a plant to store reserves has many interesting aspects and offers possibilities for practical application to the field of agronomy. If differences between species and differences between varieties are found to be significant, it might be possible to select those with higher storage coefficients, under like conditions, for breeding purposes, in that these plants should have higher resistance to disease and other plant enemies.

If we can know the storage abilities of different grasses and their subsequent growth recovery, we may be able to rotate pasturing so as to allow for maximum storage by the plant in order to keep it in a highly competitive and vigorous condition. Thus we would have a valuable aid in rotation grazing.

A knowledge of the problem may help in the application of fertilizers. Graber (5) [1] found that frequent and close removals of succulent top growth of grasses having abundant

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[1] Numbers in parentheses refer to Literature Consulted, page .

reserves made for a heavy draft on the supplies of available nitrogen with this element soon becoming the limiting factor of growth. He also found that when regeneration is constantly stimulated by abundant fertilizer, the carbohydrate reserves are rapidly consumed and may become the limiting factor.

If we can determine the periods of growth during which the individual plant stores the largest amount of reserves and those periods in which the least amount of storage takes place, we may be able to regulate applications of fertilizers in order to obtain a more desirable carbohydrate-nitrogen balance within the plant, thereby regulating growth to obtain a maximum yield and storage coefficient.

These points and many others prove the value of a more thorough knowledge of the ability of plants to store food reserves and the subsequent effect on early spring growth and total seasonal production as affected by different cutting treatments. This study was made to try to devise a simple indirect method whereby the reserves of plants and their effect on subsequent growth could be measured.

REVIEW OF LITERATURE

A number of studies have been conducted on the effect of cutting treatments in relation to the storage of food reserves and the subsequent growth of grasses. The results obtained from these studies indicate conclusively a definite correlation between cutting treatments and the amount of root reserves.

Weaver and Darland (24) found that an excellent test of vigor under conditions favorable for development is that of prompt removal of growth in spring after transplanting. They transplanted blocks of sod of vigorous bluestems, needle grass, and tall panic grass obtained from native prairie in the spring before resumption of growth. These blocks were transplanted in sandy loam soil in boxes ten inches long, ten inches wide, and twenty-four inches deep, with one removable side. Plants which had been clipped four times at weekly intervals had lost much of their vigor. While all controls developed extensive root systems during forty-two days, as revealed by washing away the soil, clipped plants had very few or no roots.

In a similar test using eight species of range grasses, they found the dry weight of tops of weakened plants was 32 to 84 per cent less than that of plants which had good to fair vigor. New roots were always shorter and less branched, and dry weight was 28 to 94 per cent less than that of controls.

Graber (5) states:

> "Marked quantitative responses of root, rhizome, and top growth of various grasses grown under field and greenhouse conditions are correlated with cutting treatments which affect the internal environment. It is clearly evident that the productive capacity of grasses is not only dependent upon adequate supplies of available nutrients and moisture combined with favorable light and temperature conditions, but also upon the food reserves of the plant. When photosynthesis is interrupted by frequent removal of top growth the limitations of subterranean development may involve greater susceptibility to drought, lessened absorptive capacity and increased winter and insect injury."

McCarty (13) states, "Grass plants are living organisms and their individual growth requirements must be considered in grazing practices if they are to be maintained on the range, and moderate grazing use is essential to allow for proper carbohydrate food storage."

There is considerable variation between methods employed by workers experimenting with the effect of clipping treatments on various plants. These methods vary as to the frequency, time, and height of cuttings.

Gernert (4) found that clipping native grass more than twice annually did not return enough additional production in the fifth year to pay for the labor. As the number of clippings increased, production declined.

Graber and Ream (9) found in working with bluegrass that the height of clipping greatly influenced any later productivity and concluded that "the photosynthetic parts of plants which remain after cutting are potential sources of reserve foods."

"In *Stipa pulchra* food deposit was found to be related to low or declining growth velocity and to be dependent upon the amount of leaf area available for its manufacture. The advent of flowers and seed coincided with depression in the growth rate. Accumulation of foods, therefore, is related to low or declining growth velocity and is most active near the close of the annual growth cycle." (19)

D. G. Sturkie (22), working with Johnson grass, found that cutting late in the season reduced the food reserves as much as continuous cutting throughout the season. Cutting discontinued in the middle of the season permitted the Johnson grass to develop forty per cent more rootstalks than continued cutting. Usually the largest yield of top growth was produced when the plants were cut when the seeds were in the late milk stage.

Pierre and Bertram (18) in experiments with kudzu regarding the effect of number of cutting treatments on yields and on the production of reserve foods in the roots brought out the following facts:

(1) The fewer the number of cuttings the greater is the production of root reserves. The roots of plants receiving six cuttings per season decreased in weight during a period of two years, those from plants receiving four cuttings increased approximately 400 per cent, and those from plants receiving one cutting increased about 1,250 per cent.

(2) Yields of tops were found to be dependent on the amount of reserve food stored in the roots. The greater the amount of root storage, the greater is the yield of tops.

(3) The greatest yield of tops was secured with the two-cutting treatment when the roots were of equal size at the beginning of the experiment. Due to the great amount of storage material formed in the roots during the first year from plants cut only once, however, the greatest yield secured the second year was from the one-cutting treatment.

(4) The percentage of reserve starch and nitrogen was found to be less than one-half as much in the roots from plants receiving six cuttings as in the roots of plants receiving four or a less number of cuttings. The percentage of total sugars, however, was found to be greater. This is taken to indicate that a change from starch to sugar is taking place in the roots of plants receiving six cuttings in order to produce new top growth.

McCarty (13) in a study of the carbohydrate content of mountain brome states:

> "Except for the hemicellulose fraction, carbohydrate storage is inversely related to the rate of growth of the herbage, i.e., high growth rate, low carbohydrate storage. Minimum values prevail in the roots and stem bases during the active growth stages of the plant, and evidence indicates the utilization of carbohydrates in excess of their manufacture during the most active growth periods. Maximum storage occurs during the autumn period after current seasonal and secondary herbage growth is completed."

"The carbohydrates and other organic foods cannot be supplied to green plants in a commercial way. The living plant must manufacture them itself. The plant producer can vary treatment so that formation, utilization, storage and destruction of these materials will affect the quantity and quality of the crop produced. Such cultural practices include cutting, grazing, fertilization with nitrogenous fertilizers and limitations of light." (5)

MATERIALS AND METHODS

Sod samples were selected from plots under cultivation and treatment at the Montana Experiment Station at Bozeman, Montana. These plots were part of an experiment being conducted by Dr. R. E. Stitt, Associate Agronomist, Division of Forage Crops and Diseases, Bureau of Plant Industry, Agricultural Research Administration, U.S. Department of Agriculture, and the Montana Agricultural Experiment Station.

Planting was conducted the latter part of May, 1945, and in September of that season all plots were clipped high. Three different treatments were imposed upon individual plots of each variety in 1946, in 1947, and in 1948. These treatments were (1) cut for seed, (2) cut for hay, (3) cut to simulate grazing. These cutting treatments and the clipping dates of each treatment for each year are given in Tables I, II, and III. (Pages 15, 16, and 17) Previous to this study seed plots were cut a total of three times, hay plots a total of five times, and pasture plots a total of twelve times. Also, in April of 1948, a fertilizer application of five hundred pounds of ammonium sulphate per acre was made to one-half of each plot.

From the above treated plots the following three species and three varieties of each species were selected to be used in this study:

Table I

Clipping dates of cutting treatments in the season of 1946 imposed upon species and varieties used in this study.

Species & Variety	Seed	Hay	Pasture
<u>Poa pratensis</u>			
P.I. 119684	7/11	6/6 & 9/3	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
Commercial (F.C.22934)	7/16	6/6 & 9/3	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
Arboretum	7/16	6/6 & 9/3	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
<u>Dactylis glomerata</u>			
Ft. Ellis Strain	7/22	6/28 & 9/20	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
Aberystwyth S-143 (Mont.)	7/22	6/28 & 9/20	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
Maryland (F.C.22883)	7/22	6/28 & 9/20	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
<u>Bromus inermis</u>			
Parkland (Mont.)	8/5	6/28 & 9/20	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
Lincoln	8/5	6/28 & 9/20	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5
Utah 13	8/5	6/28 & 9/20	4/25, 5/20, 6/14, 7/8, 7/28, & 9/5

Table II

Clipping dates of cutting treatments in the season of 1947 imposed upon species and varieties used in this study.

Species & Variety	Seed	Hay	Pasture
<u>Poa pratensis</u>			
P.I. 119684	7/14	6/16	5/20, 6/19, & 8/13
Commercial (F.C.22938)	7/14	6/16	5/20, 6/19, & 8/13
Arboretum	7/14	6/16	5/20, 6/19, & 8/13
<u>Dactylis glomerata</u>			
Ft. Ellis Strain	8/20	7/14	5/20, 6/19, & 8/13
Aberystwyth S-143 (Mont.)	8/20	7/14	5/20, 6/19, & 8/13
Maryland (F.C.22883	8/20	7/14	5/20, 6/19, & 8/13
<u>Bromus inermis</u>			
Parkland (Mont.)	8/20	7/14	5/20, 6/19, & 8/13
Lincoln	8/20	7/14	5/20, 6/19, & 8/13
Utah 13	8/20	7/14	5/20, 6/19, & 8/13

Table III

Clipping dates of cutting treatments in the season of 1948 imposed upon species and varieties used in this study.

Species & Variety	Seed*	Hay	Pasture
<u>Poa pratensis</u>			
P.I. 119684	7/11	6/28 & 9/7	6/7, 7/6, & 9/7
Commercial (F.C.22938)	7/16	6/28 & 9/7	6/7, 7/6, & 9/7
Arboretum	7/6	6/28 & 9/7	6/7, 7/6, & 9/7
<u>Dactylis glomerata</u>			
Ft. Ellis Strain	7/19	6/28 & 9/7	6/7, 7/6, & 9/7
Aberystwyth S-143 (Mont.)	7/19	6/28 & 9/7	6/7, 7/6, & 9/7
Maryland (F.C.22883)	7/19	6/28 & 9/7	6/7, 7/6, & 9/7
<u>Bromus inermis</u>			
Parkland (Mont.)	7/19	6/28 & 9/7	6/7, 7/6, & 9/7
Lincoln	7/19	6/28 & 9/7	6/7, 7/6, & 9/7
Utah 13	7/19	6/28 & 9/7	6/7, 7/6, & 9/7

*Only the seed head was harvested. The remainder of growth was left.

Kentucky Bluegrass (Poa pratensis)

P.I. 119684 - An introduction from Turkey which begins growth and produces seed earlier in the season than commercial bluegrass and is a less vigorous spreader.

Commercial (F.C.22934) - From seed harvested in eastern South Dakota.

Arboretum - A selection from Missouri Botannical Gardens. Originally selected to be used as a lawn grass.

Orchardgrass (Dactylis glomerata)

Ft. Ellis strain - A selection from plots of commercial orchardgrass grown at Ft. Ellis, Montana.

Aberystwyth S-143 (Mont.) - A strain developed at the Welsh Plant Breeding Station, Aberystwyth, Great Britain. Plants are relatively spreading with a profusion of tillers, the leaves being broad and palatable. The strain is valuable for hard grazing, especially on dry slopes, where the soil is light. Plants in this experiment were grown from seed of plants grown in Montana whose original seed source was the Soil Conservation nursery in the state of New York.

Maryland (F.C.22883) - A selection made at Beltsville, Maryland.

Smooth Bromegrass (Bromus inermis)

Parkland (Mont.) - A northern strain selected from a single plant along a roadway near Saskatoon, Canada. Rhizomes are present in the strain, but the spread of the plant is restricted to about sixty per cent of that of ordinary bromegrass. The percentage of leaf is about fifty-two compared to about forty-two for common bromegrass. This is due largely to a higher percentage of sterile culms. The strain is adapted from semi-arid to fairly humid conditions, and to soil varying in texture from clay to sandy loam. It does best in a fairly cool summer climate. The latitude of adaption is from about forty to forty-five north, to the limit of northern settlement. The strain is comparable to common bromegrass in drought resistance and winter hardiness.

Lincoln - A selection from old fields of bromegrass at Superior, Nebraska. A persistent, tall, and leafy strain.

Utah 13 - A strain tracing to ten plants selected at the end of the third flowering season on a basis of vigor. Five plants were vigorous spreaders, five were non-spreaders, and all were high yielding and leafy. One of the best seed producers in Montana.

From plots of the above listed species and varieties, four sod samples were taken from each non-fertilized plot of three field replications and, in the case of the strains of bromegrass, from the fertilized half of the plot as well. Replications in this experiment are synonymous with the field replications. Replication 1 was taken on April 7, replication 2 on April 9, and replication 3 on April 11. These samples were three inches in depth and three inches in diameter. A three-inch soil tube was used to take the samples, being driven into the sod, and the sample then cut off at a three inch depth. Sampling was done as soon as the field became readily accessible and at that time very few green shoots were showing.

Four methods of treatment were imposed upon the samples taken, designed to find a simpler method than chemical analysis, whereby the carbohydrate storage capacity of plants affected by various cutting treatments can be readily determined. These methods of treatment will be hereinafter referred to as methods 1, 2, 3, and 4, and will be described individually.

Method 1 - Cores taken from the field were trimmed of old growth, washed free of all soil, and planted in quart waxed milk shake containers containing pure acid-washed quartz sand. These containers were placed in the greenhouse and the sand thoroughly wet down once daily with distilled water until the foliage was cut.

Plants were cut when it appeared that growth had diminished to such an extent that very little gain would be obtained in dry weight of the tops by prolonging the growth period. Replication 1 was cut on May 9, replication 2 on May 10, and replication 3 on May 11. The foliage from each pot was clipped at the surface of the sand, placed in paper bags, oven dried at 90°C for twelve hours and then weighed on a chain balance.

Method 2 - Cores taken from the field were treated as in Method 1--trimmed, washed, placed in pure sand in waxed containers, and grown in the darkroom rather than in the greenhouse. Plants were thoroughly watered once daily with distilled water. The temperature of the darkroom was maintained between 70° and 80°F, and the humidity remained at between 40 and 50. Grown in this manner, in the absence of light and nutrients, all new growth theoretically would have to come from those carbohydrates stored within the roots.

Plants were harvested when the new foliage began withering and falling over. Replication 1 was cut April 26, replication 2 on April 28, and replication 3 on May 1. The foliage was cut at the surface of the sand, placed in paper bags, oven dried at 90°C for twelve hours and weighed on a chain balance.

Method 3 - Cores taken from the field were carefully trimmed of all old growth and placed in river sand contained in six-inch clay pots. These pots were placed in the greenhouse and watered once daily with tap water. These plants were harvested while still maintaining a vigorous growth. Replication 1 was cut on May 19, replication 2 on May 20, and replication 3 on May 21. Top growth was cut at the surface of the core, placed in paper bags, oven dried for twenty-four hours at a temperature of 90°C and weighed on a torsion balance.

Method 4 - Cores taken from the field were treated as in method 3--trimmed, placed in river sand in six-inch clay pots and then placed in a darkroom. The temperature of the darkroom was maintained between 70° and 80°F, and the humidity remained at between 40 and 50. The cores were watered once daily with tap water.

Plants were harvested when the foliage began to wither and fall over. Replication 1 was cut April 29, replication 2 on May 1, and replication 3 on May 2. The foliage was cut at the surface of the core, placed in paper bags, dried at 90°C for twelve hours and weighed on a chain balance.

Spring Clippings - In order to correlate growth from these four methods with early spring growth, clippings were made May 24 on all plots from which the samples had been taken. Yield samples were taken from a three-foot swath eight feet long, the swath being centralized within the plot. Clippings were oven dried, weighed, and the weights converted to and expressed in pounds per acre.

EXPERIMENTAL RESULTS

Nutrient Deficiencies - Observations for nutrient deficiencies were made during the growth of the plants in method 1 in which the cores were washed free of soil, placed in nutrient free sand in waxed containers and grown in the greenhouse. Nutrient deficiencies became apparent at the beginning of the third week and an attempt was made to record them. Potash deficiency symptoms were the first to materialize in all cases wherein one limiting factor became apparent before other deficiency symptoms could mask its expression. Following the first potash symptoms it appeared that abnormalities were due to more than one limiting factor and appeared in such a simultaneous manner that it was impossible to make any further recording as to which limiting factor appeared first. Mass symptoms observed were yellowing of leaves, purpling of culms and margins of leaf blades, browning of leaf tips, appearance of chlorotic spots on the leaf blades, and the twisting and curling of leaf blades.

Statistical Analyses - The yield data from the four methods of treatment of this experiment and from spring clippings were analyzed statistically by means of analysis of variance. Additional statistical analyses were made to determine: (1) correlation coefficients of different methods and spring clippings for the treatment means, with each variety yield total under individual cutting treatments for both fertility levels being considered as a treatment; (2) correlation coefficients between the yield data from each method and the yield data of spring clippings; (3) correlation coefficients between yield data of cores of bromegrass from plots previously fertilized with nitrogen and the data from cores of this species taken from plots previously unfertilized.

Combined Yields Response - Yields as affected by previous cutting treatments are given in Table IV. Methods 1 and 2 (cores washed free of soil) gave higher yields of tops for the cores from plots previously cut for seed. Other methods and spring clippings exhibited the same general trends.

Table IV

Average combined yields of three varieties of each of three species as affected by previous treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

previous treatment	Method 1	2	3	4	Spring Clipping
	grams of tops produced				lbs. per acre
Seed	.1517	.0753	1.39	.1119	102
Hay	.0686	.0373	1.03	.0764	92
Pasture	.0951	.0279	1.26	.0929	101
Sig. Dif.	.0495	.0358	N.S.	N.S.	N.S.

Combined bromegrass yield averages from plots previously fertilized and unfertilized and their response to previous cutting treatments will be found in Table V. The spring clipping yields of those plots previously cut for seed were higher than the yields of those plots cut for hay or pasture in the spring clippings.

Table V

Average of yields of three varieties of bromegrass, each at two fertility levels, as affected by previous cutting treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Method 1	2	3	4	Spring Clipping lbs. per acre
	Grams of tops produced				
Seed	.1006	.0311	.58	.0765	152
Hay	.0825	.0242	.74	.0641	114
Pasture	.1252	.0183	.58	.1117	105
Sig. Dif.	N.S.	N.S.	N.S.	N.S.	29

<u>Species Response</u> - A comparison of species yields and their differential response to previous treatment is given in Table VI. (Page 26) In all four methods orchardgrass produced more tops than bromegrass or bluegrass. This trend reversed itself for the spring clippings, in that bluegrass and bromegrass yields were higher than the yields of orchardgrass.

Table VI

Yields of three species of grass not previously fertilized as affected by previous cutting treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Grass species	Method 1	Method 2	Method 3	Method 4	Spring Clipping lbs. per A
		grams of tops produced				
Seed	Bluegrass	.0567	.0361	1.14	.0854	126
	Orchardgrass	.3188	.1480	2.32	.1802	63
	Bromegrass	.0797	.0485	.71	.0702	115
	Sig. Dif.	.1173	.0960	1.12	.0895	29
Hay	Bluegrass	.0403	.0159	.57	.0598	117
	Orchardgrass	.1021	.0792	1.50	.1093	46
	Bromegrass	.0633	.0167	1.06	.0602	113
	Sig. Dif.	.0388	.0188	.62	.0431	40
Pasture	Bluegrass	.0705	.0180	.69	.0645	117
	Orchardgrass	.1511	.0540	1.96	.1443	74
	Bromegrass	.0638	.0118	1.12	.0698	114
	Sig. Dif.	N.S.	.0420	.97	N.S.	N.S.
All Treatments	Bluegrass	.0558	.0233	.80	.0699	120
	Orchardgrass	.1907	.0938	1.93	.1446	61
	Bromegrass	.0689	.0234	.96	.0667	114
	Sig. Dif.	.0495	.0358	.43	.0377	21
Sig. Dif. necessary when comparing response of a species to previous cutting treatment						
	Bluegrass	N.S.	.0133	.38	N.S.	N.S.
	Orchardgrass	.0643	N.S.	N.S.	N.S.	22
	Bromegrass	N.S.	N.S.	N.S.	N.S.	N.S.

Fertility Levels - A comparison of core and spring clipping yields from bromegrass plots previously fertilized and unfertilized is given in Table VII. (Page 28) In the seed treatment of method 1, the pasture treatment of method 2, and the seed treatment of spring clippings, plots previously fertilized yielded significantly higher than those plots not previously fertilized. In general, this trend appeared to be true in any individual cutting treatment and in a combined average of cutting treatments for all of the experimental methods employed.

Variety Response - Comparisons of bromegrass variety yields and their differential response to previous cutting treatment is given in Table VIII. (Page 29) These yields are derived by averaging the yields of the nitrogen and no nitrogen values for each cutting treatment. In the spring clipping yields, Lincoln bromegrass yielded higher than either Parkland or Utah in the hay treatment and in an average of all treatments, and was higher yielding, but not significantly so, for the other two cutting treatments. Parkland appeared to be the highest yielding variety for each of the four methods.

Bromegrass variety yields from plots not previously fertilized and their response to previous treatment are given in Table IX, (Page 30) and a comparison of these same varieties from plots previously fertilized is given

Table VII

Yields of bromegrass from plots previously fertilized and unfertilized as affected by previous cutting treatment. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Fertilizer	Method 1	2 (grams of tops produced)	3	4	Spring Clipping lbs. per A
Seed	None	.0797	.0419	.71	.0702	116
	Nitrogen	.1215	.0203	1.05	.0828	188
	Sig. Dif.	.0352	N.S.	N.S.	N.S.	46
Hay	None	.0633	.0112	1.06	.0602	113
	Nitrogen	.1017	.0318	1.18	.0680	115
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Pasture	None	.0638	.0118	1.12	.0698	114
	Nitrogen	.1865	.0457	.65	.1535	96
	Sig. Dif.	N.S.	.0203	N.S.	N.S.	N.S.
All Treatments	None	.0689	.0234	.96	.0667	114
	Nitrogen	.1366	.0326	.96	.1015	133
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Sig. Dif. necessary when comparing response of a species to previous cutting treatment						
	None	N.S.	N.S.	N.S.	N.S.	N.S.
	Nitrogen	N.S.	N.S.	N.S.	N.S.	45

Table VIII

Yields of three varieties of bromegrass as affected by previous cutting treatments. Yields from plots previously fertilized averaged with yields of plots previously unfertilized for each variety and expressed in grams of dry weight for methods and in pounds per acre for spring clippings..

Previous treatment	Variety	Method 1	Method 2	Method 3	Method 4	lbs. per A Spring Clipping
		grams of tops produced				
Seed	Parkland	.1126	.0390	.78	.0733	146
	Lincoln	.0781	.0220	.52	.0840	181
	Utah 13	.1111	.0156	.46	.0721	129
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Hay	Parkland	.1378	.0277	.85	.0661	88
	Lincoln	.0579	.0204	.71	.0686	169
	Utah 13	.0519	.0245	.66	.0575	83
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	48
Pasture	Parkland	.1870	.0311	.88	.2137	88
	Lincoln	.0618	.0270	.39	.0630	139
	Utah 13	.1267	.0283	.49	.0556	88
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
All Treatments	Parkland	.1458	.0326	.84	.1175	107
	Lincoln	.0654	.0231	.54	.0730	163
	Utah 13	.1016	.0228	.54	.0617	101
	Sig. Dif.	N.S.	N.S.	.30	N.S.	29
Sig. Dif. necessary when comparing response of a variety to previous cutting treatment						
	Parkland	N.S.	N.S.	N.S.	N.S.	38
	Lincoln	N.S.	N.S.	N.S.	N.S.	N.S.
	Utah 13	N.S.	N.S.	N.S.	N.S.	35

Table IX

Yields of three varieties of bromegrass from plots not previously fertilized as affected by previous cutting treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Variety	Method 1	2	3	4	Spring Clipping lbs. per A
			grams of tops produced			
Seed	Parkland	.1112	.0874	1.21	.0572	101
	Lincoln	.0489	.0224	.60	.0663	132
	Utah 13	.0789	.0157	.31	.0870	115
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Hay	Parkland	.0449	.0137	1.11	.0551	103
	Lincoln	.0759	.0191	1.16	.0591	173
	Utah 13	.0691	.0171	.84	.0665	62
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Pasture	Parkland	.0481	.0125	1.67	.1298	110
	Lincoln	.0419	.0121	.76	.0430	143
	Utah 13	.1014	.0108	.92	.0366	88
	Sig. D.f	N.S.	N.S.	.43	.0647	N.S.
All Treatments	Parkland	.0681	.0379	1.33	.0807	104
	Lincoln	.0545	.0179	.84	.0561	149
	Utah 13	.0832	.0145	.69	.0634	88
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	43
Sig. Dif. necessary when comparing response of a species to previous cutting treatment						
	Parkland	N.S.	.0172	N.S.	N.S.	N.S.
	Lincoln	N.S.	N.S.	N.S.	N.S.	N.S.
	Utah 13	N.S.	N.S.	.44	N.S.	N.S.

in Table X. (Page 32) Apparently the two fertility levels produced no effect on the reaction of bromegrass varieties to previous cutting treatments. In general, the reaction of the varieties under each fertility level to previous treatment is the same as that given for Table VIII. (Page 29)

The yields of orchardgrass varieties and their response to previous cutting treatment are given in Table XI. (Page 33) In the hay and pasture treatments of method 3, the Ft. Ellis strain yielded higher than the Maryland strain, and in the seed treatment of spring clippings, the Ft. Ellis and Maryland strains yielded higher than Aberystwyth S-143. In an average of all treatments Aberystwyth S-143 yielded higher than either of the other two strains in method 2.

A comparison of bluegrass varieties and their response to previous treatment is given in Table XII. (Page 34) The P.I. 119684 strain produced a higher yield of tops for the seed treatment than for the hay treatment in method 3.

Correlations - With the exception of the correlation coefficient for methods 1 and 4, correlation coefficients were positive and highly significant for any two methods for the treatment means. (See Table XIII, page 35) Correlation coefficients were negative and significant for any one method and spring clippings for the treatment means, with the exception of method 4.

Table X

Yields of three varieties of bromegrass from plots previously fertilized as affected by previous cutting treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Variety	Method 1	2	3	4	Spring Clipping
		grams of tops produced				lbs. per A
Seed	Parkland	.1140	.0239	1.14	.0895	190
	Lincoln	.1072	.0217	.95	.1018	230
	Utah 13	.1433	.0154	1.07	.0573	143
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Hay	Parkland	.2306	.0417	1.44	.0772	72
	Lincoln	.0399	.0216	.96	.0781	166
	Utah 13	.0346	.0319	1.14	.0485	103
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Seed	Parkland	.3259	.0496	.96	.2976	65
	Lincoln	.0817	.0418	.42	.0897	135
	Utah 13	.1519	.0458	.56	.0747	88
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
All Treatments	Parkland	.2235	.0384	1.18	.1543	109
	Lincoln	.0763	.0284	.78	.0899	177
	Utah 13	.1200	.0310	.93	.0601	113
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	45
Sig. Dif. necessary when comparing response of a variety to previous cutting treatment						
	Parkland	N.S.	N.S.	N.S.	N.S.	82
	Lincoln	N.S.	N.S.	N.S.	N.S.	N.S.
	Utah 13	N.S.	N.S.	N.S.	N.S.	N.S.

Table XI

Yields of three varieties of orchardgrass as affected by previous cutting treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Variety	Method 1	2	3	4	Spring Clipping
		grams of tops produced				lbs. per A
Seed	Ft. Ellis	.3186	.0855	1.01	.1500	70
	Aberystwyth S-143 (Mont.)	.3205	.3052	2.09	.1029	38
	Maryland	.3137	.0535	2.84	.2876	82
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	14
Hay	Ft. Ellis	.1344	.0914	2.26	.1328	53
	Aberystwyth S-143 (Mont.)	.1381	.1143	1.75	.1437	38
	Maryland	.0338	.0320	.47	.0513	47
	Sig. Dif.	N.S.	N.S.	1.61	N.S.	N.S.
Pasture	Ft. Ellis	.0975	.0797	2.34	.2232	82
	Aberystwyth S-143 (Mont.)	.3098	.0686	1.87	.1651	68
	Maryland	.0493	.0138	1.67	.0446	72
	Sig. Dif.	N.S.	N.S.	.50	N.S.	N.S.
All Treatments	Ft. Ellis	.1824	.0855	1.87	.1687	68
	Aberystwyth S-143 (Mont.)	.2784	.1626	1.90	.1373	48
	Maryland	.1334	.0331	2.00	.1279	68
	Sig. Dif.	N.S.	.0860	N.S.	N.S.	N.S.
Sig. Dif. necessary when comparing a variety response to previous cutting treatment						
	Ft. Ellis	N.S.	N.S.	.10	N.S.	N.S.
	Aberystwyth S-143 (Mont.)	N.S.	N.S.	N.S.	N.S.	N.S.
	Maryland	N.S.	N.S.	N.S.	N.S.	N.S.

Table XII

Yields of three varieties of bluegrass as affected by previous cutting treatments. Yields expressed in grams of dry weight for methods and in pounds per acre for spring clippings.

Previous treatment	Variety	Method 1	Method 2	Method 3	Method 4	Spring Clipping lbs. per A
		grams of tops produced				
Seed	P.I. 119684	.0520	.0231	1.16	.0771	120
	Commercial (F.C. 22934)	.0550	.0562	1.03	.0764	112
	Arboretum	.0629	.0289	1.27	.1028	148
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Hay	P.I. 119684	.0491	.0157	.47	.0489	140
	Commercial (F.C. 22934)	.0281	.0167	.58	.0517	95
	Arboretum	.0438	.0153	.67	.0786	117
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	25
Pasture	P.I. 119684	.0516	.0132	.66	.0523	155
	Commercial (F.C. 22934)	.0922	.0132	.63	.0614	107
	Arboretum	.0676	.0277	.76	.0798	90
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
All Treatments	P.I. 119684	.0509	.0173	.76	.0594	138
	Commercial (F.C. 22934)	.0584	.0287	.75	.0632	104
	Arboretum	.0581	.0240	.89	.0871	118
	Sig. Dif.	N.S.	N.S.	N.S.	N.S.	N.S.
Sig. Dif. necessary when comparing a variety response to previous cutting treatment						
	P.I. 119684	N.S.	N.S.	.68	N.S.	N.S.
	Commercial (F.C. 22934)	N.S.	N.S.	N.S.	N.S.	N.S.
	Arboretum	N.S.	N.S.	N.S.	N.S.	N.S.

Table XIII

Correlation coefficients between different methods and spring clippings for the treatment means. N = 36.

Method	II	Method III	IV	Spring Clipping
I	0.60**	0.51**	0.70**	-0.56**
II	———	0.44**	0.29	-0.49**
III	———	———	0.65**	-0.34*
IV	———	———	———	-0.31

* 5% level of significance r=0.330
** 1% level of significance r=0.424

A statistical analysis, in which the yield data of each method was correlated with the yield data of spring clippings, produced no significant correlation coefficients. Correlation coefficients of spring clippings with bluegrass were negative for methods 1 and 2, and positive in methods 3 and 4. Orchard-grass was positively correlated and bromegrass negatively correlated for all four methods. (See Table XIV, page 36)

A statistical analysis, in which the yield data of bromegrass from cores taken from plots previously fertilized were correlated with the yield data of cores from plots previously unfertilized, produced correlation coefficients as follows:

Spring Clipping	.45
Method 1.........................	-.28
Method 2.........................	-.36
Method 3.........................	.17
Method 4.........................	.78*

Table XIV

Correlation coefficients for spring clippings and methods. N = 9.

Species	Method I	II	III	IV
Poa pratensis	- .02	- .16	.17	.03
Dactylis glomerata	.13	.31	.44	.57
Bromus inermis	- .35	- .27	- .03	- .20

DISCUSSION

There was a large margin of variability in this study as shown by the coefficients of variability which were as follows: spring clippings, 38.9; method 1, 90.0; method 2, 69.8; method 3, 68.0; and method 4, 74.2. This variation between methods and within methods was to be expected due to the entirely different set of conditions under which the plants of each method were grown and due to the large margin for error in sampling and treating the cores. There were, however, differences between species and between varieties in their response to previous cutting treatment. Some of these differences were statistically significant, but the majority were not, and, therefore can only be subject to speculative theory.

There is little evidence to substantiate a statement as to which of the four methods employed gave the most exact measurement of carbohydrate storage. The interaction between core methods and treatments was highly significant, indicating that although all core methods may be a measurement of the amount of root reserves stored, other factors due to the difference in methods were affecting that measurement. On the basis of the coefficient of variability, method 3 exhibited the least variability, indicating that it would probably be the most reliable of the four methods.

Methods 1 and 2 gave significant values for the total yields of tops of the seed treatment over the other two previous cutting treatments. The data of methods 3 and 4 follow the same general trend, although the differences were not significant.

It is evident that the methods used in this study are not measuring the same factor as is measured by spring clippings. In all but a few cases, orchardgrass yields were significantly higher than the yields of either of the other two species for all three treatments and a combined average of treatment yields in all four methods of the experiment. In the spring clippings this trend reversed itself in that bluegrass and bromegrass yields are significantly higher than the orchardgrass yields for the seed and hay treatments and in a combined average of all three treatment yields. (Note Table VI, page 26).

In taking root cores of a bunch type grass such as orchardgrass, the soil tube can be placed directly over the clone, whereas in taking root cores of a sod grass such as bluegrass or bromegrass, the soil tube is placed randomly over the sod, allowing for a greater variation in the amount of roots in a three inch core. The quantity of roots, therefore, in a three inch core of orchardgrass should exceed the quantity of roots taken in a similar sample of a rhizomatous type grass such as bluegrass or bromegrass. The subsequent growth from these cores would favor the bunch type grass species in that there would be a greater quantity of reserves due to the larger amount of root volume, even though the percentage of reserves per unit of volume or weight might be lower.

In the case of the spring clippings in which the yields of orchardgrass were exceeded significantly by the two rhizomatous species, this trend could reverse itself in that under field conditions the rhizomatous species have a larger volume of roots from which to draw reserves and consequently a larger amount of reserves.

Another possible explanation of the difference in behavior of these species under methods of treatment as compared to spring clippings might be found in the earliness of spring growth. Under Montana conditions orchardgrass apparently suffers a physiological disturbance during the winter and early spring months which retards the earliness of spring growth, as was evidenced by spring clipping yields. Under the methods some of the causes, such as temperature relationships, could have been alleviated, which would allow for a more normal type growth to be made by the species.

Apparently nitrogenous fertilization had little effect on bromegrass variety response to previous cutting treatment. In a combined average of the three cutting treatment yields, Parkland was higher yielding, but not significantly so, for the four methods. This was true in yields of cores from previously fertilized plots as well as in yields of cores from plots not previously fertilized. This trend can hypothetically be supported in that Parkland is a less vigorous spreader and would less likely be sod bound after four seasons of growth than the other two varieties and would consequently have more vigor and higher yields.

In spring clipping yields from bromegrass plots previously fertilized as well as from those not previously fertilized, the yields of Lincoln bromegrass were higher than the yields of the other two species in a combined average of cutting treatment yields. This trend is the reverse of that found in the methods used and lends further evidence that a different factor was being measured in spring clippings than that which was measured in methods.

In a combined average of treatment yields the Aberystwyth S-143 strain of orchardgrass yielded significantly higher in method 2 than the other two strains and in method 1 was higher yielding with a difference of yields approaching the level of significance. In the spring clipping yield data the trend appears to be for the Aberystwyth S-143 strain to be the lowest yielding variety. This reversal further substantiates the theory that a different factor was being measured in spring clippings than that which was measured in methods.

The yields of the arboretum variety of bluegrass appear to be higher than either of the other two varieties for all three cutting treatments in methods 3 and 4, in which the cores were not washed free of soil. This trend is contrary to the trend of the yields in spring clippings wherein P.I. 119684 appears to be the highest yielding in a combined average of treatment yields. P.I. 119684 is an early bluegrass and consequently it is to be expected that spring clipping yields would be higher than for the other two varieties. However, the trend in two methods of the experiment was that arboretum stored more reserves, thereby again substantiating the statement that a different factor is being measured in spring clippings than that which is being measured in methods.

If the methods data is a true indication of root reserves, the factor being measured by spring clippings may well be certain capabilities, inherent within a species or variety, for the more complete and efficient utilization of those reserves present. It would appear that early spring growth is not entirely dependent upon those reserves stored within the roots, but also upon physiological elements affecting the utilization of those reserves.

SUMMARY

Root core samples, three inches in depth and diameter, were taken with a soil tube from three replications of three varieties of each of three species of grass. These plots had previously been exposed to three different cutting treatments: (1) cut for seed, (2) cut for hay, (3) cut to simulate pasture. In May of the season preceding this study, one-half of each plot was fertilized at the rate of five hundred pounds of NH_4SO_4/acre. Core samples of bromegrass varieties were taken from both fertilized and unfertilized plots.

Samples taken were subjected to the following methods of treatment:

(1) Cores washed free of soil, placed in nutrient-free sand in quart waxed paper containers and grown in greenhouse.

(2) Cores washed free of soil, placed in nutrient-free sand in quart waxed paper containers and grown in darkroom.

(3) Cores placed in river sand in six-inch clay pots and grown in greenhouse.

(4) Cores placed in river sand in six-inch clay pots and grown in darkroom.

Methods 1 and 2 were watered once daily with distilled water; methods 3 and 4 with tap water.

Top growth made by the cores under the above methods was clipped, oven dried, and the yields expressed as grams of dry matter.

On plots from which core samples had been removed, spring clippings were taken, oven dried, and the yields expressed in pounds per acre.

Yield data of methods and spring clippings were analyzed statistically by means of analysis of variance.

The results of this study exhibited considerable variability.

A definite response to previous cutting treatment was noted when the yields of the three species were averaged, in that top growth yields of cores from plots previously exposed to the seed cutting treatment were higher than those of either of the previous hay or simulated pasture cutting treatments.

A different factor was being measured by spring clippings than that which was being measured by methods, as was evidenced by a reversal of yield trends in these measurements.

Nitrogenous fertilization apparently had little effect on the response of bromegrass varieties to previous cutting treatments. Although the yields of cores from plots previously fertilized were higher than the yields of cores from plots not previously fertilized, they followed the same trend.

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