Effects of clipping on carbohydrate reserves and dry matter yields of basin wildrye
by Lawrence Joseph Perry

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University

Abstract:
After establishment, spaced basin wildrye plants were clipped to 10 or 30 cm at three developmental stages in 1971. Total nonstructural carbohydrates (TNC) were measured 1, 2, 3, and 10 weeks following the initial clipping and after a regrowth clipping which was three weeks after each initial clipping. Seasonal TNC trends of unclipped plants were also determined. In an additional experiment, the effect of clipping to 45, 30, or 15 cm at three, six, and nine week intervals at three starting dates on total seasonal dry matter production of spaced basin wildrye plants in 1970 was studied. The same treatments were imposed in 1971 with three additional starting dates, earlier than in 1970.

Seasonal TNC levels of unclipped plants declined rapidly during June when many developmental events were occurring. After this time, TNC levels increased through the summer, except for a decline in mid-August associated with the following year's tiller development. TNC of plants clipped once or twice to 10 cm was significantly lower than plants clipped to 30 cm for all developmental stages at all dates following clipping with a greater decline associated with plants clipped twice to 10 cm. A restoration of TNC occurred within three weeks with plants clipped to 30 cm,but only a slight restoration occurred with plants clipped to 10 cm. TNC levels of clipped plants ten weeks after the initial clipping were generally lower in plants clipped to 10 cm than in unclipped plants or plants clipped to 30 cm.

Total seasonal dry matter yields were greatly reduced due to clipping, particularly at the later starting dates, during one year's clipping. The amount of regrowth following clipping appeared directly related to growing point removal. The dry matter yields during the second year of clipping were markedly lower on plants clipped to 15 cm, less so on plants clipped to 30 cm and not reduced by the 45 cm clipping. Yields associated with three week intervals were significantly lower than the six or nine week intervals.

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by

LAWRENCE JOSEPH PERRY, JR.

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DOCTOR OF PHILOSOPHY

in

Crop and Soil Science

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Bozeman, Montana
August 1972

ACKNOWLEDGMENT

My sincere appreciation to:

Dr. S. R. Chapman, my major professor, for his advice, and wisdom, in preparation of this manuscript, as well as his generosity of time throughout the past two years.

Drs. C. S. Cooper and J. H. Brown for their assistance in the research and reviewing this manuscript.

Drs. W. E. Booth, J. M. Capric, and W. J. Dorgan for reviewing this manuscript.

The concerned M.S.U. faculty and students for their suggestions and inspiration.

Mr. Dennis Roseleip and Mr. Dave Roseleip, Project Technicians, for their assistance and interest in this study.

Montana State University for the monetary contributions which financed my assistantship.

My wife, Kathleen not only for typing the manuscript, but also in taking an active part in assisting with the research.

My daughter, Mary Eileen for the greeting smiles every day during this program.

My son, Lawrence Joseph III, for unknowingly active participation in life during the past year and a half.

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ABSTRACT

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INTRODUCTION

Basin wildrye (Elymus cinereus Scribn. and Merr.) has attracted attention of pasture and range managers because of its prolific production and early spring growth. This species was in the past confused with giant wildrye (Elymus condensatus Presl.). The spikes are usually compound on giant wildrye and not on basin wildrye (33). The blades are somewhat narrower (5 to 15 mm wide) on basin wildrye than on giant wildrye (15 to 35 mm wide) (33). The lemmas are more or less pubescent on basin wildrye, but glabrous to sparsely strigose on giant wildrye (33). Basin wildrye is found on river banks, in ravines, on moist or dry slopes and on the plains from Minnesota to British Columbia and south to Colorado and California. Giant wildrye is found on sand dunes, sandy or rocky slopes, and moist ravines, mostly near the coast from Alameda County to San Diego County, California, and on the adjacent islands off the coast (3).

Basin wildrye is a coarse, robust, bunch type perennial plant with stems up to 12 feet high; however, rhizomes have been reported. It produces an enormous number of tillers and large amounts of forage. In Montana it can be found growing in clumps of from 2 to 4 feet in diameter and from 3 to 6 feet or more in height (51). It is grazed to some extent while young, but soon becomes coarse and increasingly unpalatable as the plant matures. Lack of resistance to spring grazing is one of the major problems associated with basin wildrye (3, 42).

Basin wildrye formerly was very important as a winter forage plant in parts of Nevada, Utah, and Idaho, but overgrazing, especially during the spring months when growth was starting, has greatly reduced or eliminated it. It is moderately palatable to cattle and horses in California and the Northwest, except during the fall when it becomes very hard and dry. Winter rains soften it, and it is again grazed (3). In addition to forage use, another proposed use for basin wildrye may be as a snow catcher (vegetative barrier) on cultivated land.

Ergot (Claviceps purpurea) is another major problem associated with basin wildrye besides its lack of resistance to spring grazing. Livestock consumption of grass infected with ergot (sclorotia) may cause death loss.

Chapman (12) reported that basin wildrye is a highly cross pollinated species, indicating genetic variability. Basin wildrye is slightly higher in ash, crude fiber, and crude protein than are 67 common western range grasses but is slightly lower in ether extract and nitrogen-free extract (40).

Basin wildrye, an early cool season grass, begins growth at Bozeman, Montana in the later part of March, with the first leaves emerging considerably earlier than most other cool season grasses. It remains in the vegetative stage for a long time. The developmental events of this species occur over an extended period. Basin wildrye appears as the rancher's dream because of the extended vegetative stage and prolific production. But this dream is plagued with the major problem of maintaining the species as a pasture plant. It seems to lack resistance to spring grazing (3, 42).

The sensitivity of basin wildrye to spring grazing may be related to low carbohydrate reserves. Experience has shown that it is hard to maintain this species under spring grazing conditions. This may be due to lack of adequate carbohydrate reserves when plants are grazed at a critical developmental stage; thus, the level of carbohydrate reserves may indicate why basin wildrye is sensitive to spring grazing.

LITERATURE REVIEW

Food reserves are essential for plant survival and production of tissues during periods when the photosynthetic activity cannot keep pace with food utilization. The formation of food reserves is dependent upon photosynthesis and available plant nutrients and moisture, as well as other factors. The principal organic materials stored in plants are carbohydrates, proteins, fats and oils (58). Carbohydrates, such as sugars, starch, or fructosans, are most readily available to the plant as building material or as a source of energy and usually are utilized before proteins and fats.

Smith (60) prefers the term "total nonstructural carbohydrates" to "total available carbohydrates". Total nonstructural carbohydrate (TNC) content is an estimate of the carbohydrate energy readily available to plants. Smith contends that the term "total available carbohydrates" is often confusing to animal scientists since ruminant animals also obtain energy from at least part of the structural carbohydrates. Sullivan and Sprague (64) and Weinmann (73) stated that structural carbohydrates—hemicellulose and cellulose—are not a significant source of reserve energy to the plant.

The type as well as the relative proportions of individual carbohydrate reserve components varies among grass species. Perennial forage grasses fall in two groups based on the type of nonstructural polysaccharide accumulated (59, 75). Grasses of subtropical and tropical origin accumulate starch; whereas, those of temperate origin accumulate fructosans. All species in the tribes Aveneae, Festuceae, and Hordeae, of which Elumys cinereus is a member, appear to store fructosans (59, 75).

The particular plant part where reserve carbohydrates are stored varies widely between species. Carbohydrate reserves are stored in the roots, stem, and seed. Smelov and Morozov (57) reported that the significant accumulation of carbohydrate reserves is not confined to the underground plant parts but is found in the lower regions of the stems in grasses. In perennial ryegrass (Lolium perenne L.), Baker (4) reported that the percentage of total water soluble carbohydrate was consistently higher in stubble than in roots. Other workers (5, 64) have reported similar findings. Bromegrass (Bromus inermis Leyss.) and reed canarygrass (Phalaris arundinacea L.) store the largest proportion of their reserve carbohydrates in the rhizomes, and orchardgrass (Dactylis glomerata L.) and timothy (Phleum pratense L.) in the stem bases (58).

Seasonal fluctuations in carbohydrate reserves are certain to occur because of the dynamic changes in the seasonal growth pattern of perennial plants. Hyder and Sneva (35) concluded that growth rate and plant developmental phase determine the level of carbohydrate reserves in the stem bases of grasses. McCarty (48) concluded that carbohydrate storage in stem bases of mountain bromegrass (Bromus carinatus Hook.

and Arn.) throughout three seasons was inversely related to herbage growth. Working with Colorado wildrye (Elymus ambiguus Vasey and Scribn.) and mountain muhly (Muhlenbergia gracilis Hitchc.), McCarty (47) found that carbohydrate reserves decreased during periods of fast herbage growth and increased during periods of slower growth.

In perennial plants, the onset of spring growth usually causes a decline in stored carbohydrates (69, 73, 74, 75). Although the spring decline in carbohydrates is general, the level of carbohydrate reserves through the rest of the season is quite variable. One pattern is recovery of carbohydrate storage after the initial spring loss, with continuing increases in carbohydrate storage to the end of the season. For example, Lindahl et al. (43) reported that carbohydrates in rhizomes of switch cane (Arundinaria tecta Walt.) declined until the third leaf stage, then began to increase. Other examples of this pattern have been reported (48, 56, 71).

In many grass species carbohydrate reserves recover early in the season, but in others the reserves continue to decline until midseason (2, 27, 68). The lowest level for the season then occurs with flowering. Another pattern is a rise following the spring decline, and then later a decrease during seed ripening (22, 35).

The level of carbohydrate reserves of grasses varies not only seasonally but also diurnally. Holt and Hilst (34) found that a significant portion of the total nonstructural carbohydrates in bromegrass herbage was utilized during the night, but the diurnal fluctuations for other grass species were less. For the grass species they studied, TNC content in the herbage was lowest at 6 AM and increased linearly to a high at 6 PM.

Various environmental factors such as temperature affect the seasonal change in reserves. Above-optimum temperatures decreased the percentage of carbohydrates in Canada bluegrass (Poa compressa L.), Kentucky bluegrass (Poa pratensis L.) and orchardgrass (9) and also in timothy (6). Water stress as well as low light intensity may very well influence the amount of reserves.

The effect of herbage removal on carbohydrate reserves has been discussed extensively. Such questions as: At what degree of herbage removal will the reserves be severely depleted? What are the effects of plant development upon TNC depletion? What are the management considerations? These questions have been discussed in the literature for some time.

Carbohydrate reserves (TNC) are assumed to be used for the growth of new leaves after defoliation. After a certain quantity of leaf tissue is developed, restoration of reserve carbohydrates occurs, most often to a value near the original level. The carbohydrate reserves appear to be translocated to the aerial parts of the plant where they are used to produce new leaves. When sufficient new leaf tissue is formed, the carbohydrate is replenished in the reserve plant part.

Sampson and McCarty (56) found that grazing or cutting purple needlegrass (Stipa pulchra Hitchc.) once or twice during early growth did not prevent maximum accumulation of reserves, but removal of herbage (by grazing or cutting) between the time of flower stalk formation and seed maturity did prevent maximum accumulation of carbohydrate reserves. McCarty (48) found that clipping mountain bromegrass three times at 5 day intervals during the spring decreased the sugars and starch stored in stem bases by one third. In a further contribution McCarty and Price (49) reported that clipping as well as grazing lowered the percentages of reserve carbohydrates in stem bases of mountain bromegrass and slender wheatgrass (Agropyron trachycaulum Hitchc.); the degree of reduction depended on the time, frequency and closeness of herbage removal. Clipping plants early and at or near the close of the season decreased carbohydrate reserves less than clipping during the middle of the season, during seed ripening. The level of reserves was lowest in those plants clipped closely and frequently. Eight clippings to a height of 1 inch at 15-day intervals during the growing season reduced the reserves of mountain bromegrass by 57%, and reserves of slender wheatgrass by 30%. Hanson and Stoddart (28) reported that there was 7% sugars and starch in the roots and stem bases of beardless wheatgrass (Agropyron inerme Scribn. and Smith) on protected areas and only 4.7% in those plants on heavily grazed areas. Clipping little bluestem (Andropogon scoparius Michx.) to the crown level at 2-week intervals during 8 weeks of the vegetative stage reduced the combined percentage of sugars and polysaccharides by 50% in the roots and 73% in the herbage (lower internodes) (2).

Donart and Cook (23) found that the carbohydrate reserves of beardless wheatgrass and letterman needlegrass (Stipa lettermani Vasey) were significantly reduced when 90% of the herbage was removed during the 3 to 5 leaf stage. Herbage removal on both grasses during early season, when carbohydrate reserves were low, was considerably more detrimental than during late season, when carbohydrate reserves were high. Intensive clipping reduced the level of carbohydrate reserves in stem bases of hardinggrass (Phalaris tuberosa var. Stenoptera Hack.) more than clipping only at maturity (50).

Paulsen and Smith (53) reported that clipping bromegrass decreased the carbohydrate reserves, but not to the extent as reported by other workers with other species. Carbohydrate reserves recovered within five weeks following clipping. In Colorado grazing did not significantly decrease the carbohydrates of sand reedgrass (Calamovilfa longifolia Scribn.) on most sampling dates (76).

The effect of clipping during spring is important on the level of reserves present during the autumn. Plants require energy for respiration throughout the winter and for initiation of spring growth when there is insufficient photosynthetic area to meet energy demands. Hyder and Sneva (36) found that clipping crested wheatgrass (Agropyron *cristatum* Gaertn.) between heading and anthesis resulted in lower autumn-storage of carbohydrate reserves than in unclipped plants. This pattern of clipping effects appeared to be related to a seasonal decrease in carbohydrates of unclipped plants during this period (35).

Davidson and Milthorpe (17, 18, 19) concluded that regrowth of orchardgrass following clipping was dependent upon carbohydrate reserves for only the first 2 to 4 days. During this period, stored carbohydrates were used for regrowth and respiration. Afterwards, regrowth was dependent upon other factors, such as photosynthetic rate and nutrient uptake. Ehara et al. (24) found that carbohydrate reserves, assimilated as labeled CO_2 by bahiagrass (*Paspalum notatum* Flugge.), were used to form leaves for six days after herbage removal. Smith and Marten (62) found that labeled nonstructural carbohydrates initially stored in the root and crown of alfalfa (*Medicago sativa* L.) were utilized as substrate for respiration of both roots and tops and as structural components of top growth. Ward and Blaser (69), working with orchardgrass, stated that carbohydrate reserves stimulated regrowth production for 25 days after partial or complete herbage removal. Davidson and Milthorpe reexamined Ward and Blaser's data and concluded that the rate of regrowth was only dependent upon carbohydrate reserves for the first 2-5 days and afterwards the rate of regrowth was dependent upon leaf area.

The effect of clipping on the accumulation of carbohydrates has been well reviewed by many other workers with other species. Carbohydrates generally decline for several days following herbage removal, then begin to recover after one to three weeks. However, the depletion of reserves as well as recovery varies among species, time of sampling, and intensity of clipping. Reviewing the literature concerning carbohydrate reserves is confusing, as many factors have to be considered in addition to the above such as: (1) Amount of photosynthetic material remaining following clipping, (2) Time lapse between clipping and actual sampling, (3) Plant part sampled, and (4) Method of carbohydrate analysis (77). Many factors other than the level of carbohydrate reserves need to be considered in order to make valid conclusions from the literature.

Excessive herbage removal will reduce carbohydrate reserves which will thus reduce vigor. Severe herbage removal by cutting or grazing not only decreases current herbage growth, but the reduction of reserves will reduce productivity during following years. For example, Odgen and Loomis (52) reported that, when carbohydrate reserves of intermediate wheatgrass (Agropyron intermedium (Host) Beauv.) were depleted to 1% dry weight, vigor of the grass was too low for recovery from a clipping treatment. Depletion of reserves below a certain critical level may lead to the death of the plant, and on a large scale manifests itself in the reduction of basal cover in range land subjected to excessive defoliation by cutting or overgrazing.

Plants with low reserves may be more susceptible to adverse conditions, such as drought, heat, frost, and disease. According to Julander (39), a high level of carbohydrate reserves is essential to heat and drought resistance. If clipping and overgrazing decrease the reserve level, then plants are more susceptible to exposure to high temperatures than plants with a high content of reserves.

Many errors may be made by assuming that the effects of clipping are similar to those of grazing. Grazing removes herbage at varying heights from plant to plant; whereas, clipping removes all herbage to a certain height. Watson and Ward (70) found that carbohydrate reserves of dallisgrass (Paspalum dilatatum Poir.) increased as the percentage of unclipped tillers increased from 0 to 10%. Therefore it appears that if grazing leaves intact tillers while removing others, grazing may be less detrimental than clipping. However, grazing may be more detrimental than clipping if grazing removes herbage from some plants and not others. The ungrazed plants may compete for light, nutrients, and water with grazed plants.

The effects of clipping on dry matter yield have been investigated many times. In most cases where only a single species rather than a mixture of species has been treated, clipping has reduced dry matter yield. Previous reviews of the literature (14, 29, 30, 67) have all pointed out that the more frequent and severe the clipping, the more dry matter yield is depressed. In addition to literature considered by these reviews, reduction of dry matter yield by increased frequency and intensity of harvesting has been shown also by other investigators (13, 20, 54). For example, clipping switchgrass (Panicum virgatum L.) sods at 14 day intervals reduced the total dry weight of tops by 13.1% and sideoats grama (Bouteloua curtipendula (Michx) Torr.) by 47.5% (7). Carter and Law (11) found a similar relationship for many native species of the northwestern United States. Everson (25) working with western wheatgrass (Agropyron smithii Rybd.) found that clipping plants to 2.5, 5.0, 7.5, and 10.0 cm four times at 3-week intervals reduced the total yields of tops, roots, and rhizomes.

Studies that have considered the effect of clipping on dry matter yield have usually included one to three heights of cutting combined with several frequencies of cutting. Frequency has been variously defined by a fixed interval between treatments, or cutting was repeated when regrowth reached a predetermined height or growth stage. Cutting when regrowth reaches a certain height or growth stage seems to have considerable merit when the objective is to determine desirable practices of harvesting hay. Cutting at specified intervals may be more useful for designing grazing systems.

Generally clipping reduces yields, but it may increase yields the first year or effects of clipping may increase with repeated treatments over successive seasons. Delayed effects of clipping seem to be most common for low-growing grasses, such as blue grama (Bouteloua gracilis (H.B.K.) Lag.), buffalograss (Buchloe dactyloides (Nutt.) Engelm.) and Kentucky bluegrass. In a study by Albertson et al. (1), production of blue grama and buffalograss was not affected or increased after one year of clipping, but continued mid-season clipping reduced yields compared to plots clipped only at the end of the season. Graber (26) found that three close clippings of Kentucky bluegrass increased the first year's production but decreased the second year's production. Canfield (10) obtained essentially the same results with black grama (Bouteloua eripoda (Torr.) Torr.).

Height of cutting may be more important than frequency of cutting in grasses. Jacques and Edmond (37) found this to be true for orchard-grass and perennial ryegrass. Frequent clipping may prevent recovery of carbohydrate storage, and height of clipping becomes confounded with removal of various plant parts. Matches (45) studied the effect of clipping tall fescue (Festuca arundinacea Schrab.) to 1, 2.5 or 4 inches in a factorial combination of leaving 0, 10%, 20% or 30% intact (uncut) tillers. Increasing the height of stubble or leaving intact tillers increased tillering, yields, and carbohydrate reserves.

Generalizations about the effects of clipping at various times during the season are difficult because results have not been clear. Hedrick (29) concluded from his review of the literature that early removal of herbage was more harmful than later removal. Smith (61) found that clipping of native tropical tallgrass range of Northern Territory, Australia, early in the season reduced yields more than clipping later in the season. Sampson and McCarty (56), however, reported that two early clippings had little effect on total yield of purple needlegrass. Stoddart (63), working with bluebunch wheatgrass (Agropyron spicatum Scribn. and Smith) concluded that enough time should be left after the last defoliation or before the first defoliation for the plants to store carbohydrates before the end of the growing season. Over a four year period Knoblauch et al. (41) found that clipping timothy during anthesis was less detrimental than clipping during early heading.

Clipping generally reduces yield, but not in all cases. Fall mowing increased yield of crested wheatgrass from 1,374 pounds per acre to 1,755 pounds per acre (44). Cooper (16) recorded no effect of clipping at two, four, and six inches for four years in a native meadow in Oregon. Heinrichs and Clark (31) in southern Saskatchewan, Canada, found that Russian wildrye (Elymus junceus Fisch.), crested wheatgrass, and streambank wheatgrass (Agropyron riparium Scribn. and Smith.) produced more forage when cut at six-week intervals for five years than when cut at three- or eight-week intervals.

The relationship of dry matter yield to physiological processes has been studied. Leaf area index (LAI), which is the ratio of leaf area to ground area, has been studied in reference to pasture growth (21). If optimum LAI's are not present, production will be reduced by defoliation, since productivity depends on leaves to intercept light. Tall-growing grasses, such as orchardgrass, bromegrass, and basin wild-rye, that have most of their leaf area high on the plant are almost totally dependent on stored reserves to produce recovery growth after close clipping since all or most of the photosynthetic area is removed. The initial regrowth of short-growing grasses, such as Kentucky bluegrass and creeping red fescue (Festuca rubra L.) are less dependent upon stored reserves because clipping does not remove all photosynthetic material.

The location of the meristematic tissue and the manner in which the stems elongate may influence the response of grasses to clipping or grazing. Branson (8) and Rechenthin (55) have shown that grass species vary in the number of short basal internodes on the stems and also in the ratio of fruiting to vegetative stems. Branson (8) concluded that grasses producing mostly fruiting stems were less tolerant to grazing than those producing mostly vegetative stems.

The amount of regrowth produced by certain grasses following cutting in the spring may depend on the stage of bud development as well as the level of carbohydrate reserves. In bromegrass, Teel (65, 66) found the critical stage occurred when the young stems were beginning to elongate. Close spring clipping or grazing at this "early-jointing" stage removes the majority of the growing tips. Regrowth then had to come from basal buds. Regrowth was slow, however, because the basal buds were not yet well enough developed to initiate growth, or they initiated growth slowly. This critical stage or date when clipping removes the growing point is reached by different grasses on different dates. After bromegrass had reached the early heading stage, there was good regrowth, because the basal buds were well developed and readily initiated new growth (66).

Cook and Stoddart (15) found that if harvesting crested wheatgrass while the terminal bud was still relatively close to the crown removed any part of the developing culm below the uppermost culm node, regrowth came only from stimulated axillary buds at the base of the culm. If clipped above the last node, the shoot continued to elongate and develop.

It is apparent that in making reliable management decisions, knowledge of morphological and physiological development of grasses is needed. One needs to know when the shoots begin to elongate, the length of period of elongation, crown bud and tiller development, and the status of carbohydrate reserves at various stages of development.

Carbohydrate reserve and dry matter data have been used to formulate management concepts. Management practices and the effect of clipping often can be evaluated by observing the level of carbohydrate reserves. The effects of clipping on seasonal trends of carbohydrate reserves of species sensitive to spring grazing such as basin wildrye will help pasture and range managers to formulate better management systems (42).

Concerning this problem with basin wildrye, Krall et al. (42) reported the effects of differential herbage removal from growth initiation to full bloom, followed by removal of all growth to a 5 cm height in the fall. They found that yields were reduced in the year of clipping and the year following, particularly when plants were clipped at the boot stage. This period coincided with the rapid elevation of growing points above the soil surface and a decrease in total available carbohydrates (Figure 1).

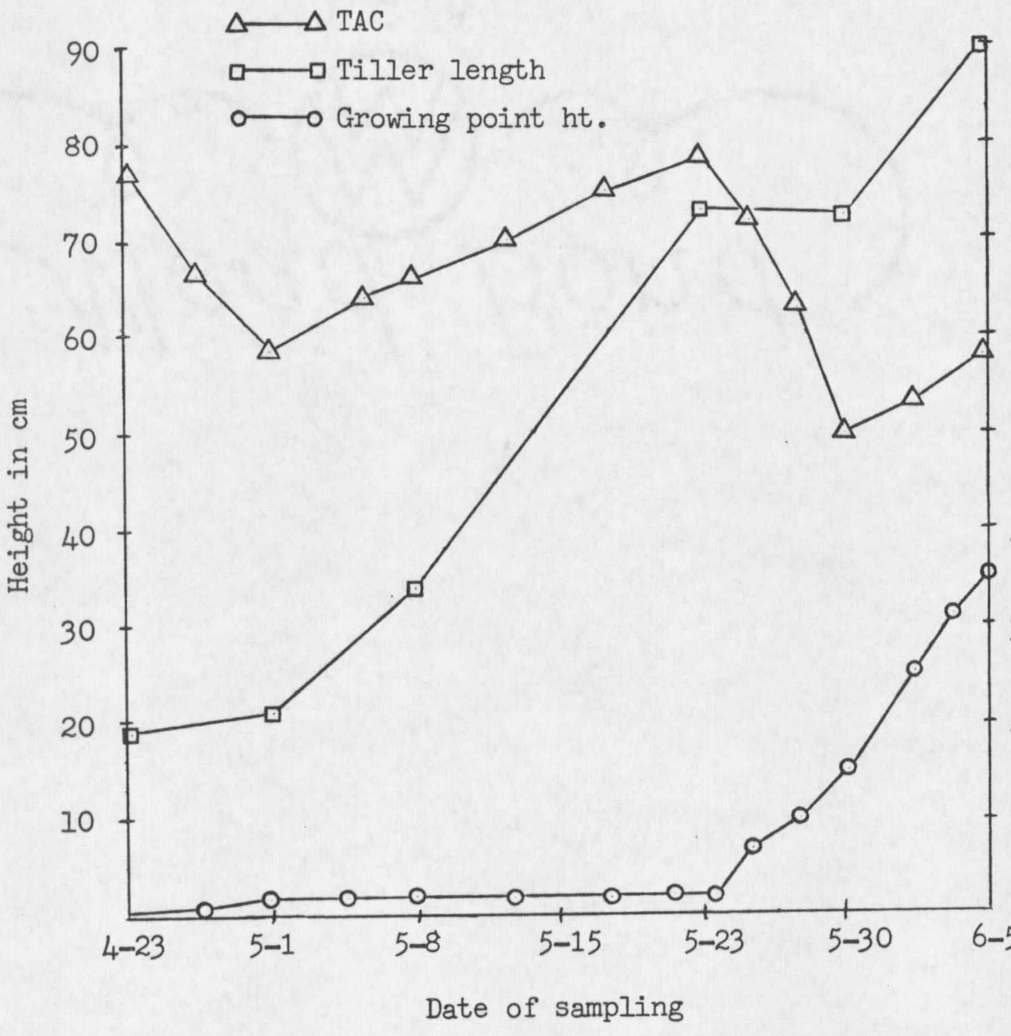

Figure 1. Tiller length, height of growing point and total available carbohydrates (TAC) in crowns of basin wildrye during the early spring growing season at Bozeman, Montana (42).

MATERIALS AND METHODS

Carbohydrate Studies

One thousand individual basin wildrye seedlings from a Soil Conservation Service accession, No. P-15609 (M-48)[1], were grown in peat-moss pots in the greenhouse to the 4-5 leaf stage. On August 5, 1970, 840 seedlings were transplanted to the field in a 3-foot grid and hand watered each day for one month to assure establishment. Replacements of the same age were transplanted for those seedlings which died. Nothing more was done with the nursery until Spring 1971. Individual plants were scored as to degree of vigor in the Fall, 1970, and Spring, 1971, on a visual scale of one (excellent) to five (poor). The nursery consisted of 28 rows and 30 columns with one row on the outside as a border.

To determine the seasonal trends in total nonstructural carbohydrates (TNC), four plants per date were analyzed for TNC beginning on April 20, 1971, and at seven day intervals thereafter until October 26. Plant height in cm was measured. For each sampling interval, location of the growing point and new tillers at the basal stem area were noted for each plant.

To determine the effect of one clipping on TNC, plants were clipped to 10 or 30 cm starting at three developmental stages. The developmental

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1/ Seed stocks were provided by the Soil Conservation Service, Plant Materials Center, Bridger, Mont. I gratefully acknowledge their cooperation.

stages were late vegetative (clipped on June 1), early boot (clipped on June 14), and inflorescences completely emerged (clipped on June 23). The immediate effect of clipping was measured by TNC samples taken 1, 2, and 3 weeks following the initial clippings for each developmental stage. TNC was also estimated 10 weeks after the initial clipping for the first two developmental stages and 11 weeks after the last stage. This interval represented recovery from clipping or the level of TNC going into the fall.

To determine the effect of two clippings on TNC, additional plants were reclipped three weeks after each initial clipping to 10 or 30 cm. TNC was estimated 1, 2, and 3 weeks following the second clipping as well as in the fall (i.e. the same time as those plants clipped once).

To determine the effect of clipping to 10 or 30 cm on dry matter accumulation, the herbage was removed to these heights from the plants which were sampled for TNC, and dried in an oven to a uniform moisture level of about 12%. Height of plant regrowth in cm was measured at each TNC sampling. The type of regrowth was scored in terms of vegetative and/or fertile tillers.

The experiment was conducted as a randomized complete block design with two replications. The basic experimental unit consisted of four plants. The net result is that each treatment mean is of eight plants treated alike. A separate analysis of variance was conducted for plants clipped once or twice within each developmental stage.

Therefore a total of six analyses of variance were conducted. The same procedure was used for dry matter accumulation and plant height.

During 1971 no supplemental irrigation or fertilizers were applied. Weeds were hand removed.

That portion of the plant which was analyzed for TNC was the basal 10 cm of all tillers except for those plants sampled for seasonal TNC during April and May. The basal 5 cm was analyzed during April and May as stem height was less than 10 cm. Leaf sheaths were not included in the sample. After removing the sampled portion from the plant, the material was washed and placed in an oven at 100 C for 60 minutes followed by 24 hours in an oven at about 70 C. The dried samples were passed through a 40-mesh Wiley Mill screen and stored for TNC analysis.

The method of TNC analysis was a modification by Smith (60) that was first described by Weinmann (72) and later changed slightly by Lindahl et al. (43). The TNC was extracted with takadiastase enzyme solution (Clarase 900, Miles Laboratories, Inc., Elkhart, Ind.). The fructosans extracted in the solution were hydrolyzed to monomers with sulfuric acid. Reducing power was measured by the Shaeffer-Somogyi copper-iodometric titration method as described by Heinze and Murneek (32). Results were reported on a percentage dry weight basis using a glucose standard.

In September 1971, two new tillers on each of 12 plants were tagged with fish line to determine if these were the following year's tillers.

Seasonal trends in TNC were also determined for 1970 and the spring of 1971 from plants grown in the dry matter management study nursery described below. Four plants per date were analyzed for TNC beginning on June 7, 1970, and at seven day intervals thereafter until September 14, 1970. During the spring, 1971 plants were sampled for TNC from April 6 to June 15 at seven day intervals. Plant height, height of growing point, and length of inflorescence in cm were also determined at each TNC sampling date in 1970. The basal 10 cm of a representative sample of tillers from each plant was analyzed. The basal 10 cm of the attached previous year's tillers were included for plants sampled during 1971 and June 1970 as it was felt the previous year's plant material was furnishing energy to the new tillers. For each TNC sampling period, except in 1971, the number of new tillers and individual tiller lengths were measured from 12 representative stems of a single plant.

Dry Matter Management Study

Individual basin wildrye seedlings from the S.C.S. collection, Wyo. 107, were grown in peat-moss pots in the greenhouse to the 2-3 leaf stage. Seedlings were then transplanted to the field in early August, 1968, in a 3-foot grid and hand watered each day for one month to assure establishment. Replacements of the same age were transplanted for those seedlings which died. In May, 1969, timothy was interseeded in 30 inch bands for weed control. Other than a single irrigation in mid-July, 1969, nothing more was done with the nursery until the spring of 1970. The nursery consisted of 28 rows and 34 columns with one row on the outside as a border.

No supplemental irrigation, except as noted above, or fertilizers were applied from 1969 to completion of the study. Weeds were hand cultivated during 1968 and the spring of 1969. Thereafter, weeds were hand removed. The growth of timothy throughout the study was controlled by mowing with a lawn mower to about two inches.

To determine the effect of clipping on dry matter production, individual basin wildrye plants were clipped to 45, 30, or 15 cm starting on June 6, 15, and 22, 1970. Dry matter accumulation was then measured at 3, 6, and 9 week intervals thereafter until the current year's production ceased. The material was dried in an oven to a uniform moisture content of about 12%. Height of growth in cm from soil surface to the top of the plant was also measured for each harvest. These treatments were also imposed during 1971 with three additional starting dates (May 17 and 25, and June 2), all earlier than in 1970. The same clipping treatments are being continued during 1972 and 1973 as part of a continuation of the present study. Plants were observed as to characteristics of regrowth, location of growing point, and relative size in growth at each harvest.