6-1946

Bulletin No. 324 - Some Physical and Chemical Responses of Agropyron Spicatum to Herbage Removal at Various Seasons

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Logan, Utah

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L. A. Stoddart[2]

MANAGEMENT of arid western ranges must be based upon the physiology of the individual plants which constitute the range. Too little is known of the ability of range plants to continue normal functioning under stress of grazing. Grazing doubtless has some beneficial influences in arid climates because it reduces transpiring surface. Possibly "pruning" has some stimulating effect, especially upon shrubs, and also, grazing animals plant seeds through trampling action. Despite these possible benefits, both trampling and removal of herbage by grazing must be regarded as fundamentally detrimental to the welfare of plants, especially in arid climates. Trampling, especially on wet soils during early spring months, is injurious to both mature plants and new seedlings; however, in general, removal of herbage is probably far more injurious. Ability of the individual plant to withstand herbage removal appears to be basically important in range conservation.

Studying effect of grazing by artificial means, such as clipping the herbage with shears, has been criticised, yet it seems the most sound method of studying forage plant physiology, since clipping permits accurate measurement of herbage yield. The experiment reported herein was designed to test the basic response of a single grass species to herbage removal at various seasons as measured by forage production and chemical composition.

Literature Review

PLANTS harvested frequently and closely are believed more susceptible to winter killing and drought injury (11, 14). Such harvesting is also known to affect reproduction by both rhizome and seed through reduction of plant vigor (4, 13, 24, 28). Frequency and height of clipping have been shown generally to affect herbage yield (2, 4, 10, 11, 15, 16, 23, 25). Generally, close clipping and frequent clipping proved more detrimental than less close and less frequent clipping.

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Sampson and Malmsten (22) found inverse correlation between frequency of harvesting and total yield from mountain grasses in the Wasatch range of Utah. Canfield (5) found that complete harvesting of desert grasses in New Mexico to two-inch height reduced basal area and forage yield severely, regardless of frequency and season of harvesting. Holscher (15) found that clipping western wheatgrass (*Agropyron smithii* Rydb.) reduced numbers of stems. For example, clipping each 2 weeks at 3 centimeters reduced numbers to 11 percent of the original in 4 years. Clipping each 4 weeks reduced numbers to 34 percent, and about the same loss resulted from clipping at 8 centimeters each 2 weeks. Herbage yields under these 3 treatments were reduced to 16, 38, and 79 percent, respectively, of the original.

A few exceptions have been reported in which frequent or close clippings were not the most harmful. Lang and Barnes (16) observed a greater yield of short grasses on the eastern Wyoming plains when harvested frequently at ground level than when harvested but once at the end of the growing season. Over a 2-year trial, no density decrease was observed to accompany the heavy clipping. Midgrasses, primarily western wheatgrasses, reacted differently, yield being reduced almost half by frequent clipping. Archibald, *et al.* (2) in eastern Canada, under conditions of high precipitation, found continued close clipping did not reduce the yield of bluegrass pasture. Clipping at one-half inch each 3 weeks resulted in better yields than did clipping at 1, 2, 3 or 4 inch heights. One cutting per season gave higher herbage yield than cutting each 1, 2 or 3 weeks, but, because of decreased protein in mature feed, clipping each 3 weeks gave the highest total protein yield and clipping each week gave the highest percentage of protein.

Most studies have dealt with frequency and intensity of clipping rather than season of clipping, although some have considered this factor (1, 3, 19). In general, early-season harvesting has proved more harmful, but, in other cases, harvesting at the time of seed formation was more harmful.

Many experiments have relied upon stored food reserves in the root as a measure of plant response to grazing. Frequent clipping reduces stored reserves and, in general, close clipping is more detrimental than less close. However, Brown (4) showed that Kentucky bluegrass cut at a 1-inch height stored carbohydrates in the rhizome in fall almost as rapidly as that cut at 2½ inches. In spring, when top growth was rapid, this was not true. Clipping at 1-inch semi-monthly had little effect upon roots in surface soil, but did reduce quantity of rhizomes. McCarty and

Price (19) found quantity of photosynthetic tissue present at the late-season storage period to be the most reliable index to quantity of carbohydrates stored by grasses. When clipped early, at 4-inch height, the growth cycle could be completed before the end of the growing season and near normal storage effected. Plants clipped during the period of active reproduction suffered higher percentage of death, and yielded less forage than plants clipped early or plants clipped at the end of the growing season. Plants clipped at the soil line 3 times at 5-day intervals immediately following snow disappearance for three years showed as great a carbohydrate content as did unclipped plants at the close of the grazing season. Season and intensity of clipping were found to be more important than frequency of clipping in determining food storage.

Herbage yield is not alone the measure of forage production, since quality also is directly influenced by method of harvesting. Experimental work has shown mature forage to be lower in protein and phosphorus and higher in fiber and lignin, hence less digestible. Delaying grazing may seriously impair the forage value of a range or pasture. Further, if plants are allowed to mature, they are less palatable to animals, hence "spotty" grazing results. Regrowth of already-grazed spots will be regrazed and old and mature plants will be unused. Local overgrazing in this way may cause serious damage to the range.

Methods have been developed for measuring chemically the value of range herbage whereby digestibility and general value to the animal can be closely approximated (6, 7, 12, 17, 21, 22). Norman (20) suggests that "it would be an important advance if the determination of the crude fiber fraction and its use in expressing composition were abandoned as inadequate, unreliable, and misleading." Rather than a carbohydrate breakdown to crude fiber and nitrogen-free extract as has been common practice, most nutritionists now suggest a breakdown to lignin, cellulose, and "other carbohydrates", or soluble carbohydrates. These other carbohydrates are nitrogen-free materials, largely sugar and starch, and generally are determined by subtraction.

Lignin is highly indigestible itself and degree of lignification of a forage plant probably indicates general digestibility more directly than any chemical constituent. As lignin increases progressively with plant maturity, it reduces the availability of cellulose and, perhaps to a lesser extent, the availability of almost all other constituents (12, 20). This may be accomplished either by physically incrusting the other constituents or by combining with them chemically to form unavailable compounds (21). Certainly the supposed "indigestible" crude fiber of the usual carbohydrate analysis is not the best index to forage value, for, actually, it may be as digestible as the supposed "digestible" nitrogen-free extract (7). Actually, in 25 percent of a group of 284 samples, crude fiber was as digestible as nitrogen-free extract, and averages for the entire experiment were 55.6 percent for crude fiber compared to 69.5 for nitrogen-free extract. In comparison, pasture grasses averaging 9 percent lignin proved to be digested as follows: lignin 2.2 percent, cellulose 52.9 percent, and other carbohydrates 86.4 percent.

Studies on pasture herbage by Crampton and Jackson (8) showed lignin to range from 2 to 58 percent digestible during the pasture season, with an average of 34 percent. Cellulose had a range of 41 to 84 percent, with 74 percent average, whereas soluble carbohydrates ranged from 75 to 85, with an 80 percent average.

Chemical analysis and digestibility studies on *Agropyron spicatum* in Montana (18) showed fall herbage to be low in protein, none of which was retained by lambs. The species was considered poor forage in the mature stage and failed to meet maintenance requirements for lambs.

Methods

THE experiment was conducted on a natural stand of *Agropyron spicatum* (Pursh) Scribn. and Smith (fig. 1), a bunchgrass which dominates most of the low-elevation grasslands in the northern intermountain region from northern Utah and Nevada to Canada (26), (fig. 2). The study plot was located on foothill land at 4800-foot elevation. near Logan, Utah. Annual precipitation averages 16.5 inches and falls largely as snow, 57 percent coming in the non-growing season (27). Summer heat and drought gen-

Figure 1. A natural stand of almost pure *Agropyron spicatum* in northern Utah upon which these studies were conducted

Figure 2. Bunch wheatgrass—*Agropyron spicatum*

erally are such as to prohibit grass growth between about June 15 and October 1. Spring growth begins normally about April 1, but is very slow previous to about May 1.

To facilitate observation of the response of individual plants, 400 single and well-defined bunches of grass were selected and marked by permanent, numbered, wire stakes. The plants were in 4 blocks of 100 plants each. The clipping plan was identical on each block, except 2 blocks were cut at 1-inch height and the others at 2-inch height. The 100 plants in each block were further designated into 10 groups of 10 plants each. Each of the 10 groups was clipped at a different season or frequency, and herbage from each of the 10 plants of each group was collected, air-dried, and weighed separately. At each date, the material from each 10-plant group was composited after weighing to constitute a sample for chemical analysis. The clipping program was as follows:

Group 1. April 15, April 22, May 1, May 7.
Group 2. May 1, May 7, May 15, May 22.
Group 3. May 15, May 22, June 1, June 7.
Group 4. June 1, June 7, June 15, June 22.
Group 5. April 15, May 1, May 15.
Group 6. May 15, June 1, June 15.
Group 7. April 15, May 1, May 15, June 1, June 15.
Group 8. September 15, October 1, October 15, November 1.
Group 9. May 1, May 7, May 15, May 22, September 15, October 1, October 15, November 1.
Group 10. Check, clipped December 1.

It will be noticed that clipping was weekly for 4 consecutive periods, biweekly for 3 consecutive periods, or biweekly for 5 consecutive periods. Weekly clipping was tested at 4 dates in the spring and biweekly clipping was tested at 2 dates. In addition, fall clipping was tested both with and without spring clipping.

All plants were cut at 1-inch height on December 1, at which time the tops were considered in a state of dormancy or, actually, no longer living. The yields at this date were used in calculating total annual production of herbage. The first such clipping was made in 1943, at which time all plants were clipped and weighed to determine a "base" weight for use in measuring response to future clipping treatments. Yields in later years were calculated in terms of percent of the initial weight, and were adjusted according to yield of the "check" groups to eliminate annual variation. Differential clippings to determine plant response were begun in April of 1944 and continued for 2 years.

Chemical analysis by methods of the Official Agricultural Chemists was used to determine crude protein, phosphorus, total ash, and ether extract of each sample. Lignin, cellulose, and "other carbohydrates" were determined by the methods suggested by Patton (22). In 1945, because of reduced yields resulting from intensive clipping, 1-inch clippings were combined with 2-inch clippings to procure sufficiently large samples for analysis. The 1944 analyses showed little significant difference between 1-inch clippings and 2-inch clippings, hence for comparison with 1945 data, the 1944 data were averaged to obtain a single datum for each clipping.

Check-plot yields showed 1943 to be the highest producing year, followed in order by 1945 and 1944. Both 1944 and 1945 were abnormally wet in the spring growing months, but cold weather delayed growth and reduced total production.

Phenological development was about 10 days earlier in 1945 than in 1944 during April, but cold weather in late April and late May reduced growth rate; therefore, development in 1945 was only 7 days earlier by mid-May, and little or no difference existed by the end of June.

Growth records obtained in the 2 years are summarized below:

	1944	1945
April 1.	Winter snow covering part of plots Agropyron 0-1 inch high	Snow-free since March 15 Agropyron 1-2 inches high
April 15.	Snow and cold Agropyron 1½-2 inches high	Snow and cold Agropyron 2-2½ inches high
May 1.	Very wet and cold Agropyron 3-4 inches high	Warm and dry Agropyron 5-6 inches high

May 15.	Hot and dry Agropyron 8-10 inches high	Cold and very wet Agropyron 12-14 inches high
June 1.	Wet and cold Agropyron 14-20 inches high, heads just showing in sheath	Wet and cold Agropyron 16-20 inches high, heads just showing in sheath
June 15.	Very wet and cold Agropyron 20-22 inches high, heads fully out of sheath	Very wet and cold Agropyron 20-24 inches high, heads fully out of sheath
July 1.	Dry and cool Agropyron in anthesis	Average moisture and hot Agropyron in anthesis

For purpose of applying the data to other areas and species, the following phenological correlations are interesting:

Agropyron 4-6 inches high:
- White loco (*Astragalus cibarius* Sheld.)....beginning bloom
- Yellow violet (*Viola vallicolla* A. Nels.)................full bloom
- Wild carrot (*Lomatium Graylii* C. and R.)................full bloom

Agropyron 10-12 inches high:
- Balsam root (*Balsamorhiza sagittata* (Pursh) Nutt..full bloom
- Stone seed (*Lithospermum ruderale* Dougl.)..........full bloom
- Bitterbrush (*Purshia tridentata* (Pursh) D C.)................ just beginning bloom
- Wild dandelion (*Agosaris glauca* (Pursh) D. Dietr.) just beginning bloom
- Dock (*Wyethia amplexicaulis* Nutt.)....showing yellow petals
- Death camas (*Zygadenus paniculatus* S. Wats.)............. beginning bloom
- Phlox (*Phlox longifolia* Nutt.)....................................full bloom
- Sandberg's bluegrass (*Poa secunda* Presl.)...................... head evident, stamens not exerted
- Blue penstemon (*Penstemon cyananthus* Hook.)........full bud
- Low larkspur (*Delphinium Menziesii* D C.)..beginning bloom

Agropyron 12-16 inches high:
- Stickseed (*Hackelia floribunde* (Lehm.) Johnston..full bloom
- Blue penstemon (*Penstemon cyananthus* Hook.)............. beginning bloom
- Bitterbush (*Purshia tridentata* (Pursh) D C.)......full bloom

Dock (*Wyethia amplexicaulis* Nutt.)............beginning bloom
Low larkspur (*Delphinium Menziesii* D C.)............late bloom
White loco (*Astragalus cibarius* Sheld.)..........very late bloom
Downy bromegrass (*Bromus tectorum* L.)..................anthesis
Sandberg's bluegrass (*Poa secunda* Presl.)..............anthesis
Red paintbrush (*Castilleja angustifolia* (Nutt.) G. Don.) beginning bloom

Agropyron heads beginning emergence:

Bitterbrush (*Purshia tridentata* (Pursh) D C.)....blooms gone
Sandberg's bluegrass (*Poa secunda* Presl.)................in milk
Downy bromegrass (*Bromus tectorum* L.)......in milk to dough
Yarrow (*Achillea lanulosa* Nutt.)...................................late bud
Red paintbrush (*Castilleja augustifolia* (Nutt.) G. Don.) full bloom
Dock (*Wyethia amplexicaulis* Nutt.)..........................full bloom
Blue penstemon (*Penstemon cyananthus* Hook.)....full bloom
Death camas (*Zygadenus paniculatus* S. Wats.).......full bloom
Stickseed (*Hackelia floribunda* (Lehm.) Johnston....full bloom
White loco (*Astragalus cibarius* Sheld.).............blooms gone

Agropyron heads fully emerged, pre-anthesis:

Yarrow (*Achillea lanulosa* Nutt.)................................full bloom
Sandberg's bluegrass (*Poa secunda* Presl.)........in early dough
Downy bromegrass (*Bromus tectorum* L.)...................in dough
Wild rose (*Rosa Fendleri* Crepin)..................beginning bloom
Sego lily (*Calochortus Nuttallii* Torr. and Gray).......... beginning bloom

Agropyron in anthesis:

Dock (*Wyethia amplexicaulis* Nutt.)...................blooms gone
Blue penstemon (*Penstemon cyananthus* Hook.)..blooms gone
Bitterweed (*Senecio utahensis*)........................beginning bloom
Alfalfa (*Medicago sativa* L.)...........................beginning bloom
Sego lily (*Calochortus Nuttallii* Torr. and Gray)....full bloom

Results

AFTER clipping had been carried on for a single growing season, pronounced physiological responses became apparent. Several plants were killed by as few as 4 clippings at 1-inch height, and all spring clipping, regardless of intensity, resulted in significantly reduced yield. At the beginning of the second growing season, heavily clipped plants showed more spindling shoots, but were not later beginning spring growth. Number of stems rather than height or season of growth seemed most affected by clipping.

Heavy death losses were incurred during the second season under all clipping treatments, excepting very early spring clipping and fall clipping (table 1). In all cases, clipping at 1-inch height was more injurious than clipping at 2-inch height.

Table 1. *Effect of various clipping treatments upon average herbage yield and survival of Agropyron spicatum. All yields include one clipping made December 1. Yields are expressed in percentages of original (1943) yield adjusted by check-plot yields to eliminate natural yearly variation in yield*

Group	Clipping treatment	Percent total annual yield was of original yield 1944	1945	Percent of original plants alive fall of 1945
		percent	*percent*	*percent*
	Average of blocks clipped at 1-inch height			
1	Weekly, April 15-May 7	41.34	20.49	100
2	Weekly, May 1-May 22	23.48	1.24	25
3	Weekly, May 15-June 7	40.95	4.25	50
4	Weekly, June 1-June 22	79.00	6.91	55
5	Biweekly, April 15-May 15	35.03	11.41	75
6	Biweekly, May 15-June 15	45.13	2.99	20
7	Biweekly, April 15-June 15	30.36	.37	0
8	Biweekly. Sept. 15-Nov. 1	128.41	88.02	100
9	Spring and fall	30.65	2.88	65
	Average of blocks clipped at 2-inch height			
1	Weekly, April 15-May 7	53.54	40.17	100
2	Weekly, May 1-May 22	38.80	9.93	90
3	Weekly, May 15-June 7	49.89	7.48	50
4	Weekly, June 1-June 22	70.30	8.53	75
5	Biweekly, April 15-May 15	76.67	39.75	100
6	Biweekly, May 15-June 15	46.92	5.04	35
7	Biweekly, April 15-June 15	37.20	3.35	45
8	Biweekly, Sept. 15-Nov. 1	109.18	73.21	100
9	Spring and fall	57.50	17.48	90

Examination of yield data in table 1 suggests that date of cessation of clipping is the factor of greatest importance to the physiology of the plant. Frequency of clipping seems much less important. In areas of little or no summer growth, spring-grazed plants must be given opportunity to regrow before the dormant period if they are to avoid serious physiological disturbance. This is evidenced by the fact that plants not clipped after mid-May suffered less injury than any other spring-clipped plants, regardless of height of clipping. Almost no death loss occurred among these plants and greater herbage production was attained.

It must be remembered in considering table 1, that the data do not represent forage that would be available in the "grazing season" represented, since regrowth made after the grazing season was harvested on December 1 and this yield was added to make the total annual yield as shown in the table. The data are, however, an index to physiological normality of the plant when grazed at the dates indicated. Yields in the "grazing season" alone will be discussed later.

The importance of early cessation of clipping is forcefully demonstrated by comparing group 1 and group 5 in the 1-inch clipping blocks. Group 1 was clipped weekly four times, but not after May 7. Group 5 was clipped only three times and only each 2 weeks. The last clipping date, however, was May 15. Despite more clippings and reduced time-intervals, group 1 produced almost twice as much during the second year and suffered no death loss as compared to a 25 percent loss in group 5.

When group 1 is compared to group 2, a similar condition is found. Group 2 was clipped exactly the same, except all clippings were 2 weeks later. This 2 weeks reduced the yield in plants clipped at 1-inch level to about 6 percent of the group 1 yield and resulted in 75 percent death loss as compared to no loss in group 1.

There is evidence that if the grass is allowed a growth period before clipping begins, during which time it can store food, it suffers less damage from late spring clipping. Slightly greater yields and lesser death losses occurred in the 1-inch clipping blocks when weekly clipping was not begun until May 1 or June 1, even though this extended the clipping later into the spring. Presumably when clipping was continued late enough in spring so that regrowth was not possible, then further delay, as in groups 3 and 4, did not make the summer situation any more disastrous, yet it did provide a longer period of food manufacture previous to clipping. When plants were clipped at 2-inch height, cessation of clipping on June 7 proved most harmful, whereas when plants were clipped at 1-inch height, May 22 was most harmful.

Group 7, which was clipped in both early and late spring, suffered a worse reduction in herbage yield than did any other group, even though it was clipped only each 2 weeks. At 1-inch clipping level, the plants were all killed in 2 years and many were killed in only 1 year.

Fall clipping reduced yields somewhat in the second year. Apparent increase in yield on fall-clipped plots the first year resulted from comparing to check plots clipped on December 1, 2½ months later. Natural corrosion and weathering reduced check-plot yields below what might have been expected had they been clipped in September, as were grasses in group 8.

Yield During Grazing Season

Actually, yields shown in table 1 are not true indexes to forage yields, since they represent total annual production, including the aftermath and regrowth which was harvested at 1-inch height from all plants on December 1. The material harvested during the clipping season or "grazing season" simulated under various treatments would represent herbage available to animals grazing a range during the various periods. Data in table 2 show how yield from each treatment during the "grazing season" compared to yield from the "ungrazed" check plot when adjusted to allow for natural differences in original yield from various plant

Table 2. *Adjusted yields of Agropyron spicatum showing (1) yield in percent of ungrazed plot yields produced in the "grazing season" (i. e., excluding aftermath harvested at the end of the growing season) and (2) percent of the total annual production which was harvested in the "grazing season" as contrasted to that remaining as aftermath and harvested at the end of the growing season*

Group	(1) Percent grazing-season yield was of ungrazed "check" plot yield		(2) Percent grazing-season yield was of total annual production	
	1944	1945	1944	1945
	percent	*percent*	*percent*	*percent*
Average of blocks clipped at 1-inch height				
1	14.0	7.2	34.0	35.3
2	21.9	0.9	93.4	74.3
3	39.5	3.9	96.4	93.1
4	75.8	6.8	96.0	99.5
5	20.5	5.8	58.6	50.5
6	44.7	2.8	99.1	96.3
7	30.4	0.4	100.0	100.0
8	128.4	80.0	100.0	90.9
9	30.6	2.9	100.0	100.0
Average of blocks clipped at 2-inch height				
1	8.3	5.6	15.5	14.0
2	21.8	4.4	56.3	43.8
3	34.9	6.2	70.0	83.6
4	56.9	7.5	80.9	87.9
5	23.6	10.3	30.8	25.9
6	34.5	4.5	73.5	90.0
7	28.9	2.8	77.6	84.2
8	96.2	63.7	88.1	87.1
9	44.4	13.8	77.3	79.1

Table 3. *Chemical analysis of Agropyron spicatum at initial clipping at various dates, together with certain carbohydrate relationships. Average of herbage clipped at one and two-inch heights, expressed in percent dry basis*

Date	Phenological stage	Crude protein	Fat	Total ash*	Phosphorus	Total Carbo-hydrates†	Lignin	Cellulose	Other carbo-hydrates	Cellulose to lignin ratio	Other carbo-hydrates to lignin ratio	Percent lignin is of total carbo-hydrates
		percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
April 20, '44	2 inches high	26.24	2.75‡	8.56	.489	62.45	3.96	24.21	34.28	6.11	8.66	6.34
May 1, '44	3-4 inches high	24.91	2.55	8.39	.439	64.15	5.14	24.93	34.08	4.85	6.63	8.01
May 15, '44	8-10 in. high	19.28	2.80	8.75	.332	69.17	6.45	30.88	31.84	4.78	4.93	9.32
June 1, '44	Heads just protruding from sheath	13.38	2.69	7.04	.250	76.89	8.28	33.14	35.47	4.00	4.28	10.77
June 15, '44	Heads fully out of sheath	9.12	2.52	6.80	.190	81.56	9.35	33.99	38.22	3.64	4.09	11.46
Sept. 15, '44	Dry and mature	2.92	3.06	7.45	.073	86.57	12.92	32.88	40.77	2.54	3.16	14.92
April 1, '45	Old growth	2.50	2.42	6.45	.036	88.63	17.70	43.24	27.69	2.44	1.56	19.98
April 15, '45	2-2½ in. high	23.37	3.90	8.95	.432	63.78	5.62	24.75*	33.41	4.40	5.94	8.81
May 1, '45	5-6 in. high	23.62	4.12	9.76	.345	62.50	6.24	25.53	30.73	4.09	4.92	9.98
May 15, '45	12-14 in. high	17.00	3.41	8.18	.282	71.41	7.30	28.06	36.05	3.84	4.93	10.22
June 1, '45	Heads just protruding from sheath	14.12	2.82	8.53	.292	74.53	8.88	32.56	33.09	3.67	3.72	11.91
June 15, '45	Heads fully out of sheath	9.75	2.67	7.07	.208	80.51	11.00	33.32	36.19	3.03	3.29	13.66
Sept. 15, '45	Dry and mature	4.62	3.14	8.93	.135	83.31	14.48	31.84	36.99	2.20	2.55	17.38

*Includes phosphorus
†Composed of lignin, cellulose and other carbohydrates
‡Estimated

groups. During the first year, very early clipping resulted in low yield, since plants had not grown large previous to clipping. Yield from early-clipped plants was high in the second year, because the plants had better vigor than plants clipped at later dates. Plants on which clipping was started latest in the spring and which, therefore, had the longest time for early-spring food synthesis, produced the second largest percent yield among the spring-clipped groups during the second year. Plants clipped both early and late (group 7) produced the lowest percentage yield.

Shown also in table 2 are data concerning "grazing season" yield as compared to total annual production (i. e., material harvested during the course of the regular clipping treatments plus aftermath and regrowth harvested December 1). In all cases, early clipping resulted in the lowest percent of total yield being harvested during the grazing season, hence the highest percent being allowed to remain for food synthesis during the growing season. This may explain in part the lesser damage resulting from early-season clipping. These percentages are in a way analogous to "utilization percent" as used in range management to apply to the percent of total herbage production which is harvested by grazing animals. Here, however, differences in "utilization" result primarily from differences in quantity of regrowth after clipping ceased. In addition, plants clipped at 2-inch height had lower "utilization" than plants clipped at 1-inch height, since the 2-inch clipping left some stubble or aftermath which was not harvested until December 1 as a portion of the total annual production.

Fall clipping resulted in very high "utilization" percentage, because it was so late as to allow little or no regrowth. Yet it resulted in the highest total production and the least damage to the plant as measured by death losses. This demonstrates that season of grazing must be considered in interpreting range utilization. Likewise, in estimating utilization, season must be considered, for table 2 shows, in 1945, utilization from 35.3 up to 100 percent, despite the fact that all plants were harvested at identical height. Plants "grazed" from April 15 to May 7 were harvested as closely as a cow can graze on four occasions, yet "utilization" was only 35.3 percent.

Chemical Analyses

Chemical analysis showed protein level to drop consistently as the grasses matured, old and weathered material having only about one-tenth as much protein as did the first growth in the spring (table 3). For example, leaves two inches high in the spring of 1944 contained an average of 26.24 percent protein. When the heads first protruded, the protein had dropped to about one-half the spring level and by fall had dropped to 2.92 percent, or slightly over one-tenth of the spring level.

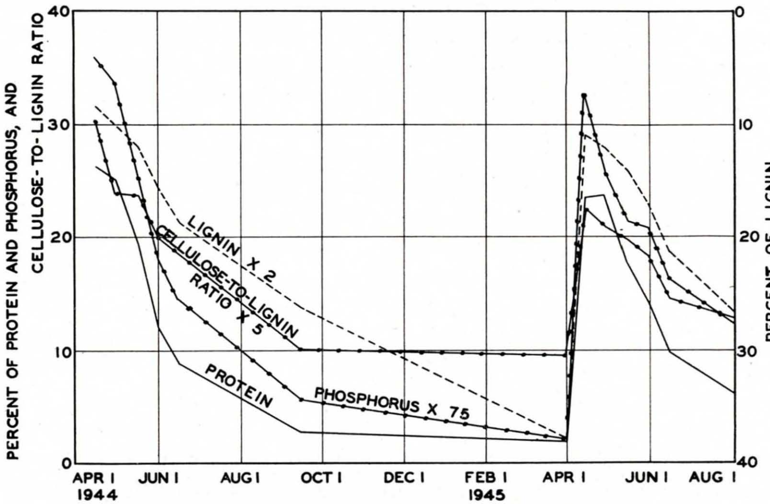

Figure 3. Some chemical constituents of *Agropyron spicatum* at initial clipping at various dates

Very close parallelism is noted between protein and phosphorus (fig. 3). Phosphorus was high in spring, but reached levels in the fall and winter below requirements for all grazing animals. Early-spring growth in 1944 contained .489 percent phosphorus. This level dropped, however, to .073 percent by early fall and to .036 percent by the end of winter, according to numerous studies on range forage. Levels of at least .12 to .15 percent appear to be necessary for proper balance in the diet of all grazing animals.

Total carbohydrate content of this grass increased consistently as age of the herbage increased. However, when the composition of the carbohydrate fraction is considered, some interesting variations are observed. Lignin, considered an excellent index to general digestibility of herbage, increased consistently from as low as 3.96 percent in very early spring to as high as 13 to 14 percent in early fall and 17.7 percent in late winter. Cellulose, intermediate in digestibility, increased from early to late spring, was again lower in autumn and was again very high at the end of winter. Exactly when these breaks occurred is not known. The "other carbohydrates," largely soluble and readily digestible by the grazing animal, showed no trend in early spring, but appeared to be increasing by late spring. By fall they were at the highest level, but by the end of winter were at a very low level.

Certain ratios between these carbohydrate fractions are also of great interest. The cellulose-to-lignin ratio has been proposed by Norman (20) as an even better index to general forage digestibility than is lignin alone, high ratios indicating high digestibility. The ratio between cellulose and lignin in this study decreased consistently as the herbage increased in age. Thus, although both lignin and cellulose increased with maturity of the plant, the lignin increase was of much greater magnitude. This increasingly large quantity of indigestible lignin presumably encrusts the cellulose and makes it less subject to bacterial digestion within the ruminant stomach.

The ratio of "other carbohydrates," the most available fraction of the carbohydrates, to lignin also decreases regularly as the season progresses. For example, in early spring of 1944, the forage contained 8.66 times as much of the more readily digestible "other carbohydrates" as the indigestible lignin. By early fall the ratio was only 3.16 and, by the end of winter, there was only a 1.56 ratio.

Lignin makes up an increasingly large percentage of the total carbohydrates as herbage matures. In early spring of 1944, lignin made up but 6.34 percent of the total, but increased to about 15 percent by early fall and to about 20 percent by the end of winter.

Chemical Analysis of Regrowth

Chemical study was also made upon the regrowth of grass harvested at various dates to determine whether seasonal decline in forage value was overcome by close grazing.

Regrowth 1 week old and regrowth 2 weeks old was found in general to decrease in forage value with each successive clipping, although the decline was infinitely less rapid than was found in herbage previously unclipped (table 4). Generally, protein and phosphorus tended to decline as the season progressed, whereas lignin tended to increase (fig. 4). No trend was evident in cellulose-to-lignin ratio.

There was definite evidence among plants clipped during mid-spring of herbage quality being higher at the second clipping date (table 5). This resulted from the older herbage harvested at the initial clipping having already deteriorated in quality and

Table 4. *Some chemical constituents expressed in percent, dry basis, of Agropyron spicatum herbage, when plants were reclipped at two-week intervals as compared to plants harvested the same date but not previously clipped*

Date	Crude protein		Phosphorus		Lignin		Cellulose		Other carbohydrates		Cellulose to lignin ratio	
	First clipping	Re-clipped	First clipping	Re-clipped	First clipping	Re-clipped	First clipping	Re-clipped	First clipping	Re-clipped	First clipping	Re-clipped
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
April 20, 1944	26.24	26.09	.49	.48	3.96	4.03	24.21	24.16	34.28	32.55	6.11	5.99
May 1, 1944	24.91	27.60	.44	.54	5.14	4.38	24.93	26.70	34.08	28.75	4.85	6.09
May 15, 1944	19.28	28.28	.33	.41	6.45	5.69	30.88	31.31	31.84	22.11	4.78	5.50
June 1, 1944	13.38	18.93	.25	.45	8.28	6.64	33.14	34.77	35.47	27.05	4.00	5.24
June 15, 1944	9.12	19.91	.19	....	9.35	6.52	33.99	35.59	38.22	27.86	3.64	5.45
April 15, 1945	23.37	23.37	.43	.43	5.62	5.62	24.75	24.75	33.41	33.41	4.40	4.40
May 1, 1945	23.62	23.81	.34	.38	6.24	5.48	25.53	26.25	30.73	30.52	4.09	4.79
May 15, 1945	17.00	18.19	.28	.34	7.30	6.44	28.06	32.51	36.05	32.13	3.84	5.05
June 1, 1945	14.12	16.75	.29	.36	8.88	6.40	32.56	34.83	33.09	31.14	3.67	5.44
June 15, 1945	9.75	15.25	.21	.36	11.00	6.86	33.32	33.10	36.19	34.12	3.03	4.83

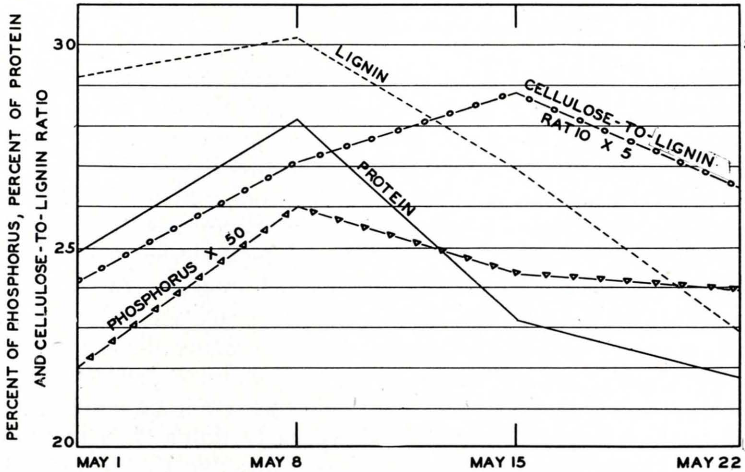

Figure 4. Some chemical constituents of *Agropyron spicatum* reclipped at weekly intervals during May, showing improved forage value of herbage after first cutting

new growth harvested at the second clipping being distinctly higher in quality. Subsequent herbage yield tended to decline in forage value with each clipping. For example, in table 5 are shown analyses of plants clipped May 1 and each week thereafter for 4 consecutive weeks. A glance at the 1944 analysis shows protein to increase the second week and to decline in both the third and fourth weeks. Phosphorus follows a similar curve and lignin is exactly reversed, with the lowest level occurring at the second clipping.

Table 5. *Some chemical constituents of Agropyron spicatum herbage when reclipped at one-week intervals expressed in percent, dry basis*

Date	Crude protein	Phosphorus	Lignin	Cellulose	Other carbo-hydrates	Cellulose to lignin ratio
	percent	*percent*	*percent*	*percent*	*percent*	*percent*
May 1, 1944	24.91	.44	5.15	24.93	32.17	4.84
May 8, 1944	28.34	.52	4.98	27.24	26.60	5.47
May 15, 1944	23.31	.49	5.57	32.26	26.25	5.79
May 22, 1944	21.93	.48	6.39	33.91	26.57	5.31
May 1, 1945	23.62	.34	6.24	25.53	30.73	4.09
May 8, 1945	22.44	.35	6.09	31.18	28.25	5.12
May 15, 1945	18.19	.34	6.44	32.51	32.13	5.05
May 22, 1945	19.62	.42	6.30	33.03	29.59	5.24

Discussion and Conclusions

THE results of clipping *Agropyron spicatum* to determine effect of season of herbage removal upon yield showed very early spring grazing to be less harmful than later spring grazing, because it allowed regrowth before the end of the growing season, hence plants had a significant quantity of foliage for photosynthesis during the summer months. Further, the early-spring clipping resulted in a lower percentage of herbage removed, because the plants were still small when clipped. When translated in terms of grazing, early use might have a disadvantage, because soil generally is wet in early spring and animals grazing at this time are likely to compact and displace soil as well as to trample plants, especially seedlings, into the soil. Chemically, the plant appears to be much more nutritious and easily digested at these early dates than at later dates. Further, young foliage is more attractive to the animal, hence is eaten in larger quantity, with greater gains resulting. By fall, the forage not only is of low nutritive value, but also it is so dry and unattractive to the animal that good gains without protein and phosphorus supplement appear unlikely.

Since clipping vegetation removes all items from the clump, which is unusual in actual grazing, and since even the 2-inch clipping height was probably somewhat more intense than normal grazing would effect, only the most serious overgrazing would result in as great plant damage as herein reported. However, the close "utilization" practiced in this clipping does serve to show the season in which the grass is most subject to injury. Very different results might have been expected in a climate where summer growth is possible. Drought in early summer prohibits regrowth after about June 1 in the area where this study was conducted. Hence clipping must cease well before that date if the plant is to manufacture new leaves to carry on photosynthesis during the non-growing season. Damage to this grass from herbage removal was in inverse proportion to the amount of herbage exposed to sunlight during the warm season as attained by (a) less close clipping, (b) clipping early enough to allow regrowth, or (c) clipping late enough to allow food storage before herbage was removed.

Although no summer clipping was studied, since this foothill range is a spring-fall grazing area, there is reason to believe that summer grazing would become increasingly less harmful to the plant as date of grazing is delayed. Therefore, it is concluded that, in this climate, *Agropyron spicatum* is physiologically most subject to grazing damage during the month of May. Earlier grazing is less harmful and later grazing becomes progressively less harmful. Any system of close removal of herbage likely induces a detrimental disturbance of normal photosynthetic activity of the plant.

Chemical composition and nutritive value of *Agropyron spicatum* vary directly with season of the year. Protein and phosphorus, which are the most likely deficiencies in the animal diet on these ranges, are abundant in early spring, but become deficient by fall. Lignin, a key to digestibility, increases with maturity of the plant. Both this fact and the steadily decreasing cellulose-to-lignin ratio indicate rapid decline in forage value as the plant matures. However, at least throughout the month of June, the plant appears to retain very satisfactory feeding value and surely is less subject to grazing damage at this time than in somewhat earlier stages.

It has been observed (26) that foothill grass range throughout a large part of the intermountain region has suffered serious disturbance from livestock grazing. The majority of the former bunchgrass ranges have passed from perennial grass to either downy bromegrass (*Bromus tectorum* L.) or to big sagebrush (*Artemisia tridentata* Nutt.). The former is an annual grass able to thrive by early spring growth, with seed development preceding normal summer drought. The latter is a deep-rooted shrub which thrives because its deep roots are able to tap sub-soil moisture reserves during dry summer months. These foothill ranges are grazed in the spring months by cattle and sheep in transit from desert winter range to mountain summer range. Concentrated grazing has been the practice on spring range in most of Utah, because of limited acreage of foothill range compared to mountain and desert range. This concentrated grazing is at the very season when herbage removal is most detrimental to the plant and accounts for the widespread deterioration of the range. The climate is such as to make spring-fall use of this land almost essential, yet the climate is unsuited to grasses, except early-growing species which depend almost entirely upon winter and early spring precipitation for growth. This grassland range appears ill suited to spring use and has suffered accordingly.

These studies emphasize the importance of careful management of foothill grassland ranges in the intermountain country. The management should be founded upon light utilization in spring months by reduced numbers and possibly upon a deferred rotation system whereby normal growth is permitted throughout the spring months at least each third year. Deferring grazing until the grass is 4-6 inches high, as is often suggested, does not appear to be the solution, since the grass is very subject to grazing injury at this time. Less intensive utilization appears of much greater importance.

Summary

STUDIES were conducted on a foothill range near Logan, Utah, to determine physical and chemical response of bunch wheatgrass, *Agropyron spicatum*, to clipping at various dates and intensities.

Four hundred individual plants were marked and harvested over a 2-year period. Herbage yield was weighed and analysis was made to determine crude protein, fat, total ash, phosphorus, lignin, cellulose, and other carbohydrates. In addition, certain carbohydrate relationships were determined.

Both herbage yield and death losses suggest that, in early spring, date of cessation of clipping was the most important factor influencing plant response, early cessation being least harmful. In late spring and summer, date of beginning clipping was the most important factor, late beginning being least harmful. In summary, damage to the grass from herbage removal was inversely proportionate to herbage exposed to sunlight during the warm season as attained by (a) less close clipping, (b) clipping early enough to allow regrowth prior to summer drought, or (c) clipping late enough to allow food storage before herbage was removed.

All chemical analyses indicated progressive decline in forage value of the plant as herbage matured and weathered. This decline was marked by regular decrease in such important components as protein and phosphorus and by regular increase in indigestible lignin. Both increasing lignin and decreasing cellulose-to-lignin ratio suggest decreasing digestibility. Regrowth herbage declined somewhat in forage value as season progressed, but retained far higher value than did unclipped herbage.

It was concluded from these studies that the intermountain climate, marked by summer drought, is ill suited to perennial grasses for spring grazing, therefore, careful range management is important to maintain production. This management should be founded upon moderated intensity of grazing and upon deferred grazing throughout the entire growing season under a rotation system rather than upon short-time deferment in the spring.

Literature Cited

1. Aldous, A. E. Management of Kansas permanent pastures. Kansas Agr. Exp. Sta. Bul.272. 1935.
2. Archibald, E. S., *et al.* Pasture improvement in eastern Canada. Canada Dept. Agr. Farmers' Bul. 51. 1938.
3. Bailey, R. Y., and Mayton, E. L. Kudzu in Alabama. Ala. Agr. Exp. Sta. Cir. 57. 1931.
4. Brown, E. Marion. Seasonal variation in the growth and chemical composition of Kentucky bluegrass. Mo. Agr. Exp. Sta. Res. Bul. 360. 1943.
5. Canfield, R. H. The effect of intensity and frequency of clipping on the density and yield of black grama and tobosa grass. U. S. Dept. Agr. Tech. Bul. 681. 1939.
6. Crampton, E. W., and Whiting, Frank. A proposed scheme of feeding stuffs analysis. Jour. Anim. Sci. 2 (4): 278-284. 1943.
7. Crampton, E. W., and Maynard, L. A. The relation of cellulose and lignin content to the nutrition value of animal feeds. Jour. Nutr. 15: 383-395. 1938.
8. Crampton, E. W., and Jackson, I. R. C. Seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. Jour. Anim. Sci. 3 (4): 338-339. 1944.
9. Ellett, W. B., and Carrier, L. The effect of frequent clipping on total yield and composition of grasses. Amer. Soc. Agron. Jour. 7 (2): 85-87. 1915.
10. Gernert, W. B. Native grass behavior as affected by periodic clipping. Amer. Soc. Agron. Jour. 28 (6): 447-456. 1936.
11. Graber, L. F., and Ream, H. W. Growth of bluegrass with various defoliations and abundant nitrogen supply. Amer. Soc. Agron. Jour. 23 (11): 938-944. 1931.
12. Guilbert, H. R., and Goss, H. Digestion experiments with range forages and flax hulls. Calif. Agr. Exp. Sta. Bul. 684. 1944.
13. Hanson, W. R., and Stoddart, L. A. Effects of grazing upon bunch wheatgrass. Amer. Soc. Agron. Jour. 32 (4): 278-289. 1940.
14. Harrison, C. M. Effect of cutting and fertilizer applications on grass development. Plant Physiol. 6 (4): 669-684. 1931.
15. Holscher, C. E. The effect of clipping bluestem wheatgrass and blue grama at different heights and frequencies. Ecology 26 (2): 148-156. 1945.
16. Lang, Robert, and Barnes, O. K. Range forage production in relation to time and frequency of harvesting. Wyo. Agr. Exp. Sta. Bul. 253. 1942.
17. McCall, Ralph, Clark, R. T., and Patton, A. R. The apparent digestibility and nutritive value of several native and introduced grasses. Mont. Agr. Exp. Sta. Bul. 418. 1943.
18. McCall, Ralph. The digestibility of mature range grasses and range mixtures fed alone and with supplements. Jour. Agr. Res. 60 (1): 39-50. 1940.
19. McCarty, E. C., and Price, Ray. Growth and carbohydrate content of important mountain forage plants in central Utah as affected by clipping and grazing. U. S. Dept. Agr. Tech. Bul. 818. 1942.

20. Norman, A. G. Biochemical approach to grass problems. Amer. Soc. Agron. Jour. 31 (9): 751-760. 1939.

21. Patton, A. R., and Gieseker, L. Seasonal changes in the lignin and cellulose content of some Montana grasses. Jour. Anim. Sci. 1 (1): 22-26. 1942.

22. Patton, A. R. Seasonal changes in the lignin and cellulose content of some Montana grasses. Jour. Anim. Sci. 2 (1): 59-62. 1943.

23. Sampson, A. W., and Malmsten, Harry E. Grazing periods and forage production on the national forests. U. S. Dept. Agr. Bul. 1405. 1926.

24. Sampson, A. W. Livestock husbandry on ranges and pastures. New York, John Wiley & Sons, Inc., 1928.

25. Sampson, A. W. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. Jour. Agr. Res. 3 (2): 92-148. 1914.

26. Sarvis, J. T. Grazing investigations on the northern Great Plains. N. Dak. Agr. Exp. Sta. Bul. 308. 1941.

27. Stoddart, L. A. The Palouse grassland association in northern Utah. Ecology 22 (2): 158-163. 1941.

28. Stoddart, L. A. Seeding Utah ranges, with special reference to precipitation. Utah Agr. Exp. Sta. Cir. 122. 1946.

29. Sturkie, D. C. The influence of various topcutting treatments on rootstocks of Johnson grass (*Sorghum halepense*). Amer. Soc. Agron. Jour. 22 (1): 82-93. 1930.