TECHNICAL BULLETIN 71 SEPTEMBER 1963

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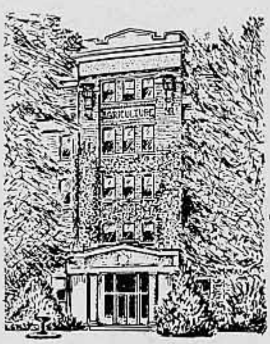
Agricultural Experiment Station
Oregon State University
Corvallis



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This bulletin is a contribution from Squaw Butte Experiment Station, Burns, Oregon. This station is jointly operated and financed by the Crops Research Division, Agricultural Research Service, United States Department of Agriculture, and the Oregon Agricultural Experiment Station, Oregon State University, Corvallis.

AUTHORS: D. N. Hyder is Research Agronomist (present address—Fort Collins, Colorado) and Forrest A. Sneva (Burns, Oregon) is Range Conservationist, Crops Research Division, Agricultural Research Division, U. S. Department of Agriculture.

Studies of Six Grasses Seeded on Sagebrush-Bunchgrass Range

Yield, Palatability, Carbohydrate Accumulation, and Developmental Morphology

D. N. Hyder and Forrest A. Sneva

Summary

Crested, siberian, beardless, pubescent, and tall wheatgrasses and big bluegrass were planted in rows spaced 6, 12, 24, 36, 48, and 60 inches apart on sagebrush-bunchgrass range in April and May 1956. Herbage yields were measured in 1957-1961, inclusive, and adjusted to a median precipitation amount to evaluate productivity by age of stands. The preferences exhibited by cattle among plots were observed in July and early August in 1959-1961. Seasonal trends in the accumulation of total water-soluble carbohydrates (TWSC) in stem bases were obtained in 1959 and 1960, and crude protein contents in stem bases were sampled in 1960. The developmental morphology of stems was described in 1959 and 1960.

Crested wheatgrass exhibited maximum productivity in the second growing season, a stable productivity in the fifth and sixth seasons, low palatability in July and August, early and fast accumulation of TWSC, and morphological characteristics favorable to spring grazing. Siberian wheatgrass was very similar to crested wheatgrass in the characteristics observed.

Beardless wheatgrass exhibited maximum productivity in the fourth growing season, a stable productivity in the fifth and sixth seasons, moderate palatability in July and August, late and slow accumulation of TWSC, and morphological characteristics favorable to late spring, summer, and fall grazing.

Big bluegrass exhibited maximum productivity in the fourth growing season, a stable productivity in the fifth and sixth seasons, a strong yield decrease with increasing row spacing, high palatability in July and August, intermediately early accumulation of TWSC,

weak rooting and susceptibilty to pull-up in the first three years, and morphological characteristics favorable to early spring and late summer or fall grazing.

Pubescent and tall wheatgrasses exhibited declining productivities throughout the six years, and appeared to be poorly adapted to sagebrush-bunchgrass range.

Introduction

The semiarid sagebrush-bunchgrass range presents two general problems in forage production that result from the short growing season. First, the quantity of forage available is in short supply until herbage growth is sufficient to sustain both plants and animals. Second, the quality of forage depreciates rapidly after about mid-June. Introduced grasses are often evaluated with practical reference to these problems. Crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult.) has become a favorite for seeding sagebrush-bunchgrass ranges to increase the supply of spring forage. Mature crested wheatgrass is usually unpalatable to livestock, but some desirable late-summer or fall forage can be produced where spring grazing can be scheduled to result in the growth of a second crop of stems (Hyder and Sneva, 1963). Other native and introduced species need to be evaluated for characteristics that may alleviate the shortage of early-spring forage or the low quality of summer and fall forage.

This bulletin includes information on the yield, palatability, carbohydrate accumulation, and developmental morphology of six grasses seeded in rows spaced from 6 to 60 inches in southeastern Oregon. The characteristics studied define opportunities for seeding introduced species to obtain forage benefits in specific seasons.

Procedure

A site representing the *Artemisia tridentata/Agropyron spicatum* habitat type (Eckert, 1957), with an uncorrelated sandy loam, Brown soil, and supporting big sagebrush (*Artemisia tridentata* Nutt.) and a scattered stand of bunchgrasses, primarily bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith), was selected for seeding studies. Clearing and homesteading activities about the turn of the century left this area with a thin stand of bunchgrasses.

The area was plowed twice with a one-way disc in 1954, cleared of sagebrush by piling and burning in 1954, and summer fallowed in 1955. Early in April 1956, the seedbed was prepared by discing, harrowing, and cultipacking. Bulbous bluegrass (P-4847, *Poa bulbosa* L.) was seeded over all the area by broadcasting, harrowing, and cultipacking to suppress the growth of cheatgrass (*Bromus tectorum* L.) and Jim Hill mustard (*Sisymbrium altissimum* L.).

A split-plot experiment in 4 replications included row spacings of 6, 12, 24, 36, 48, and 60 inches on whole plots (30 by 360 feet) and 6 grasses on subplots (30 by 60 feet). The species, planted at a rate of about 20 seeds per foot of row with a single-row, double-disc, cone-type seeder, were as follows: standard crested wheatgrass, P-27 siberian wheatgrass (*Agropyron sibiricum* (Willd.) Beauv.), whitmar beardless wheatgrass (*Agropyron inerme* (Scribn. and Smith) Rydb.), topar pubescent wheatgrass (*Agropyron trichophorum* (Link) Richt.), alkar tall wheatgrass (*Agropyron elongatum* (Host) Beauv.), and sherman big bluegrass (*Poa ampla* Merr.). These varieties were reviewed by Hanson (1959).

Drilling was started April 16 and concluded May 9, 1956. Precipitation was above normal (Table 1), and contributed to the establishment of good stands, except with big bluegrass on plots in replications 3 and 4, which were seeded in May.

Table 1. Crop-year precipitation amounts with precipitation and yield indexes at Squaw Butte Experiment Station

Crop year (Sept. 1-June 30)[a]	Precipitation	Precipitation[b] index	Yield index[b]
	(inches)	*(%)*	*(%)*
Median	11.3	100	100
1955	5.9	52	47
1956	14.3	127	130
1957	13.1	116	118
1958	16.2	143	148
1959	6.1	54	49
1960	9.7	86	85
1961	7.2	64	60

[a] Precipitation amounts are identified by the year in which the crop-year periods terminate.

[b] See Sneva and Hyder, 1962.

Herbage yields of the six grasses were measured in late July or early August annually from 1957 to 1961, inclusive. Center strips covering 48 square feet of area were mowed, and the herbage was oven dried at 70° C., weighed, and expressed in pounds of dry matter per acre. Herbage yields were adjusted each year to a median amount of precipitation using precipitation and yield indexes (Table 1) computed according to procedures described by Sneva and Hyder (1962). This adjustment removes major year differences and permits a more direct consideration of trends in yield by age of stands.

After sampling herbage yields, cattle were turned onto the area to graze the cured herbages. To determine relative palatabilities of cured herbages, cattle preferences among plots were evaluated by ocular estimates of utilization percentages in the first two weeks of grazing in 1959, 1960, and 1961. Ungrazed herbage was mowed and removed from the plots in September.

The underground parts of stem bases were sampled about biweekly to determine total water-soluble carbohydrate (TWSC) concentrations in 1959 and TWSC and crude-protein concentrations in 1960. Stem-base samples were washed, held at 120° C. for 1 hour or less to inactivate, dried at 70° C., ground to pass a 20-mesh screen, and sealed in glass jars for subsequent chemical determinations.[1]

Crude-protein contents were determined by a standard Kjeldahl procedure. TWSC contents were determined by cold-water extraction and anthrone color development (Sullivan, 1951), and are expressed in percent glucose equivalents by oven dry weights.

Results

Adjusted Herbage Yields

Species, age, species by age, and row spacing by age were sources of highly significant (1%) variation in adjusted herbage yields, and species by spacing introduced significant (5%) variation.

Crested wheatgrass was most productive, and siberian wheatgrass second-most, considering all row spacings and years (Table 2). However, big bluegrass was most productive in stands with 6-inch row spacings, and was the only species that expressed large yield decreases with increasing row spacing. The small main effect of row spacing is surprising (McGinnies, 1960), but the bulbous-bluegrass understory may have minimized the expression of spacing effects.

[1] All chemical determinations were performed in the Department of Agricultural Chemistry, Oregon State University, Corvallis.

Considering total yields in the first five years, the wheatgrasses were quite insensitive to spacings from 6 to 60 inches, but big bluegrass was weakly competitive under these conditions, and open stands of it permitted vigorous growth of competing vegetation.

Table 2. HERBAGE YIELDS OF SIX GRASSES PLANTED IN ROWS SPACED AS INDICATED, AVERAGED OVER FIVE HARVEST YEARS

	Yields by species						
	Wheatgrasses						
Row spacing	Crested	Siberian	Beardless	Tall	Pubescent	Big bluegrass	Mean
(inches)			*(lb./A. oven-dry[a])*				
6	1,548	1,425	1,162	1,077	1,168	1,677	1,343
12	1,616	1,290	1,498	1,102	1,343	1,325	1,362
24	1,630	1,450	1,272	1,498	1,353	1,130	1,389
36	1,785	1,471	1,369	1,143	1,184	954	1,318
48	1,766	1,496	1,376	1,447	1,022	721	1,305
60	1,528	1,587	1,449	1,314	1,041	874	1,299
Mean[b]	1,645	1,453	1,354	1,264	1,185	1,114	1,336

[a] Herbage yields were adjusted to a medium amount of precipitation.
[b] L.S.D. at 5% among species means is 188 lbs./acre.

Yield trends by age of stands reveal interesting species differences (Figure 1). Crested and siberian wheatgrasses attained maximum productivity in the first harvest year, 1957. Yields then declined with increasing age to the fourth harvest year, when productivity was equal between the two species and about half that of maximum in the first harvest year.

Pubescent and tall wheatgrasses also became established quickly and attained maximum productivity in the first harvest year. Their yields, however, continued declining with age and indicate marginal adaptation to these conditions.

Beardless wheatgrass and big bluegrass became established rather slowly and exhibited maximum productivity in the third harvest year. Their yields, averaged over all row spacings, stabilized in the fourth and fifth harvest years at an amount very near that of crested wheatgrass. Age effects by species exceeded row spacing effects and indicate that yield trends by age were more physiological than ecological.

The interaction spacing by age expresses ecological effects of plant spacing (Figure 2). Maximum productivity was attained in

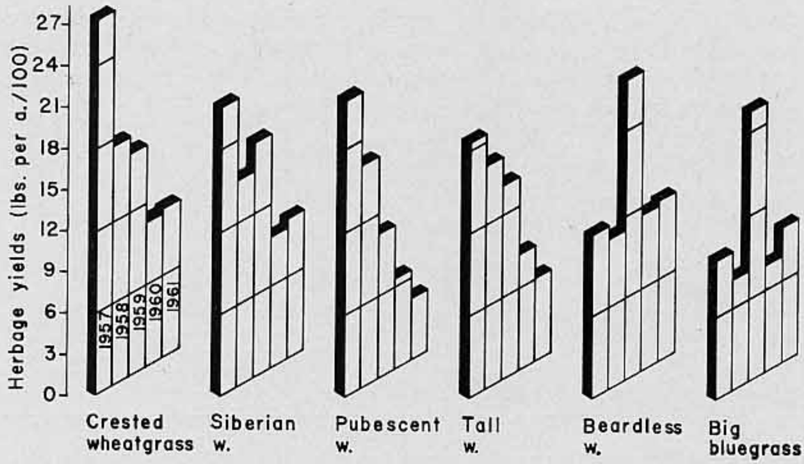

Figure 1. Adjusted herbage yields of six grasses in five consecutive years after planting in 1956, averaged over six row spacings.

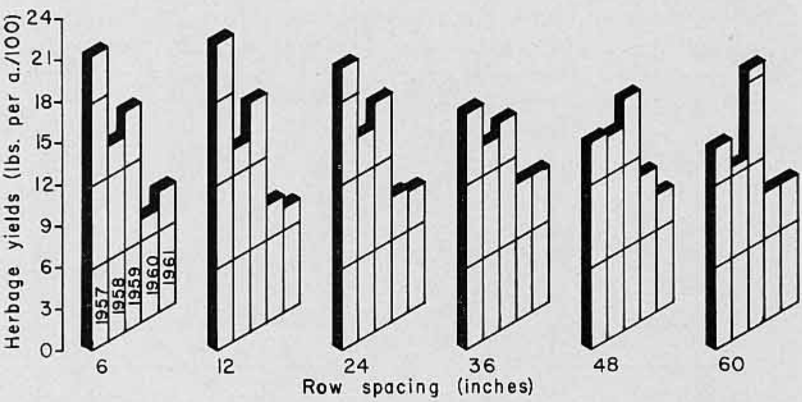

Figure 2. Adjusted herbage yields in five consecutive years after planting in rows spaced as indicated, averaged over six species.

the first harvest year with row spacings of 6, 12, and 24 inches, but yields were about equal in the first three harvest years with row spacings of 36 and 48 inches and were highest in the third harvest year with rows spaced 60 inches. These yield trends could be expected because widely spaced rows should not close the community and utilize all growth factors as quickly as narrowly spaced rows. Nevertheless, the consideration of yields without reference to individual species is abstract.

Crested wheatgrass at all spacings was most productive in the first harvest year. Siberian wheatgrass closed the community a little slower than crested wheatgrass because maximum productivity in 48- and 60-inch rows appeared in the second and third harvest years.

Pubescent and tall wheatgrasses in rows 6, 12, and 24 inches apart were most productive in the first harvest year, but in rows spaced 36, 48, and 60 inches they were equally productive in the first and second harvest years.

Beardless wheatgrass and big bluegrass at all spacings were most productive in the third harvest year. Big bluegrass was always more productive in rows 6 and 12 inches apart, except in the fifth harvest year when high productivity extended to rows spaced 24 and 36 inches. Beardless wheatgrass yields exhibited strong spacing by age interaction by uniform yields among row spacings in all but the third harvest year, when yields increased markedly with increasing row spacing and were about 90% higher in 60-inch rows than in 6-inch rows.

Cattle Preferences for Cured Herbages

Species, row spacing, species by age, and spacing by age were highly significant sources of variation in cattle preferences. Species by spacing and species by spacing by age introduced significant (5%) variation.

Beardless and tall wheatgrasses and big bluegrass were preferred, but the preferences shown for these two wheatgrasses declined markedly with increasing row spacing (Table 3). Tall wheatgrass was most green in July, but is not well adapted to these environmental conditions. Therefore, beardless wheatgrass and big bluegrass are better choices for summer and fall grazing. Each of these two species should be planted in fairly thick stands, rows not wider than 12 inches, for high productivity, weed control, and palatability.

Crested and siberian wheatgrasses, though relished by cattle when green, were essentially rejected in July and August, especially so where seeded in widely spaced rows. The moderate preference for pubescent wheatgrass seemed surprising because its growth activities stopped and its herbage turned brown very quickly with the depletion of soil moisture.

Table 3. CATTLE PREFERENCES FOR CURED HERBAGE OF SIX GRASSES PLANTED IN ROWS SPACED AS INDICATED, AVERAGED OVER THREE YEARS

	Cattle preferences by species						
	Wheatgrasses						
Row spacing	Crested	Siberian	Pubescent	Beardless	Tall	Big Bluegrass	Mean
(inches)	*(% of herbage grazed)*						
6	26[a]	31	48	62	80	77	54[b]
12	21	26	37	52	70	70	46
24	8	16	47	48	65	65	41
36	7	12	33	36	61	65	36
48	8	6	44	34	58	65	36
60	18	11	44	35	55	72	39
Mean	15[c]	17	42	44	65	69	42

[a] L.S.D. at 5% among interaction means is 11%.
[b] L.S.D. at 5% among row-spacing means is 6%.
[c] L.S.D. at 5% among species means is 5%.

Cattle-preference differences attributable to row spacing tended to decrease with increasing age of the stands, and thus coincided with the decrease in ecological differences among spacings. Preferences among species and row spacings were less different in the driest year (1959), and coincided with the amounts of reproductive stems. In fact, variable amounts of reproductive stems appeared largely to determine cattle preferences among species, row spacings, and years. Preferences decreased with increasing amounts of reproductive stems. Considering just the available leaf tissues, however, the cattle appeared to prefer those that were green. As grazing began, the cattle tended to select plots with widely spaced rows and greener leaves, but as grazing continued, they selected narrowly spaced rows and finer herbage for closest grazing.

TWSC in Stem Bases

Total water-soluble carbohydrate concentrations in stem bases differed among species and were a little greater in 1960 than in 1959. TWSC accumulated early and rapidly in the stem bases of crested and siberian wheatgrasses, early but slowly in pubescent

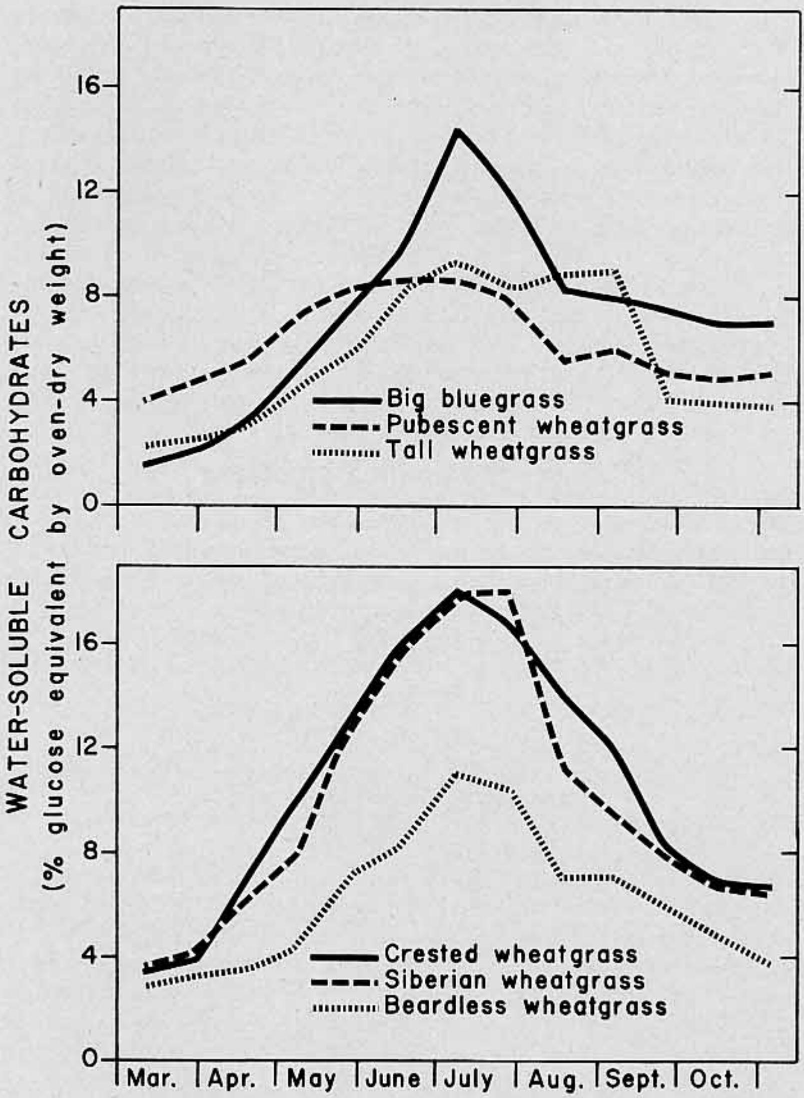

Figure 3. Total water-soluble carbohydrates (TWSC) in the stem bases (underground parts) of six grasses planted in rows spaced 24 inches apart in March 1956, and sampled in 1959 and 1960.

wheatgrass, intermediately early in big bluegrass and tall wheatgrass, and relatively late in beardless wheatgrass (Figure 3). The comparison of crested and siberian wheatgrasses with beardless wheatgrass is especially appropriate because the first two are tolerant of spring grazing while the latter, and its close relative bluebunch wheatgrass (*Agropyron spicatum* (Pursh.) Scribn. and Smith), is sensitive to spring grazing. Crested and siberian wheatgrasses were accumulating TWSC about five weeks earlier than was beardless wheatgrass.

Concentrations of TWSC in the stem bases of pubescent and tall wheatgrasses are probably lower than would occur under a moisture regime more favorable for their growth. Tall wheatgrass exhibited peak concentrations later in the season than the other species, and this result could be related to its late anthesis.

Crude Protein in Stem Bases

Crude-protein contents in stem bases decreased in April and May, reached a minimum in June, and increased in July and August to a level that was about the same as prevailed in late March (Table 4). Species differences in crude-protein contents were small.

Table 4. Crude protein concentrations in the stem bases of six grasses in 1960

Harvest date	Crude-protein concentrations by species						
	Wheatgrasses						
	Crested	Siberian	Pubescent	Tall	Beardless	Big bluegrass	Mean
			(%)				
March 22	5.7	4.3	5.0	4.4	5.3	5.3	5.0
April 6	6.2	5.7	5.2	4.6	5.2	5.3	5.4
April 19	5.1	5.9	5.9	5.5	6.7	4.7	5.6
May 14	5.2	4.6	5.3	5.4	6.2	3.9	5.1
May 19	3.8	4.2	3.7	4.1	4.3	3.8	4.0
May 31	4.0	4.5	4.0	4.4	3.9	3.8	4.1
June 14	3.4	2.8	3.4	3.4	3.8	3.7	3.4
June 29	3.3	3.8	3.1	2.4	3.8	3.5	3.3
July 13	3.2	3.4	5.6	3.8	3.6	3.9	3.9
July 26	3.5	3.0	4.0	3.4	3.8	3.9	3.6
August 9	4.3	4.3	4.2	3.5	5.1	4.5	4.3
September 1	5.8	5.3	4.8	5.4	5.1	3.4	5.0
Mean	4.5	4.3	4.5	4.2	4.7	4.1	4.4

Developmental Morphology

Crested wheatgrass. The morphological development of crested wheatgrass and its relation to physiological performance and clipping effects, has been presented elsewhere (Cook and Stoddart, 1953, Hyder and Sneva, 1963) and will not be repeated in this paper.

Siberian wheatgrass. The morphological and phenological development of siberian wheatgrass was very similar to that of crested wheatgrass, and the suggestions given for one- and two-crop grazing systems are extended to this species. The reproductive culms of siberian wheatgrass were a little taller than those of crested wheatgrass, but generally had five internodes and leaves (often six, seldom four) as compared with a mode of six internodes and leaves for crested wheatgrass. The four-internode culms had one shortened internode and six-internode culms usually had two shortened. Shortened basal internodes were uniformly about one-fourth inch long, became enlarged toward the base, and lived two years or more. The proportion of reproductive shoots increased with increasing row spacing, and aborted ones, in which the upper internode and head had died, were common. Vegetative shoots had three to seven slender internodes and leaves, and lengths of the first three internodes were similar to those in reproductive culms. Anthesis occurred about one week later than on crested wheatgrass.

Beardless wheatgrass. The shoots of beardless wheatgrass grew from basal axillary buds of old stem bases and were enclosed in membraneous sheaths (underground leaves) that grew about the buds in the previous year. Mature reproductive shoots had five leaves and four (infrequently five) distinct internodes. The first two leaves generally were not separated by a distinct internode, remained very short (blades 1 to 3 inches long), and dried up in April by the time culm elongation was apparent. Thus, an individual shoot retained just three active leaves through the growing season. The third leaf blade was about 5 inches long, but the fourth and fifth were about 12 inches long. This growth form elevated all important photosynthetic tissues to a position subject to grazing at an early time.

Growth began in March and individual shoots had three leaf blades showing (the first two completely exposed) by the first of April. By April 15, the plants appeared very leafy with a maximum height of 7 inches. Individual reproductive shoots had four leaves showing and three blades completely exposed by mid-April, but culm internodes were obscure. The leaf blades apparently did not elongate after complete exposure.

Beardless wheatgrass leaves were up to 12 inches long by the first of May, and individual stems exhibited all five leaves—two dry and brown and the fifth immature. The first culm internode was about $1\frac{1}{2}$ inches long, but other internodes were obscure. The first internode and all leaf sheaths were extremely slender and fragile.

The bases of heads were elevated about 2 inches above the soil by May 15. The first two leaves were dry and brown and the first internode, near a mature length of 2 to 3 inches, was but little larger and stronger than on May 1. The second internode, slender and weak, was about 1 inch long, and higher internodes were obscure. The heads were about 1 to 2 inches long and in early boot development. Axillary buds were just becoming apparent at the base of culms.

During May, the culms were easily broken in the first internode at about ground level by pulling on the leaves. Such breakage removed active meristematic tissues, so grazing could be inappropriate at this time. Since the slender stem bases accumulated very little TWSC during May, susceptibility to grazing damage could result from both morphological and physiological weaknesses prior to heading.

In late May, culm elongation continued in the first two internodes and proceeded into the third, while the heads continued to develop. The heads were 3 to 4 inches long and high in the boot by June 1. The first internode had reached a mature length of 2 to 3 inches, the second was about 2 inches and still very slender, the third was less than 1 inch, and the fourth was still obscure. Axillary buds, with membraneous sheaths up to one-half inch long, were readily apparent at stem bases by June 1. The lowermost internode was rarely short enough to place the first culm node at or below the soil surface, but, in that case, the underground node supported an axillary bud.

The plants headed out in early June and culm elongation proceeded rapidly in the third and fourth internodes. The reproductive shoots were mature by July 1, when the spikelets generally were in anthesis. The first internode was 2 to 3 inches long each year, the second was 4 to 6 inches, and the third and fourth varied from 5 to 8 and 6 to 13 inches, respectively, depending on the duration of soil moisture and growth activity.

Aborted reproductive shoots were very common, more so than in crested wheatgrass. The shoots that remained vegetative elongated through the first one or two internodes with phenology and lengths as in reproductive shoots, but they remained very slender and did not grow much beyond the second internode. Reproductive shoots had developed separate rooting systems, and probably expressed competitive dominance over the vegetative ones. The proportion of reproductive shoots increased with increasing row spacing.

Big bluegrass. The growth of big bluegrass was very different from that of the wheatgrasses in that vegetative shoots were culmless and more numerous than reproductive ones. The proportion of reproductive shoots increased with row spacing. It was 18, 23, and 34%, respectively, in rows spaced 6, 12, and 24 inches apart. In a separate experiment where rows were spaced 12 inches apart, the proportion of reproductive shoots increased from 9% without nitrogen fertilization to 18% with fertilization at 30 pounds of N per acre. Thus, improved growing conditions increased differentiation to reproductive status.

Big bluegrass often grew slowly in the winter and nearly always grew rapidly in March. The leaves were about 6 inches tall by April 1, and could supply sufficient herbage for grazing about 3 to 4 weeks earlier than crested wheatgrass or other species studied.

The reproductive shoots grew from shoot apices enclosed in dead leaves of a previous year. That is, they differentiated from apical meristems that were previously vegetative. Growth from axillary buds appeared to remain vegetative in the first year, but could differentiate to reproductive status in the second season. This characteristic suggests a requirement for cold stratification and a mean maximum of 50% reproductive shoots. A single isolated plant that appeared very strongly reproductive had 41% reproductive shoots—a proportion that approaches the presumed maximum of 50%. The culms of reproductive shoots elongated rapidly in April and were about 4 inches long, excluding heads, by May 1. In late April, the culms were long enough to be grazed along with leaf blades. Thus, clipping low enough to remove active intercalary meristems stopped growth in the culms.

All culm internodes appeared to elongate simultaneously in early May. The heads emerged from leaf sheaths about May 15, and the culms were mature and spikelets in anthesis about June 15. Mature culms had three or four internodes and two or three culm leaves. The first (lowermost) internode was about 2 inches long, but approximately 70% of culm length occurred in the uppermost internode. Thus, culm leaves were attached relatively close to the ground. The blades of culm leaves remained short (about 5 inches) and unfolded to appear wide and flat. By July 15, the seed was shattering, reproductive culms and leaves were brown, and leaves of vegetative shoots were beginning to die at the tips. The culms died after seed maturation, except that the first internode could live more than one year and support a new stem at the elevated node, if located below the soil surface.

The region of origin of reproductive shoots (the culm-crown junction) was very weak, but roots and culms were strong. Culm bases supported lateral roots, and pulling broke them off with culm-base roots. All reproductive shoots had developed individual rooting systems. Where reproductive culms were numerous, pulling several of them simultaneously removed a group of reproductive and vegetative shoots. This species is notorious for pull-up damage, and suffered considerably under July and August grazing in the second and third growing seasons, especially in widely spaced rows where reproductive shoots were numerous. Pull-up was immaterial after the third growing season.

Vegetative shoot apices remained at or below the soil surface, and produced three or four leaves per season. The growth of leaves subsided as growing conditions became unfavorable in the summer and resumed promptly when favorable growing conditions were restored because immature leaves were always present in the leaf sheaths.

Mature leaves died back from the tips during the summer, but did not die entirely when the summer drouth was broken by late summer rains. Precipitation in late summer restored green color in the lower parts of mature leaves from vegetative shoots and reactivated growth in immature ones. Mature leaves died completely in the winter, but immature ones died only in the exposed portions. Dead leaf tips were characteristic and common after each dormant (or nongrowth) period, both summer and winter.

The leaves of vegetative shoots were very long (up to 20 inches) and remained slender and folded. The leaf sheaths were short so that the leaf collars were found near the soil surface. Vegetative growing points could not be removed by clipping, and herbage removal from vigorous plants induced a prompt appearance of new leaves if growing conditions were favorable. In general, the morphology of big bluegrass, especially the predominance of culmless vegetative shoots, provides characteristics that are desirable in a pasture grass. However, this species presents serious problems in seeding methods, plant establishment, temperature relations in root development, and rooting strength that remain unaccounted for.

Pubescent wheatgrass. The shoots of pubescent wheatgrass grew from axillary buds of rhizomes and old culm bases. The large rhizomes had internodes about one-half inch long, roots at each node, and infrequent shoots. All shoots had culms, but the vegetative ones were very small and dried up early, probably as a result of drouth conditions and competitive dominance of reproductive shoots. About 55% of the reproductive shoots aborted and had withered immature heads in the upper leaf sheath.

Growth, especially of rhizomes, began early. New rhizomes were up to 4 inches long by March 5, 1959, and leaves were up to 4 inches tall. By April, maximum leaf height was 5 inches and the largest shoots exhibited three leaf blades, all less than 3 inches long. Maximum leaf height was 9 inches by May, but the culms were still obscure. The heads were about one-fourth inch long and situated near the soil surface in mid-May and were high in the boot by June, when active meristematic tissues could be removed by clipping or grazing. The first two leaves had dried up by June and others were turning yellow. Well developed reproductive culms had five or six internodes. The first internode was about 1 inch long, the second was about 2 inches, and higher ones were extremely variable in length under the conditions at Squaw Butte. The heads emerged in early June and the spikelets were in anthesis in early July. Heading and anthesis were only about five days later than for crested wheatgrass. An early and rapid loss of green color was an outstanding characteristic of pubescent wheatgrass under the conditions studied.

Tall wheatgrass. The growth of tall wheatgrass seemed very abnormal. Heads appeared in July and anthesis occurred in August, but growing conditions rarely were sufficient to sustain growth even into July. All shoots had culms, but the vegetative ones withered and died with not more than three small leaves and a single internode about one-half inch long. Most reproductive shoots aborted in early boot development, but culm leaves retained green color very well. Active meristematic tissues could be removed by clipping in mid-June. Axillary buds developed early in the growing season, and, under favorable growing conditions, could surely produce a second crop of shoots after herbage removal in mid-June.

Discussion and Conclusions

Four of the six grasses were well adapted to conditions in the *Artemisia tridentata / Agropyron spicatum* habitat type. Widely spaced rows were favorable to the morphological differentiation of all species and especially for pubescent and tall wheatgrasses, but the morphological differences among row spacings diminished with age of stands. Pubescent and tall wheatgrasses exhibited declining productivity throughout the six years, and are considered undesirable choices for seeding sagebrush-bunchgrass range.

Crested, siberian, and beardless wheatgrasses and big bluegrass exhibited good adaptation and desirable forage characteristics. Crested and siberian wheatgrasses became established to maximum productive potential in the second growing season. Their physiological and morphological characteristics indicate preferred grazing in May and June, but each can provide some desirable forage for late summer or fall by grazing in May to stop culm development and promote the growth of a second crop of tillers. The authors have suggested that crested wheatgrass should be grazed specifically to obtain one or two crops of shoots (Hyder and Sneva, 1963), and this suggestion is extended to siberian wheatgrass.

Beardless wheatgrass exhibited morphological and physiological characteristics suggesting that the plants can be especially susceptible to damage by May grazing. Information about bluebunch wheatgrass seems to apply equally well to beardless wheatgrass (Branson, 1956; McIlvanie, 1942).

All shoots of beardless wheatgrass have culms; the vegetative ones are short and slender; the reproductive ones (prominent in proportions) depend on photosynthetic production in just three well-elevated leaves. The lowermost culm internodes are long and weak; stem bases are deficient of carbohydrates through most of the growing season; and axillary buds, from whence new tillers and photosynthetic tissues must grow, appear to develop relatively late. This list of characteristics demotes beardless wheatgrass, but established stands produce a lot of herbage that is quite palatable to cattle in late spring, summer, and fall. Thick stands (rows about 12 inches apart) are desirable because new seedings establish to maximum productivity rather slowly and vegetative and aborted-reproductive shoots (predominating in thick stands) are preferred by cattle over normal reproductive shoots. We suggest that appropriate grazing times include late spring (not earlier than heading), summer, and fall. The more or less common practice of early spring and fall grazing seems inappropriate under the conditions studied.

Big bluegrass exhibited morphological characteristics that are highly desirable for both early spring and late summer or fall grazing. Grazing in April and adjusting stocking rates to achieve relatively close utilization by May 1 to 10 can stop the development of reproductive shoots. Subsequently, the vegetative shoots can produce, in May and June, an abundance of vegetative growth that is preferred forage in late summer and fall. A spring-fall grazing pattern probably can minimize pull-up because it is largely the reproductive culms that are strong enough to permit such damage. Practical application of the desirable characteristics will not be fully achieved until the problems involved in seeding, establishment, tolerance of spring grazing, and pull-up are better accounted for.

Big bluegrass seed could, perhaps, be planted in furrows so that the crowns of established plants could be covered more deeply and rooted more firmly by harrowing across the rows. Late winter or very early spring plantings have been most successful, and planting later in warmer soils seems to have limited root development. Thick stands (rows 6 to 12 inches apart) are needed, not only to permit high herbage production, but also to minimize reproductive differentiation and pull-up. Planting big bluegrass in a mixture with crested wheatgrass, as sometimes recommended for minimizing pull-up, is undesirable because big bluegrass is weakly competitive under the conditions studied, and the desirable characteristics of very early growth and high palatability of cured herbage are not compatible with those of crested wheatgrass.

The adjustment of herbage yields to a median amount of precipitation (Sneva and Hyder, 1962) permitted the consideration of yield trends with age. The adjusted yields indicate rate of establishment and relative adaptability to the environmental conditions. Four species exhibited stable productivities in the fourth and fifth harvest years, and two species (pubescent and tall wheatgrasses) exhibited declining productivities throughout the six years. Since productivity can be affected by fluctuations of environmental conditions other than moisture, the adjustment of yields to median precipitation does not exclude all annual variations in herbage production. For example, the yields of well established stands of crested wheatgrass and native vegetation were much lower in 1958 than was expected from the precipitation received. Lower-than-expected yields appeared to result from nitrogen deficiency because (a) plots fertilized with 20 to 40 pounds of N per acre produced expected amounts, and (b) the crude protein contents of herbage from unfertilized plots were lower than in any year of record. Precipitation was much greater in 1956, 1957, and 1958 than the median amount (Table 2). This three-year sequence of high precipitation permitted high herbage yields and apparently contributed to high nitrification rates and a reduction of soil nitrogen contents by 1958. Consequently, the adjusted yields given for 1958 in Figures 1 and 2 are smaller than expected of these grasses in their third growing season. In Figure 2, for example, the median-yield potentials of crested and siberian wheatgrasses should not decrease so much from 1957 to 1958, and the yield potentials of beardless wheatgrass and big bluegrass should increase from 1957 to 1958 and again from 1958 to the maximum potential in 1959, the fourth growing season.

Except for 1958, the adjusted yields are believed to be reasonably accurate indications of productivity, and the adjustment procedure is recommended for other experimental trials on sagebrush-bunchgrass range as a way to remove large variations in yields attributable to variations in precipitation among years.

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