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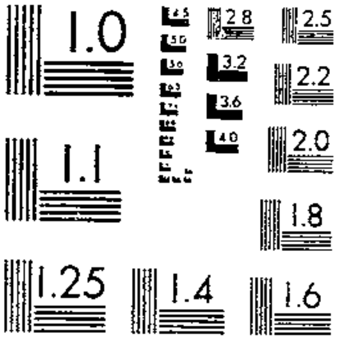

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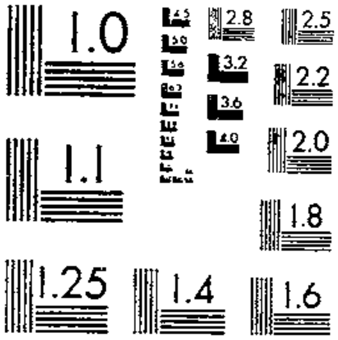

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GRAZING INTENSITIES AND SYSTEMS ON CRESTED WHEATGRASS IN CENTRAL UTAH: RESPONSE OF VEGETATION AND CATTLE

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PREFACE

Crested wheatgrass has been successfully seeded and established on millions of acres of badly depleted rangelands in the western United States and Canada. These seeded stands are now an important international forage resource. Even though the research on which this report is based was conducted some time ago, the results reported herein are still applicable and they provide critically needed answers for public and private land managers in order to maintain the resource and achieve the greatest returns from livestock through its wise management.

CONTENTS

HIGHLIGHTS

1. Crested wheatgrass can fill an important need for early spring grazing in the intermountain region. Under conditions at Benmore, Utah (elevation 5,600–5,800 ft., rainfall 13 in.), crested wheatgrass may be grazed from about April 20 to June 20 at an intensity of approximately 65 percent of herbage by weight. This intensity of use will give optimum cattle gains per acre and maintain grass production.

2. Two important principles brought out in this study are: (1) Delaying the start of grazing in the spring will contribute toward maximum basal area and yields of grass; (2) shortening the grazing season at the end of the spring growing season will contribute toward maximum plant numbers. Combinations of these principles can lessen the adverse effects of heavy grazing. A good rule of thumb is "Do not graze a particular area at the same part of the growing period every year."

3. Although shrub invasion increased with intensity of grazing, in wet years some sagebrush and rabbitbrush will invade crested wheatgrass even under no grazing, if a seed source is present. Sagebrush depresses grass yields more than rabbitbrush. It is likely that brush control will be required when sagebrush seriously limits grass production.

4. Using a population composed of yearlings, 12.7 percent; dry cows and steers older than 1 year, 20.0 percent; pregnant cows calving in the pasture, 7.7 percent; lactating cows, 29.8 percent; and calves, 29.8 percent, approximately 3.2 acres per animal would be required for the 2-month spring grazing season at an intensity of 65 percent. This would amount to 2.5 acres per month for a cow-calf unit or 1.5 acres per month for yearlings.

5. The following daily gains may be expected at 65-percent utilization for the various classes of cattle: Yearlings, 2.6 lbs.; dry cows and steers, 3.2 lbs.; pregnant cows calving in the pasture, 3.1 lbs.; lactating cows, 2.7 lbs.; and calves, 1.8 lbs. Cows having suckling calves were the most sensitive animals to intensity of spring grazing.

6. The total gain per acre that could be expected at 65-percent utilization of herbage is approximately 43 lbs. The rotation treatment produced the highest animal gain per acre in 7 out of 11 years; the delayed-10-days treatment produced the highest gains in the other 4 years. All systems of grazing, however, permitted sufficient gains for efficient beef production providing the pastures were grazed at 65-percent utilization or less.

7. Lightest spring grazing permits most fall grazing. Spring grazing that utilizes 65 percent or less of grass by weight would leave sufficient grass for some fall grazing, which would be enhanced in years when grass regrowth occurs in late summer and fall. Grazing at 80-percent utilization in the spring does not leave sufficient grass for fall grazing.

8. On the basis of these findings it is recommended that, for spring use in the intermountain region, crested wheatgrass should be managed under a rotation system utilizing about 65 percent of the herbage grown.

INTRODUCTION

The extensive use and widespread adaptability of crested wheatgrass[1] and fairway wheatgrass[2] indicate their importance to the range livestock industry. Bleak and Plummer (1954)[3] estimated that crested wheatgrass had been seeded on 1 million acres in the intermountain West, and that eventually it would be seeded on 10 million acres. About the same time, Newell (1955) estimated that crested wheatgrass had been seeded on more than 10 million acres in the Western United States and on an additional half million acres in Canada. Since then, crested wheatgrass has been seeded on additional depleted sagebrush-grass and adjacent ranges of the intermountain region so that now it is an important forage resource in many localities.

Since such extensive range areas were being seeded to crested wheatgrass, it was deemed necessary to determine what grazing treatments could bring the greatest returns from livestock and still maintain this valuable forage resource. The study on the Benmore Experimental Area in west-central Utah was conducted by the Intermountain Forest and Range Experiment Station, U.S. Forest Service, and Utah Agricultural Experiment Station. Originally the U.S. Soil Conservation Service and subsequently the U.S. Forest Service's Wasatch National Forest, Utah, cooperated administratively and furnished many of the facilities.

The study extended over 14 years (1947 through 1960). It included 1 year of preliminary calibration, 11 years of grazing treatment, and 2 years of post-treatment evaluation of vegetation. Grazing treatments included all possible combinations of four systems and three intensities of grazing cattle in the spring. Results were measured in terms of cattle gains and response of the vegetation to grazing. Fall grazing, though initially included, was discontinued after 3 years when it proved impractical on the heavily grazed pastures. The present publication enlarges upon an earlier one, which reported results of only the first 5 years of study (Frischknecht et al. 1953).

LITERATURE REVIEW

Response of Grass to Grazing

Information about the response of crested wheatgrass to grazing is less abundant than information about seeding and establishment.

Williams and Post (1945) reported that in Montana crested wheatgrass became unpalatable to animals after it matured, and recommended that it be grazed heavily enough in the spring to prevent formation of numerous seedstalks. Later, Bleak and Plummer (1954) reported on crested wheatgrass pastures in central Utah that had been grazed in the spring for 7 consecutive years by sheep. Pastures utilized 88 percent showed less production, more die-out of plant centers, and more growth of Russian-thistle than pastures utilized 59 and 71 percent. Differences in response to grazing were not apparent between pastures where grazing began when the grass was 2 to 3 inches high and those where grazing began 13 days later when grass was 4 to 5 inches high.

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[1] Common and scientific names of species mentioned in this bulletin are listed on page 44.

[2] Previously these grasses were known as Standard crested wheatgrass and Fairway crested wheatgrass, respectively. Since both were included in early seedings on the Benmore Experimental Range, sometimes separately, sometimes mixed, "crested wheatgrass" as used throughout this report applies to both grasses unless otherwise noted.

[3] Names followed by dates refer to Literature Cited, page 45.

On a 10-year-old stand of crested wheatgrass in northern Nevada, Frischknecht and Bleak (1957) observed that the number of grass plants having dead centers increased under heaviest intensities of use and that young sagebrush invaded most aggressively where grazing was heaviest.

In a comprehensive clipping study in northern Utah, Cook et al. (1958) found generally that yield from plants clipped at a height of 3 inches was greater than yield from plants clipped at 1 inch; also that increased frequency of clipping decreased herbage yield. In Oregon, Hyder and Sneva (1959) measured the seasonal trend of carbohydrate storage in ungrazed crested wheatgrass. Results supported the contention for early range readiness and high tolerance of crested wheatgrass to grazing.

In the Southwest, Reynolds and Springfield (1953) earlier reported that for greatest sustained returns in total herbage, utilization of this grass should not exceed 45 percent by weight each year. Later work by Springfield (1963) indicated that on better sites in northern New Mexico the optimum intensity of spring grazing during a 1-month period was 65 to 70 percent of the spring growth. This did not include regrowth after the grazing season ended.

Nutritive Value of Forage

As grasses approach maturity, both their nutritive value and their consumption by cattle decline due to lowered palatability (Graves et al. 1933; Johnstone-Wallace and Kennedy 1944). The decline in nutritive value can be delayed by grazing or clipping (Stoddart 1946; Newell and Keim 1947). Black et al. (1937) reported that forage from heavily grazed pastures had more nutritive value than forage from moderately grazed areas; but Cook et al. (1953) showed the opposite to be true on desert shrub winter ranges where heavier utilization forced animals to consume less nutritious parts of plants.

Sotola (1940) found the dry matter of crested wheatgrass collected early in May contained 20.5 percent of crude protein, compared to 3.22 percent in grass collected in September. Hopper and Nesbitt (1930) found that crested wheatgrass that was frequently clipped maintained a crude protein content nearly twice that of unclipped grass. Likewise, Cook et al. (1958) found that plants frequently clipped appeared to maintain a high percentage of protein and total digestible nutrients. However, dry matter—hence total protein and digestible nutrients—decreased each year.

Response by Cattle

Hein and Cook (1937) found no significant difference in gains between animals grazing pastures continuously and animals grazed in rotation at the same intensity. Hargrave (1949) reported that cattle grazed continuously at moderate intensity gained more than cattle grazed on a deferred rotation system at moderate intensity. McIlvain and Savage (1951) reported that heavy continuous summer grazing on native range produced greater gains than rotation grazing, but found that this difference was considerably reduced when cattle were shifted more frequently. Rotational grazing of crested wheatgrass gave a 6-percent greater total gain per acre than continuous grazing, but this small gain seemed not to justify the extra time and expense required in a rotation system (Williams and Post 1945).

Studies by Sarvis (1941), Lush et al. (1930), and Thomson (1936) showed that gains on grass from about mid-April to June approximately equal gains expected from drylot feeding. Williams and Post (1945) reported that cattle gained about 2 pounds per day during a 75-day grazing period on crested wheatgrass. Barnes and Nelson (1950) found it necessary to keep crested wheatgrass pastures grazed at uniform intensity and to have them fully grazed by early June in order to obtain maximum daily gains.

Hargrave (1949) found that 2-year-old steers gained more than any other class of stock during the grazing season. In terms of percent gains, animals having light initial weight made greatest gains (Stoddart 1944; Knox and Koger 1946). Knox and Koger pointed out that under feedlot conditions the initial size and weight of the animal influence the total gain more than either type or age. Knapp et al. (1942) found that weight gained by a cow while nursing her calf was correlated negatively with the weaning weight of the calf.

DESCRIPTION AND HISTORY OF STUDY AREA

Benmore Experimental Area is in the southeastern corner of Tooele County, Utah, approximately 65 miles southwest of Salt Lake City. It lies in the south end of Rush Valley, about 2 miles from the foot of the Sheeprock Mountains, within a belt used as spring-fall range. Elevation varies between 5,600 and 5,800 feet.

Topography and Soils

The topography is generally level but is shallowly dissected by intermittent stream channels and swales. Drainage is to the north on about a 2-percent average slope. Sheet erosion was generally severe throughout the area before seeding. Gully erosion was present but not severe.

Soils are typical of those found under similar climatic conditions within the Basin and Range province. They are primarily clay loams having moderate permeability (Nelson 1939). Surface soils are calcareous, friable, loose, and light brown to grayish brown. Over much of the area a soft, platy crust about 2 inches thick that commonly occurs on the surface is underlain by a soft, very fine granular material. Below this is a grayish-brown moderately hard calcareous subsoil, which crumbles to a very fine cloddy and granular condition. At depths varying from less than 12 to about 18 inches, this grades either into a similar material containing many soft lime aggregates or into a heavier textured soil that breaks easily into small cubical fragments usually less than one-half inch thick. Underlying, waterworn gravel beds may be found at varying depths averaging about 2 feet. A caliche-type subsoil is present in some areas 12 to 14 inches below the surface. Gravels on the surface cover substantial areas, especially toward the higher southern part of the experimental area.

Climate

Precipitation.—Annual precipitation averages 12.88 inches and is fairly well distributed through the year. About 75 percent falls during the 8 months from October 1 through May 31 (table 1). Probably 60 percent

Table 1—*Precipitation at Benmore Utah, by month and year during period of study compared to longtime average*

Month	Year[1]													Study period average	Long-time average
	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959		
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Jan.	0.70	0.36	1.49	3.43	1.23	1.69	0.48	1.34	0.52	1.48	1.38	0.82	0.33	1.17	1.05
Feb.	0.64	0.49	1.03	0.85	0.62	2.36	0.21	0.17	1.07	0.72	1.03	1.62	1.87	0.97	1.24
Mar.	0.67	1.99	1.17	0.74	1.37	3.22	1.29	0.94	0.06	0.58	0.41	2.84	0.71	1.23	1.52
Apr.	2.47	0.75	0.42	0.37	2.20	0.87	1.77	0.57	0.48	0.72	1.51	1.41	0.83	1.10	1.21
May	0.77	0.09	2.41	1.12	1.98	1.01	0.21	1.10	1.13	0.76	2.61	1.10	2.06	1.26	1.19
June	0.91	1.48	1.10	0.42	0.64	0.75	0.29	0.48	1.86	0.03	1.03	0.00	1.03	0.77	0.80
July	0.87	0.07	0.29	0.60	1.50	3.34	1.57	0.81	1.62	0.29	0.31	0.00	0.04	0.87	0.88
Aug.	1.32	1.01	0.39	0.03	0.87	1.75	0.61	0.70	1.58	0.50	0.40	0.33	1.40	0.84	0.95
Sept.	0.87	0.35	0.76	0.80	0.13	0.00	0.14	1.58	1.10	0.12	0.07	0.38	1.10	0.57	0.76
Oct.	1.46	0.81	2.14	0.55	1.16	0.00	0.59	1.20	0.24	0.77	1.02	0.02	0.33	0.84	1.26
Nov.	1.24	0.70	0.17	1.31	1.85	1.02	0.38	0.72	1.20	0.14	0.38	1.65	0.00	0.83	0.96
Dec.	1.57	2.04	1.96	0.54	3.66	0.75	0.52	0.93	1.24	0.72	1.51	0.52	2.20	1.40	1.06
Total	13.49	10.14	13.33	10.76	17.21	16.76	8.06	10.54	12.10	6.83	12.26	10.69	11.90	11.85	12.88

[1] Data for 1947–52 from U.S. Weather Bureau "Climatological Data, Annual Summaries," for 1949 calculated from precipitation at Oak City, Utah, for 1953–59 from storage gauge maintained near Benmore, Utah, by U.S. Forest Service Intermountain Forest and Range Experiment Station.

of the yearly total falls as snow. Summer precipitation often comes as thunder showers, sometimes with cloudburst intensity.

Since 1911, yearly precipitation at Benmore has varied from 19.01 inches (1913) to 6.83 inches (1956). Through the 8-year period of 1928–35, precipitation averaged only 9.10 inches annually. Precipitation during the last 6 years of experimental grazing (1953–58) averaged only 10.08 inches—some 3.54 inches less than the average for the preceding 6 years and 2.80 inches less than the longtime annual average.

Temperature.—Temperature data for Benmore were not available. A 30-year Weather Bureau summary for Government Creek, Utah (elevation 5,277 ft.), 15 miles west of Benmore, showed the average annual temperature to be 48.4° F., with an average maximum of 61.5° F. and an average minmum of 35.4° F. Highest and lowest extremes were 102° F. and −22° F., respectively. The average dates of last and first killing frosts were May 30 and September 25. At Government Creek the number of clear, partly cloudy, and cloudy days averaged 182, 96, and 87, respectively.

Native Vegetation

Grasses.—In order of abundance the most prominent native grasses surrounding the Experimental Area are bluebunch wheatgrass, Sandberg bluegrass, thickspike wheatgrass, western wheatgrass, Indian ricegrass, squirreltail, and Great Basin wildrye. Cheatgrass brome, an introduced annual that has spread over much of the western spring-fall range, is present in varying amounts.

Forbs.—Prominent forbs on the spring-fall ranges of this area are lupine, Utah sweetvetch, longleaf phlox, hoary phlox, low fleabane, desert globemallow, groundsel, hawksbeard, false-dandelion, loco, and such annuals as Russian-thistle, clasping pepperweed, and halogeton. Povertyweed grows profusely along gullies and intermittent stream channels. All these species grow on the Experimental Range but most are scarce.

Shrubs.—Rubber rabbitbrush and big sagebrush are by far the most prominent shrub species. In much lesser amounts but next in order are snakeweed and Douglas rabbitbrush.

History of Use

Pioneers in the Benmore area were impressed by the abundance of native grasses, which made it a superior grazing area for livestock. Thousands of cattle and horses are reported to have grazed this area almost year round when snow conditions permitted. Big sagebrush was found mainly in the foothills and in local areas on the valley floor. In time, herbaceous species declined and sagebrush increased until it dominated the remnant herbaceous understory. Shortly after 1900 this area was considered to have possibilities for dryfarming. Consequently, sagebrush and the remnant grass and forb understory were plowed out. In seasons when rainfall was average or greater, yields of wheat were fair to good, but failures or near failures were too frequent for dryfarming to be profitable.

Under the Central Utah Purchase Project of the Agricultural Resettlement Administration, most of the dryfarm area was purchased by the Federal Government from 1934 to 1936, together with some adjacent land. At the time of purchase 3,240 acres of about 45,000 acres were set aside for research and surrounded by a boundary fence. Twenty-eight 100-acre pastures were fenced for seeding to grass. A 280-acre holding pasture was established, and another 160 acres was designated as study plots for reseeding. A well, a 5,000-gallon tank, two storage reservoirs, and pipelines to the pastures were installed. Practically all facilities on the experimental area were constructed and the seeding done by Works Progress Administration and Works Projects Administration during the depression years 1935–40.

The original seeding in 1938 and 1939 used the following mixture:

	Pounds/acre
Crested wheatgrass	2.5
Smooth brome	1.0
Slender wheatgrass	.5
Western wheatgrass	.5
Tall oatgrass	.5

Bulbous bluegrass was later broadcast at 1 pound per acre. Parts of some pastures where initial stands were poor were reseeded with crested wheatgrass at 4 pounds per acre in 1941 and some even a second time up to 1945. Other than crested wheatgrass, bulbous bluegrass and western wheatgrass were the only species that became established, mostly in small amounts.

Crested wheatgrass developed more slowly on some pastures because of the low rate of initial seeding and competition from annual weeds, principally cheatgrass. Fall grazing was permitted on 12 pastures in 1941 and 1942, and on all 28 pastures in 1943. Spring grazing began on 14 pastures in 1944 and continued on 18 in 1945 and 1946; this was in addition to fall grazing.

Grazing during the period when stands were developing was intended to be at light or moderate intensity. As a result, many plants were ungrazed and developed into so-called wolf plants that contained an excessive amount of old, dry material. This occurred most frequently where parts of pastures were reseeded, and some plants from the original seeding also developed. Animals avoided the old plants and grazed the younger ones.

METHODS OF STUDY

Experimental Design

All possible combinations of four systems and three intensities of spring grazing were compared for the 11 years 1948 through 1958. The 12 grazing treatments were duplicated, thereby involving 24 range pastures (fig. 1). Treatments were assigned to pastures within blocks (reps) at random; the 12 pastures having the highest initial carrying capacity comprised block 1, and the 12 poorer pastures block 2. Within a short time, differences between blocks (reps) were negligible.

The four grazing systems were:

1. **Rotation,** in which pastures were divided into three sections by electric fences, and each section was grazed twice in regular order each spring, beginning with a different section each year.
2. **Continuous.**
3. **Continuous, but delayed 10 days** at the beginning of the season to allow greater initial grass growth.
4. **Continuous, but removed 10 days early** at the end of the season when ungrazed grass is approaching maturity.

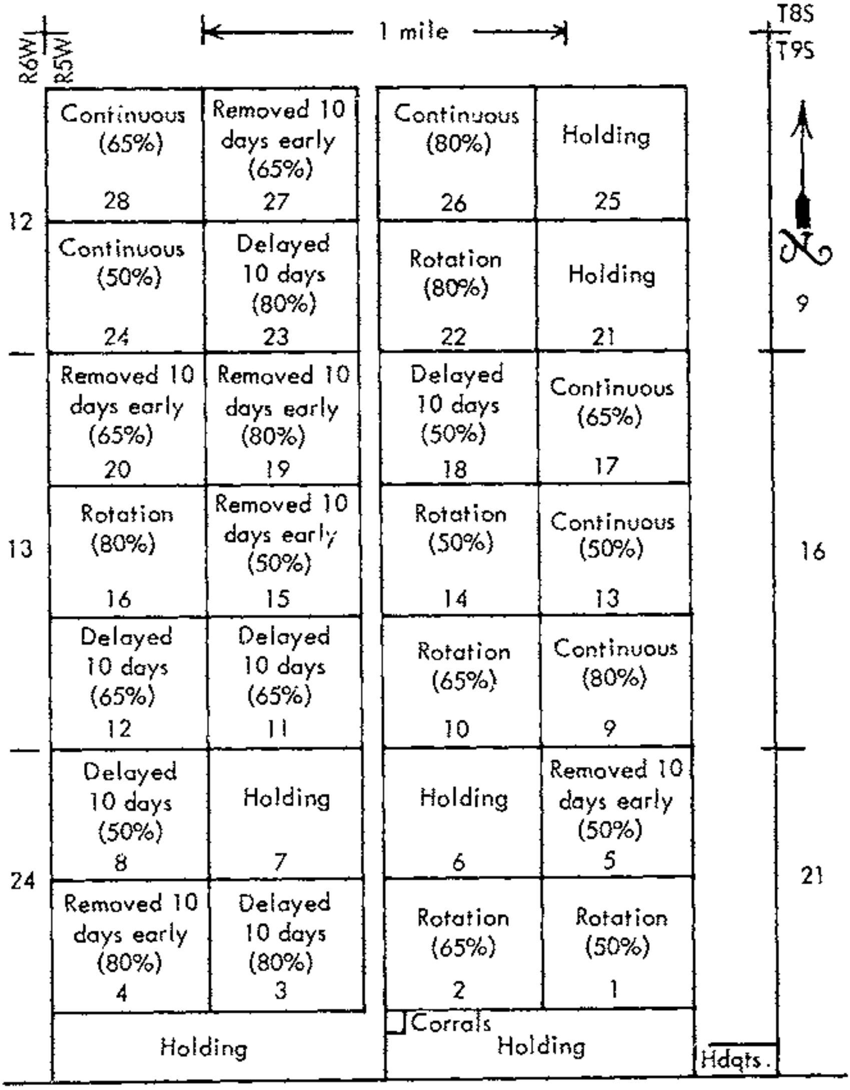

Figure 1.—Experimental layout and pasture assignment of the 12 duplicated treatments for four systems and three intensities of grazing at Benmore Experimental Area in Utah.

The three proposed grazing intensities were **50-, 65-, and 80-percent utilization,** by weight, of total herbage.[4] The measured intensities of actual utilization for the whole experiment averaged 53, 65, and 80 percent, respectively, and are referred to as **light, medium,** and **heavy** throughout this report. Annual fluctuations in the forage crop during the

[4] Percent utilization is that proportion of the current year's plant growth that is consumed or destroyed by grazing animals. This is the *grazing intensity* or *intensity of use* of the forage.

study required that stocking rates[5] be adjusted from year to year to maintain constant utilization.

During 1947, the year used for preliminary calibration, all pastures were grazed to about 65-percent utilization to determine initial grazing capacities.[6] Numbers of cattle were adjusted as necessary to achieve the desired degree of use. The total animal gains or cattle-days per pasture during 1947 were later used in covariance analyses to adjust for initial differences in carrying capacities of the pastures. Data on vegetation were adjusted for initial differences existing in 1948, since that year was the first that data were taken on permanent plots.

In early years of the experiment, spring grazing started when crested wheatgrass was about 4 inches tall, usually between April 15 and 30. As stands aged and thickened, early growth was shorter on corresponding calendar dates; grazing started when the grass was 3 to 3½ inches tall. The grazing period of approximately 2 months ended about the time the grass stopped growing. Cattle were then moved to an adjacent National Forest summer range.

Handling of Cattle

Depending upon the year, 500 to 600 head of cattle over 6 months of age, plus calves, were used in this experiment. These were provided by 18 cooperators in the Vernon Soil Conservation District. Most cattle were Herefords, but a few showed dairy ancestry. The average distribution of the animals for calculating weight gain was:

	Percent
Yearlings (both sexes)	12.7
Dry cows and steers older than 1 year	20.0
Pregnant cows calving in the pasture[1]	7.7
Lactating cows and calves entering pastures with their dams	59.6

[1] For calculating weight gain of this class, the out-weight of the calf was added to the out-weight of its dam.

All animals older than 6 months were identified by a neck chain bearing a numbered metal tag. Calves were identified with their dams by ear tags with corresponding numbers.

All cattle were weighed at the beginning of the grazing season, and approximately one-fourth of the total number were weighed 10 days later, when they were placed in the "Delayed 10 days" pastures. Toward the end of the season, another one-fourth of the total number were "Removed 10 days early" and weighed; the remaining animals were weighed 10 days later. A few animals were also weighed during the grazing season before being shifted into other pastures to achieve the designated intensity of forage use.

All cattle were placed in the holding pastures from 1 to 3 days before the first weighing. This practice partially equalized the fill of the animals.

[5] Stocking rate is the number of animal units on a specific area for a specific period of time.

[6] Grazing capacity is the maximum number of animal units which a specific area of range can carry for a certain period of time without damaging the vegetation or soil.

For further equalization of fill, all animals were held in the corrals without feed or water for the last 12 hours before weighing (fig. 2); they were randomly assigned to pastures after weighing.

When the cattle were to be weighed out of the pastures, they were moved to the holding corral and held without feed or water for 12 hours. Cattle from each replication of pastures were mixed together and weighed in random sequence. They were separated according to ownership after being weighed out.

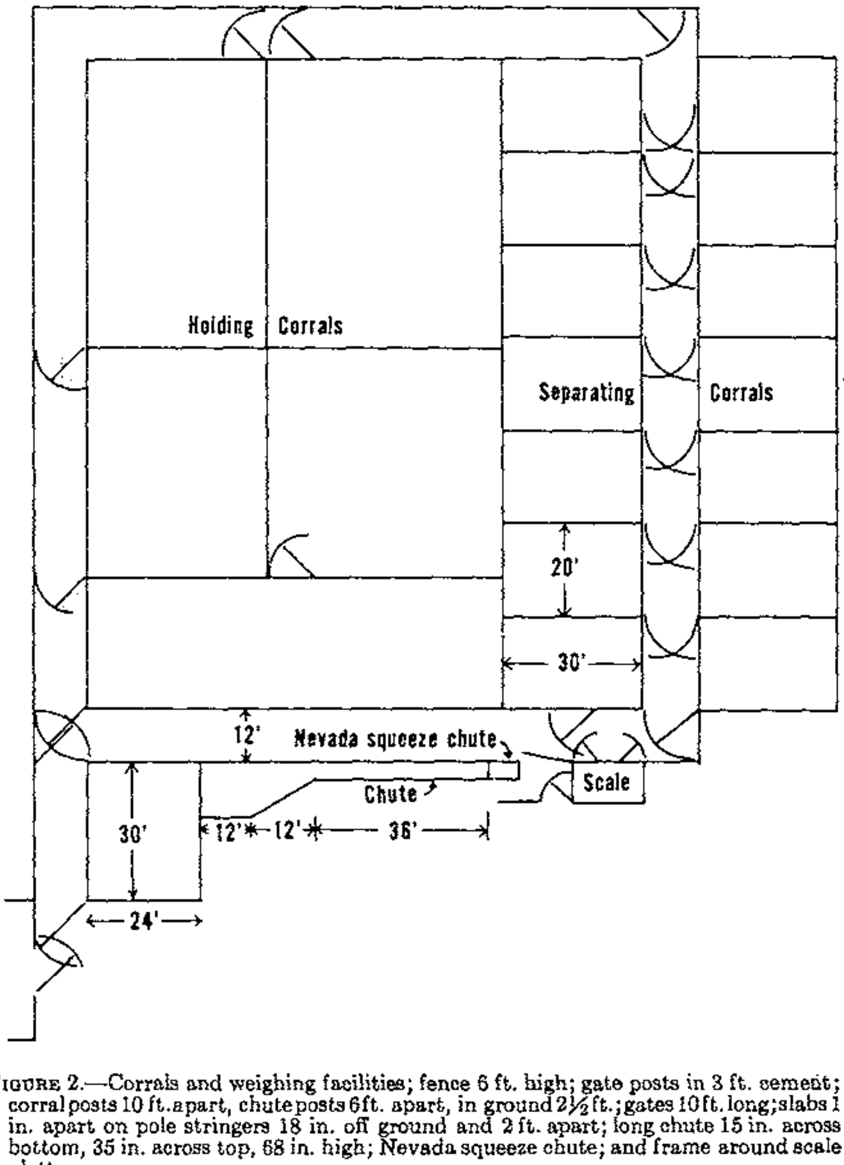

FIGURE 2.—Corrals and weighing facilities; fence 6 ft. high; gate posts in 3 ft. cement; corral posts 10 ft. apart, chute posts 6 ft. apart, in ground 2½ ft.; gates 10 ft. long; slabs 1 in. apart on pole stringers 18 in. off ground and 2 ft. apart; long chute 15 in. across bottom, 35 in. across top, 68 in. high; Nevada squeeze chute; and frame around scale platform.

Calculation of Digestible Energy

Digestible energy produced per acre was calculated by the formula of Winchester and Hendricks (1953):

$$TDN = .0553\, W^{2/3}\, (1 + 0.805\, G)$$

where W equals pounds body weight and G equals pounds daily gain. One pound of total digestible nutrients is assumed to equal 2,000 kilocalories of digestible energy (Crampton et al. 1957).

Plot Methods for Evaluating Changes in Vegetation

Changes in the vegetation were observed on 40 permanent plots per pasture. The plots were representative of 200 initial temporary plots that were used in sampling each pasture for size of grass plants and yields of forage. The temporary plots were mechanically spaced along four transects crossing each pasture; transects were chosen at random within stratified units. One-fifth of the plots were made permanent and identified by means of orange-colored steel stakes.

During the first year (1948), cattle were curious about the colored stakes. Undue trampling was prevented by replacing the colored stakes with large spikes to which short wires were attached; spikes were driven flush with the ground. The colored stakes were then offset 10 feet north as location markers.

Grass studies.—The plots used for recording data about grass (Frischknecht and Plummer 1949) were 9.6 square feet in area. Wire hoops segmented radially into sixths (fig. 3) facilitated taking the following kinds of data on herbaceous species:

1. Basal area to the nearest 0.1 square foot, an adaptation of the square-foot method described by Stewart and Hutchings (1936).
2. Numbers of plants by two sizes: less than 1-inch crown diameter, and 1 inch and larger.
3. Numbers of ungrazed or lightly grazed wolf plants.

These data were recorded after grazing in the even-numbered years from 1948 through 1958 except for data on basal area and numbers of plants, which were taken in 1951 and not in 1952.

Every year a record of forage utilization on the permanent plots was taken after the final spring grazing by using the ocular-estimate-by-plot method (Pechanec and Pickford 1937). Data in this record included the amount of remaining herbage, percentage of utilization, and estimates of stubble height. Yields of crested wheatgrass on each plot were calculated from estimates of the amount left and percentage utilization. The presence of the other most prominent species, including western wheatgrass, bulbous bluegrass, cheatgrass brome, and forbs, on permanent plots was recorded.

About 200 wire cages, each covering an area slightly more than 9.6 square feet (Robertson 1954) were distributed over the 24 pastures as guides in estimating utilization (fig. 4). Some caged and grazed plots were clipped during the grazing season to determine the progress of growth and utilization. Others were clipped at the end of the season prior to making estimates of forage production and utilization.

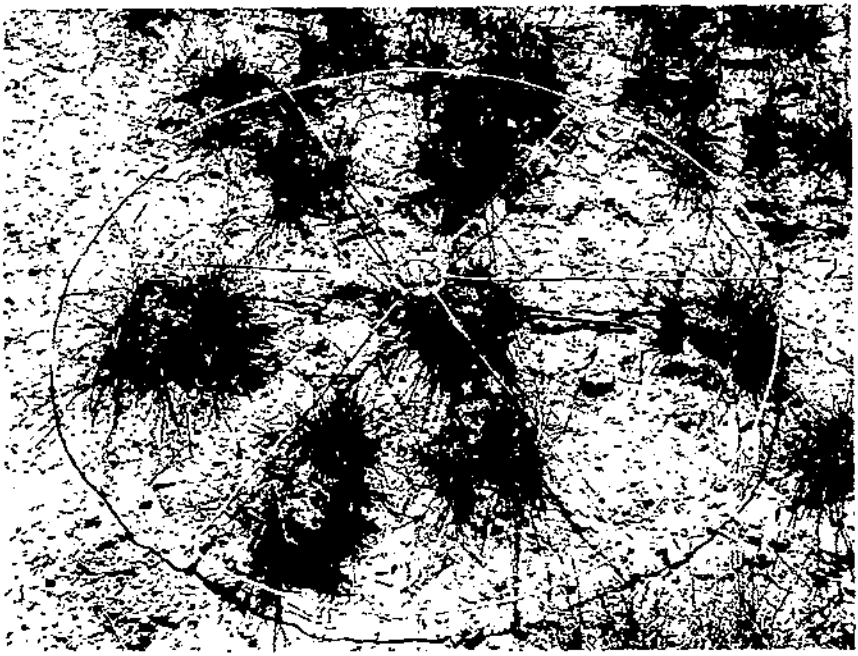

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FIGURE 3.—Wire hoop encircling 9.6 square feet was divided into sixths by crosswires to aid in recording data on crested wheatgrass and other herbaceous species. Colored tape on crosswires, corresponding to subdivisions of 0.1, 0.5, and 1.0 square foot within each 1.6-square-foot section, facilitated estimating grass basal area to the nearest 0.1 square foot. Inner ring maintained accurate centering over plot markers.

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FIGURE 4.—Wire cage encompasses an area slightly larger than 9.6 square feet to protect samples of ungrazed vegetation for comparison with grazed plots.

Shrub studies.—In even-numbered years throughout the study including 1960, information about big sagebrush and rubber rabbitbrush was recorded; both of these species heavily invaded the experimental area.

At the beginning of the study in 1948, wherever either of these species occurred on a permanent 9.6-square-foot plot used for grass data, a 100-square-foot circular plot was superimposed for taking shrub data. Information recorded about brush included:

1. Counts of plants in two size classes: less than 4 inches high, and 4 inches or more in height.

2. Estimates of herbage yields in pounds per acre. Beginning in 1952, similar data were taken on 100-square-foot plots, which had been superimposed over all 960 of the 9.6-square-foot plots. In addition, invasion of both shrub species onto the smaller (9.6-square-foot) plots was noted by plant counts and estimates of herbage yield throughout the study.

Post-treatment evaluation.—In the spring of 1959, no pastures were grazed. In late June and early July, data on basal area, yields, and plant heights of grasses were obtained on the permanent plots as residual measures of grazing treatments. Additional data on grass yields were obtained by clipping herbage from 80 temporary plots per pasture; these data were taken in four periods or cycles so as to minimize differences due to successive sampling dates. A cycle was one of four transects of 20 plots in each pasture. The entire sampling was completed within a 3-week period. Additional shrub counts were made in 1960 on 100-square-foot plots superimposed on the 80 temporary small plots. These final shrub counts included plants in three size classes: 0 to 4 inches, 4 to 12 inches, and over 12 inches high.

Supplementary Observations

Photographs were taken during and after the grazing season each year. Every fall, all pastures were inspected to observe conditions and changes that had not been apparent in the spring. This inspection provided information on summer-growing annuals, such as Russian-thistle and halogeton, as well as the main shrub species that reach maximum development and are most conspicuous in late summer or fall. Photo contrasts between the shrubs and grasses are greatest in the fall.

Although the main study deals with spring grazing, information on fall grazing was obtained in 1947, 1949, and 1952.

RESULTS AND DISCUSSION

Utilization

The three planned intensities of utilization were approximately achieved (fig. 5) by adjusting the numbers of cattle on the pastures at the start and during each grazing season. Under the three grazing intensities, utilization of crested wheatgrass averaged 53, 65, and 80 percent and left stubble 3.8, 2.9, and 1.9 inches high, respectively, at the end of the grazing season. Utilization for the lightest grazing treatment averaged 3 percent heavier than had been anticipated; actually, in each of the last 2 years, utilization was approximately 5 percent heavier than had been planned.

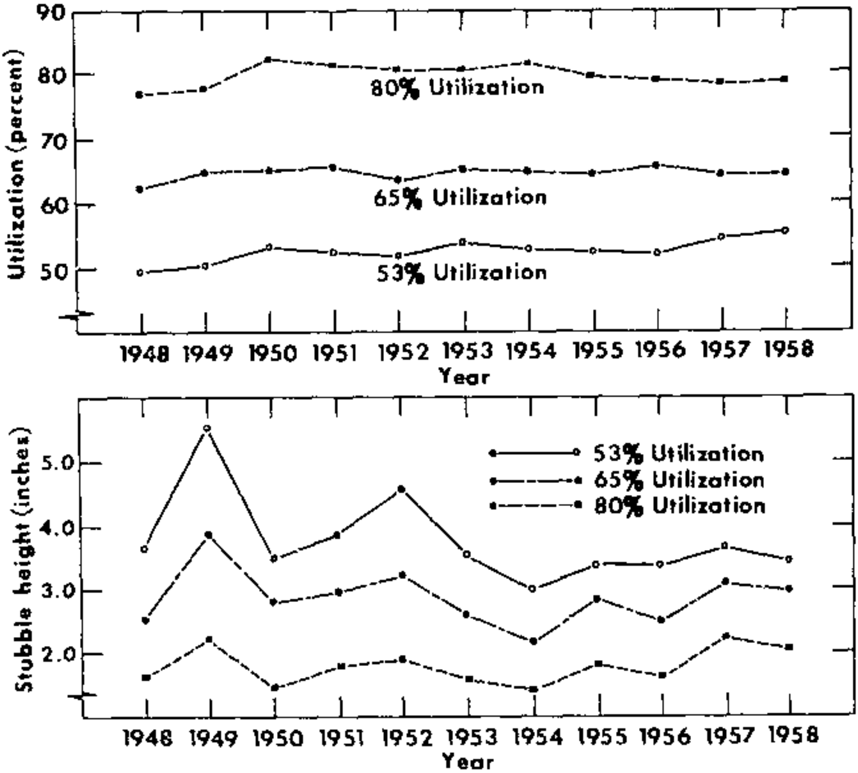

FIGURE 5.—*Top*, Percent utilization; *bottom*, average plant height following grazing, by intensities of utilization and years.

An immediate effect of the lightest grazing was an increase in the number of so-called wolf plants (fig. 6) except where the relatively fine-stemmed fairway wheatgrass predominated. Wolf plants are plants left ungrazed year after year because of unpalatable, accumulated old growth. Some wolf plants persisted throughout the study period, but their numbers were greatly reduced by the heavy snowpack in 1952 that laid most of the old stems on the ground. Under light use, animals tended to avoid these wolf plants year after year. Old growth was soon removed under heavy use; reduction was gradual under medium use. Below-average precipitation during the latter years of the study undoubtedly contributed to reduction of these wolf plants.

Obviously, grazing to the specified percentages of utilization caused fluctuations in stubble height (fig. 5, bottom) from year to year as herbage yields fluctuated. Thus, heights of stubble for grass used at the medium and heavy intensities in years of heavy production were higher than stubble heights for the next lighter intensities in years when precipitation was low (1957 and 1954). In most years, the differences in stubble heights between the four systems of grazing were relatively small.

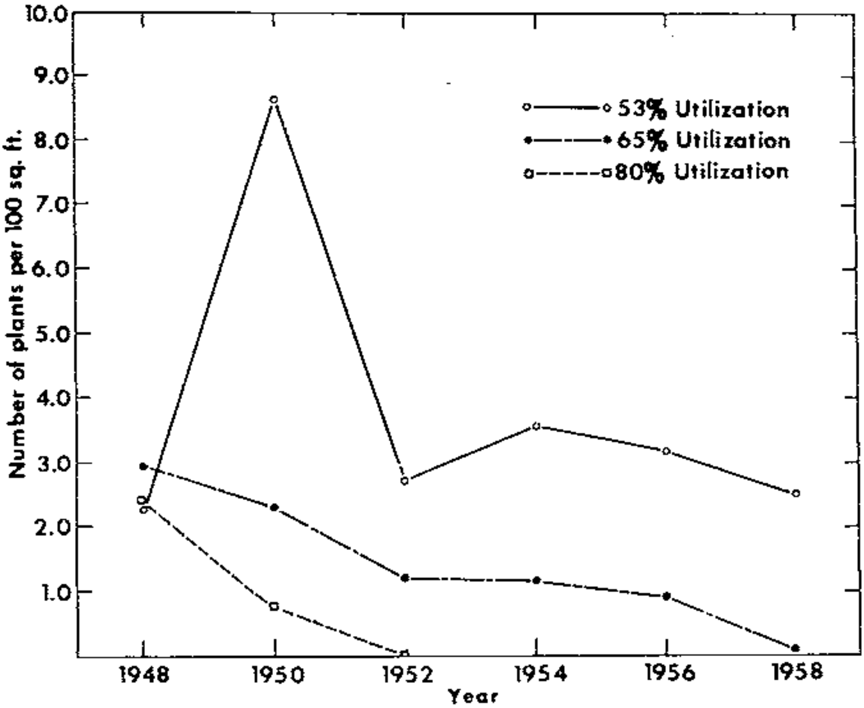

FIGURE 6.—Concentrations of crested wheatgrass wolf plants under three intensities of grazing, by years.

Numbers of Grass Plants

Stands of crested wheatgrass improved gradually during the first few years of the experiment. Total plant numbers increased 9 percent from 1948 to 1950 irrespective of grazing treatment (Frischknecht et al. 1953). Numbers of large plants (more than 1-inch crown diameter) increased 35.5 percent during this period. The increased numbers of large plants approximated the numbers of young plants existing at the beginning of the experiment, so it seems likely that most of the original small plants grew into the larger size class during that early period. More small plants became permanently established during the period 1948–50 than during the period 1950–56—a further indication that maximum plant numbers (density) were being approached by 1950 (figs. 7 and 8).

Individual grass plants could be identified with fair accuracy until 1956 but with progressively increasing difficulty. By 1958 it was impossible to identify many original plants, mainly because of complete or partial die-out and associated breaking up of many plant crowns, particularly of fairway wheatgrass (fig. 9). This die-out was attributed directly or indirectly to extreme drought during the summer and fall of 1956, which followed 3 dry years.

Plants having crown diameters larger than 1 inch were 33.1 percent more numerous in 1958 than in 1956 mainly because of the breaking up

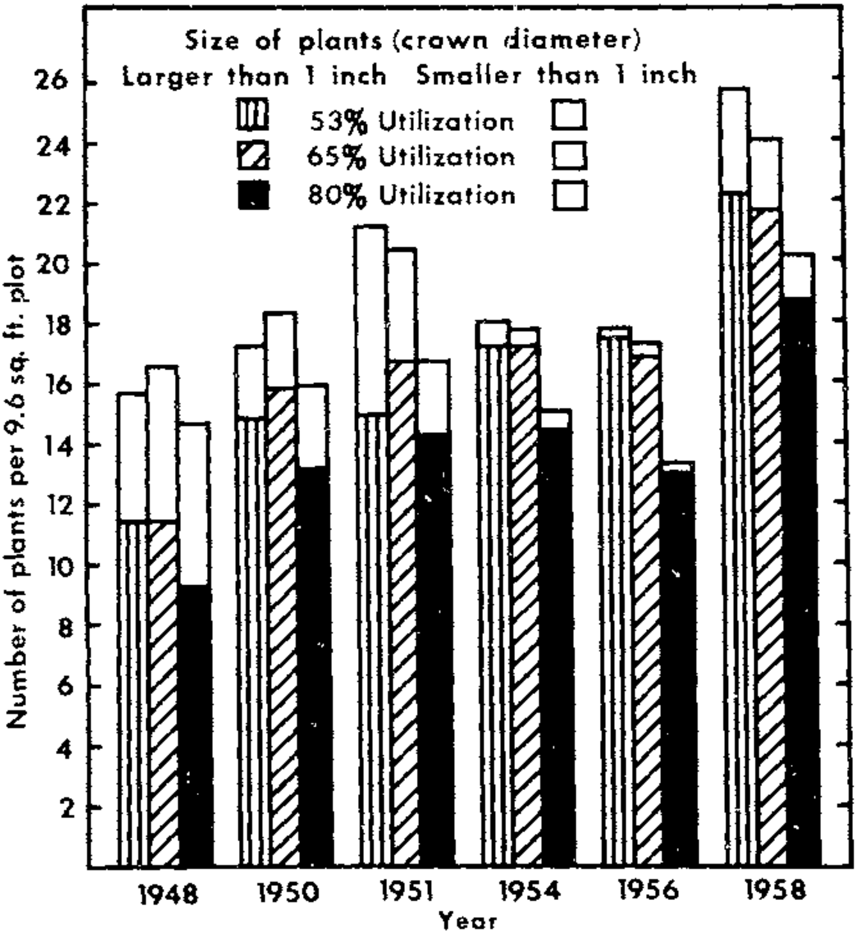

FIGURE 7.—Numbers of crested wheatgrass plants of different crown diameters under three intensities of grazing, by years.

of plant crowns. Covariance analysis comparing numbers of large plants in 1956 (*Y* variable) with total plants in 1948 (*X* variable) revealed significant differences that were caused by grazing treatment. Differences, however, were not statistically significant when data for 1958 were used as the *Y* variable. In 1956, areas grazed at the light and medium intensities contained significantly more plants than the heavily grazed areas, but differences in numbers of plants on the lightly grazed and medium grazed areas were not significant (table 2). Largest numbers of plants were present in rotation-grazed and removed-10-days-early pastures and fewest in the pastures where grazing was delayed 10 days.

The slight decline in numbers of large plants from 1954 through 1956 as utilization increased (fig. 7) indicated that heavy grazing caused some large plants to disappear faster than they were being replaced by young plants. The same might be said about systems of grazing other than rotation (fig. 8). Less than average precipitation from 1953 through 1956 probably contributed to the decline. Any losses from 1954 through 1956

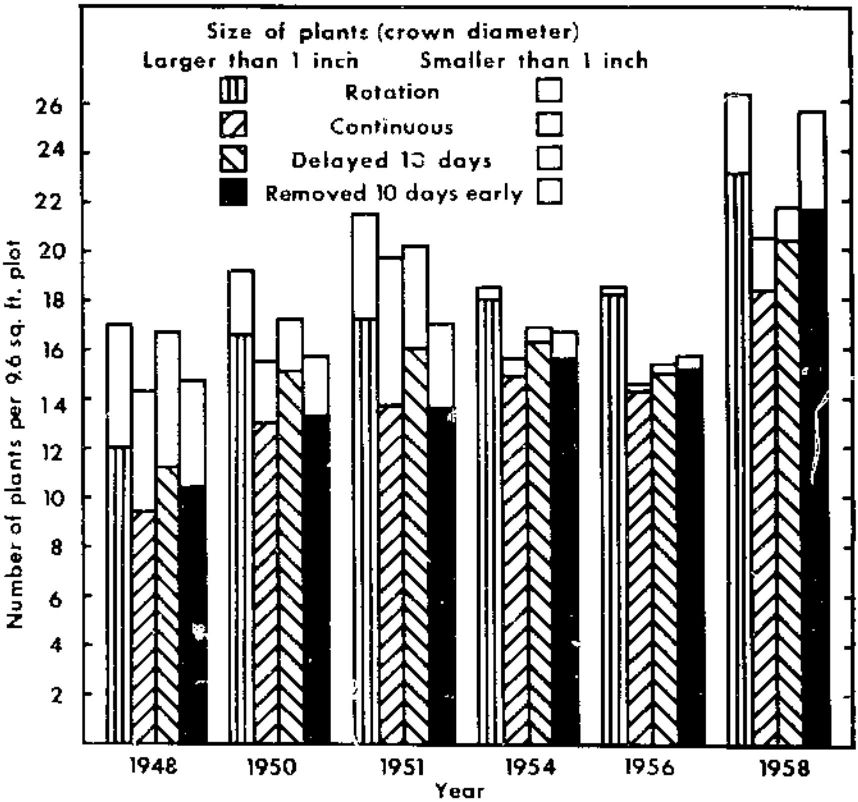

FIGURE 8.—Numbers of crested wheatgrass plants of different crown diameters under four systems of grazing, by years.

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FIGURE 9.—Sparse spring growth of fairway wheatgrass in 1957 resulted from partial die-out and breakup of plant crowns, presumably from the drought in 1956. No die-out occurred in swales and depressions similar to the one near the center of the photo, where snow and extra moisture accumulated.

TABLE 2.—*Average numbers of grass plants, crown diameter greater than 1 inch, per 9.6 square feet (1956 adjusted means*[1])

System of grazing	Intensity of grazing (percent)			Mean for systems
	53	65	80	
	Number	*Number*	*Number*	
Rotation	18.0	16.0	15.6	16.5[c]
Continuous	17.0	15.1	14.0	15.4[cd]
Delayed 10 days	15.2	16.0	11.4	14.2[d]
Removed 10 days early	17.2	17.1	13.8	16.0[c]
Mean for intensities	16.8[a]	16.0[a]	13.7[b]	

[1] Means having different superscripts are significantly different (P < .05).

under light grazing and also under the rotation system were more than offset by replacement by young plants.

Differences in numbers of newly established plants attributable to differences in intensities of grazing were statistically significant only in 1951 (Frischknecht et al. 1953) and 1958. (It should be remembered that data were not taken every year.) In 1958 most young plants were found in pastures lightly grazed, whereas fewest young plants appeared in heavily grazed pastures (table 3); this situation was similar to that in 1951. In general, differences in numbers of young plants between treatments are a reflection of the amount of seed produced. Differences between years result mainly from spring growing conditions favorable for seed germination. A high percent of the small plants present in 1958 started as seedlings in the favorable spring of 1957, when precipitation was above average. During periods of drought such as 1954 and 1956, young plants may be eliminated in competition with older established plants.

TABLE 3.—*Average numbers of grass plants, crown diameter less than 1 inch, per 9.6 square feet (1958 adjusted means*[1])

System of grazing	Intensity of grazing (percent)			Mean for systems
	53	65	80	
	Number	*Number*	*Number*	
Rotation	4.2	3.4	2.1	3.2[c]
Continuous	1.8	1.8	2.6	2.1[d]
Delayed 10 days	1.8	1.4	0.8	1.3[d]
Removed 10 days early	7.0	3.0	1.9	4.0[c]
Mean for intensities	3.7[a]	2.4[b]	1.8[b]	

[1] Means having different superscripts are significantly different (P < .05).

Differences in numbers of small plants related to the four systems of grazing were statistically significant ($P < .05$) only in 1958; the removed-10-days-early and rotation treatments produced the largest number of small plants, whereas the continuous and delayed-10-days treatments produced the fewest. This might be expected, considering that for rotation pastures grazing terminated about 16 days early in one section and 6 days early in another each year, which in certain years allowed some regrowth and seed production. In certain years also, some regrowth and seed production occurred in the removed-10-days-early treatments. In contrast, only slight, if any, regrowth usually occurred in the continuous and delayed-10-days treatments. The significant interaction between intensities and systems is partly caused by more small plants under lighter intensities of grazing for rotation and removed-10-days-early systems than under continuous and 10-days-deferred systems.

Basal Area of Grass

The increase in average basal area of grass in the early years of the Benmore study was caused by the increased size of existing plants and the establishment of new plants (fig. 10). Before 1951, differences in basal area of grass among pastures on different grazing treatments were not statistically significant (Frischknecht et al. 1953). But after 1951, differences in average basal area increased—both between *intensities* of grazing (fig. 11) and between *systems* of grazing (fig. 12). Overall basal areas of grass were largest in 1954. Their slight decline between 1954 and 1956 was attributed mainly to the low precipitation in 1953 and 1954 (table 1) and was more noticeable on pastures subjected to heaviest use. Excessive trampling and reduced vigor (resulting from heavy use) restricted grass basal areas under the 80-percent intensity (fig. 13).

As plant crowns enlarged by tillering, some die-out appeared in the centers, particularly in the older and most heavily grazed plants. Therefore, in 1956 both total and live basal areas were measured; later only live basal area was determined (figs. 11 and 12). In 1956, dead plant centers occupied 28.7, 33.5, and 43.3 percent of the total basal area for the light, medium, and heavy grazing, respectively. A tendency toward more numerous and larger dead centers under heavy grazing was likewise observed on a 10-year-old crested wheatgrass pasture in northeastern Nevada (Frischknecht and Bleak 1957).

Covariance analyses of live basal area in 1956 with total basal area in 1948 showed that important differences had developed, both between intensities and methods of grazing. Live basal area was significantly less where grazing had been heavy than where it had been at light or medium intensity (table 4). In comparing systems of grazing, it was apparent that

TABLE 4.—*Average basal areas of live crested wheatgrass, square feet per 9.6-square-foot plot (1956 adjusted means[1])*

System of grazing	Intensity of grazing (percent)			Mean for systems
	53	65	80	
Rotation	1.10	1.24	0.75	1.10[c]
Continuous	1.10	0.96	0.78	0.95[cd]
Delayed 10 days	1.06	1.18	0.86	1.03[c]
Removed 10 days early	1.12	0.69	0.75	0.85[d]
Mean for intensities	1.10[a]	1.02[a]	0.83[b]	

[1] Means having different superscripts are significantly different ($P < .05$).

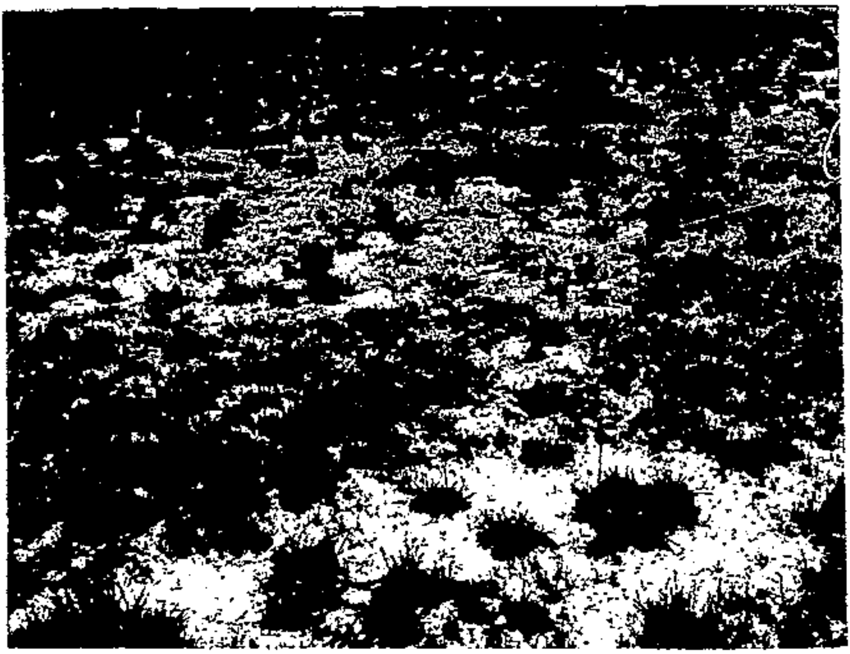

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FIGURE 10.—Crested wheatgrass invades a patch of Russian-thistle. In earlier years, this had been an island of cheatgrass.

total basal area of live grass averaged greatest under rotation and delayed-10-days grazing, and least under the removed-10-days-early treatment. Covariance analyses of subsequent data showed similar relations in the final year of treatment (1958) and again in the following year, when pastures were ungrazed. Apparently, estimates of basal area contained little bias that was caused by differences in stubble height in the years of grazing.

It might be expected that the most ground cover or total basal area of grass would be found where plants are most numerous. This was true for the rotation treatment only. The removed-10-days-early treatment developed relatively large numbers of plants, but showed the least basal area of live grass for the four systems of grazing. On the other hand, the delayed-10 days treatment had the fewest plants (table 2) but relatively large total basal area.

Whereas removing animals early toward the end of the grazing season tended to produce more plants, delayed grazing at the start of the season tended to produce the most live basal area (ground cover). The rotation treatment had both relatively high basal area and numbers of plants; the part where grazing terminated about 16 days early one year received about 16 days deferment from grazing at the beginning of the season the following year.

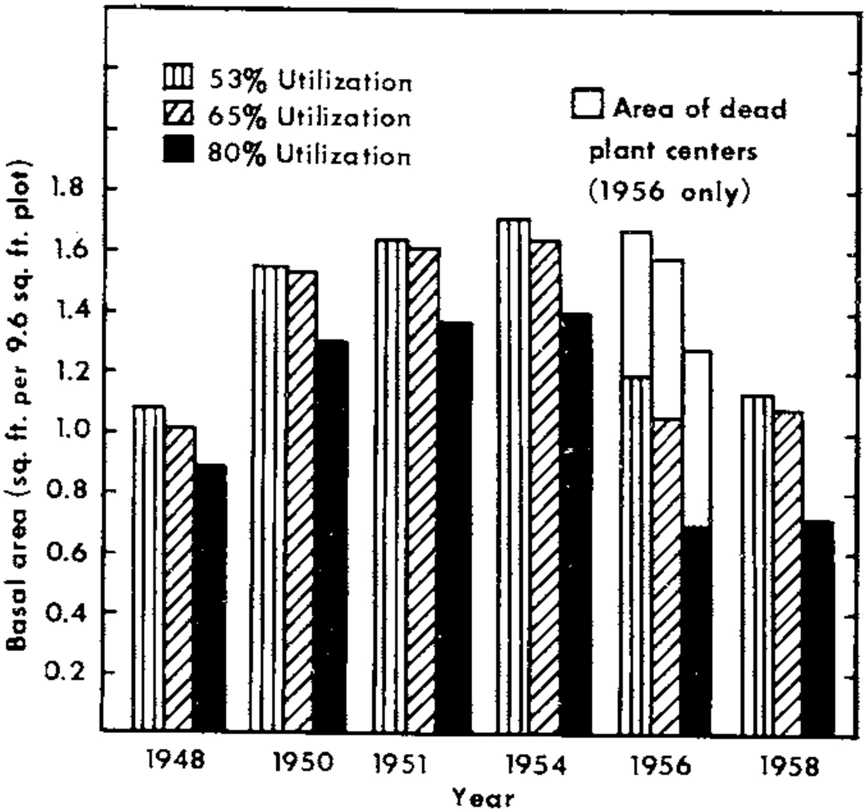

FIGURE 11.—Basal areas of crested wheatgrass under three intensities of grazing, by selected years; live basal area only is shown for 1958.

Grass Production

Grass yields during the 11 years of grazing generally fluctuated with the winter-spring precipitation (fig. 14). Correlation between precipitation and yield was higher during the last 6 years of study, when precipitation was recorded at Benmore headquarters, than in earlier years when recorded at Bennion's ranch, which is 1 mile east and closer to the mountains. The correlation coefficient was 0.94 for November-May precipitation and grass production during the last 6 years of study on pastures grazed at the light and medium intensities. Relatively light grass yields in 1957 resulted, in part, from grass die-out during the drought in 1956. In 1957 regrowth was considerable after the utilization survey, but almost nil in all other years.

Yields on the permanent plots in each pasture in 1959, when there was no spring grazing, required only one estimate—total herbage weight. Grass yield estimates were checked and adjusted at each fourth plot by first estimating and then clipping a plot adjacent to the permanent plot. Estimated yields in 1959 from the 40 permanent plots were very close to the actual yields on the 80 clipped plots, as was indicated by a correlation coefficient of 0.91. Means were 400 pounds per acre from the 40 estimated

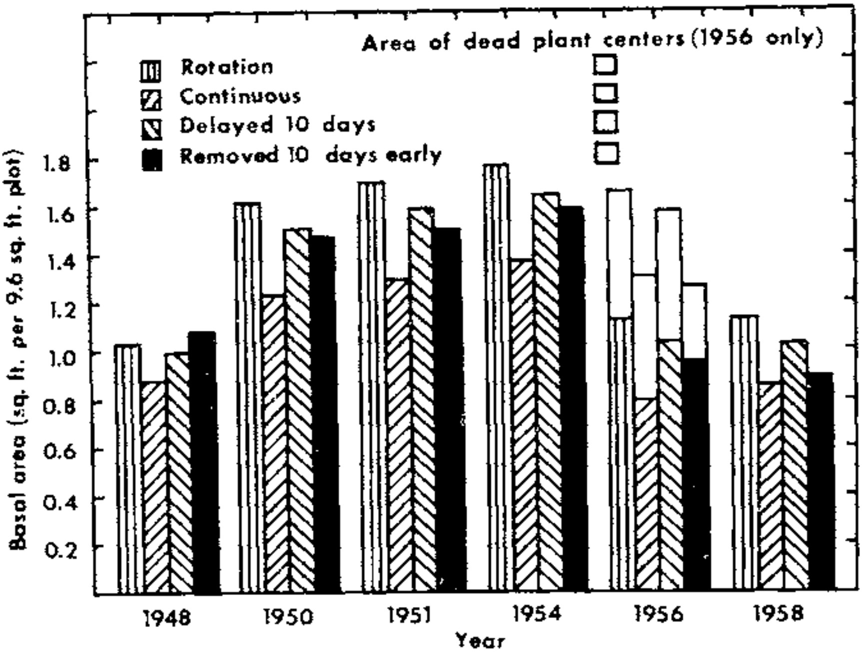

FIGURE 12.—Basal areas of crested wheatgrass under four systems of grazing, by years; live basal area only is shown for 1958.

plots and 371 pounds from the 80 clipped plots. These yields were lower than average, as might be expected, considering that the November-May precipitation was only 75 percent of average (table 1).

Covariance analyses of 1959 data from permanent plots with comparable 1948 data showed that the heavy grazing had reduced grass yields, but there was little difference in yield between pastures grazed at light and medium intensities (table 5). Differences in yields under the four systems of grazing were not statistically significant, although under rotation and delayed-10-days treatments they averaged 50 pounds higher than the other two treatments. However, when systems were combined into two groups (rotation and delayed-10-days versus continuous and removed-10-days-early) and intensities were combined into two groups (heavy versus moderate and light), the interaction between systems and intensities was significant at the 0.057 level of probability. Thus, it appears that under 80-percent utilization, grass yields were maintained better under rotation and delayed-10-days treatments than they were under continuous and removed-10-days-early.

Shrub Invasion

Big sagebrush and rubber rabbitbrush were present in varying amounts at the beginning of the experiment, but neither species appeared to be a problem (fig. 15). Populations of both species increased greatly during the study (fig. 16). Most rapid invasion was into patches of annual weeds, where competition was less than in crested wheatgrass stands.

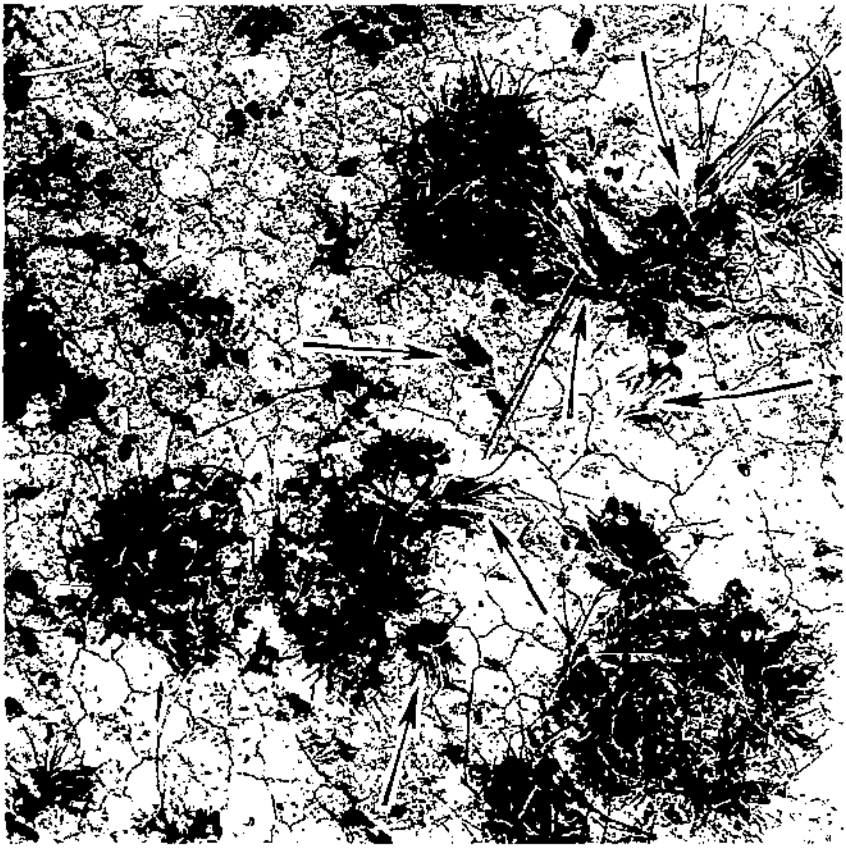

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FIGURE 13.—Wheatgrass crowns (arrows) partially destroyed by excessive grazing (80-percent utilization).

TABLE 5.—*Yields of grass, dry weight, following 11 consecutive years of grazing (1959 adjusted means*[1]*)*

System of grazing	Intensity of grazing (percent) 53	65	80	Mean for systems
	Lbs./acre	*Lbs./acre*	*Lbs./acre*	
Rotation	462	435	391	429[c]
Continuous	428	444	242	371[e]
Delayed 10 days	435	421	406	421[c]
Removed 10 days early	445	432	262	380[d]
Mean for intensities	442[a]	433[a]	325[b]	

[1] Means having different superscripts are significantly different ($P < .05$).

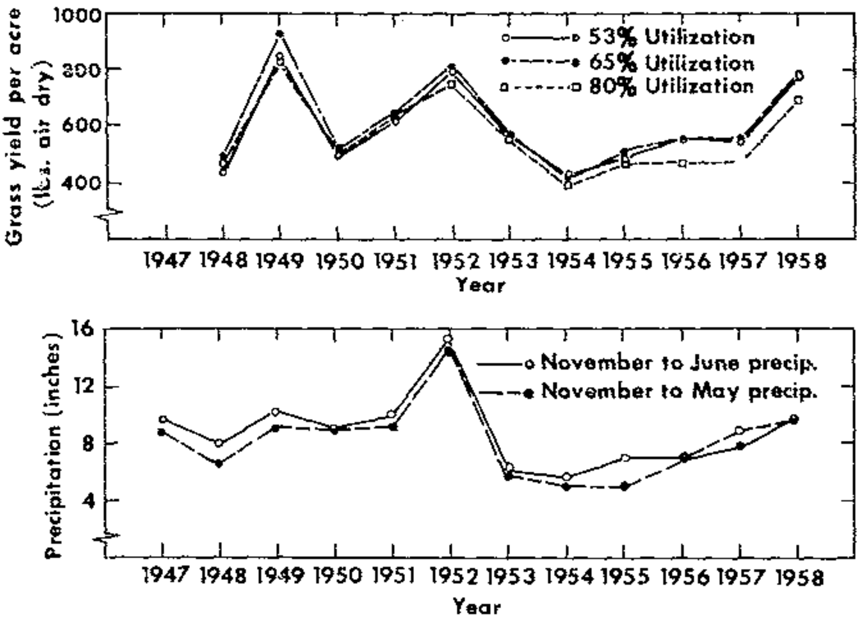

FIGURE 14.—Production of crested wheatgrass by years related to three intensities of utilization (top), and precipitation (bottom).

Frequency data showed that rabbitbrush was more widespread than sagebrush at the outset of the study and that this continued (fig. 17), probably because the hairy achenes of rabbitbrush were carried farther by wind than the hairless achenes of sagebrush (Frischknecht 1962). Both species spread gradually until 1956, but increased greatly in 1957. This acceleration is attributed to the exceptionally wet spring of 1957, which

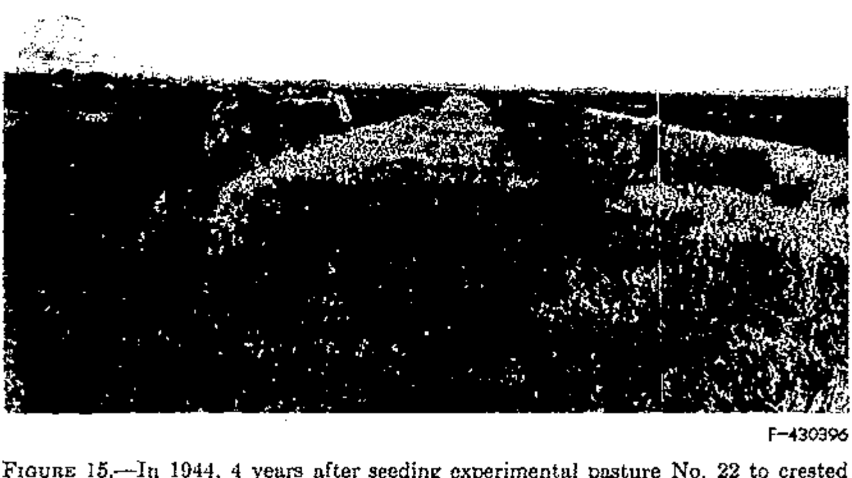

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FIGURE 15.—In 1944, 4 years after seeding experimental pasture No. 22 to crested wheatgrass and before the start of the experiment, cheatgrass dominated alternate drill strips where crested wheatgrass was not seeded.

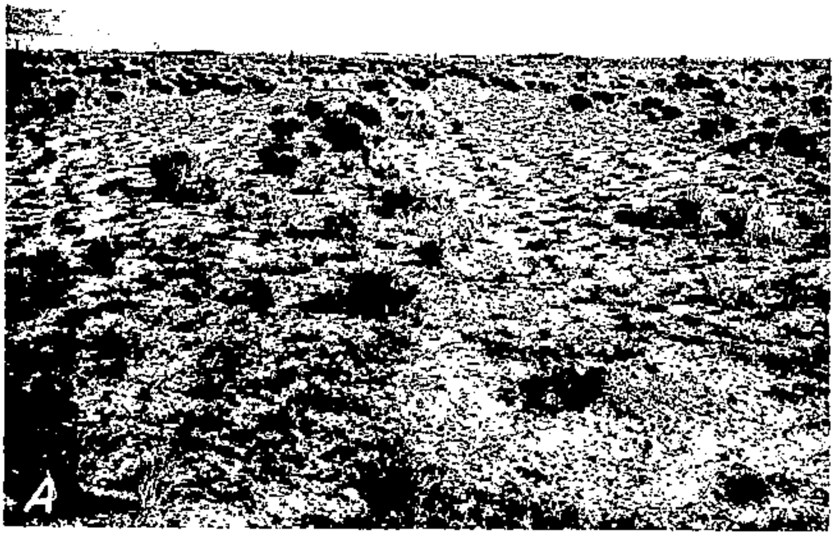

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Figure 16.—*A*, In 1953, after six spring seasons of heavy grazing by cattle, rubber rabbitbrush, big sagebrush, and Russian-thistle had taken over the former cheatgrass area. Large brush was noticeably absent in crested wheatgrass, but small plants were beginning to invade. *B*, In 1960, after 12 years of heavy grazing (1959 excluded), brush was prominent in areas of crested wheatgrass where it had previously been excluded. Both these photos and Fig. 15 were taken from the same camera point.

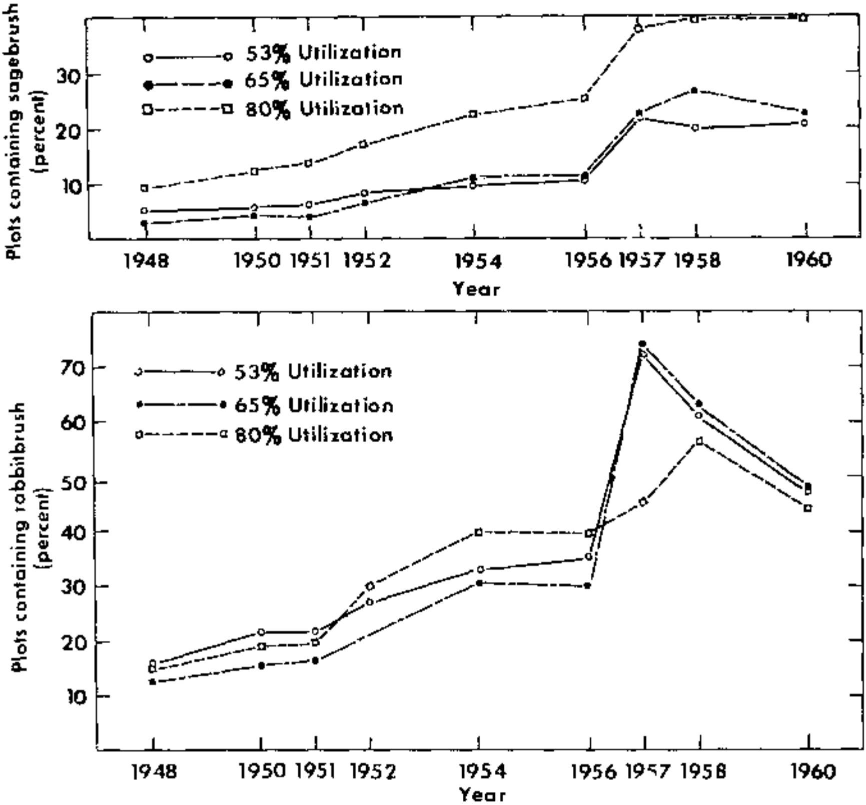

FIGURE 17.—Presence of sagebrush (*top*) and rabbitbrush (*bottom*) on total permanent plots (9.6 sq. ft.), by years and intensities of utilization.

followed the driest calendar year on record, in which parts of many grass plants (especially fairway wheatgrass) died.

Before 1956, both brush species spread most rapidly where the grazing was heaviest. Sagebrush continued this trend. However, in 1957, rabbitbrush began to spread more widely under light and medium grazing than under heavy grazing, and this trend continued until 1960. Sagebrush may have limited the spread of rabbitbrush in certain of the most heavily grazed pastures where sagebrush was most prominent (fig. 18). Sagebrush has been observed to invade rabbitbrush stands, but rabbitbrush has not been seen to invade dense stands of sagebrush. This suggests that big sagebrush will become dominant at the expense of rubber rabbitbrush. This is most unfortunate because big sagebrush suppresses grass much more than rabbitbrush does (Frischknecht 1963). Pastures showing the greatest reduction in grazing capacity were those that had the greatest increase of sagebrush.

It is doubtful that rubber rabbitbrush adversely affects production of crested wheatgrass under the conditions that exist at Benmore. Hindrance to grazing would be its main adverse effect, but under fall grazing this would be minor. Grass that is beneath rabbitbrush remains more succulent throughout the summer than grass in the open, and cattle prefer it in the

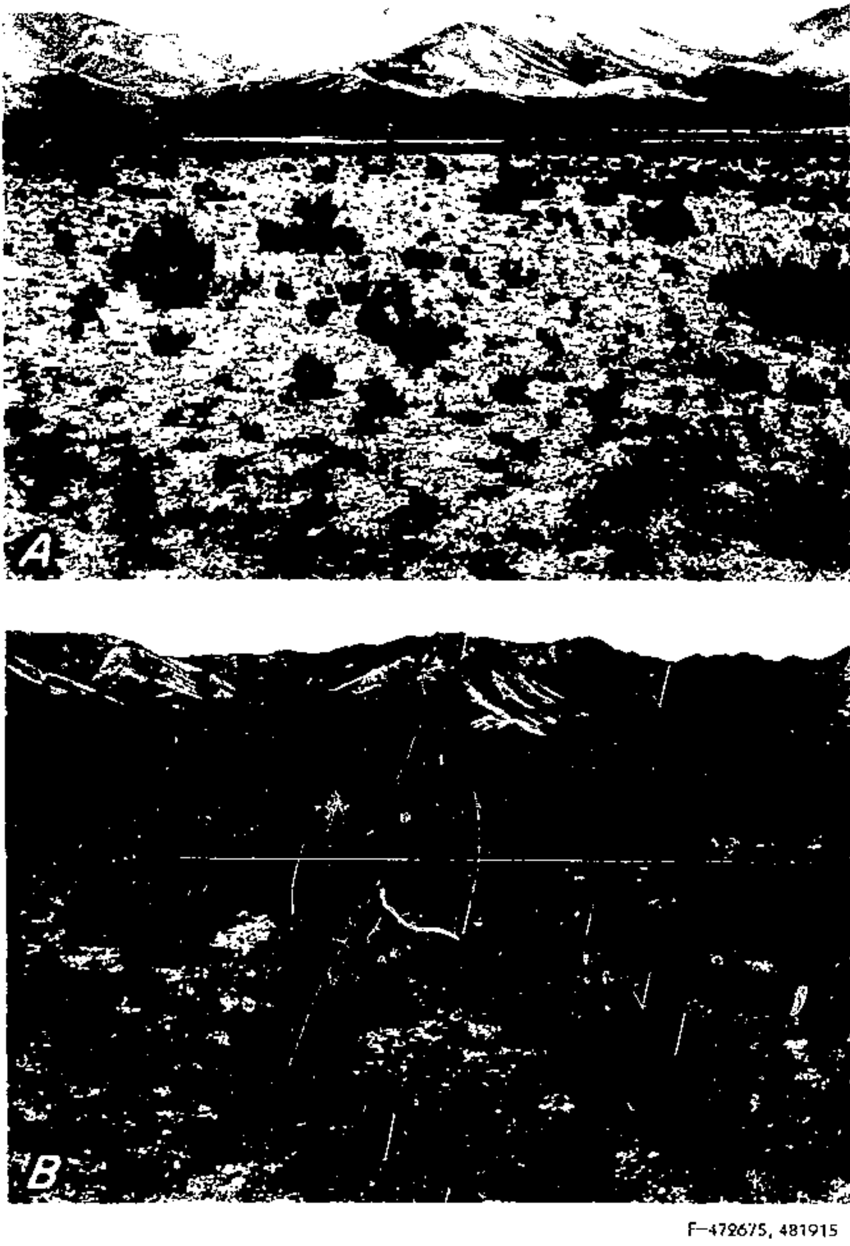

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FIGURE 18.—*A*, In 1950, young plants of big sagebrush were profusely invading this heavily grazed crested wheatgrass pasture—progeny of many well distributed old plants. *B*, In 1956, big sagebrush appeared to be the dominant vegetation.

fall. Also, regrowth of grass in late summer and fall is more abundant under rabbitbrush than in the open; this further enhances fall grazing.

Information about brush density provides further evidence that big sagebrush is much more competitive than rabbitbrush. The number of sagebrush plants more than 4 inches high increased far more than the number of rabbitbrush plants of this size on the original permanent plots (figs. 19 and 20). The high peaks in numbers of small plants of both species resulted from heavier winter-spring precipitation in 1952 and 1957.

Records from the 1959 survey confirmed that the largest number of shrub plants grew on plots grazed at heavy intensity, particularly invading plants represented by the two smaller size classes (table 6). Sagebrush plants in these two size classes were approximately double the numbers of rabbitbrush plants in these classes.

The permanent shrub plots were not sampled in 1959, but correlations of data on shrubs in the 80 temporary plots in 1959 with the 40 permanent plots in 1960 gave coefficients of 0.93 for number of sagebrush plants, and 0.83 for numbers of rabbitbrush plants per 100 square feet. This suggests that the 40 permanent plots were representative of overall pasture condition.

Other Herbaceous Plants

Bulbous bluegrass, western wheatgrass, and forbs increased generally, irrespective of grazing treatments. Together, these species provided not over 5 percent of the total forage. Bulbous bluegrass invaded the perma-

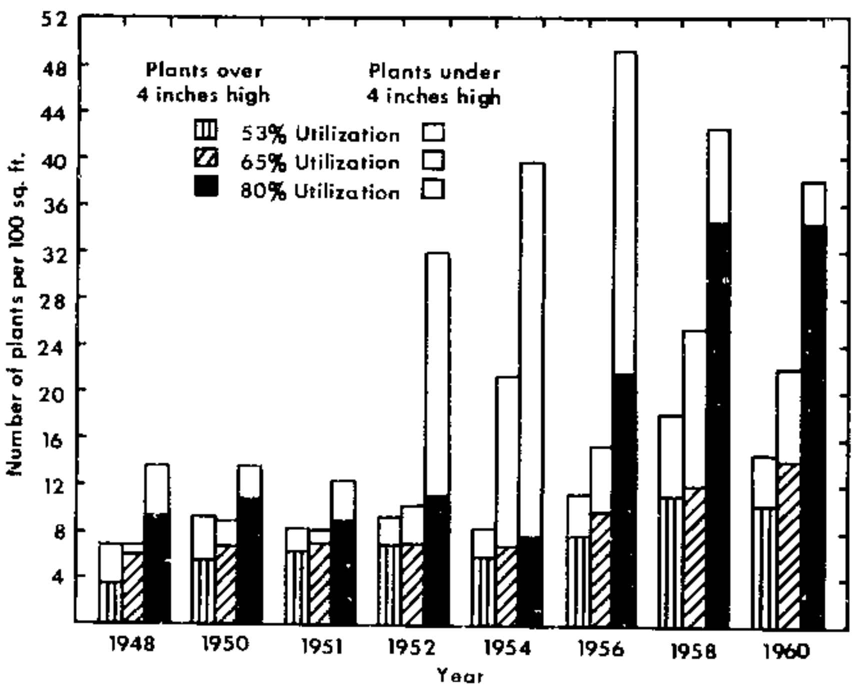

FIGURE 19.—Number of sagebrush plants by height class and grazing intensity on 54 plots, in selected years.

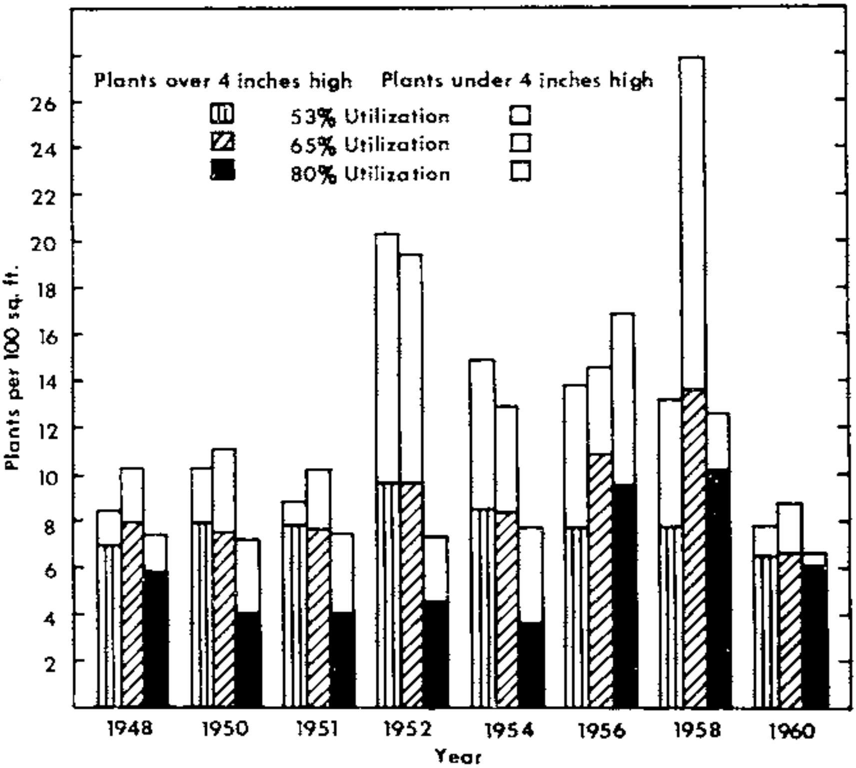

FIGURE 20.—Number of rabbitbrush plants, for selected years, by height class and grazing intensity on 137 plots on which brush originally was observed.

nent plots most rapidly. It was present on 16 percent of them in 1948 but on 39 percent in 1958 (fig. 21). Because growth is usually short and dries early, this species provides very little forage for cattle under conditions at Benmore. It appears to affect production of crested wheatgrass adversely. Bulbous bluegrass grows mainly within or closely adjacent to crowns of crested wheatgrass plants. It grows very early in the spring and uses moisture that otherwise would be available to the crested wheatgrass. These observations suggest that this grass should not be planted with crested wheatgrass under conditions at Benmore.

The gradual spread of western wheatgrass from 4 percent of the plots in 1948 to 11 percent in 1958 suggests that this trend will continue. All observed spread has been vegetative, mainly from small characteristic patches (fig. 22). A somewhat larger area of the native remnant is present in a swale extending through parts of two pastures, but even here this native wheatgrass provides a very minor part of total forage. Cattle do not eat western wheatgrass in the spring until crested wheatgrass has been well grazed, but they prefer it to dry crested wheatgrass in the fall. Western wheatgrass, a rhizomatous species, yields much less herbage than crested wheatgrass, but it provides much more uniform ground cover and is superior for control of soil erosion.

The quantity of forbs on permanent plots has fluctuated more in successive years than the quantity of perennial grasses, partly because

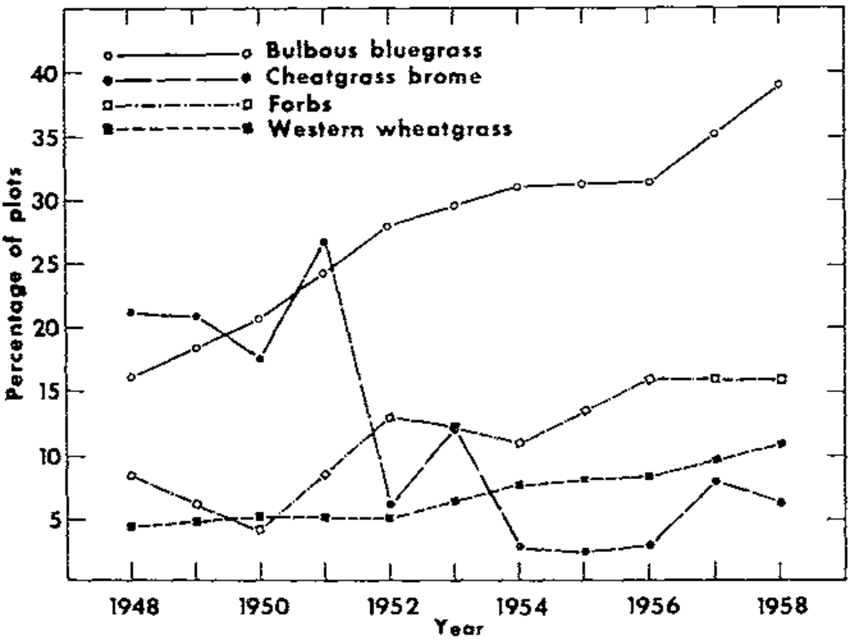

FIGURE 21.—Percentage of permanent plots on which four prominent species other than crested wheatgrass appeared in selected years.

TABLE 6.—*Average numbers of brush plants per 100-square-foot plot, 1959*

Height of brush (inches)	Big sagebrush			Rubber rabbitbrush		
	Intensity of grazing (percent)			Intensity of grazing (percent)		
	53	65	80	53	65	80
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
More than 12	2.1	2.6	2.8	2.2	2.8	2.8
4 to 12	2.3	2.2	9.1	2.5	4.4	4.7
Less than 4	3.8	4.5	7.9	2.6	3.3	3.6
Total (plot density)	8.2	9.3	19.8	7.3	10.5	11.1

annual and perennial forbs were recorded as a single unit. Records of individual species were taken during the latter years, but species were not differentiated early in the study. In 1948, forbs were present on 8.1 percent of the permanent plots; by 1958, they were on 15.8 percent of the plots.

The most prominent perennial forb is povertyweed. It is confined mainly to swales and low areas where moisture accumulates (fig. 23). Povertyweed increased considerably following the heavy spring runoff in 1952. Cattle do not graze it much in spring, but they eat it readily in the fall when crested wheatgrass is dry.

Cheatgrass, the most abundant species other than crested wheatgrass in 1948, reached a peak in 1951, when it was found on 26.9 percent of the permanent plots. The following year it was present on only 5.6 percent

F-481947

FIGURE 22.—In 4 years western wheatgrass spread vegetative a maximum of 12 inches with an average of about 6 inches around the patch perimeter. Inner white cord denotes extremities of small patch existing in one of the heaviest grazed pastures in 1952; the outer white cord denotes the extremities in 1956 when photograph was taken.

of these plots. This abrupt decline may be related to the unusually heavy snow cover throughout the winter of 1951–52 and the late spring snowmelt. A foot of dense snow covered the whole area as late as April 14. The rapid melt immediately following this date saturated surface soil and produced much runoff. Established crested wheatgrass responded with rapid early growth, but cheatgrass was noticeably absent. Since 1952, cheatgrass has fluctuated yearly but has remained relatively scarce. In 1958, it was present on 4, 5, and 10 percent of the permanent plots under light, moderate, and heavy grazing, respectively.

Russian-thistle increased considerably in 1952, the year when cheatgrass declined, and was most prominent in 1955, when it was found on 6.7 percent of the permanent plots. It declined to 5.4, 2.2, and 1.0 percent of these plots in the 3 succeeding years. In contrast to Russian-thistle,

F-481960

FIGURE 23.—Povertyweed is fairly abundant along drainage channels and in some low spots where extra moisture accumulates from snowmelt and high intensity summer storms.

pepperweed increased from 3.0 percent of permanent plots in 1956 to 7.6 percent of the total plots in 1959. These changes in populations of the most prominent annuals are somewhat different from the changes in annuals reported by Piemeisel (1951) in Idaho. He found that the order of succession in annuals was from Russian-thistle to mustards to downy chess (cheatgrass). In the Benmore study, changes in these annuals began in 1952 when cheatgrass declined and Russian-thistle increased.

Halogeton was first observed in the experimental area in 1952; a few isolated plants were found in the northwest corner pasture. Since then it has invaded at least 22 of the 28 pastures; it has been almost nonexistent in the six southernmost pastures. A few isolated plants have appeared in certain years, but halogeton has not successfully invaded this part of the experimental area.

The spread of halogeton appears to be influenced by at least three factors: Intensity of grazing, soil type, and weather—particularly precipitation. The weed has been most widespread in the most heavily grazed pastures but has also appeared on isolated heavily grazed spots. These heavily grazed spots often have characteristics similar to slick spots in cultivated fields; that is, relatively high concentration of total soluble salts, particularly sodium, near the surface. Grass plants on these areas are relatively widespaced, usually pedestalled, and sometimes shortlived, depending on the concentration of salts and grazing pressures.

Halogeton has also been found around anthills and on disturbed areas in the medium and lightly grazed pastures. Its spread and plant numbers have fluctuated (fig. 24). It increased most in 1955 when precipitation from May through September totaled 7.29 inches; average precipitation for these months during the study was 4.58 inches. Halogeton remained fairly prominent in 1956.

Daily Gains by Cattle

Daily gains in weight by cattle are influenced by both quantity and quality of forage. Peak daily gains usually were measured in years when effective rainfall was high and forage production was maximum (fig. 14), but other factors such as initial condition of the cattle and temperatures favorable for early growth of grass were important.

Daily gains varied with intensity of grazing, system of grazing, class of cattle, and individual years. Average daily gains in weight under 12 grazing treatments for the 11 years were:

	Pounds
Dry cows and steers	3.06
Pregnant cows	3.03
Lactating cows	2.49
Yearlings	2.47
Calves	1.77

Differences in daily gains of cattle were much greater between the 80- and 65-percent intensities of grass utilization than they were between the 65- and 53-percent intensities (fig. 25). Average daily gains for the three intensities of utilization during the 11 years were: 2.84 pounds on light utilization, 2.69 pounds on intermediate, and 2.16 pounds on heavy utilization. Daily gains in spring for all five classes of animals were significantly less at 80-percent utilization than at 65 percent (fig. 26).

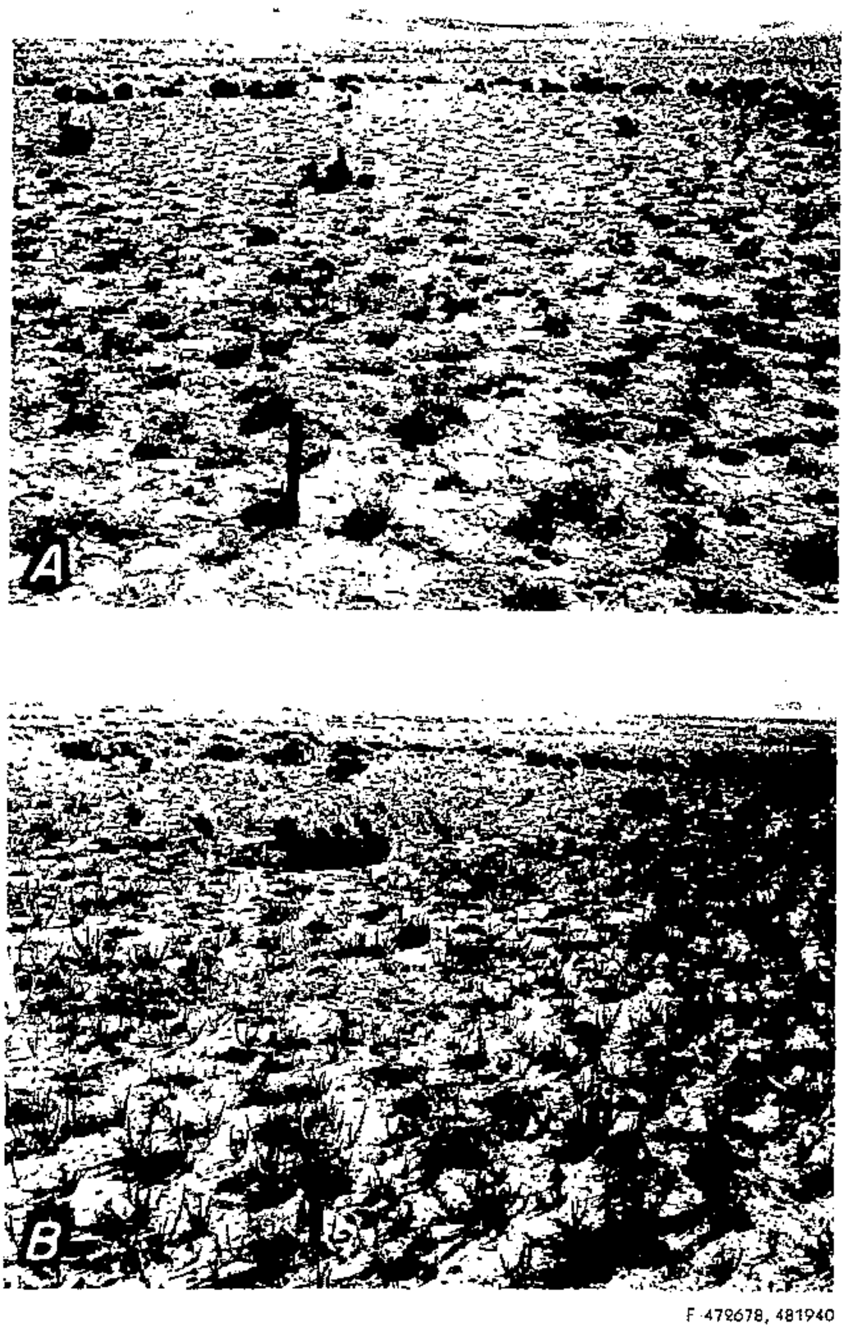

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FIGURE 21.—*A*, This pasture had been grazed heavily for three spring seasons before this photo was taken (1950). *B*, This photo from the same camera point (1956) shows how aggressively halogeton has invaded and how brush has increased.

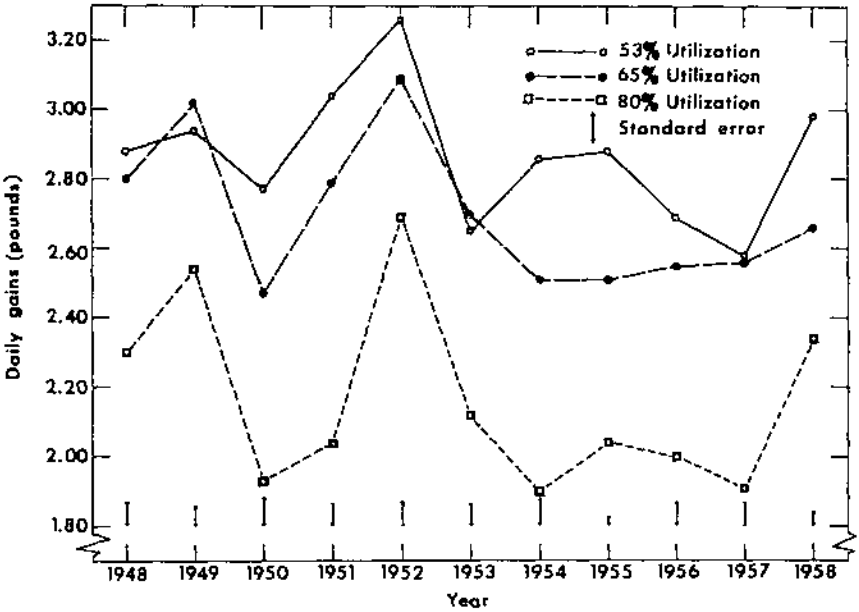

FIGURE 25.—Average daily weight gains of all five classes of cattle by intensities of grazing and years.

Lactating and pregnant cows gained less throughout the experiment (by 0.23 and 0.50 pound daily, respectively) on the 65-percent intensity of utilization than on the 53-percent intensity. Other classes of cattle were not significantly affected by this difference in intensity. Since pregnant cows calved in the pastures and were lactating at least part of the time, it is obvious that cows having suckling calves were the most sensitive class of cattle in response to grazing intensity in this study. This class of cattle naturally requires the most forage, but the supply becomes progressively more limited as grazing intensity increases. For other classes of cattle, utilization can approximate 65 percent without seriously affecting individual gains. Indirectly, these findings support those of Johnstone-Wallace and Kennedy (1944) indicating that forage consumption (hence animal gain) declines when the amount of available forage is reduced.

Based on these results, utilization of crested wheatgrass during spring grazing of about 60 days should be lighter than 65 percent for maximum gains by lactating cows. Cows that calved on lightly grazed units entered the summer range 30 pounds heavier than cows calving on moderately grazed units and 73 pounds heavier than cows calving on heavily grazed units. In comparison, cows that entered lightly grazed units with calves at their sides gained 14 pounds more than similar cows on moderately grazed units and 69 pounds more than cows on heavily grazed units. The small deficiencies between the light and moderate grazing were likely made up on the summer range, but this point was not checked. Certainly, the larger deficiencies resulting from heavy grazing would be made up more slowly than those from moderate grazing.

Daily gains averaged least under the rotation system (fig. 27), but the reasons are not well understood. Likely they relate to changing the quantity and quality of available forage during the grazing season rather than the mere effects of moving animals from one unit to another. McIlvain

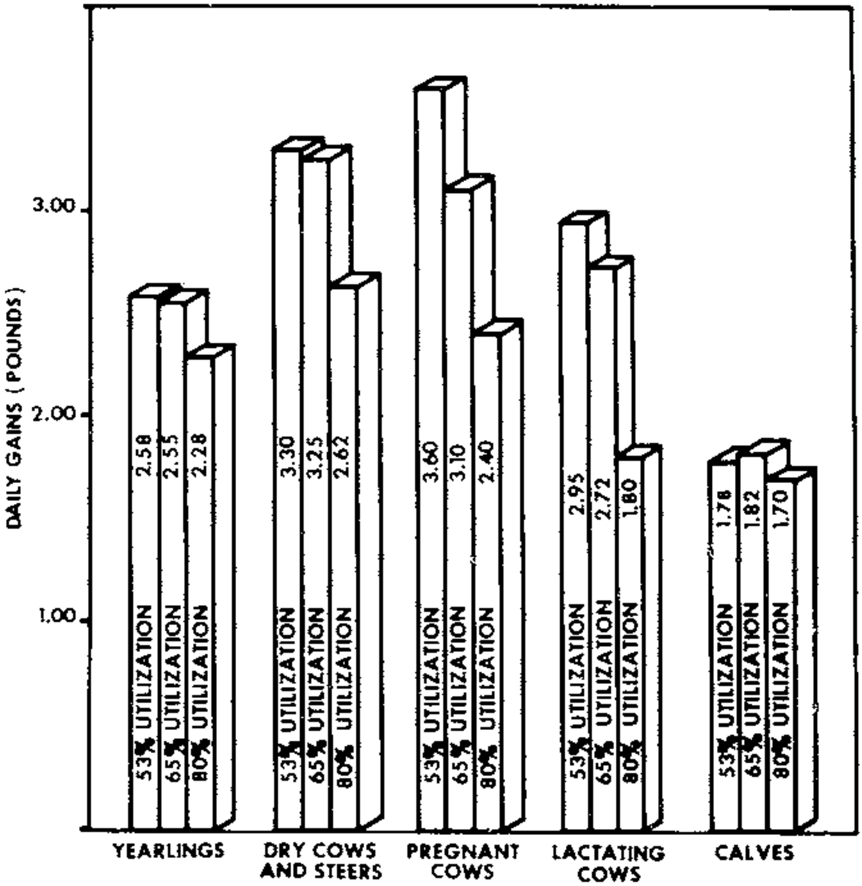

FIGURE 28.—Average daily weight gains for five classes of cattle related to three intensities of spring grazing.

and Savage (1951) found on native range that shifting cattle more frequently improved daily gains under rotation grazing.

Of the four systems of grazing, removal from pastures 10 days early produced the highest daily gains over the years. This early removal affected yearlings and calves less than it did the older classes (fig. 28). These observations confirm findings by Williams and Post (1945) that daily gains of animals are greatest in early spring and tend to decrease as crested wheatgrass matures toward the end of the season.

Gains per Acre

Animal gains per acre over a period of years provide another effective evaluation of grazing treatments. The total gains per acre were adjusted for initial different carrying capacities of the pastures by covariance analyses using the 1947 data as the X variable.

Analyses of variance of adjusted means show significant differences between intensities of grazing, years, year by intensity, and year by systems of grazing. The heaviest grazing intensity initially (1948, 1949,

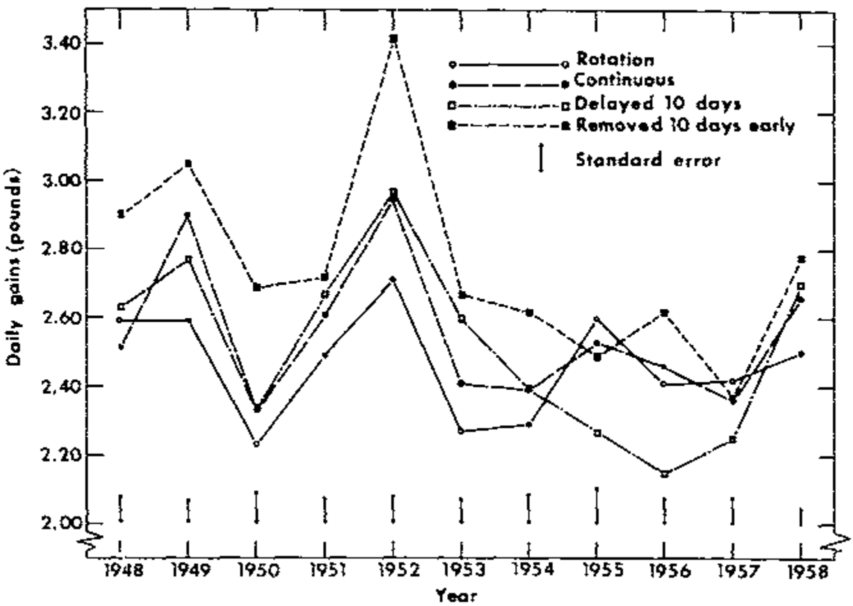

Figure 27.—Average daily weight gains of all five classes of cattle by systems of grazing and years

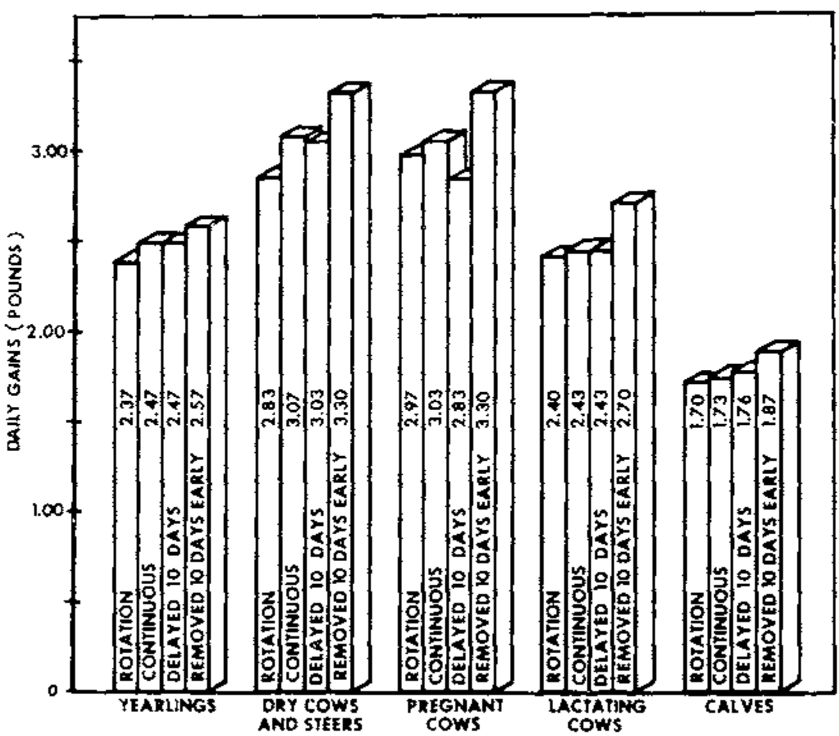

Figure 28.—Average daily weight gains of all five classes of cattle under four systems of spring grazing.

1952) produced the most gain per acre (fig. 29). Although daily gains of individual animals were lowest on heavy grazing, total gains per acre were highest. Total gains associated with 80-percent utilization were about the same as those from 65-percent utilization in 1950, and they were intermediate between the medium and light intensities in 1951 and 1953. After 6 years, gains per acre for 80-percent utilization declined below those for 53-percent utilization; this indicated that forage production had been decreased greatly by the heavy use year after year.

Over the 11-year period, gains produced per acre averaged 43.4, 39.7, and 36.8 pounds for the medium, heavy, and light intensities, respectively. Utilization on the lightly grazed pastures in the last 2 years of study averaged approximately 55 percent—5 percent heavier than had been planned; this would partly account for the relatively high gain per acre on lightly grazed pastures in 1958.

There were no significant differences among systems of grazing for the 11 years. However, average gains per acre for the systems were: Rotation, 42.9 lbs.; delayed-10-days, 40.6; continuous, 39.0; and removed-10-days-early, 37.3.

The rotation treatment produced the highest gains per acre in 7 of the 11 years (fig. 30). The delayed-10-days treatment showed the highest gains in the other 4 years and otherwise followed closely the rotation treatment except for 1955, 1956, and 1957. During these 3 years, cattle used in the delayed-10-days system had better than average forage during the 10 days before they were put on the pastures inasmuch as they were held on good seeded range. Thus, they entered the experimental pastures in better than average condition. The removed-10-days-early treatment produced the lowest gains per acre in 7 of the 11 years.

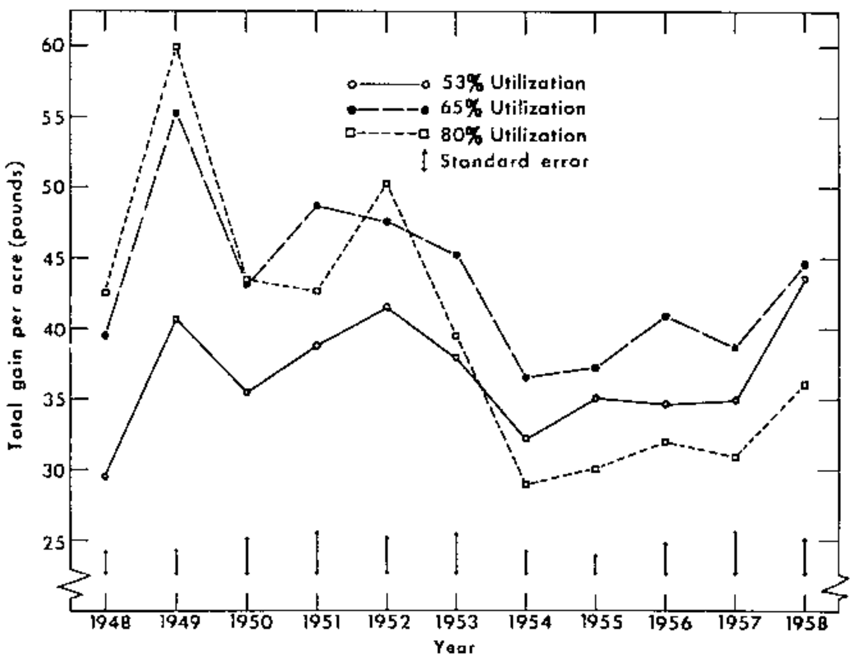

FIGURE 29.—Adjusted total gains in weight per acre for all five classes of cattle, by intensities of grazing and years.

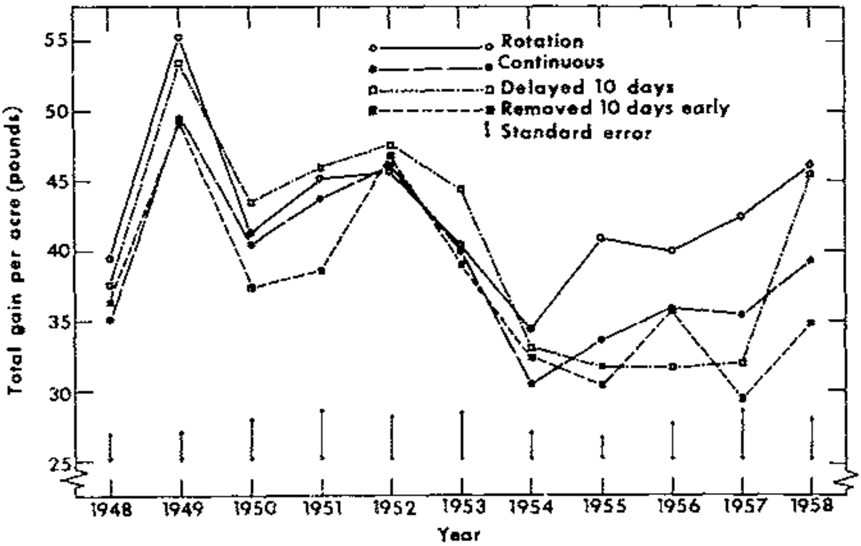

FIGURE 30.—Adjusted total gains in weight per acre for all five classes of cattle by systems of grazing and years.

In general, cattle gains per acre support grass data on basal area and yields at the end of the study (tables 4 and 5). Since there were no differences in daily gains of calves, yearlings, and dry stock between light and moderate grazing, it is suggested that crested wheatgrass be grazed in the spring by all classes of cattle at a utilization of 65 percent of the spring growth of grass by weight. *This intensity will give optimum cattle gains per acre and maintain grass production.* Delaying the start of grazing in the spring will contribute toward maximum basal area and yields of grass. On the other hand, shortening the grazing season toward the end of the spring growing season will contribute toward maximum plant numbers. Incorporation of these principles into a management program should insure maximum livestock production on crested wheatgrass range having a climate similar to Benmore's. A rotation system similar to that described in this study includes both these principles. A good rule of thumb is to not graze the same area at the same time every year.

Levels of Stocking

The yearly total cattle-days per acre for the five classes of animals for the 11 years averaged 20.2, 16.6, and 13.4 for the heavy, medium, and light intensities of grazing, respectively, but trends in stocking over the 11-year period warrant attention. Stocking level that produced 80-percent utilization was greatly reduced during the course of the study (fig. 31). This reduced stocking accounted for lower gains per acre (fig. 29); daily gains per animal for this intensity remained in nearly the same proportion to other intensities. Stocking levels for the other two intensities remained fairly constant.

Removing cattle 10 days early did not permit carrying sufficiently increased numbers to compensate for the shorter grazing period. Conversely, starting grazing 10 days later in the spring permitted a few

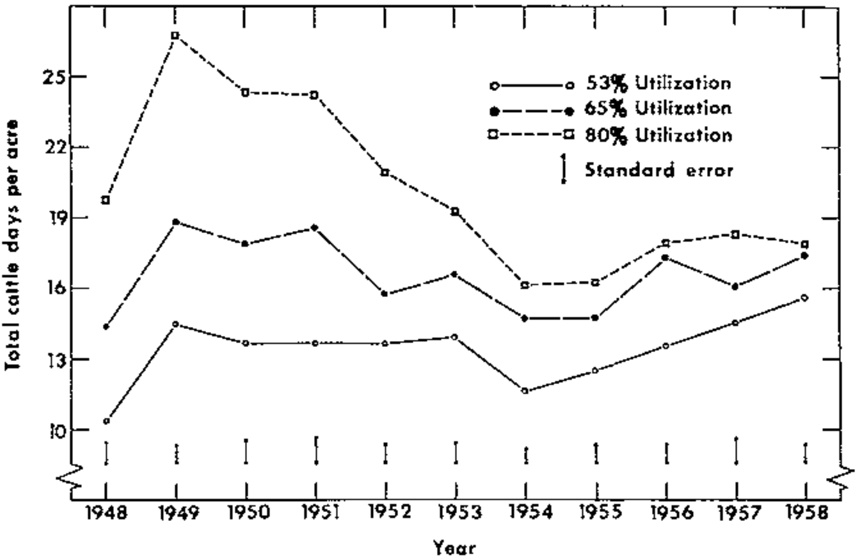

FIGURE 31.—Adjusted total cattle-days per acre for all five classes of cattle, by intensities of grazing and years.

additional animals to graze. This compensated for the shorter grazing period both in total gains and stocking levels. The numbers of cattle-days per acre for the delayed-10-days and continuous treatments were similar throughout the study.

Average numbers of cattle-days per acre for the 11 years for the four systems of grazing were:

Rotation	18.6
Continuous	16.9
Delayed 10 days	16.6
Removed 10 days early	14.7

This relative order was generally consistent throughout the study (fig. 32) and parallels the total gains per acre (fig. 30).

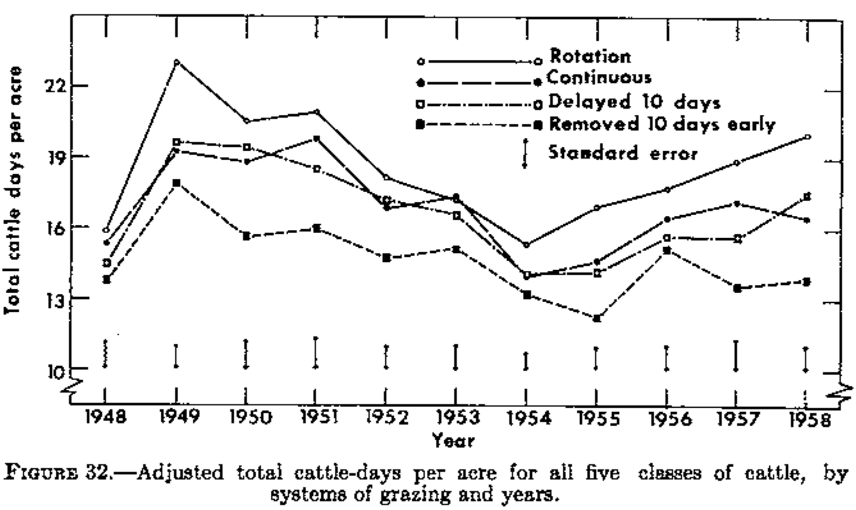

FIGURE 32.—Adjusted total cattle-days per acre for all five classes of cattle, by systems of grazing and years.

Digestible Energy

Digestible energy per acre includes the energy for maintenance as well as for gain. For this reason it has some advantage over gain per acre in expressing the total production of a pasture.

Digestible energy produced per acre was calculated in megacalories for each year of the experiment. The yearly trends of digestible energy for intensity and systems of grazing were similar to those for gain per acre (figs. 29 and 30). There was a significant interaction for digestible energy ($P < .01$) between grazing intensity and year. This was mainly caused by a decline in forage production under heavy intensity as time passed, while forage production under moderate and light intensity remained about the same. The 65- and 80-percent utilizations produced more digestible energy than the 53-percent utilization for the 11 years (fig. 33). The differences in amount of digestible energy produced under the four systems of grazing for the 11 years were not significant, but the relationships were similar to those for total gains per acre.

Fall Cattle Gains

Crested wheatgrass usually becomes dry and somewhat dormant during the hot summer months of July and August. However, if summer moisture is available, growth begins again in August or September and often continues through the fall period. This condition existed during the 3 years when fall grazing was permitted. The original plan was to graze pastures in both spring and fall, but fall grazing was discontinued on all pastures, because there was inconsistent and inadequate forage available on the heavily grazed pastures. Fall grazing on some but not all pastures would have biased the results from the spring treatments. It is believed that pastures grazed at medium or light intensity in spring could be grazed every fall, at least lightly.

During the calibration year (1947) the pastures provided fall grazing for about half the cattle that had grazed in the spring. Fall grazing lasted for 41 days after cattle came off the National Forest summer range on October 15. Calves and dry stock gained 1.88 pounds and 0.75 pounds per day, respectively. During 54 days of fall grazing in 1949 (Oct. 20 to Dec. 15), calves and dry stock gained an average of 0.73 and 0.34 pounds daily. In the fall of 1947 lactating cows lost an average of 0.04 pounds per day, whereas in 1949 they lost an average of 0.22 pounds per day. The above gains might not be possible in years of poor fall regrowth or when early snows cover the ground.

Of the 3 years when fall grazing was permitted, highest daily gains were achieved in 1952, when pastures were grazed for only the 30 days from October 15 to November 14. Adult animals gained an average of 1.25 pounds daily, and calves gained 1.76 pounds. Lactating cows gained as much as the dry stock that fall. On the basis of available forage in the fall in both 1949 and 1952, pastures that had been utilized in the spring at 65 percent were stocked one-third less than the pastures utilized at 53 percent. Pastures grazed heaviest in the spring received one-third lighter stocking in the fall than those grazed at the medium intensity.

Cattle are fat when they come off the summer range and under these conditions low gains are to be expected. It would probably pay owners to

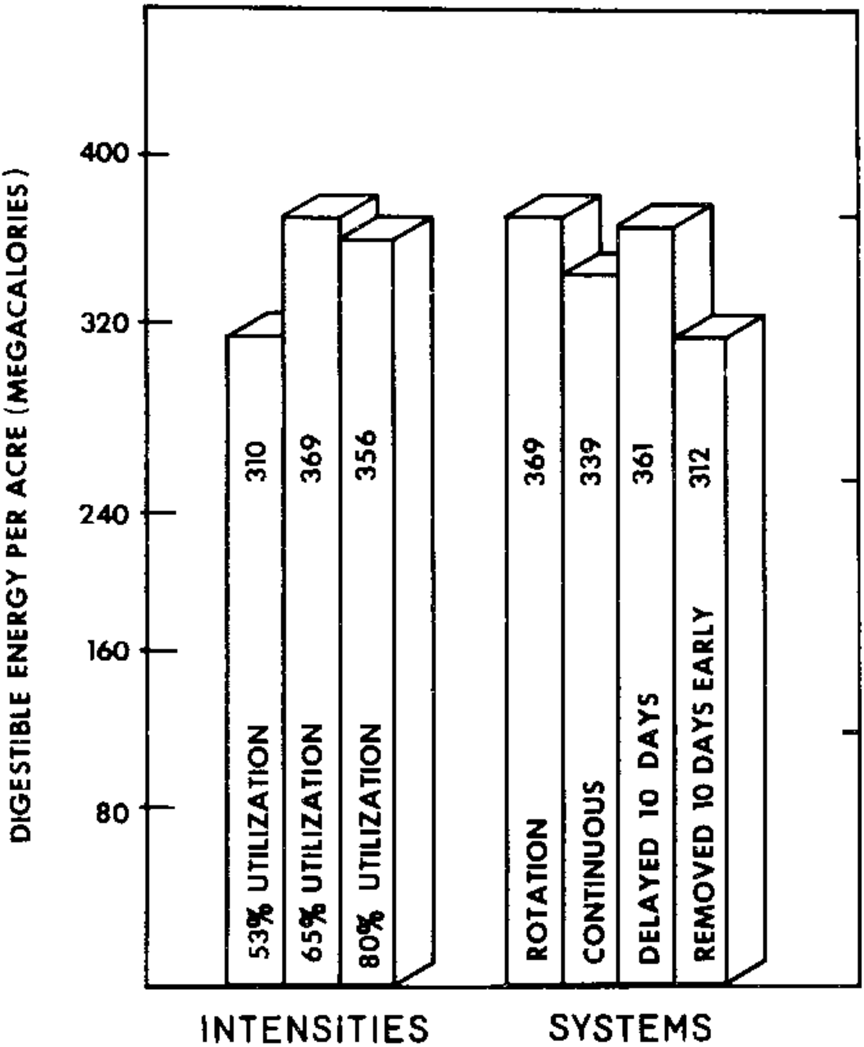

FIGURE 33.—Adjusted digestible energy produced per acre, by three intensities and four systems of grazing.

sell fat cattle when they come off the summer range, and use crested wheatgrass pastures for the breeding herd or for stockers. There is no assurance that fall grazing will be possible on pastures grazed in the spring, because there is usually an inadequate amount of fall regrowth. However, when forage is available in the fall, grazing is possible and additional weight gains can be put on some classes of stock.

SUMMARY

The 11-year study (1948–58) of grazing crested wheatgrass range by cattle at Benmore, Utah, used all 12 possible combinations of four systems of grazing at three intensities. The systems were designated as rotational, continuous, continuous but delayed-10-days, and continuous but removed-10-days-early. Pastures in the first two treatments were grazed by cattle for approximately 60 days in the spring, and those in the latter two treatments for approximately 50 days. Under the three grazing intensities, utilization of crested wheatgrass averaged 53, 65, and 80 percent and left stubble 3.8, 2.9, and 1.9 inches high, respectively, at the end of the grazing season. Desired levels of utilization were achieved by removing or adding cattle during the grazing season.

Grazing treatments were evaluated in terms of (1) vegetation response, and (2) cattle response.

Vegetation response.—After 8 years of treatment, before the drought of 1956, pastures grazed most heavily had fewer large grass plants than pastures grazed at lighter intensities. The rotation and removed-10-days-early grazing systems produced more plants than either the delayed-10-days or continuous treatments, suggesting that early removal of livestock toward the end of the spring growing season contributed to greater numbers of plants. In the rotation treatment, grazing terminated about 16 days early on a different section of rotation pastures each year. In certain years at least, early removal was conducive to regrowth and added seed production.

The drought in 1956 caused breaking up of some plant crowns into smaller segments and thus tended to obscure the effects of treatment on plant numbers. Because of this, differences in plant numbers that were significant in 1956 were not statistically important in 1958, when the study ended. However, in 1958, small plants (less than 1-inch crown diameter) were most abundant on pastures grazed under the rotation and removed-10-days-early systems at lightest intensity; this suggested that differences in numbers of large plants would develop again.

Total basal area of live grass averaged greater under the light and medium intensities than under 80-percent utilization. For systems of grazing, it was greatest under rotational and delayed-10-days grazing and least under the removed-10-days-early and continuous treatments. Whereas early removal of animals toward the end of the spring grazing period favored high numbers of plants, delayed grazing at the beginning of the season favored total live basal area of grass. The rotation treatment contained both features; the section where grazing terminated about 16 days early one year received about 16 days deferment from grazing at the beginning of spring grazing the following year—a different section being involved each year.

Grass production was reduced significantly by grazing at 80-percent utilization. Although differences in yield between the four systems were not statistically significant, grass yields under heavy grazing tended to remain higher under rotation and delayed-10-days systems than under continuous and removed-10-days-early systems. Yearly grass yields were correlated positively with winter-spring (November through May) precipitation (0.94).

Big sagebrush and rubber rabbitbrush increased most on pastures grazed at heavy intensity until the drought in 1956; but in 1957— a wet spring—both species increased rapidly under all treatments. Pastures where grass yields decreased most were those where big sagebrush spread most. Rabbitbrush had little or no adverse influence on grass yields.

Cattle response.—Daily gains of cattle were influenced by intensities and systems of grazing, classes of cattle, and years. Daily gains of all classes of animals were significantly less at 80-percent utilization than at 65 percent. The difference between 53- and 65 -percent utilization did not affect dry cows and steers, yearlings, and calves, but reduced daily gains of lactating and pregnant cows. Pregnant cows that calved on lightly grazed units entered the summer range 30 pounds heavier than cows calving on moderately grazed units and 73 pounds heavier than cows calving on heavily grazed units. Cows that calved before entering lightly grazed units gained 14 pounds more than similar cows from moderately grazed units and 69 pounds more than cows from heavily grazed units.

For systems of grazing, daily gains averaged highest for cattle removed 10 days early, and generally were lowest for cattle grazed under rotation.

Gains per acre over the 11-year period averaged 43.4, 39.7, and 36.8 pounds for the medium, heavy, and light intensities of utilization, respectively. Although heaviest grazing produced the greatest gain per acre in early years, after 6 years it produced the least gain per acre. Differences in gain per acre between the four systems of grazing were not statistically significant, but they tended to be highest under rotation and delayed-10-days treatments.

Over the years, cattle-days per acre averaged highest for the heaviest intensity of use, but the carrying capacity dropped greatly when compared to the 53- or 65-percent intensities. The cattle-days per acre averaged highest on rotational-grazed pastures and lowest on pastures where cattle were removed 10 days early. Between these extremes, continuous and delayed-10-days systems averaged nearly equal.

The digestible energy produced per acre followed the same trends as the gains per acre.

During 3 years when fall grazing was applied, lactating cows nearly maintained their weight, but young dry stock and calves gained weight. Heaviest fall stocking was possible where spring use had been lightest. Pastures utilized at 80 percent in spring could not be depended upon for fall grazing; so fall grazing was discontinued. However, some fall grazing is practicable on pastures utilized not more than 65 percent in the spring, especially if regrowth is produced from summer storms.

It is recommended that crested wheatgrass used for spring grazing in the intermountain region should be managed under a rotation system utilizing about 65 percent of the herbage produced. This procedure will allow maximum livestock gains per acre and maintenance of the forage resource. At the same time it will allow some fall grazing, particularly in pastures grazed during the first part of the spring season.

COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

Common name	*Species*
False-dandelion	*Agoseris* Raf. spp.
Fairway wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Crested wheatgrass	*A. desertorum* (Fisch.) Schult.
Thickspike wheatgrass	*A. dasystachyum* (Hook.) Scribn.
Western wheatgrass	*A. smithii* Rydb.
Bluebunch wheatgrass	*A. spicatum* (Pursh) Scribn. and Smith
Slender wheatgrass	*A. trachycaulum* (Link) Malte.
Tall oatgrass	*Arrhenatherum elatius* (L.) Presl.
Big sagebrush	*Artemisia tridentata* Nutt.
Loco	*Astragalus cibarius* Sheld.
Smooth brome	*Bromus inermis* Leyss.
Cheatgrass brome	*B. tectorum* L.
Rubber rabbitbrush	*Chrysothamnus nauseosus* (Pall.) Britt.
Douglas rabbitbrush	*C. viscidiflorus* (Hook.) Nutt.
Hawksbeard	*Crepis* L. spp.
Great Basin wildrye	*Elymus cinereus* Scribn. and Merr.
Low fleabane	*Erigeron pumilus* Nutt.
Snakeweed	*Gutierrezia sarothrae* (Pursh) Britt. and Rusby
Halogeton	*Halogeton glomeratus* (M. Bieb.) C. A. Mey.
Utah sweetvetch	*Hedysarum boreale* Nutt. var. *utahense* (Rydb.) Roll.
Povertyweed	*Iva axillaris* Pursh
Clasping pepperweed	*Lepidium perfoliatum* L.
Nevada lupine	*Lupinus nevadensis* (Heller) Muhl.
Indian ricegrass	*Oryzopsis hymenoides* (R. & S.) Ricker
Hoary phlox	*Phlox hoodii* Rich. subsp. *canescens* (T. & G.) Wherry
Longleaf phlox	*P. longifolia* Nutt.
Bulbous bluegrass	*Poa bulbosa* L.
Sandberg bluegrass	*P. secunda* Presl.
Russian-thistle	*Salsola kali* L. var. *tenuifolia* Tausch.
Groundsel	*Senecio* L. spp.
Squirreltail	*Sitanion hystrix* (Nutt.) J. G. Smith
Desert globemallow	*Sphaeralcea ambigua* A. Gray

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