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Grazing Periods and Forage Production on the National Forests

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UNITED STATES DEPARTMENT OF AGRICULTURE

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CONTENTS

MORE AND BETTER FORAGE

Stockmen in the West have always had confidence in the adequacy of the native forage crop to provide pasturage for their livestock. Indeed, under normal climatic conditions this enormous natural resource has not failed the grazier, except where it has been called upon to meet unreasonable demands. The productivity of the range has declined sharply, however, wherever the requirements of plant growth have been disregarded for many years in succession. Where there has been too early or too frequent and to heavy grazing, undue trampling, or some other unsatisfactory feature of range use, the results have been uniformly bad. Many conspicuous examples show that abundant nutritious forage can not be expected in the absence of rational grazing and livestock management.

More and better forage, as well as the maximum production of beef, wool, and mutton, is a primary object of grazing management. To maintain the forage productivity of a range unit it is necessary

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to be able to determine (1) when the range is ready for grazing, (2) the degree, or intensity, and frequency of grazing that may be allowed, (3) how to handle the stock in order to begin at the right time and to regulate intensity and frequency of grazing, and (4) the natural revegetation of the range that may be relied on in making plans for handling the stock. How this may be done is indicated in this bulletin on the basis of observations made over an extensive region, but particularly at the Great Basin Experiment Station and in other parts of the Wasatch Mountains of Utah.

MAJOR FORAGE TYPES OF THE WASATCH MOUNTAINS

The forage cover in the major portion of the Wasatch Mountain Range may be classified into three major types or zones, the boundaries of which are largely determined by climate. These types are designated according to the characteristic tree species, as oak-brush, aspen-fir, and spruce-fir.

OAK-BRUSH TYPE

The oak-brush type, the lowest of the three, occurs between elevations of about 6,500 and 8,000 feet, or in what is often termed "the foothills." Limited rainfall and comparatively high temperatures are characteristic. The brush species are often comparatively dense, the perennial herbaceous species ordinarily occurring in a scattered stand as an understory of the brush, partly as a result of too early grazing and of overgrazing in the past.

Gambel oak (*Quercus gambelii*) predominates throughout this type. The principal browse species associated with it are snowberry (*Symphoricarpos oreophilus*), sagebrush (*Artemisia tridentata*), service berry (*Amelanchier alnifolia*), birch-leaf mahogany (*Cerocarpus montanus*), chokecherry (*Prunus demissa*), squaw apple (*Peraphyllum ramosissimum*), and bitter brush (*Purshia tridentata*). The principal herbaceous vegetation is composed of one or more species of the following genera: Blue grasses (*Poa*), wheat grasses (*Agropyron*), fescues (*Festuca*), needle grasses (*Stipa*), mountain rice (*Oryzopsis hymenoides*), June grass (*Koeleria cristata*), butterweed (*Senecio*), bluebell (*Mertensia*), and yarrow (*Achillea lanulosa*).

ASPEN-FIR TYPE

The aspen-fir type is highly valuable for grazing. It lies between elevations of about 7,500 and 9,500 feet, the lower boundary adjoining the oak-brush type and the upper merging into the spruce-fir type. Aspen (*Populus tremuloides*) [1] occurs over extensive areas, and where overgrazing has not destroyed the forage the aspen type supports a dense stand of valuable plants. Douglas fir (*Pseudotsuga taxifolia*) and white fir (*Abies concolor*) occur as individual scattered trees in the aspen type and on rather steep north exposures join with Engelmann spruce (*Picea engelmannii*) and Colorado spruce (*P. pungens*) to form small areas of a distinct timber type

[1] Tidestrom maintains that the western aspen is a distinct species, and employs the name *Populus aurea* therefor.

which support but a sparse stand of forage. Small openings also occur throughout the zone, but they are ordinarily in a depleted condition from past abuse and now support a stand largely of annuals and unpalatable perennials.

Of the browse plants, snowberry clearly predominates throughout the aspen-fir type. The principal associated woody species are chokecherry, service berry, elderberry (*Sambucus*), wild rose (*Rosa*), spine currant (*Ribes montigenum*), honeysuckle (*Lonicera*), and manzanita (*Arctostaphylos*). The herbaceous vegetation consists chiefly of various species of brome grass (*Bromus*), wheat grass, blue grass, spiked trisetum (*Trisetum spicatum*), pine grass (*Calamagrostis*), wild geranium (*Geranium*), vetch (*Vicia*), lupine (*Lupinus*), bluebell, butterweed, pea vine (*Lathyrus*), niggerhead (*Rudbeckia occidentalis*), dandelion (*Leontodon taraxacum*), beardtongue (*Pentstemon*), sweet-cicely (*Osmorrhiza*), yarrow, sneezeweed (*Helenium hoopesii*), tall larkspur (*Delphinium*), meadow rue (*Thalictrum fendleri*), death camas (*Zygadenus*), and Indian paintbrush (*Castilleja*).

SPRUCE-FIR TYPE

The spruce-fir type occupies the high plateaus at elevations ordinarily above 9,000 feet. Engelmann spruce and alpine fir (*Abies lasiocarpa*) form dense stands on north exposures and other favorable sites and also occur as small clusters over the whole area. The bulk of the type is open and supports a cover that is chiefly herbaceous, with here and there an admixture of browse. Because of the high quality of the forage, the abundant water, and the moderate summer temperatures, the type embraces the best summer range in the Wasatch Mountains. The cover of greatest value for grazing, especially in the open parks, consists largely of grasses and other herbaceous plants, with considerable browse in the timbered lands. In the nineties and the early part of the twentieth century overgrazing was excessive here, and extensive areas are still in a badly depleted condition. Untimbered areas which were not seriously injured in the past, and on which the forage has had a chance to recover fully, support a dense stand of very valuable grasses and other forage plants.

The herbaceous vegetation is composed chiefly of species of wheat grass, needle grass, sedge (*Carex*), brome grass, blue grass, pine grass, meadow barley (*Hordeum*), sweet sagebrush (*Artemisia*), blue beardtongue, yarrow, bluebell, dandelion, mountain dandelion (*Agoseris*), tall and low larkspur, death camas (*Zygadenus*), lupine, aster (*Aster*), butterweed, cinquefoil (*Potentilla*), Mexican dock (*Rumex*), and knotweed (*Polygonum*). The most important browse plants are spine currant, elderberry (*Sambucus*), rabbitbrush (*Chrysothamnus*), willow (*Salix*), wild raspberry (*Rubus*), and sagebrush (*Artemisia tridentata*).

CLIMATIC FACTORS IN RELATION TO GRAZING PERIODS

Careful meteorological records have been kept since 1914 in each of the three major types on the Ephraim Canyon watershed, the oak-brush at 7,100 feet elevation, the aspen-fir at 8,700 feet, and the

spruce-fir at 10,000 feet. Such factors as air temperature, soil temperature, precipitation, air humidity, evaporation, wind velocity, and sunshine duration and intensity all directly or indirectly affect plant growth, but those most closely related to the grazing periods are air temperature and precipitation. Air-temperature records were obtained by using thermographs and maximum and minimum thermometers exposed in shelters 4½ feet above the ground. Precipitation was measured in standard rain gauges.

AIR TEMPERATURE

The records show temperature characteristics typical of mountain regions and clearly indicate the effect of elevation. The highest

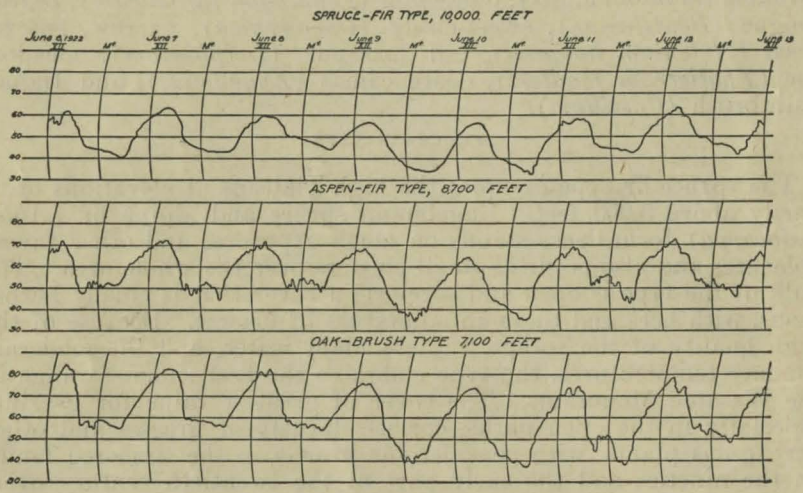

FIG. 1.—Typical thermographic records in the first half of June, 1922, showing the relation of temperatures and the differences in the daily range

maximum temperature and the widest daily variation are found in the lowest type; with increase in altitude there is a slow decrease in the minimum temperature and a larger decrease in the maximum, which is responsible for the flattening of the daily temperature curve for the spruce-fir type, as shown in Figure 1. Mean temperatures accordingly diminish regularly with increased elevation. During the main growing season, from June to September, inclusive, the mean-temperature decrease gradient for every 1,000 feet difference in elevation is 4.05° F. from the oak-brush to the spruce-fir type, 3.91° from the oak-brush to the aspen-fir type, and 4.23° from the aspen-fir to the spruce-fir type. The mean-temperature decrease gradient for the year is somewhat similar to that for the growing season, although owing to temperature inversions in winter the exact rates of decrease are somewhat different.

TABLE 1.—*Average temperature (in hours) above and below 40° F., and number of hours freezing, period 1914 to 1922, inclusive*

Month	Oak-brush type			Aspen-fir type			Spruce-fir type		
	Hours above 40°	Hours below 40°	Hours freezing	Hours above 40°	Hours below 40°	Hours freezing	Hours above 40°	Hours below 40°	Hours freezing
January	59	685	533	19	725	670	14	730	698
February	74	598	467	22	650	568	8	664	619
March	107	637	462	58	686	550	2	742	704
April	260	460	248	195	525	321	57	663	546
May	483	261	79	409	335	157	186	558	285
June	671	49	17	627	93	33	548	172	65
July	741	3	0	737	7	0	724	20	0
August	739	5	0	727	17	0	714	30	0
September	635	85	22	581	139	45	513	207	61
October	395	349	175	280	464	243	164	580	357
November	177	543	382	101	619	456	52	668	511
December	86	658	522	20	724	682	32	712	631
Yearly average	4,427	4,333	2,907	3,776	4,984	3,725	3,014	5,746	4,477
Monthly average	369	361	242	315	415	310	251	479	373

By reference to Table 1 and Figure 2, it will be seen that freezing temperatures did not occur during the period considered in any

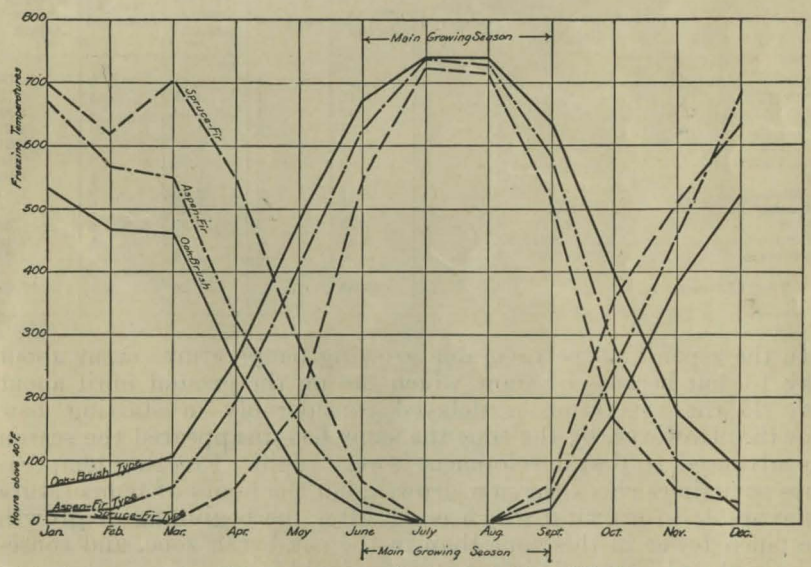

FIG. 2.—Average monthly temperature (in hours) above 40° F. and below 32° F. (Period 1914–1922, inclusive.) Temperatures above 40° F. are favorable for plant growth, while freezing temperatures are detrimental. During the main growing season the hours of favorable growing temperatures are at a maximum and the hours of freezing temperatures are at a minimum number

of the zones during July and August, but that in June and September, the other two months of the main growing season, they occurred with considerably frequency in the upper zone and are not absent even from the oak-brush zone. Still more striking is the decrease in the number of hours above 40° [2] in the spruce-fir

[2] Investigations conducted by various workers indicate that at or below 40° F. little or no growth takes place in plants of the character of those which furnish forage in the Wasatch Mountains.

zone during June and September. During July and August there is only a slight difference in the number of hours of growing temperatures in the three zones, although, of course, the highest and undoubtedly most effective temperatures are much more frequent in the lowest zone.

Favorable temperatures occur in sufficient duration for inception of plant growth in the oak-brush zone about May 1 and sometimes earlier. Frequent heavy frosts and many hours of unfavorable temperature, however, retard the early development. Beginning about the middle of May, the temperature becomes very favorable for growth and continues favorable until about October 1, when frosts are apt to arrest further development. On the whole, the plants generally found in the oak-brush type require more heat units (potential growth hours) to complete their life cycle than do the plants in the aspen-fir and spruce-fir types.

TABLE 2.—*Average monthly precipitation, period 1914 to 1922, inclusive*

Month	Oak-brush type		Aspen-fir type		Spruce-fir type	
	Years observed	Average precipitation	Years observed	Average precipitation	Years observed	Average precipitation
January	3	1.21	4	3.88	4	3.09
February	3	1.16	4	3.48	4	2.73
March	3	2.41	4	4.04	4	4.38
April	4	2.03	6	4.22	5	3.21
May	5	1.68	6	2.88	5	1.91
June	8	.54	8	.70	8	.66
July	8	1.30	9	1.88	9	1.96
August	8	1.61	9	2.00	9	1.82
September	8	1.15	9	1.25	9	1.26
October	6	1.73	8	2.25	8	1.89
November	6	1.83	8	1.97	8	2.12
December	4	2.23	5	2.71	5	2.65
Yearly average		18.88		31.26		27.68

In the aspen-fir type favorable growing temperatures occur about May 15, but because of snow which lies on the ground until about May 25 the vegetation is delayed considerably in starting new growth. However, by the time the snow has disappeared the season has advanced, so that development is very rapid. Freezing temperatures sometimes check the new growth, but the hours of temperature unfavorable to growing which occur after the beginning of growth are much fewer in this zone than in the oak-brush zone, and consequently the plant development is more rapid.

Except on the wind-swept ridges, snow usually lies on the ground in the spruce-fir zone until about June 20. The temperatures prevailing at so late a date are very favorable for plant growth and the vegetation is seldom delayed by freezing temperatures.

PRECIPITATION

There is considerable variation in the average monthly and the average yearly precipitation in the three zones. The oak-brush has the lowest yearly average and the aspen-fir the highest, while that of the spruce-fir nearly equals that of the aspen-fir (Table 2,

fig. 3). The lowest monthly average occurs in June and the highest usually in March for all types.

Air temperature and precipitation are so closely related that it is impossible to segregate them and determine the specific influence of each on the development of vegetation. The growing season in the oak-brush zone is longer than that in either of the others, partly because air temperatures are favorable for plant growth both earlier and later, and partly because of the influence of the snow in the higher zones. Not only does precipitation influence temperature, but the amount of precipitation and the time of its occurrence also have an important influence on plant growth and

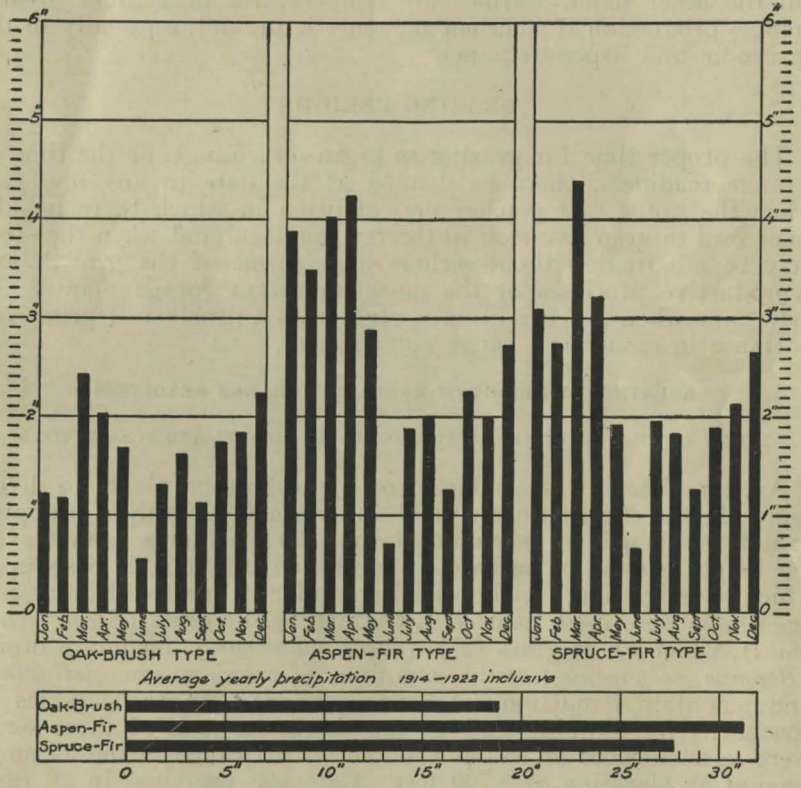

FIG. 3.—Average monthly precipitation, 1914–1922, inclusive

development. From November 1 to May 1 precipitation is usually in the form of snow, especially in the aspen-fir and spruce-fir types. Precipitation is relatively very high during these months and there is a much larger accumulation of snow in the two higher types than in the lower one. This partly explains the delay in the beginning of plant growth in the spring in these upper areas. Temperatures favorable for plant growth may occur early in May in the aspen-fir and spruce-fir types, but at that time they have little if any effect on plant development because of the deep covering of snow. On many of the steep north exposures in the upper reaches of the aspen-fir zone and in the spruce-fir zone snowdrifts may

remain until the growing season is well advanced. In the spruce-fir zone they often remain until the latter part of August, and in some years a few last almost throughout September. Their presence no doubt has some cooling effect on the air temperatures in these zones.

Scarcity of moisture and high temperatures in the oak-brush zone are responsible for the presence there of drought-enduring vegetation which is less succulent and somewhat less palatable than that at the greater elevation.

Insufficient moisture during the main growing season will in all zones result in a comparatively small yield of herbaceous forage. On the other hand, warmer air temperatures may cause greater volume production if sufficient moisture is present, especially in the spruce-fir and aspen-fir zones.

GRAZING PERIODS

The proper time for grazing to begin on a range, or the time of "range readiness," may be defined as the date in any one year when the range first reaches the condition in which there is sufficient feed to keep livestock in thrifty condition and when the stock may be admitted without serious impairment of the growth and reproductive processes of the more important forage plants. To determine when this condition is reached is a problem of prime importance in economical range management.

RELATION OF HEIGHT OF HERBAGE TO RANGE READINESS

EFFECT OF TIME OF FIRST CROPPING ON EARLY HEIGHT AND FORAGE YIELD

An experiment was conducted on typical range plants to determine (1) the effect on early yield and vigor of growth of cropping at different stages of development, and (2) whether a certain average height growth of herbaceous vegetation is a reliable basis upon which to judge range readiness. Five different species of range forage plants were used, namely, Letterman needle grass (*Stipa lettermani*), violet wheat grass (*Agropyron violaceum*), mountain brome (*Bromus polyanthus*), wild geranium (*Geranium viscosissimum*), and mountain dandelion (*Agoseris pumila*). In each species 10 specimens for clipping and 10 for checks in each of three series were selected more or less at random on the range in the aspen-fir type at an elevation of 8,700 feet. Care was exercised in all cases to locate plants of nearly the same height and in as vigorous a condition as possible. Accordingly, comparatively young plants were chosen—the bunch grasses, for instance, having a crown diameter usually not in excess of about 2.5 inches. Each specimen was staked and numbered. The herbage of those clipped was removed by a method somewhat resembling grazing, the leafage being cut about 1 inch above the ground's surface. The material removed from each plant was preserved separately and the dry weight was recorded. The first series of specimens were first measured and harvested on June 1, when the grass blades and the leafage of most other herbaceous plants were only 2 inches high or less. The second series were first harvested on June 10 and the third series on June

20. In each series the second harvesting was made 20 days after the first, the plants being allowed to grow uninterruptedly between croppings.

TABLE 3.—*Relation of height growth of native forage plants to yield and subsequent development*

Name of plant	Treated plants							Untreated plants		Remarks
	Average diameter per plant	Average dry weight per plant	Average height per plant	Average dry weight per plant	Average height per plant	Total dry weight per plant	Total height per plant	Average height per plant	Increase or decrease height growth untreated plants compared with treated plants	
	Ins.	*Gms.*	*Ins.*	*Gms.*	*Ins.*	*Gms.*	*Ins.*	*Ins.*	*P. ct.*	
	First harvesting June 1			Second harvesting June 20		June 1 and June 20		June 20	June 20	June 20:
Series I:										
Letterman needle grass (*Stipa lettermani*).	1.7	1.82	1.9	1.49	2.4	3.31	4.3	7.1	65.1	No flower stalks showing.
Violet wheat grass (*Agropyron violaceum*).	2.3	1.71	1.9	1.44	2.3	3.15	4.2	5.9	40.5	No flower stalks.
Mountain brome (*Bromus polyanthus*).	2.7	2.00	2.3	1.59	2.6	3.59	4.9	6.8	38.8	Do.
Wild geranium (*Geranium viscosissimum*).	3.3	2.00	1.4	1.99	1.7	3.99	3.1	4.6	48.4	No blossoms.
Mountain dandelion (*Agoseris pumila*).[1]	------	.07	1.6	.86	1.3	.93	2.9	3.4	17.2	No flower heads.
Average	2.5	1.52	1.8	1.47	2.1	2.99	3.9	5.6	43.6	
	First harvesting June 10			Second harvesting June 30		June 10 and June 30		June 30	June 30	June 30:
Series II:										
Letterman needle grass.	1.8	2.97	4.1	1.76	2.6	4.73	6.7	8.6	28.4	No flower stalks showing.
Violet wheat grass	1.9	2.09	3.8	1.97	2.9	4.06	6.7	8.2	22.4	No flower stalks.
Mountain brome	2.5	2.29	4.2	2.04	3.2	4.33	7.4	9.4	27.0	Do.
Wild geranium	3.4	2.37	3.8	2.38	2.2	4.75	6.0	7.6	26.7	No blossoms.
Mountain dandelion[1]	------	1.32	2.7	1.34	2.0	2.66	4.7	6.8	44.7	No flower heads.
Average	2.4	2.21	3.7	1.90	2.6	4.10	6.3	8.1	28.6	
	First harvesting June 20			Second harvesting July 10		June 20 and July 10		July 10	July 10	July 10:
Series III:										
Letterman needle grass.	2.0	4.52	6.4	3.51	6.3	8.03	12.7	12.7	0.0	10 per cent of plants showing flower stalks.
Violet wheat grass	2.4	4.09	7.0	3.49	6.3	7.58	13.3	11.9	−10.5	No flower stalks.
Mountain brome	2.8	4.38	6.6	4.07	7.6	8.45	14.2	12.3	−13.4	10 per cent showing heads.
Wild geranium	3.0	5.38	6.9	6.72	5.8	12.10	12.7	13.3	4.7	10 per cent in blossom.
Mountain dandelion[1]	------	2.06	5.8	2.86	4.8	4.92	10.6	9.2	−13.2	Do.
Average	2.6	4.09	6.5	4.13	6.2	8.22	12.7	11.9	−6.3	

[1] Good strong, average plants.

The results obtained are summarized in Table 3 and Figure 4. The more important indications brought out are the weak growth

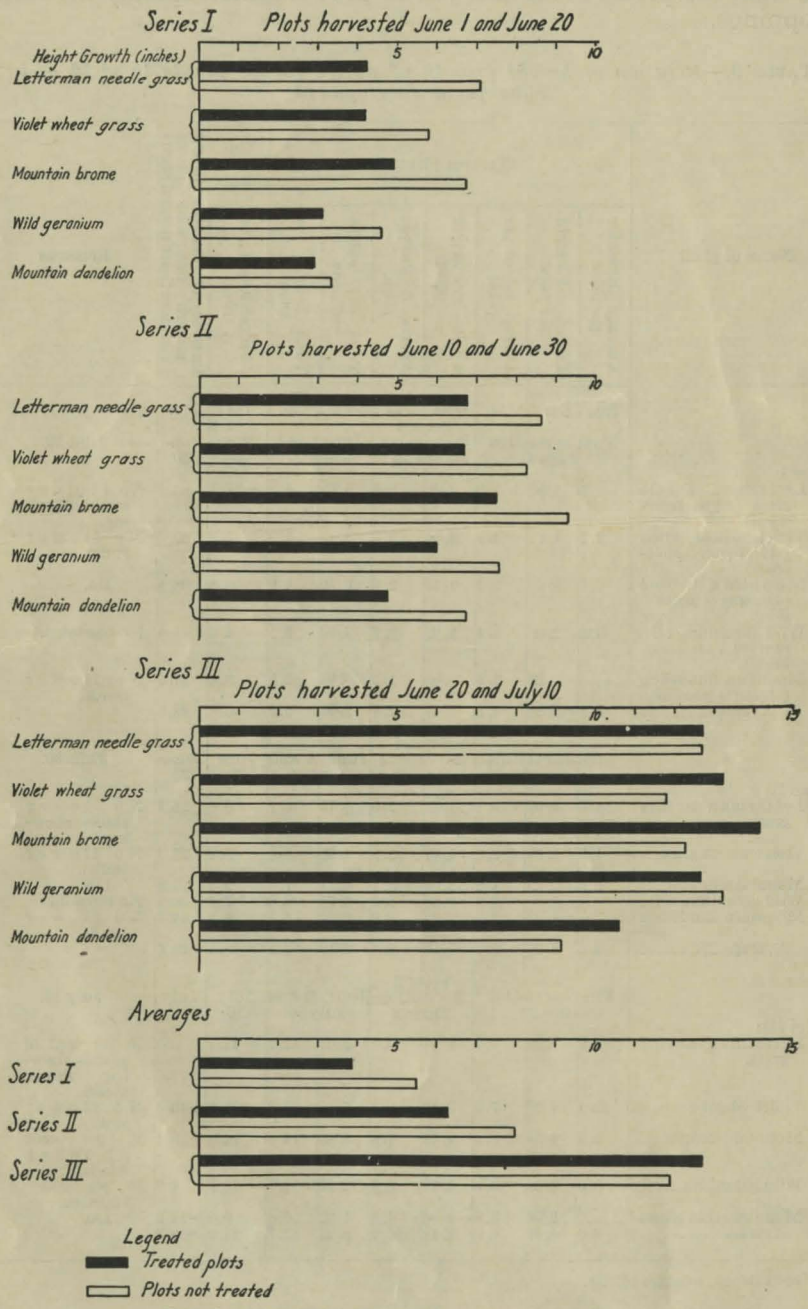

FIG. 4.—The effect of early harvesting on height growth

and small yield of forage on the plots harvested earliest in the season (Series I). The average yield of air-dry forage on June 20 of the plants in Series I was only a little more than a third of that on July 10 of plants in Series III, in which the average height at the time of the first cutting was about 6 inches. Furthermore, the average total volume of the June 1 and June 20 cuttings of Series I was but 73 per cent of the volume of the first (June 20) cutting in Series III. In every species the weight of the forage yield for the two cuttings increased sharply with delay in the first cropping.

A comparison of the average height growth of the leafage of the untreated plants of Series I with the total growth in height of the harvested specimens on June 20 shows a difference of 43.6 per cent in favor of the uncropped plants. This same relationship is less conspicuously brought out in Series II, where the height growth was 28.6 per cent greater for the untreated than for the harvested plants on June 30. In the third series the treated plants produced slightly more height growth than did the untreated ones by July 10.

When bunch grasses and other non-turf-forming vegetation which have produced from 2 to 4 inches of growth in the spring are cropped down so that only 1 or 2 inches of the leafage, or food-manufacturing surface, remains, it frequently results that the plant can not elaborate sufficient food both to replace the lost growth and to replenish the stored foods in roots and crown. On the basis of numerous microscopic examinations of the food-storage tissues and of other observations, the difference in the rate of growth and quantity of herbage produced by plants cropped with equal closeness but of different height and luxuriance of herbage when harvested may be explained as follows:

In early spring the entire plant, being without green leafage, depends for nourishment on the food which was elaborated the previous summer and stored in the cells of the plant's roots and crown. By the time the plant has attained a height of from 2 to 4 inches it has usually exhausted much of the food stored up during the previous year. The leafage is then so young that the small green bodies known as chloroplasts, where the starch grains are formed in the presence of sunlight, may be only partly developed. If the plant is clipped at that time to within 1 inch of the ground, the leaf area that is left is so limited and the digestive power so weak that the elaboration of food is almost nil. But when a plant such as violet wheat grass or mountain brome has attained a height of from 6 to 8 inches, sufficient leafage and fully developed cells are available so that a comparatively large quantity of food is elaborated by day and transferred by night to all parts of the plant. When this more developed leafage is cropped the plant has available in its underground storage tissues sufficient food to push forth the additional leafage necessary for manufacture of food for the plant as a whole.

HEIGHT OF PRINCIPAL SPECIES AS AN INDICATOR OF RANGE READINESS

Since the degree to which the vigor of forage plants is impaired by cropping depends on their degree of development when cropped, height growth of forage cover may serve as an index of the proper time for the opening of the grazing season.

The results of the experiment show that the early yield is comparatively small if the herbage is cropped when its average height is 4 inches or less. The feed is too scanty for grazing animals to satisfy their hunger in the usual period and the succulent short herbage is "washy" and comparatively low in feed value, as is attested by the restless and usually poor condition of animals when they must subsist upon it. (Pl. I.)

Moreover, when the plants are at this early stage of development the soil on mountain range is almost invariably wet, or at least very high in moisture content, so that trampling by stock injures the plant roots and seriously packs the soil, causing it to harden and bake badly when it dries. This condition of the surface soil promotes erratic run-off, so that relatively little water is absorbed from normal rains, and water is badly needed for the later plant growth and for seed formation.

When grazing is delayed until the important forage plants have reached a height of 6 inches, there is less danger of injury to the vegetation, the ground has usually dried out to the extent that trampling does not damage it, and the stock are able to obtain a sufficient quantity of more nutritious and substantial feed.

Where wheat grasses, bromes, and needle grasses are the main forage plants, they should have developed to 6 or 8 inches in height before being grazed. The necessary development of other plants will vary. Ordinarily valuable herbaceous species should have made a growth of at least 6 to 8 inches before being considered ready for grazing. In some cases it will be necessary to include consideration of the stage of development of certain portions of the plants. Where June grasses, blue grasses, and fescues are important, at least 25 per cent of the heads of these earlier forage grasses should be showing or the leaf sheaths enveloping the heads should be swollen and conspicuous (*4, pp. 11, 12*).[3]

PLANT DEVELOPMENT THAT INDICATES RANGE READINESS OR UNREADINESS

The determination of the opening date of the grazing season on a given range should be based upon the condition of the soil and the development of all the important forage species present rather than upon the condition of a few "indicator" plants. Certain conditions of the habitat may stimulate the growth of one species more than another, so that the development of a few might be in advance of that of the forage cover as a whole. Consequently the larger the list of plants used as indicators the more reliable the result. In fact, it is well to consider the development of all the important plants, since there is one early maturing group of plants whose development clearly indicates that the range is not ready for grazing, and another later-maturing group which serves as a reliable indication of range readiness and the possibility of continued vigorous forage production. The first group includes herbaceous species, which reach maturity very early in the spring, and which, being exceptionally high in water content and usually of low palatability, have little value as forage. The plants of the second group are herbaceous and browse species which mature their herbage and seeds later in the season and which are highly important, because

[3] Figures in italic in parenthesis refer to "Literature cited," p. 54.

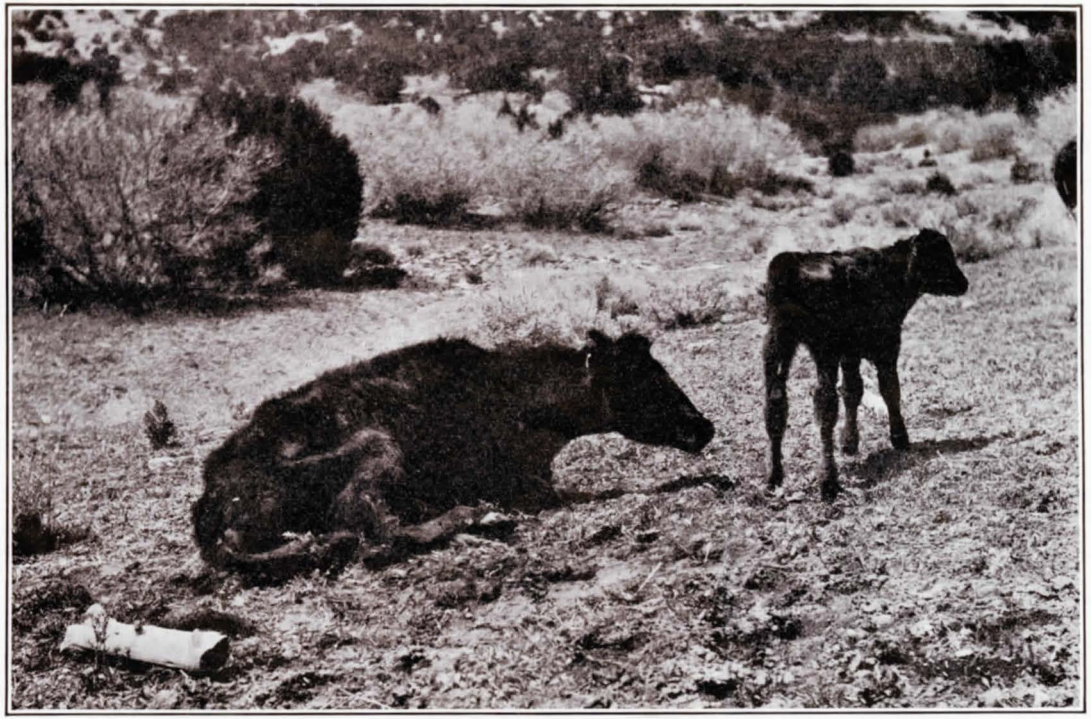

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PLATE I

Too Early Grazing Is Responsible for Poor and Weak Cattle

Lack of abundant and nutritious forage caused by too early grazing has weakened this cow so that she is unable to get on her feet. The loss of both the cow and calf is inevitable

FIG. 1.—TOO EARLY GRAZING RESULTS IN RANGE DETERIORATION

Cattle grazing in the spruce-fir type on June 25 when the ground is soft and the principal forage plants are just starting growth. Such a practice should be avoided

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FIG. 2.—TOO EARLY GRAZING OFTEN RESULTS IN LOSSES FROM POISONOUS PLANTS

Young larkspur, the leaves of which are seen protruding through the snow near the animal's head, caused this loss. The browse in the immediate vicinity of the animal is snowberry. Although the buds on it are broken the range is not ready for grazing

some of them supply the forage grazed early in the season and others during the midsummer and late fall.

PLANT INDICATORS OF INSUFFICIENT FORAGE DEVELOPMENT

The earliest spring growth on the range is often the cause of serious range abuse. Not uncommonly when the first bit of leafage shows stockmen are prompted to turn their animals on the area before the new growth of the better and more palatable vegetation appears. Cropping at the time the earliest growth begins is apt to cause a very sharp decline in the forage yield (Pl. II, fig. 1).

Plants of the following genera, when in full blossom or somewhat prior to such development, are indicators of insufficient growth of the forage for cropping (fig. 5):

Steerhead (*Bikukulla uniflora*). [4] [5]
Spring beauty (*Claytonia lanceolata*).
Little trout lily, locally called dogtooth violet (*Erythronium parviflorum*).
Waterleaf (*Hydrophyllum capitatum*). [4] [5]
Trail potato (*Orogenia linearifolia*).[4] [5]
Newberry bladderpod (*Physaria newberryi*).[4]
Smooth buttercup (*Ranunculus glaberrimus*).[4] [5]
Tongue-leaf violet (*Viola linguæfolia*).

When these plants are in full bloom such important plants as the wheat grasses and the needle grasses usually have not produced leaf blades 2 inches in length; more commonly their herbage is just beginning to appear. The leafage of other herbaceous species, like dandelion, may have attained a height growth of 2 inches, but the new growth of most of the forage cover is merely breaking the surface soil or the individual plants are showing only one or two of their leaves. The leafage of the browse plants is for the most part in the bud.

Moreover, many poisonous plants begin growth with the earliest of the unpalatable cover, and losses from eating them are usually heavier when grazing begins very early. In cases of very early grazing heavy losses are apt to occur among cattle from larkspur poisoning (Pl. II, fig. 2) and among sheep from death camas (fig. 6). Also it may lead to damage to the forest. Because of malnutrition the animals often consume more or less of the needles and tender twigs of coniferous reproduction.

PLANT INDICATORS OF SUFFICIENT FORAGE DEVELOPMENT

When the range as a whole is ready for grazing those early species given as indicators of insufficient forage development have matured. The spring beauty, little trout lily, and buttercup have all flowered and their leafage is beginning to wilt; the tongue-leaf violet has only a few flowers remaining; the trail-potato leafage is dried up and the plant has practically disappeared.

Although the adequate development of the important forage species on a particular range should be the main basis for deter-

[4] Common in the oak-brush type. [5] Common in the aspen-fir type.
Plants not otherwise designated are common in the three major types.

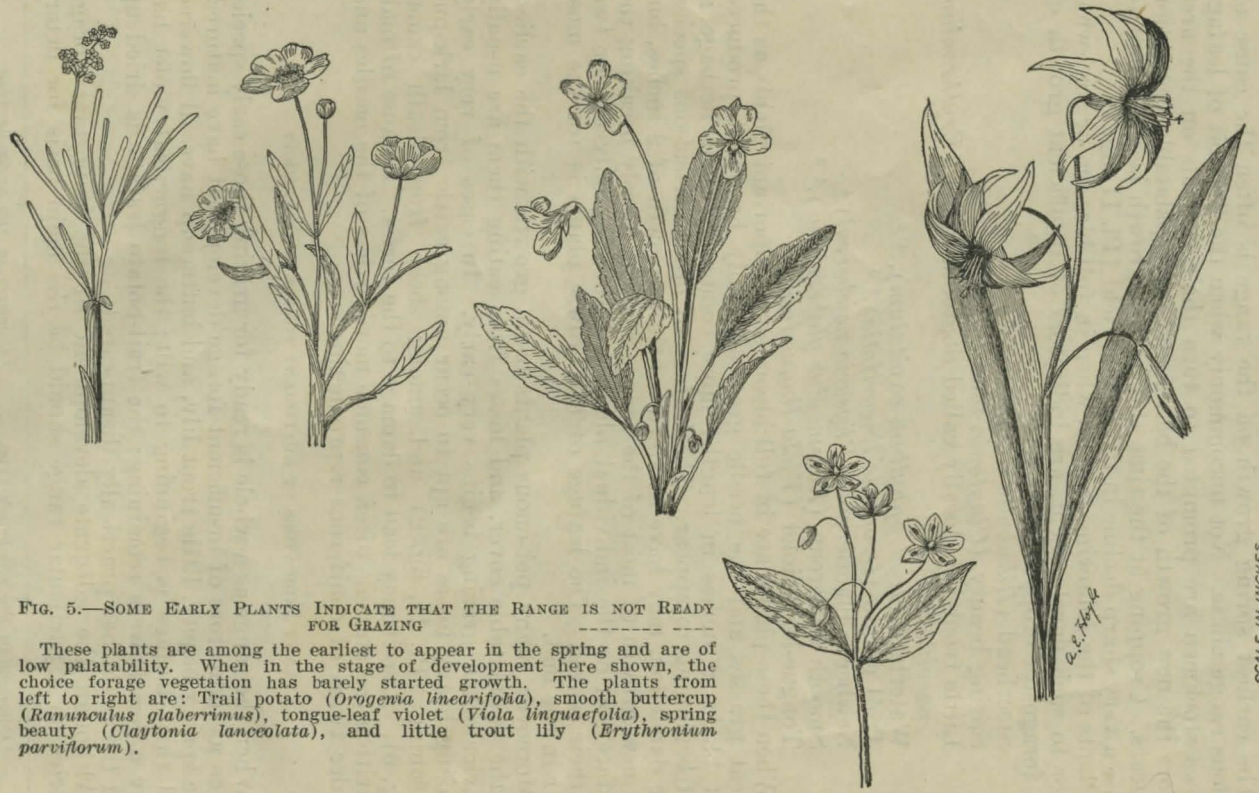

FIG. 5.—SOME EARLY PLANTS INDICATE THAT THE RANGE IS NOT READY FOR GRAZING

These plants are among the earliest to appear in the spring and are of low palatability. When in the stage of development here shown, the choice forage vegetation has barely started growth. The plants from left to right are: Trail potato (*Orogenia linearifolia*), smooth buttercup (*Ranunculus glaberrimus*), tongue-leaf violet (*Viola linguaefolia*), spring beauty (*Claytonia lanceolata*), and little trout lily (*Erythronium parviflorum*).

mining range readiness, the respective development of the following plants of the Wasatch Mountains may, when the plants are taken as a group, indicate sufficient growth for grazing in that region. (Figs. 6 and 7.) Since individual species vary under different conditions the majority of the important forage species should have reached the stage shown.

Blue stem (*Agropyron smithii*)[6]	Plant 6 to 8 inches high, no flower stalks showing.
Violet wheat grass (*Agropyron violaceum*)[6 7]	Plant 6 to 10 inches high, no flower stalks showing, no boots in evidence.
Mountain brome (*Bromus polyanthus*)[7 8]	Leaf blades 6 to 10 inches high, no flower stalks showing.
Downy brome *Bromus tectorum*)[6]	About 6 inches in height, panicles conspicuous.
June grass (*Koeleria cristata*)[6]	Leafage about 5 inches high, panicles conspicuous.
Fendler blue grass (*Poa fendleriana*)[6]	Nearly all in flower head, blossoms beginning to appear.
Letterman needle grass (*Stipa lettermani*)	Plant 6 to 8 inches high, no flower stalks showing.
Yarrow (*Achillea lanulosa*)	Leafage 2 to 4 inches long, flower stalks beginning to show.
Wafer parsnip (*Aulospermum longipes*)[6]	Through blossoming, seeds well developed.
Balsam-root (*Balsamorrhiza sagittata*)[6]	Leafage about three-fourths developed beginning to blossom.
Low larkspur (*Delphinium menziesii*)	Leafage conspicuous, commencing to blossom.
Wild geranium (*Geranium viscosissimum*)	Leafage about 4 inches high, approximately one-fourth developed.
Dandelion (*Leontodon taraxacum*)	Leafage about one-half developed, blossoms beginning to appear. A few blossoms opened.
Butterweed (*Senecio columbianus*)[6 7]	Leafage mature, plants commencing to blossom.
Foothill death camas (*Zygadenus paniculatus*)[6]	Leafage mature, plants beginning to blossom.
Service berry (*Amelanchier alnifolia*)[6 7]	Leaves one-half to 1 inch long and from three-eighth to three-fourths inch wide, flower buds about to open.
Birch-leaf mahogany (*Cercocarpus montanus*)[6]	Leaves three-eighths to one-half inch wide and one-half inch long, no flowers showing.
Squaw apple (*Peraphyllum ramosissimum*)[6]	Leaves about one-half to 1 inch long and about one-fourth inch wide, flower buds beginning to open.
Bitter brush (*Purshia tridentata*)[6]	Leaves one-fourth to one-half inch long and from one-eighth to one-fourth inch wide, flower buds conspicuously swollen.
Spine current (*Ribes montigenum*)[7 8]	Leaves about three-eighths inch long, or one-fourth developed; commencing to blossom.
Snowberry (*Symphoricarpos oreophilus*)	6 to 14 leaves showing from each bud; no blossoms; new growth of stem about 1½ inches long.

[6] Common in the oak-brush type.
[7] Common in the aspen-fir type.
[8] Common in the spruce-fir type.

Plants not otherwise designated are common in the three major types.

FIG. 6.—RANGE READINESS MAY BE DETERMINED BY THE STAGE OF DEVELOPMENT OF MANY PLANTS

Proper development of some typical plants characteristic of the oak-brush type at the time when the range is ready for grazing. A—Mountain June grass (*Koeleria cristata*), B—Letterman needle grass (*Stipa lettermani*), C—Dandelion (*Leontodon taraxacum*, and foothill death camas (*Zygadenus paniculatus*).

FIG. 7.—THE DETERMINATION OF RANGE READINESS SHOULD BE BASED ON THE DEVELOPMENT OF THE MAIN FORAGE COVER

Proper development of some typical plants characteristic of the forage cover in the spruce-fir type at the time of range readiness for grazing. A—Violet wheat grass (*Agropyron violaceum*), B—Wild currant (*Ribes inebrians*), C—Sweet sage (*Artemisia* sp.), D—Mountain currant (*Ribes montigenum*), and E—Yarrow (*Achillea lanulosa*).

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TABLE 4.—*Phenological observations of plants on north and south slopes in different forage types, 1920*

Date of observation	Plant observed	South exposure			North exposure		
		Elevation	Slope	Development of plant	Elevation	Slope	Development of plant
	OAK-BRUSH TYPE	*Feet*	*Degrees*	*Numerical value*	*Feet*	*Degrees*	*Numerical value*
May 10	Letterman needle grass (*Stipa lettermani*)	7,200	18	17	7,200	20	10
Do	Fendler blue grass (*Poa fendleriana*)	7,200	18	35	7,200	18	20
Do	Wild geranium (*Geranium viscosissimum*)	7,200	18	14	7,200	18	7
Do	Snowberry (*Symphoricarpos oreophilus*)	7,200	18	10	7,200	20	2
Do	Butterweed (*Senecio serra*)	7,200	18	16	7,200	20	5
Do	Douglas knotweed (*Polygonum douglasii*)	7,200	18	15	7,200	20	6
Do	Birch-leaf mahogany (*Cercocarpus montanus*)	7,200	16	10	7,200	17	3
Do	June grass (*Koeleria cristata*)	7,200	18	31	7,200	20	20
Do	Bitter brush (*Purshia tridentata*)	7,200	20	15	7,200	20	8
Do	Average	7,200	18	18	7,200	19	9
May 20	Streambank wheat grass (*Agropyron riparium*)	7,200	18	20	7,200	20	7
Do	Butterweed	7,200	18	35	7,200	22	19
Do	Wild geranium	7,200	18	19	7,200	18	11
Do	Average	7,200	18	25	7,200	20	12
May 28	Butterweed	7,200	18	60	7,200	22	40
Do	Fendler blue grass	7,200	18	60	7,200	18	42
Do	Average	7,200	18	60	7,200	20	41
	SPRUCE-FIR TYPE						
July 1	Violet wheat grass (*Agropyron violaceum*)	10,050	26	14	10,050	28	10
Do	Wild geranium	10,050	26	15	10,050	28	16
Do	Fendler blue grass	10,050	26	27	10,050	25	25
Do	Columbian butterweed (*Senecio columbianus*)	10,050	26	15	10,050	25	17
Do	Douglas knotweed	10,050	26	16	10,050	25	12
Do	Snowberry	10,050	22	13	10,050	20	7
Do	Spiked trisetum (*Trisetum spicatum*)	10,050	20	18	10,050	21	16
Do	Letterman needle grass	10,050	25	19	10,050	26	16
Do	Nevada blue grass (*Poa nevadensis*)	10,050	25	24	10,050	26	20
Do	Wine gooseberry (*Grossularia inermis*)	10,050	25	17	10,050	26	14
Do	Mountain elder (*Sambucus microbotrys*)	10,050	26	13	10,050	26	16
Do	Yarrow (*Achillea lanulosa*)	10,050	26	18	10,050	23	14
Do	Average	10,050	25	17	10,050	25	15
July 10	Wild geranium	10,050	26	21	10,050	25	20
Do	Letterman needle grass	10,050	25	26	10,050	26	21
Do	Violet wheat grass	10,050	26	20	10,050	25	20
Do	Average	10,050	26	22	10,050	25	20
Aug. 10	Yarrow	10,050	26	68	10,050	26	70
Do	Letterman needle grass	10,050	25	75	10,050	26	75
Do	Violet wheat grass	10,050	26	70	10,050	25	70
Do	Average	10,050	26	71	10,050	26	72

RELATION OF EXPOSURE AND SLOPE TO RANGE READINESS

Climate, because of its influence on plant growth, largely determines the time at which the range forage is ready for cropping. Elevation greatly affects climate, and is of prime importance because there is often an altitudinal difference of several thousand feet in a mountainous range unit. Exposure has a marked influence on temperature and plant growth.

The difference in the time at which the forage is sufficiently advanced to allow cropping on north and on south exposures at the same elevation in the oak-brush type may in extreme cases amount to two weeks. The difference is much less pronounced at the higher elevations than in the lower belts, except on very steep slopes where large snowdrifts occur.

On the more gently sloping north and south exposures at the same elevation the forage is sometimes in practically the same stage of development when the range as a whole is ready for cropping.

In order to study plant development on different slopes and exposures, a phenological table giving in a number the stage of development of the plant as a whole was developed, as follows:.

Beginning of growth (buds of foliage or blossoms swelling)	5
Vegetative development (leaf or leaf blade in evidence)	10
Leaf sheaths swelling (inflorescence in the "boot")	30
Inflorescence showing but flowers not expanded	40
Inflorescence showing most of flowers fully expanded	60
Seed fully developed, partly or entirely disseminated	100

In accordance with these values representative species were observed on different slopes and exposures of the same elevation in all major forage types. The numerical values assigned to height or extent of leaf expansion were recorded only after actual measurements had been made; the extent of the swelling of the buds and the development of the flowers and fruit were determined ocularly. The method must be used with discretion as to individual species, but when a considerable number of species are observed, the results should give an approximate ultimate average. In general, when these numbers are used the average which indicates vegetative readiness will be from 20 to 30 per cent, according to the composition of the vegetation.

The results of some observations in the oak-brush and in the spruce-fir types are given in Table 4, and their averages in Figure 8.

The results show that there is considerable variation in the time interval of plant development on north and south exposures. The forage in the oak-brush type develops much earlier on south than on north exposures; but with increase in elevation this difference in development decreases until at elevations of 10,000 feet in the spruce-fir type the date of vegetational readiness for grazing is practically the same for the two exposures.

It was also found that for each 1,000 feet increase in elevation the date of vegetational readiness is retarded approximately 18 days on south exposures and about 11 days on north exposures, or about 14 days on an average. This average delay varies, however, from 10 to 20 or more days in the intermountain region, according to local climatic conditions and the type and vigor of vegetation.

CLOSING OF THE SEASONAL GRAZING PERIODS

The time when livestock should be removed from the spring range to the summer range is determined chiefly by (1) the stage of growth and the abundance of forage on the summer range, (2) the grazing capacity of the early range as compared with that of the summer range, (3) the palatability of the forage on the spring range and the thriftiness of the animals grazed, (4) the water supply on both ranges, and (5) the need for and value of the forage on the

early range for fall grazing. The stage of development of the forage in the aspen-fir belt is usually the determining factor as to when the livestock should be moved from the oak-brush belt in the spring.

If the forage on the spring range is comparatively more abundant than that on the summer range, and the whole range is stocked on the basis of utilizing all of the forage, the animals should be held on the early range so long as there is sufficient palatable feed available there to keep them in thrifty condition without overgrazing. With limited summer range and abundant spring range, more animals will be maintained in good condition without injury to the forage crop in any type if they are held on the lower lands as late as possible. With a good balance in the grazing capacity of the spring and the summer range, on the other hand, the stock may be admitted to the summer range as soon as the forage there is ready

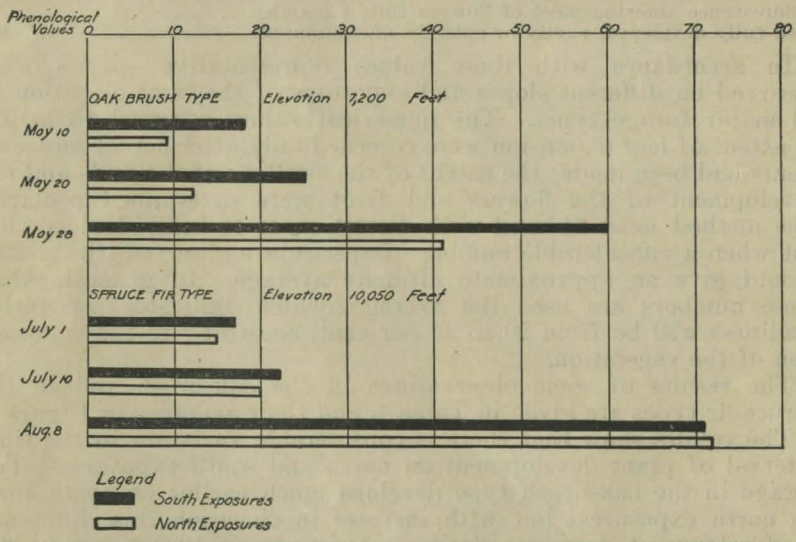

FIG. 8.—Average phenological values for north and south exposures—1920 forage development in the oak-brush type occurs earlier on south exposures than those facing the north. Increase in elevation results in less variation of plant development between exposures

for cropping. With limited spring range and abundant summer grazing grounds, which is often the case on national forests and is conspicuously so in those of the Wasatch Mountains, the situation becomes more complicated. Under such conditions it is necessary either to admit to the spring range at the beginning of the grazing season only a portion of the stock capable of being carried on the summer range, allowing the remainder to come on the range and pass immediately to the summer range when the summer forage is ready, or to delay the admission of all the animals until such a date that the summer range will be ready for grazing when they have properly utilized the forage on the spring areas.

In some localities there are areas of spring range, limited in size, where scarcity of water is the controlling factor in the period of use. Early in the spring, owing to melting snow and occasional showers, there is an ample water supply; but with the approach of

summer this dries up and it becomes necessary to move the stock to other areas.

Because of the desirability or necesity of grazing the spring-range zone for a period in the fall, it is often essential to leave a certain amount of forage for this use at the close of the spring period. Occasionally the character of forage and the soil and climatic conditions are such that the feed necessary for the fall period is produced after the close of the early season, while the livestock are on the summer range.

The closing of the grazing period on summer and fall ranges is governed largely by (1) proper utilization of the forage, (2) weather conditions and the trampling of wet soil, (3) the condition of the livestock, (4) the availability of late fall and winter forage elsewhere, and (5) the availability of water.

Proper utilization may be defined as that degree of grazing which utilizes the largest quantity of forage possible without threatening the future productivity of the type, or which allows the type to recuperate if it is depleted. It is generally conceded that if from 10 to 25 per cent of the herbage of the more important palatable species remains in the fall proper utilization has been affected. When proper utilization has been attained, irrespective of the other factors mentioned, the livestock should be removed from the range. It is never good practice on any type to crop the forage in the fall so closely that the animals merely survive. Furthermore, such close cropping often results in the exposure of the crown and buds of the plant, a condition which is responsible for much winter-killing and loss of plants by frost upheaval.

In some years weather conditions determine the proper time for the close of the grazing period on fall ranges. Frequently heavy snowfall early in the season makes it necessary to remove the livestock from the range earlier than would otherwise have been necessary. If the fall is exceptionally wet, they should be removed early to prevent damage to the range by trampling and loss in weight of the animals. It is especially undesirable to hold beef cattle overlong on the fall range, for at that season they usually lose in weight and finish. The availability of good feed elsewhere is not uncommonly a determining factor as to the time when the animals may be removed in the fall.

Livestock should be removed from winter range early enough in the spring to allow time for the forage plants on this range to make a satisfactory new growth. The date of such removal is largely determined by the character of the vegetation and the prevailing moisture conditions. Where it is necessary to remove the livestock from the winter range before the spring range is ready, supplemental feed must be provided for the interval.

GRAZING PERIODS IN EACH VEGETATIVE TYPE

The following grazing periods are those which give the best results on each of the three major types of the Ephraim Canyon watershed, where the detailed studies were made:

Oak-brush type (6,500 to 8,000 feet elevation): Spring to early summer, and late fall; May 20 to June 9, and October 1 to October 15.

Aspen-fir type (7,500 to 9,500 feet elevation): Early summer to midsummer, and late fall; June 10 to July 9, and October 1 to October 15.

Spruce-fir type (9,000 to 11,000 feet elevation): Summer to fall; July 10 to September 30.

The first date shown for each type represents the average at which the range in that particular belt is ready for grazing. This may vary from year to year owing to exceptionally heavy or light snowfall and high or low temperatures. In actual practice, however, the aspen-fir type is used by some livestock throughout the whole period from June 10 to October 15 and parts of the oak-brush type may be used later in the season than June 9.

RANGE MANAGEMENT BASED UPON PROPER SEASONAL USE

MANAGEMENT PLANS

Grazing that will meet the seasonal growth requirements of the forage can be obtained only by the application of a thoroughly sound and practical grazing-management plan.

If cattle are simply turned loose on the range, even after the first zone is ready to graze, and no particular attempt is made to distribute them or to confine them to forage that is properly developed, they will rapidly drift to areas that are not yet ready for grazing and will become "located" as a natural habit on portions of the range most suitable to their peculiar desires. Once they are thus located it is usually impracticable to hold them to proper seasonal grazing or to keep them properly distributed during the remainder of the grazing season. On the other hand, experience has shown that it is entirely practicable by reasonable management to confine cattle to elevational zones during the proper seasons of their use. It is evident, then, that specific plans for proper distribution of livestock, together with the necessary means of controlling their movements, should be definitely provided for before they are admitted to any part of the range.

As a beginning of the management plan a range must first be divided into the different seasonal zones. In doing this it will not always be possible to follow exactly the vegetative zones or types; the dividing lines must, so far as possible, be practical control lines and will often swerve into the next higher zone here and dip into the lower one there in order to follow ridges and fences or to permit gaps in topography or other barriers to be closed by short fences, since these features will aid in confining livestock, especially cattle, to the zone during the period when it should be grazed.

Not only is it important to have livestock graze each altitudinal zone during a given period, but they must be distributed within the zone so as to obtain the fullest possible use of the forage on the entire unit without local overgrazing. Usually, then, the second step in the management plan divides the range into lateral or horizontal distribution or management units, care being taken again to bound the units, so far as possible, with practical control lines.

METHODS OF CONTROLLING STOCK

Since sheep on mountain ranges are in herds under the care of herders, their control is a relatively simple matter. A band can

be held in each natural management unit, during the period when the unit can best be used, long enough for proper utilization of the forage. The band can then be shifted in accordance with the management plan to another natural unit in the same seasonal zone and so be grazed through the units of each zone during the proper season. When the forage in the next seasonal zone has developed sufficiently to allow grazing there the band is moved into that zone and again held in each natural unit of the zone only long enough to utilize properly the forage of the unit.

On cattle ranges it is essential to determine the carrying capacity of each of the natural management units and to plan the movement of the cattle so that each unit may be grazed during the proper period by the number of cattle representing its carrying capacity. The best basis for determining this carrying capacity and working out the whole management plan is grazing reconnaissance data. If this information is lacking, a careful examination must be made of the range in order to determine as closely as possible the location of the zonal and distribution units and the carrying capacity of these units.

Once the number and distribution of the cattle have been worked out, it becomes essential to provide the mechanics for controlling and moving the animals. Control may be obtained by salting, herding, or fencing, or a combination of two or all of these.

Salt forms a very essential part of the rations of livestock and because of the natural craving for it the distribution of salt on the range offers one of the most satisfactory—as well as one of the most economical—means of controlling cattle movements (*1*). Salt should be available where cattle first come on the range and should be distributed in accordance with the quantity and development of forage. No salt should be placed on or very close to areas such as upper zones not yet in vegetational readiness or overgrazed portions of the range, around watering places, on flats, in swales and other natural congregating places, or near poisonous-plant areas, recreational sites, and other places of intensive use. On the other hand, salt placed on slopes and ridges and in the more remote portions of the range has a great influence in drawing cattle to these places and obtaining proper utilization of forage which otherwise would not be grazed or at least would not be fully utilized.

The number of cattle that should be grazed in a given unit and the length of time they should remain there is the basis for determining the amount and time of salting. With correct salting and stock distribution the forage and salt will be consumed by the time the next zone is ready and the animals will move practically of their own accord to the next higher zone where salt has recently been placed and where sufficiently developed forage is available. Salt should not be left on a unit of range after the forage has been fully utilized. Surplus salt on the upper elevations should be gathered and stored over the winter, since if left on the range it will tend to draw stock to those places too early and will largely defeat the effect of salt on the lower zones in keeping the animals there.

Riding of course is essential to place cattle and salt properly on the range and to give necessary attention to the stock during the season. Also, some herding is ordinarily necessary to prevent cattle from going up drainage bottoms, along more or less level

ridges, through natural passes, or even up more or less steep slopes, and grazing the upper range too early, unless strategic points are drift fenced. Fencing for local control on low-value mountain ranges is so expensive that ordinarily it is justified only at such points. Even with each seasonal zone fenced, salting and herding must be relied upon to obtain good distribution within the units and to move the cattle from one unit to another. One rider can herd and salt about 1,000 cattle on the average mountainous range if he is employed throughout the season and given some assistance at the time when the stock first come on the range and again in the fall when the round-up is made.

MANAGEMENT PLAN FOR TYPICAL RANGE DIVISION

Figure 9 shows the area of a range division typical of the Wasatch Mountains, with types, zones, and topographic units. Figure 10 gives an example of the proposed distribution and movements of cattle intended to secure proper seasonal use and uniform utilization of the forage on the division by 1,575 cattle. The plan given in this example does not provide for ideal seasonal use but indicates what can reasonably be expected under practical range-management practices.

By reference to Figure 10 it will be seen that 860 of the total number of 1,575 cattle permitted on the division for the season May 20 to October 15 are placed in the oak-brush zone of the New Canyon cattle unit. Of this number 340 are moved on June 10 into the aspen-fir zone of New Canyon and on July 10 into the spruce-fir zone, where they remain until September 30, and then, if they have not already drifted down, are driven to the oak-brush zone to remain until October 15. A herd of 175 is allowed to remain in the oak-brush zone until July 9, when they are drifted into the aspen-fir zone, and on September 30 are brought back to the oak-brush zone to remain until the close of the grazing season. The remaining 345 cattle placed in the New Canyon cattle unit on May 20 are shifted on June 10 to the aspen-fir zone of the Ephraim Canyon cattle unit, where they are grazed with 295 head moved up from the oak-brush zone of Ephraim Canyon. These 640 head are moved on July 10 into the spruce-fir zone, remain there until September 30, and are then drifted back into the aspen-fir zone to remain until the close of the season.

In addition to the 295 cattle which are later moved into the higher zones of Ephraim Canyon, 420 head are placed in the oak-brush zone of the Ephraim Canyon cattle unit on May 20, and on June 10 are drifted to the aspen-fir zone of the Willow Creek cattle unit. Of these, 175 remain in this zone of the Willow Creek unit until the close of the season. On July 10, 245 cattle are moved into the Willow Creek spruce-fir zone, and on September 30 these are drifted back to the oak-brush zone of Ephraim Canyon.

It should be realized that these numbers of cattle are relative. In actual practice some will drift of their own accord from one zone to the next shortly before the specified dates for moving, and particularly will they drift down from the upper zones to the lower if

severe storms prevail in late September or early October. The movement of cattle, therefore, is not as difficult a task as it might appear.

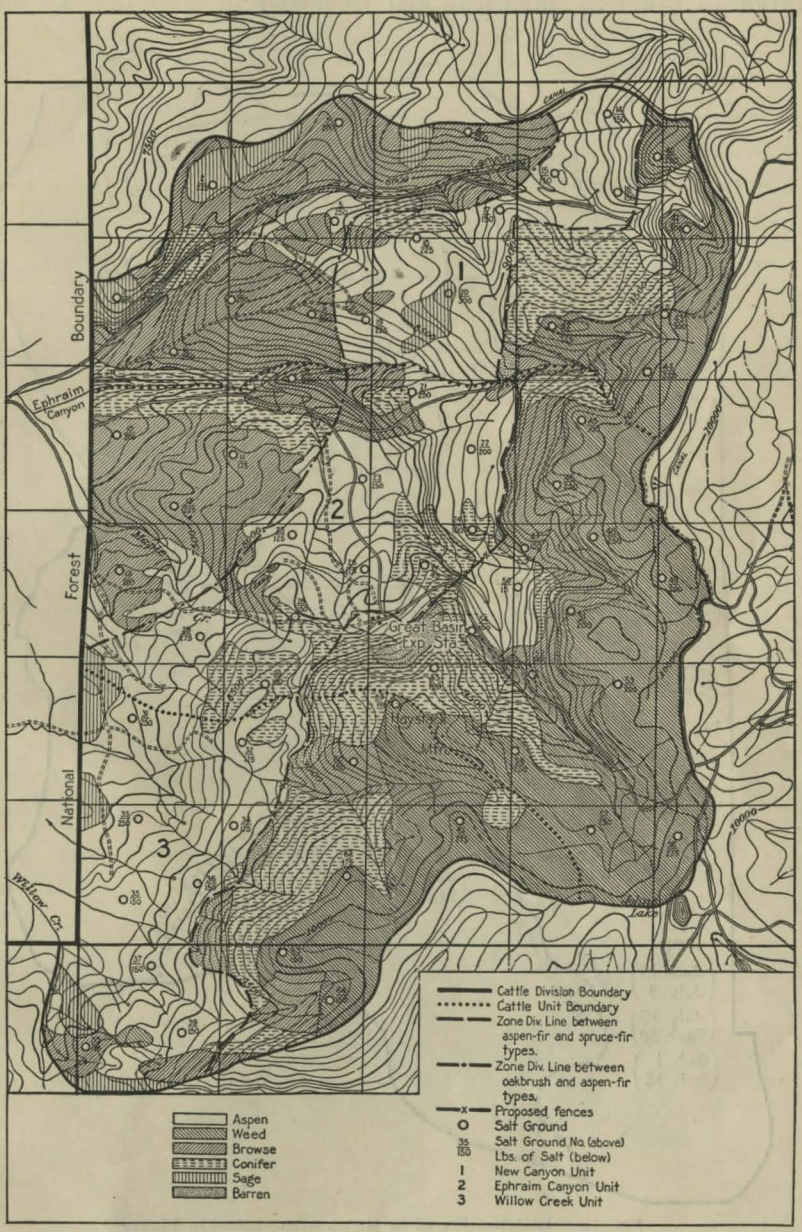

FIG. 9.—A typical cattle division of the Wasatch Mountains

EFFECT OF FREQUENCY OF PASTURING ON FORAGE PRODUCTION AND LONGEVITY OF VEGETATION

With the view of determining the specific influence on the vegetation of different intensities and frequency of cropping, a "plant

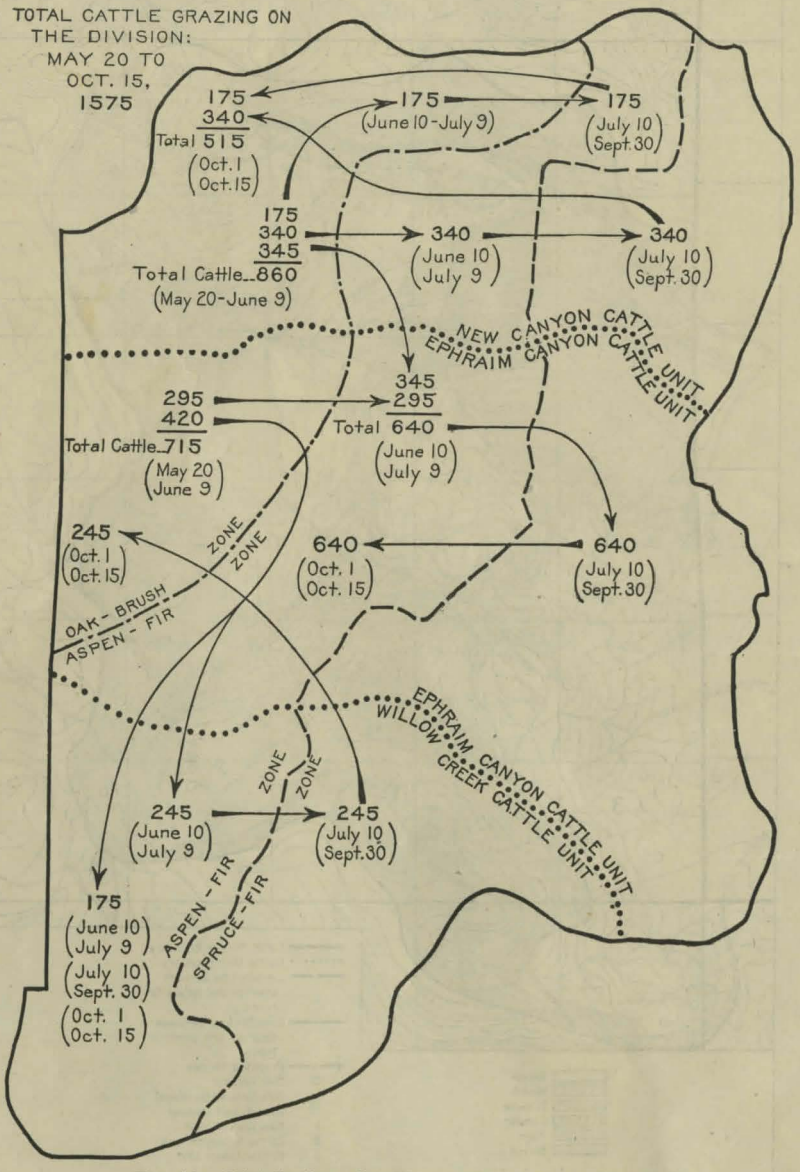

FIG. 10.—Distribution of cattle on area shown in Figure 9

vigor" experiment was initiated at the Great Basin Experiment Station in 1916.

EXPERIMENTAL PROCEDURE

ESTABLISHMENT OF PLOTS

Four plots each of mountain brome (*Bromus polyanthus*), common brome (*B. inermis*), and violet wheat grass (*Agropyron violaceum*) were planted in the forage nursery located in the aspen-fir type at an elevation of 8,700 feet. Each plot contained 30 specimens, which were uniformly spaced 1 foot apart. In order that all the specimens might be as nearly alike as possible with respect to size, age, and vigor, the plants were developed from seed sown in a seed bed a year prior to their being carefully transplanted in the regular plots.

In 1919, when the first experimental series was well under way, the investigation was expanded by the planting of a large number of additional plots in the nursery to native forage species. (Pl. III, fig. 1). Following the more extensive plot work of the nursery, it was deemed advisable to approach range conditions more nearly than was possible on cultivated ground. With this in view, in the spring of 1920 a large number of new plots were established on the range where the plants were growing naturally in association with many species and had been subjected to normal annual grazing. These were located in the oak-brush type at an elevation of 7,200 feet and in the spruce-fir association at an elevation of about 10,000 feet. Approximately 1,000 plant specimens for experimental work were contained in these series of plots and an unusual opportunity was afforded for comparative study, especially as to (1) possible variations in the response of plants of the same species to a given method of treatment, and (2) the combined effects of widely different climatic conditions and methods of harvesting. All the more important types of forage plants had a representative in the test. Although most of the work dealt with plants of the "bunch" or tufted habit of growth, such as are found commonly on high mountain range, typical turf-forming species (those which reproduce asexually or vegetatively, as from rootstocks) were also included.

METHODS OF TREATMENT

In order to procure the most accurate data possible, the forage removed from all the plots was harvested with shears in a way to resemble grazing, the season and closeness of the harvesting (the latter approximately 1 inch from the surface of the ground in most instances) representing as nearly as practicable that of certain grazing practices. In harvesting the various forage plots in one or more of the grazing types 24 methods differing as to date, frequency, and closeness of cutting were used.

During the period of experimentation on a "plant plot" basis for the purpose of ascertaining the cumulative effect of different methods of cropping on the yield of herbage, extensive observations were also made over a wide range of forage, soil, and climatic conditions where the methods of cropping were known. These observations have proved helpful, not only in checking, but also in interpreting the results of the detailed studies.

For the purpose of determining the comparative food value, pound for pound, of forage harvested at different times in the

season and at varying frequency, chemical analyses were made (by the Bureau of Chemistry) of representative forage samples taken from typical plots. Special examinations and numerous physical and chemical analyses were also made of the root systems of variously treated plants, the object being to determine their depth, spread, and weight, and also to ascertain the amount of food stored in the roots, especially at the time of inception of growth in the spring.

SPECIES OBSERVED

The following plants were included in the tests:

Violet wheat grass (*Agropyron violaceum*).
Common brome (*Bromus inermis*).
Mountain brome (*Bromus polyanthus*).
Nevada blue grass (*Poa nevadensis*).
Letterman needle grass (*Stipa lettermani*).
Yarrow (*Achillea lanulosa*).
Mountain dandelion (*Agoseris pumila*).
Wild geranium (*Geranium viscosissimum*).
Snowberry (*Symphoricarpos oreophilus*).

RESULTS

Athough conditions within the experiment were made as comparable for each cropping method studied as was possible, considerable variation occurred in individual species. These variations were attributed to fluctuations in climatic conditions within a season and from year to year, unusual wind movement, the variation in soil, soil moisture, slope and exposure, competition from adjacent vegetation, injury by rodents, and possibly other factors. Highly favorable growing seasons render obscure or practically offset the effects of a given cropping method which otherwise would show a cumulative physiological response by a diminution of yield.

Though the results presented can not yet be considered as conclusive in all cases, they do give indications of what may be expected from different methods of grazing and clearly show the undesirability of adopting or continuing certain grazing practices and the good results to be obtained from others.

PLOTS HARVESTED FREQUENTLY

The data in Table 5 typify the results obtained from cropping the herbage in the plots five times in a season to 1 inch above the ground. The first harvesting was made two weeks after growth began, the following three at monthly intervals, and the last, which provided for the removal of the aftermath, at the end of the growing season.

TABLE 5.—*Results of harvesting five times each season*

Plant	Yield per plot [1] (grams)		
	1920	1921	1922
Letterman needle grass	86.11	47.45	9.65
Do	11.21	2.86	1.65
Do	63.15	16.04	5.02
Mountain brome	334.45	.00	.00
Do	894.18	.00	.00
Do	886.20	.00	.00
Violet wheat grass	83.22	51.61	7.01
Wild geranium	19.19	1.87	.13
Do	11.41	4.59	.00
Do	128.21	31.64	2.71
Mountain dandelion	16.23	5.99	3.83
Do	33.90	29.90	15.39
Total	2,567.46	191.95	45.39

[1] These plots did not contain the same number of plants, so that a direct comparison of yields between the different plots can not be made.

Plants without rootstocks like those here studied are either killed or much weakened when the herbage is cropped 1 inch above the ground at monthly intervals. More frequent cropping has even more disastrous effects. Mountain brome, one of the most valuable forage plants in the aspen-fir and spruce-fir types and a rapid-growing and heavy-yielding plant under favorable conditions, was killed by the fourth and fifth harvestings in the first year. Wild geranium, also, is seriously affected by close, repeated cropping, for its leafage develops uniformly throughout its area, and when it is defoliated, as by grazing, leaf expansion must originate from the unfolding of new buds. A method of grazing which removes most of the herbage at monthly intervals, four or more times in a season, the first harvesting being two weeks after growth begins, results in the killing out of many plants and the serious impairment of the vigor of the others.

The closeness of the cropping during the growing season appears to have much influence on the yield and longevity of the vegetation when the plants are harvested frequently. A plot of Letterman needle grass harvested with the same frequency as those heretofore mentioned, but cut at a height of not less than 2½ inches above the ground, had at the end of three years' treatment practically retained its initial vigor and yield. The yields on this plot, consecutively, for the three years of treatment, were 29.35, 19.32, and 23.68 grams.

COMPARATIVE EFFECT OF DIFFERENT FREQUENCIES OF HARVESTING

The results on plots harvested twice and on those harvested five times in a season for three successive years are given in Table 6 [9] and Figure 11. The plots harvested twice were cropped just before seed maturity and again at the close of the growing season; those treated five times were cropped two weeks after growth began,

[9] The data presented here for plots harvested five times are essentially a repetition of those given in Table 5, but in this case a selection was made in order to compare plots having the same number of plants of the same species and occurring in the same zone.

and three times at monthly intervals, and finally at the end of the growing season. All cuttings were made 1 inch above the ground.

TABLE 6.—*Comparative yields of plots harvested five times and twice, respectively, each season*

PLOTS HARVESTED FIVE TIMES AT MONTHLY INTERVALS, THE FIRST HARVESTING BEING MADE TWO WEEKS AFTER INCEPTION OF GROWTH AND THE LAST MONTHLY HARVESTING BY REMOVAL OF THE AFTERMATH AT THE CLOSE OF GROWING SEASON

Plot No.	Plant	Zone[1]	Number of plants [2]			Yield per plant (grams)			Total yield per plot (grams)		
			1920	1921	1922	1920	1921	1922	1920	1921	1922
S-1-8	Letterman needle grass.	S-F	8	8	7	1.40	0.36	0.24	11.21	2.86	1.65
SL-1-10	do	O-B	10	10	6	6.32	1.60	.84	63.15	16.04	5.02
C-4	Mountain brome	A-F	29	0	0	30.56			886.20		
G-1-5	Wild geranium	O-B	5	5	1	3.84	.37	.13	19.19	1.87	.13
G-1-8	do	S-F	8	7	2	16.03	4.52	1.36	128.21	31.64	2.71
A-1-8	Mountain dandelion	S-F	8	6	4	2.03	1.00	.96	16.23	5.99	3.83
	Total		68	36	20				1,124.19	58.40	13.34

PLOTS HARVESTED JUST BEFORE SEED MATURITY AND AGAIN AT CLOSE OF GROWING SEASON

S-25-32	Letterman needle grass.	S-F	8	8	8	2.09	4.43	5.00	16.70	35.41	39.98
SL-41-50	do	O-B	10	10	10	12.36	4.47	3.82	123.64	44.67	38.18
C-5	Mountain brome	A-F	29	28	25	157.97	77.42	58.71	4,581.12	2,167.80	1,467.68
G-16-20	Wild geranium	O-B	5	5	5	13.39	11.80	16.44	66.94	58.99	82.21
G-25-32	do	S-F	8	8	8	13.13	18.32	16.67	105.00	146.52	133.36
A-25-32	Mountain dandelion	S-F	8	8	2	1.06	.71	1.45	8.44	5.71	2.90
	Total		68	67	58				4,901.84	2,459.10	1,764.31

[1] Zones: S-F=Spruce-fir; O-B=Oak-brush; A-F=Aspen-fir.
[2] The number of plants shown in this table represents those living at the beginning of each year's treatment.

TABLE 7.—*Effect of frequency of harvesting on yield*

Plant	Yield per plot (grams)		
	1917	1918	1919
Plots harvested four times each season:			
Violet wheat grass	65.9	85.9	69.8
Mountain brome	755.4	405.7	90.8
Total	821.3	491.6	160.6
Plots harvested twice each season:			
Violet wheat grass	285.9	538.4	789.4
Mountain brome	1,674.9	1,506.6	1,453.6
Total	1,960.8	2,045.0	2,243.0
Plots harvested once each season:			
Violet wheat grass	351.8	552.5	910.0
Mountain brome	1,058.9	943.3	1,110.0
Total	1,410.7	1,495.8	2,020.0

The fewer specimens killed and the greater maintenance of vigor of the plants harvested only at seed maturity and at the close of the growing season, as compared with those harvested five times, is clearly indicated by the data. Table 6 indicates the decline in the number of plants and the diminution in the yield per plant result-

ing from the five harvestings. There was a slight decrease from year to year in the number of mountain brome and mountain dandelion plants on the plots harvested twice in the season. In the former case it is believed that the loss was caused by frost upheaval, and in the latter pocket gophers cut the taproots. There was also a noticeable decrease in the yields of Letterman needle grass and mountain brome on these plots. Inasmuch as these plants are bunch grasses it is believed that some of the previous year's growth may have been included with the first cutting in 1920. The difference in the growth potentialities of the seasons is no doubt responsible for some variation in the yields.

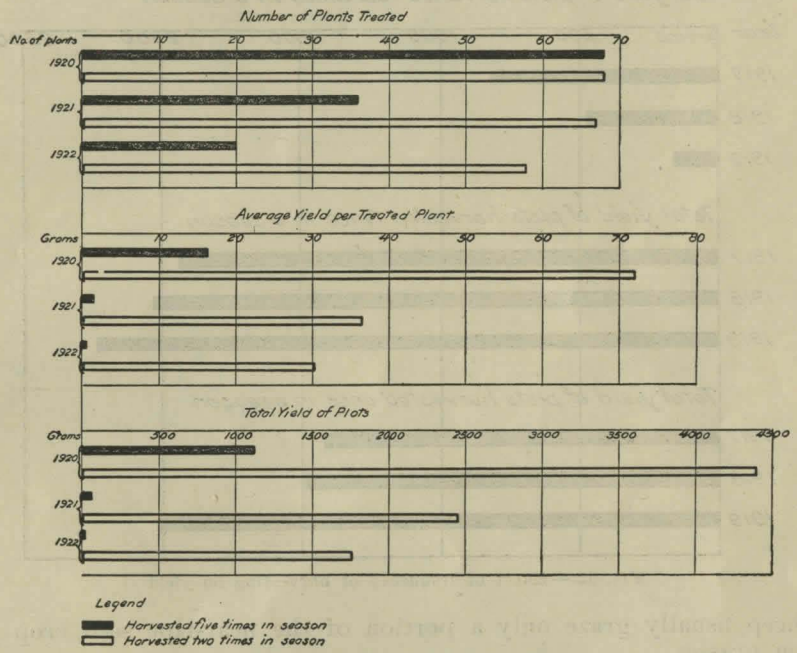

FIG. 11.—Effect on vitality and yield of frequency of harvesting. Cropping as often as five times in a season not only causes a loss in plants but lowers the yield of those surviving

The results with mountain brome and violet wheat grass harvested four times, at monthly intervals, the first harvesting approximately one month after the beginning of growth; twice, the first harvesting at seed maturity and the second at the close of the growing season; and once only, at seed maturity, are shown in Table 7 and Figure 12.

The increasing yield of violet wheat grass and the maintenance of the yield of mountain brome when harvested once or twice in the season compares strikingly with the bare maintenance of vigor in the wheat grass, and the excessive loss in the brome, when harvested four times. In contrast to the death of all the mountain brome plants in the first year when harvested five times, as shown in Tables 5 and 6, many of those harvested four times, monthly,

starting one month after the beginning of growth, though much weakened, lived through the three years of treatment.

With most species a system of grazing which would result in removal of the herbage four or five times in a season should by all means be avoided. A grazing practice based on cropping at or a few days before seed maturity and again at the close of the grazing season, however, would not generally be detrimental to the vigor of established plants. It would leave the plants physiologically strong, though it would prevent any seed from reaching maturity unless the grazing was by sheep. If not in too great numbers,

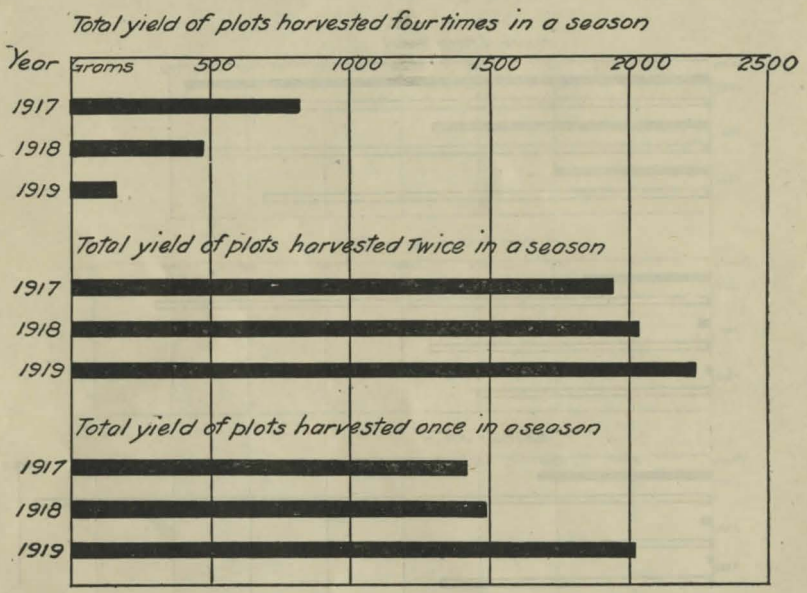

FIG. 12.—Effect of frequency of harvesting on yield

sheep usually graze only a portion of the near-ripe seed crop of the grasses.

TABLE 8.—*Results of early and late harvestings in alternate years*

Plot No.	Plant	Zone[1]	Number of plants[2]			Yield per plant (grams)			Total yield per plot (grams)		
			1920	1921	1922	1920	1921	1922	1920	1921	1922
S–17–24	Letterman needle grass	S–F	8	8	8	1.38	2.56	1.42	11.06	20.49	11.34
B–4	Mountain brome	A–F	23	22	21	8.04	28.79	18.13	185.00	633.40	380.71
G–17–24	Wild geranium	S–F	8	8	7	17.99	20.75	12.40	143.88	166.00	86.80
G–11–15	do	O–B	5	5	5	8.98	3.97	7.34	44.88	19.84	36.68
E–4	Violet wheat grass	A–F	10	10	10	10.37	19.05	19.65	103.69	190.48	196.48
	Total		54	53	51				488.51	1,030.21	712.01

[1] Zones: S–F=Spruce-fir; A–F=Aspen-fir; O–B=Oak-brush.
[2] The number of plants shown in this table represents those living at the beginning of each year's treatment.

TABLE 9.—*Yield and longevity of plants harvested twice, two weeks after, beginning of growth and again at close of growing season, each year*

Plot No.	Plant	Zone[1]	Number of plant[2]			Yield per plant (grams)			Yield per plot (grams)		
			1920	1921	1922	1920	1921	1922	1920	1921	1922
S–9–16	Letterman needle grass	S–F	8	8	8	0.95	1.51	1.44	7.62	12.09	11.50
SL–31–40	do	O–B	10	10	10	5.45	1.97	2.94	54.50	19.67	29.44
B–6	Wild geranium	A–F	15	14	14	.87	5.06	4.56	12.98	70.85	63.89
G–9–16	do	S–F	8	8	7	9.17	7.88	10.55	73.38	63.07	73.85
G–6–10	do	O–B	5	5	5	3.44	2.42	9.83	17.20	12.08	49.16
	Total		46	45	44				165.68	177.76	227.84

[1] Zones: S–F=Spruce-fir; A–F=Aspen-fir; O–B=Oak-brush.
[2] The number of plants shown in this table represents those living at the beginning of each year's treatment.

PLOTS HARVESTED EARLY AND LATE IN SEASON

The results from removing the herbage early one season and late the next are given in Table 8. Plots were harvested two weeks after beginning of growth in 1920 and 1922, and six weeks after beginning of growth in 1921. The aftermath was removed each year at the close of the growing season. The results obtained show that one moderately early grazing in alternate seasons does not impair the vigor of the plants treated.

The results of a somewhat similar method by which the herbage was removed two weeks after growth began and again at the close of the growing season each year are presented in Table 9. Not only was the stand maintained well during the three-year test of this method, but the yield was generally well sustained. Many of the plants increased in the luxuriance of their growth.

A somewhat similar but more drastic method of treatment was used on a plot of mountain brome. The plot was harvested three times a season, the first harvesting being made two weeks after beginning of growth, the second just before seed maturity, and the third at the close of the growing season. The plot contained 53 specimens at the beginning of the experiment in 1920, and 51 of these were living in 1922. The average yield per plant was 51.45, 35.69, and 51.96 grams for 1920, 1921, and 1922, respectively. Although two of the plants were lost, probably caused by rodents and frost upheaval, the yield for 1922 does not indicate any decrease in vigor. On a plot of mountain brome where the second cutting was made five weeks after the first, and in the other plots where the second harvesting was made after longer intervals, somewhat similar results were obtained. The interval between the harvestings was sufficiently long to permit the vegetation to overcome any setback that might have resulted from the one early harvesting. (Pl. III, fig. 2.)

A system of grazing which provides for the cropping of the herbage at the time of vegetational readiness or early in the season will not be detrimental if the forage is not removed too closely and subsequent croppings are not made before the vegetation has had ample time to recover from the first grazing.

FREQUENT CROPPING LATE IN THE SEASON

The results of an experiment to determine the effect of frequent croppings to 1 inch above the ground after seed maturity are shown in Table 10.

The average yields per plant of Nevada blue grass and violet wheat grass were much lower in the second year than in the first, and considerably lower in the third year than in the second. These excessive declines in yield per plant of violet wheat grass in three years, varying from about 49 to about 62 per cent in the different methods, are in striking contrast with the increases in the yield of this plant in three years shown in Table 7, amounting to 176 per cent when harvested at seed maturity and at the close of the growing season, and 159 per cent when they were harvested only at seed maturity.

TABLE 10.—*Results of frequent harvesting after seed maturity*

Plot No.	Plant	Number of plants [1]			Total yield per plot (grams)			Average yield per plant (grams)			Per cent increase or decrease per plant of yield in 1921	
		1921	1922	1923	1921	1922	1923	1921	1922	1923	1922	1923
PLOTS HARVESTED EACH YEAR AT SEED MATURITY, THEN CUT THREE TIMES AT 10-DAY INTERVALS, AND AFTERMATH REMOVED AT END OF SEASON (ONLY FOUR CUTTINGS IN 1923)												
P–1–15	Nevada blue grass	15	15	14	98.34	60.19	34.14	6.556	4.013	2.438	−38.8	−62.8
R–1–15	Violet wheat grass	15	14	13	379.20	157.22	126.51	25.280	11.230	9.732	−55.6	−61.5
Q–1–10	Wild geranium	10	10	10	222.79	237.43	240.59	22.279	23.743	24.059	+6.6	+8.0
PLOTS HARVESTED EACH YEAR AT SEED MATURITY, THEN CUT TWICE AT 15-DAY INTERVALS, AND AFTERMATH REMOVED AT END OF SEASON (ONLY THREE CUTTINGS IN 1923)												
P–16–30	Nevada blue grass	15	15	15	158.71	71.92	51.41	10.581	4.795	3.427	−54.7	−67.6
R–16–30	Violet wheat grass	15	15	15	316.85	219.03	162.34	21.123	14.602	10.823	−30.9	−48.8
PLOTS HARVESTED EACH YEAR AT SEED MATURITY, THEN CUT ONCE 20 DAYS LATER, AND AFTERMATH REMOVED AT END OF SEASON (ONLY TWO CUTTINGS IN 1923)												
P–31–45	Nevada blue grass	15	15	15	204.45	70.54	52.03	13.630	4.703	3.469	−65.5	−74.5
R–31–45	Violet wheat grass	15	15	15	303.88	186.21	115.99	20.259	12.414	7.733	−38.7	−61.8
Q–11–20	Wild geranium	10	10	10	244.81	232.07	259.98	24.481	23.207	25.998	−5.2	+6.2

[1] The number of plants shown in this table represents those living at the beginning of each year's treatment.

In 1922 and 1923 the grasses treated were inclined to be later in reaching seed maturity than were untreated specimens. Most bunch grasses produce considerable growth late in the fall, after seed maturity, which if not removed affords an excellent protection for the crown of the plant. This covering doubtless prevents the untreated plants from being killed back as far as the treated ones, and by protecting plants from unfavorable climatic conditions in the early spring enables them to start growth earlier. The results obtained with geranium indicate that frequency of cropping the late growth of that species has no detrimental effect on the vigor or subsequent yield. In contrast to the results obtained with the grasses there was no very perceptible delay in the growth of treated geranium plants

over those not treated. The aftermath produced by wild geranium is flattened to the ground by snow, withers, and affords hardly any protection to the young shoots in the spring.

The disadvantage in removing the aftermath is that the crown of the plant may be left exposed to the elements, a factor of consequence where the winter temperature is low, the soil freezes deeply, and the wind movement is high. Also, continuous close removal of the late growth is not conducive to the addition of humus to the soil, and by increasing the danger of excessive run-off and erosion it tends to decrease considerably the potential growth capacity of the soil.

TABLE 11.—*Methods used and results obtained in the harvesting of snowberry*

	Plot No.	Number of plants		Yield per plot (grams)		Yield per plant (grams)		Per cent decrease per plant on the basis of yield in 1921
		1921	1922	1921	1922	1921	1922	
Group 1[1]	SY-1-5	5	1	25.12	0.40	5.02	0.40	−92.0
Group 2[2]	SY-6-10	5	5	31.40	15.04	6.28	3.01	−52.1
Group 3[3]	SY-11-15	5	5	31.89	10.54	6.38	2.11	−66.9
Group 4[4]	SY-16-20	5	5	9.35	7.52	1.87	1.50	−19.8

[1] Plants were stripped of their leaves four times at monthly intervals and again at end of season. First stripping made two weeks after beginning of growth.
[2] One-half of the foliage was removed four times at monthly intervals and leafage was removed at end of season.
[3] Stripped once (two weeks after beginning of growth) and again just before dropping of leaves.
[4] Stripped once late in the season just before dropping of leaves.

CROPPING OF BROWSE PLANTS

Four methods were adopted for harvesting the foliage of snowberry (*Symphoricarpos oreophilus*). Vigorous young plants of reasonable uniformity, averaging about 2 feet in height, were selected on a typical range area in the oak-brush type and harvested during the seasons of 1921 and 1922. The methods used and results obtained are shown in Table 11.

The method used in Group 1 was the most severe. Four of the plants were killed by the first year's treatment, and the other died after the first defoliation during the second year. In Group 2, where one-half of the foliage was removed at each harvesting, four of the five plants were fairly vigorous at the end of the second year's treatment. In group 3, three of the five plants were vigorous and one was weak at the end of the second year's treatment. In Group 4, in which the plants were merely cropped according to the deferred grazing plan, the best results were obtained. In actual grazing practice a considerable portion of the leafage of browse vegetation usually remains even on closely utilized lands. Such a common range plant as snowberry, however, is susceptible to much the same physiological reactions as herbaceous vegetation in the matter of pasture use.

MOISTURE CONTENT OF FORAGE AND ITS SIGNIFICANCE

While a certain amount of succulence in range forage is undoubtedly an asset and appears to be associated more or less directly with

the gains made by lamb or calf, it is evident from the condition of animals that subsist entirely on very young herbage that, for the greatest food value, forage must not be "watery." The moisture content of leafage early in the spring—say 10 days or so after growth has started—is found to be higher than that of young leafage which develops later in the season, in some instances being as high as 85 per cent. At the beginning of spring growth in some localities livestock losses have resulted from (1) the green feed being sparse and containing only a small amount of "body" and nutriment, and (2) stock grazing little but the green leafage once they had a fair sample of the new growth.

A 1,000-pound animal that is not subjected to work or exercise in procuring his feed, as one maintained in a stall or corral, requires approximately 16 pounds of air-dry roughage, such as good hay, every 24 hours as a maintenance ration—that is, a ration ample merely to maintain, not to increase, his weight. When the young feed is short, as, for instance, during the first two weeks after growth begins, it is necessary for an animal to travel over a large area to gather the required 80 pounds or so of this succulent leafage or the equivalent of 16 pounds of air-dry hay. Often an animal,

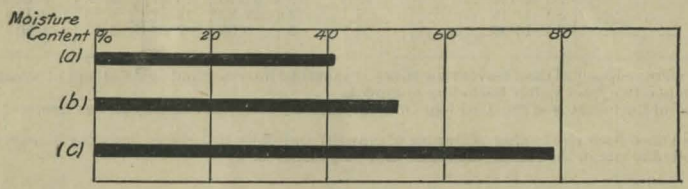

FIG. 13.—Moisture content varies with age of foliage. Average moisture content of herbage of violet wheat grass harvested (*a*) once in a season; (*b*) twice in a season, and (*c*) four times in a season.

especially a cow poorly wintered, can not gather enough of the young growth early in the spring to remain in thrifty, serviceable condition. (Pl. I.) In some cases such an animal can not even gather enough to tide her over the period of recuperation.

The moisture content of the forage of such typical and important species as mountain brome, Letterman needle grass, and violet wheat grass is remarkably uniform for a given season or for a particular stage of plant development. Figure 13 shows the average moisture content of a large number of forage samples of violet wheat grass recorded for three years in succession (1916–1918). The plants were harvested (1) once in a season, at the time of seed maturity; (2) twice in a season, 6 and 10 weeks, respectively, after the beginning of growth; and (3) four times in a season, at monthly intervals, the first cut being made four weeks after the growth had started. It is interesting to note that at the time of seed maturity the moisture content averaged 41 per cent. Plants harvested twice in a season, the first herbage removal being six weeks after growth had started, contained an average proportion of moisture of 54 per cent. In contrast to these data, plants cut four times in a season contained an average of 79 per cent of water.

FIG. 1.—SECTION OF FORAGE NURSERY, GREAT BASIN EXPERIMENT STATION GIVEN OVER TO CROPPING TESTS FOLLOWING THE PRELIMINARY STUDIES

FIG. 2.—CROPPING AT THE TIME OF PROPER FORAGE DEVELOPMENT IS NOT DEVITALIZING TO THE PLANTS UNLESS SUBSEQUENT CROPPINGS ARE MADE BEFORE THE PLANT HAS RECOVERED

The vigorous, well devoloped mountain brome specimens to the left show the results of harvesting twice a year, two weeks after growth begins and again five weeks after the first cropping, for three years. The brome specimens to the right were harvested four times in a season for the same period

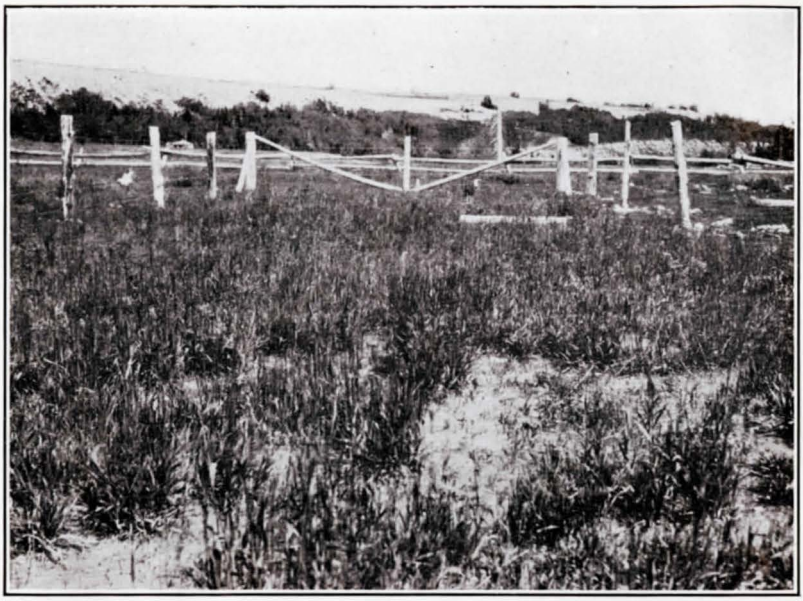

FIG. 1.—TIMOTHY SOWN ON A PLOT IN A DRY MEADOW IN THE SPRUCE-FIR TYPE, AT THE END OF THE FIFTH YEAR OF GROWTH

The stand is beginning to open up and the yield is declining. Manti National Forest, elevation 9,600 feet

FIG. 2.—MOUNTAIN BROME GROWN ON A CAREFULLY PREPARED SEED BED IN THE GRASS NURSERY OF THE GREAT BASIN EXPERIMENT STATION FOR THE PURPOSES OF SEED PRODUCTION

The stand yields at the rate of approximately 1¼ tons of hay to the acre, and the quantity of seed produced is large

COMPARATIVE FOOD VALUE OF FORAGE IN DIFFERENT STAGES OF DEVELOPMENT

Not only does the early forage lack "substance," but its food value is less pound for pound than that of the more mature leafage. Figure 14 shows the relative proportion of chemical constituents in leafage of different development and harvested with varying frequency, according to analyses made by the Bureau of Chemistry. The data given are the averages obtained for two seasons. Only

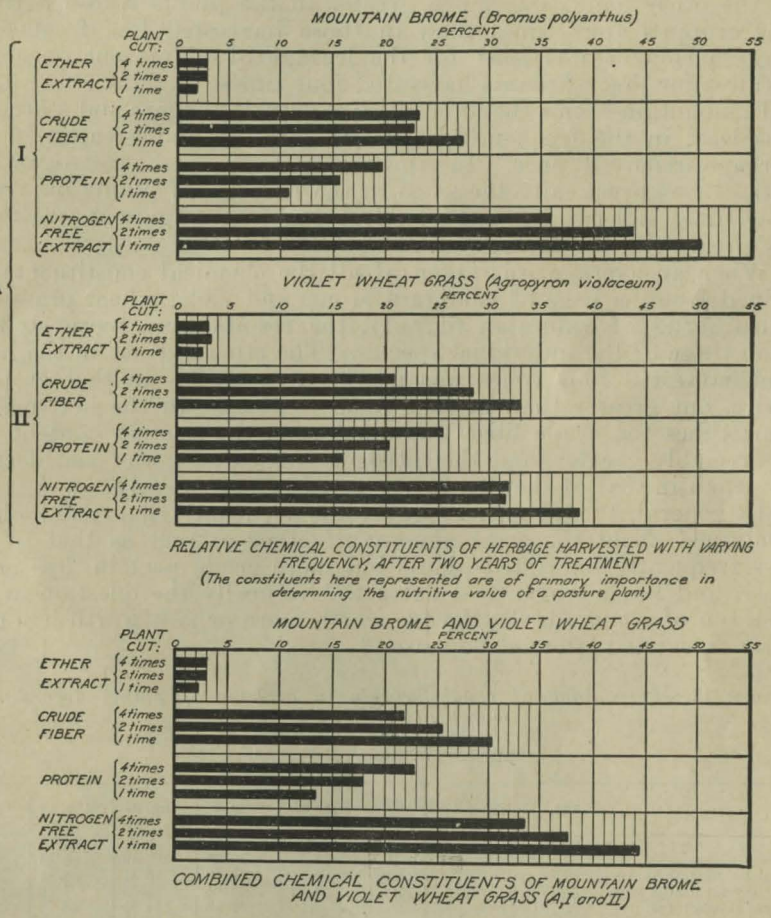

FIG. 14

those constituents are here considered that are recognized as being of primary importance in determining the nutritive value of the pasture plants. Those taken into account are:

Ether extract (oils and fats).
Crude fiber (cellulose—largely indigestible material).
Crude protein (Nitrogenous compounds—muscle and tissue building constituents).
Nitrogen-free extract (carbohydrates—sugars and starches, or heat and energy producing constituents).

It is significant that both violet wheat grass and mountain brome when cut four times in a season generally contained as much ether extract (oil and fat) as when harvested less frequently. The crude fiber in the herbage of violet wheat grass cropped four times in a season was appreciably less than in that of plants harvested less frequently; in mountain brome the herbage removed four times contained considerably less crude fiber than that harvested once, but slightly more than that cropped twice. The protein content, on the other hand, was much greater in the plants whose herbage was cropped four times than in those harvested less frequently. Protein content was least for the leafage of plants cut once and greatest for that of plants harvested four times.

In mountain brome the nitrogen-free extract (sugars and starches) was least in the frequently harvested samples and greatest in the herbage removed once. In violet wheat grass the nitrogen-free extract was practically the same in the herbage of plants harvested four times and two times, respectively, and here again it was much the greatest in the herbage cropped once.

When an average was taken of all the chemical constituents obtained from herbage of mountain brome and violet wheat grass (see third series of values in fig. 14), the results were more striking than those of the individual species. The ether extract in the herbage harvested four times was nearly the same as in that cropped twice, but greater than in that removed once. In the herbage cut four times the crude fiber was much less, the protein content was appreciably greater, and the nitrogen-free extract was considerably less than in that of the plants harvested less frequently.

In general, then, the herbage of the frequently harvested plants contained about the same amount of ether extract as that of the less frequently harvested plants but more crude protein, less crude fiber, and less nitrogen-free extract. Naturally the question arises, Is a ton of young air-dry forage worth more or is it worth less than a ton harvested later in the season?

TABLE 12.—*Percentage of crude protein in herbage of plants according to march of the season, 1921*

[Analyses by Bureau of Chemistry]

Plant	June 24	Aug. 9	Aug. 29	Sept. 18	Oct. 7
Nevada blue grass	18.31	10.25	7.19	5.33	4.29
Violet wheat grass	26.81	10.60	10.31	6.81	4.03
Letterman needle grass	28.94	13.00	11.32	7.10	5.61
False cymopterus		18.19	14.31	10.78	5.61
Yarrow		13.81	14.19	13.90	8.04
Average	24.69	13.17	11.45	8.78	5.52

During the past quarter century investigators have clarified many factors pertaining to the science of animal nutrition, yet our present knowledge of this profoundly important subject is far from satisfactory. The price of cottonseed cake, for instance, may be determined largely upon the constituents of the chemical groups already enumerated. As an emergency feed cottonseed cake is most valuable because it is rich in nitrogenous materials. Not long ago it was

assumed that protein was assimilated, regardless of the character and action of the digestive ferments; now it is known that protein to be assimilated by the animal must first be converted by the various ferments into amino acids, of which not less than 18 different kinds have been recognized as occurring in varying proportion in the proteins of the different forage crops. Any protein compounds assimilated but not utilized, or those taken into the digestive tract in excess of the supply needed to build muscle and to maintain the animal's "machinery" generally, are eliminated either in the form of urea or uric acid or in the feces. A deficiency in the protein content results in the development of an inferior, undersized animal.

The forage of very young plants, besides being generally more palatable, has an appreciably higher protein content than that of older plants, as is shown in Table 12. On June 24, when the first of the samples analyzed for protein content were taken in the spruce-fir type at an elevation of 10,000 feet, the forage growth was not more than about five days old. The October 7 samples were taken after a frost and the close of the grazing season. The protein content is remarkably large in the early stages of growth and in these tests declines in amount as the season advances.

The amount of protein in the young leafage that is digestible, however, may be comparatively low. The greater proportion of nitrogenous substances contained in young herbage may not be transformed by the digestive ferments into amino acids, but exists in the amido stage, in which form it is assimilated probably only in part. In the nutrition of the animal the chemical composition of the forage consumed is much less important than the proportion which the animal can digest (*2*). Even if the food value of young pasturage were equal to that of the older growth, the advantages are clear in permitting the vegetation to reach a reasonable developmental stage before it is cropped, for then a much larger quantity of digestible nutrients is produced.

ROOT DEVELOPMENT AND STORAGE OF PLANT FOOD

Any condition that stunts aerial growth or otherwise interferes with the normal physiological processes of range plants is likely also to restrict development of the underground organs and thereby curtail the storage of plant food essential to growth later on. The results of this phase of the study appear to be quite uniform among bunch grasses and other herbs whose reproduction is not accomplished asexually, as by rootstocks. The outstanding facts procured are well shown in violet wheat grass (fig. 15). The effects at the end of the first year of treatment by removing the herbage once in a season (at the time of seed maturity), twice in a season (6 weeks and 10 weeks, respectively, after growth had started), and four times in a season (at monthly intervals, the first harvesting being made 2 weeks after growth had started) are shown in the plants labeled 1, 2, and 3, respectively. The plants labeled 1–A, 2–A, and 3–A represent the root development of plants whose herbage was harvested one, two, and four times, respectively, as above stated, for three successive seasons.

Considering first the root development of plants treated for a single season, it is noteworthy that the underground growth is

practically identical where the leafage was removed once (plant 1) and where it was harvested twice (plant 2) in a season. Plant 3, on the other hand (representing the removal of the herbage four times in a season), shows a comparatively poorly developed root system after a single season's treatment. The same general results are seen in Nos. 1–A, 2–A, and 3–A, representing plants treated for three seasons. Numbers 1–A and 2–A show practically the same luxuriant root development, whereas No. 3–A shows a weak root

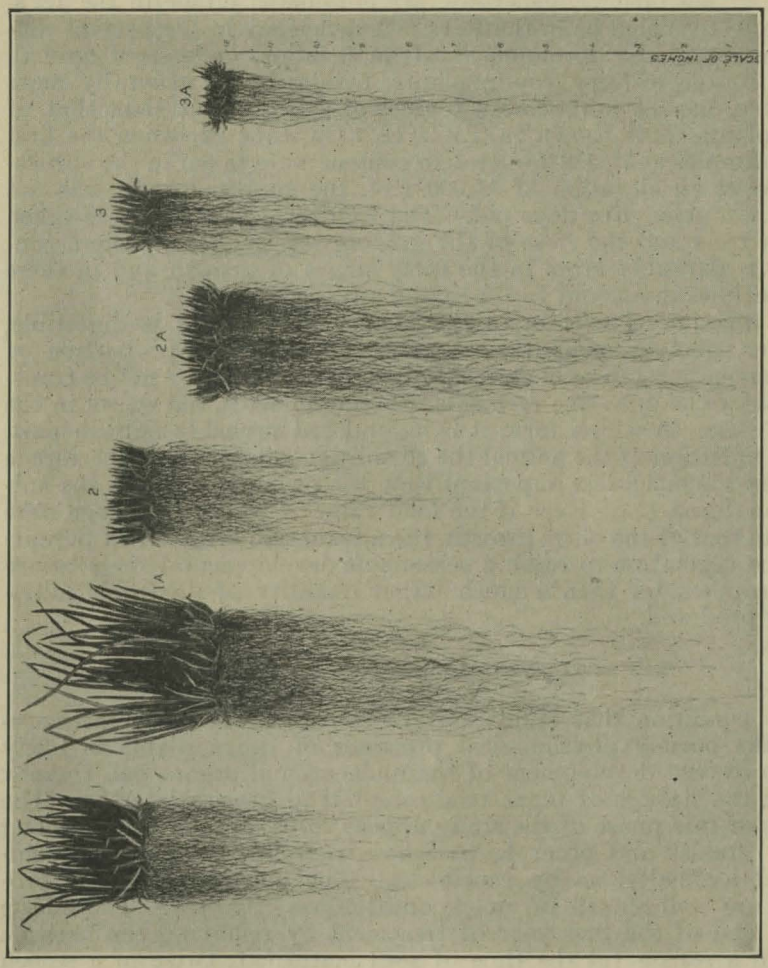

FIG. 15.—AVERAGE ROOT DEVELOPMENT OF VIOLET WHEAT-GRASS PLANTS WHOSE HERBAGE WAS HARVESTED WITH VARYING FREQUENCY

Plants labeled 1, 2, and 3 were harvested one, two, and four times for one season. Plants labeled 1–A, 2–A, and 3–A were harvested one, two, and four times for three seasons.

system which is capable of absorbing only a relatively small quantity of water and soluble salts and of storing little plant food.

By assigning a value based as nearly as possible upon the calories of the essential constituents of the roots, chemical index data are derived which appear to show the relative quantity of food materials in the roots of average plants variously treated (fig. 16). In mountain brome, the plants whose leafage was harvested four times in a season for three successive years show an index figure of less

than 100; where the herbage was removed twice the index figure is more than 250, and where the herbage was cropped once it is more than 300. In violet wheat grass an even more remarkable contrast obtains. These figures represent somewhat closely the relative quantity of forage which the plants may produce in the following season.

APPLICATION OF RESULTS IN RANGE MANAGEMENT

These results clearly indicate the necessity of so adjusting the number and distribution of livestock that the important forage plants will not be kept so closely grazed throughout the season as to be unable to make the necessary growth to maintain their vigor. On the other hand, they show that two or, in some types, three moderately close croppings in a season, provided the first is late enough and the interval between each two is sufficient for the vegetation quite to recover from each, ordinarily do not seriously affect the yield and vigor of the forage plants. Frequent close cropping of the herbage following seed maturity may cause excessive declines in yield and later maturity in succeeding years. These results indicate

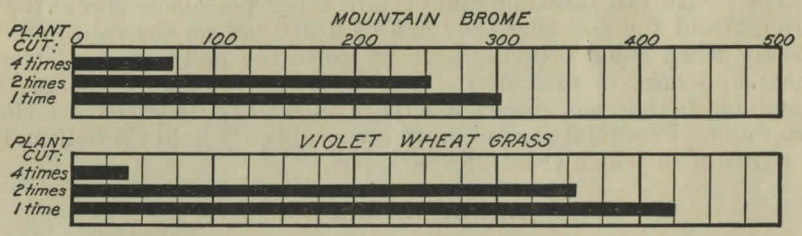

FIG. 16.—Relative index of chemical constituents of roots of an average plant representative of vegetation whose herbage was cut three successive years with varying frequency. (Average plants collected at end of growing season, 1919)

that the forage on range set aside for spring and fall use may be grazed closely at the time of vegetative readiness in the spring, and again in the fall without injury. If the important forage plants on a range become closely grazed before the end of the growing season, however, the livestock must be removed from that range until the forage plants recover their vigor in order to prevent injury. If the livestock remain on the range after it has become closely grazed, the growth is insufficient to prevent too frequent cropping or to furnish herbage of good food value.

Sheep may graze over a range two or, on types that support hardy plants, even three times during a three-months' late summer season without injuring the forage plants, provided the grazing at each time is not too close. If the range is so stocked that it must be grazed four or more times, however, injury to the forage plants is sure to occur. It is not possible to handle cattle on open ranges so as to graze the same range closely and then allow a rest several times during a summer season, as may be done with sheep under herd. On cattle ranges grazed season long, the number should be adjusted to give close, though not excessive, utilization by the end of the grazing season.

WHY GRASSES ARE SUPERIOR AS FORAGE PLANTS

Grasses generally constitute forage of the first quality on range and pasture. The particular habit of growth of grass herbage, its high nutritive value for all classes of foraging animals, its comparative permanence and slight variation in yield from year to year, make it more desirable for pasture purposes than any other great class of plants.

The active growing region of the grass blade is at the base; hence the production of herbage is not checked by grazing, provided the plant is physiologically strong. The growth of the leafage of such plants as geranium, mertensia, and snowberry, on the other hand, is uniform throughout the entire leaf, and therefore the total consumption of their leafage by grazing practically arrests further development of the leaves eaten. Perennial grasses as a whole are found to hold the climax place successionally in herbaceous vegetation, so that the grass type is much more stable than is that of other herbs. Therefore, if appreciable and permanent improvement in the grazing capacity of the range is to be obtained, it must come in large measure through the grasses.

Tests with tall larkspur and certain other poisonous species have brought out the fact that they can be killed out on the range if cut closely when about 6 inches high, twice in the first season of treatment and once in each of the two following years. Some of the palatable herbaceous species are quite as readily destroyed by close cropping. Perennial grasses, however, ordinarily hold up well under the treatment which eradicates larkspur.

RANGE RESEEDING

Occasionally a long-used grazing area supports little vegetation of value to livestock. On the steeper, poorly vegetated hillsides erosion may be leaching out and transporting to lower levels the soluble salts and organic acids essential to the establishment of an effective plant cover. Moreover, because of the small quantity of humus on the range, the soil packs heavily, especially if animals are admitted during wet weather, which decreases still more the water-holding capacity of the soil and the ability of the range to revegetate.

A large proportion of the depleted mountain meadows and well-drained parks at high elevations, where the plant cover has declined in recent years, have fertile soils capable of supporting a good stand of vegetation and usually have sufficient soil moisture. The possibility of successful reseeding to valuable cultivated and native species is considerably greater for such areas than for the drier lands lying at lower elevations (Pl. IV). Attempts to reseed artificially the plains and the drier foothills to cultivated forage plants have given results of no practical value. In view of the none too promising results obtained from the artificial reseeding of range lands, coupled with the high cost, any far-sighted stockman will take the necessary precautions to keep his range in good, vigorous productive condition, and certainly will not allow it to deteriorate beyond a stage where it can readily be brought back by natural revegetation.

NATURAL REVEGETATION

Cropping a pasture each year to the maximum of its forage production is sure, sooner or later, to cause a sharp decline in its grazing capacity. The most successful stockmen are now grazing their ranges on the basis of the quantity of forage produced in the average year rather than on the maximum yield in the best years. This plan, in view of the yearly fluctuation in forage production, nearly everywhere in the West, is insurance second to none against financial loss.

Improvement in the grazing capacity of native pasture lands, the forage of which is composed largely of bunch grasses, is dependent, periodically at least, upon a good production of fertile seed. To insure seed production of the more palatable forage plants requires avoidance of overgrazing, prevention of too early grazing, and effective control and distribution of livestock.

OPERATION OF DEFERRED AND ROTATION GRAZING

The "deferred and rotation grazing plan" has been adopted widely on national forest ranges in order to obtain the greatest possible use of the forage and at the same time keep the lands in a high state of productivity. The plan is based upon the growth requirements of range vegetation, coupled with methods of handling livestock to foster seed production, provide for the planting of the seed crop, and furnish forage for the stock during the revegetational period. Briefly, the plan is to reserve some portion of the range for cropping after the seed has ripened. The following year, in order to avoid the destruction of the seedlings which originated from the seed of the first year's crop, and to provide for additional seed where needed, the same area is usually reserved a second time. If after two years of such deferred grazing the forage plants have become vigorous and an ample number of seedling plants have become established, a second area in need of seeding is selected and the tract upon which grazing was originally deferred is cropped before seed maturity. This plan of deferring the grazing on one depleted area and then on another is continued until the entire range has been revegetated. After that, grazing after seed maturity is alternated or rotated from one portion of the range to another in order to allow an occasional seed crop of the better forage plants to develop and replace the decadent vegetation. This continuous rotation in the grazing plan has the big advantage over yearlong rest or of a heavy reduction in the stock during the period required for revegetation that it interferes not at all with the production of beef or mutton. (*3*, *5*, *6*.)

Deferred grazing has been attempted without adjustment in the number of stock on overstocked ranges where improvement in the plant cover was badly needed. Because of the overstocking it was necessary to crop the forage on the unreserved parts three or more times before seed maturity. These attempts have shown clearly that the deferred grazing plan can be applied successfully only if the number of livestock corresponds with the actual grazing capacity of the range; otherwise the parts grazed before seed maturity

will be so seriously overgrazed as to offset the benefit to the reserved area.

Deferred grazing has been applied on national-forest range in the West so widely and for so many years that the good results to both stock and range are indisputable. Improvement is invariably rapid where there remains a fair stand of seed plants. Naturally, considerable time is required to increase appreciably the forage cover on lands which for many years have been in a low state of productivity, and especially on those which support few highly palatable seed plants. Without the adoption of some grazing plan, however, such as deferring the cropping until the seed of the more desirable palatable vegetation has matured, or decreasing materially the number of livestock formerly grazed, or actually removing the animals for a year or more, there is little chance of increasing the range returns from badly depleted lands, of controlling erosion, or of improving the efficiency of important watersheds in one way or another. Any kind of plant cover is preferable to denudation or to the production of a growth so sparse that the fertility of the soil tends to decline rather than improve.

SOIL FERTILITY AND FORAGE TYPE

It is well known that different species or types or vegetation vary considerably in the quantity of water they require and in the type of soil necessary for their development (*7*). The earlier stages of plant cover, such as are found on semidecomposed soil, poor in organic matter and comparatively low in available moisture, consist of shallow-rooted early-maturing annual species. Although widely spaced at first, these plants gradually increase in density until practically all of the available soil moisture is used up by the vegetation. When this annual plant growth reaches maturity and dries up, a large proportion of the soil surface is exposed. (Pl. V, fig. 1.) Small protection is thus given the soil by annual vegetation as compared with that given by perennials. Not only does the range which supports annuals ordinarily furnish only a small quantity of rather inferior forage, and practically none unless cropped when the leafage is succulent, but it must be grazed lightly and with more than usual care. Where deferred grazing is applied for several years in succession, however, even lands on which annuals predominate show improvement in the plant cover. Eventually the vegetation changes to a more permanent or stable type, and the quantity of palatable herbage is correspondingly increased (*8, pp. 1–7*).

RESEEDING TESTS ON PROTECTED AND DEFERRED GRAZED PLOTS

In order to determine the time required to revegetate lands in different degrees of depletion, both protected and unprotected experimental plots varying in size from a few square feet to several acres were established in each of the major zones and forage types and on different slopes and exposures. The density and composition of the vegetation on these plots were carefully recorded, the quadrat plan of mapping being used with adaptations. On the larger plots the plant associations which made up the cover were merely outlined and the species and the density of each recorded.

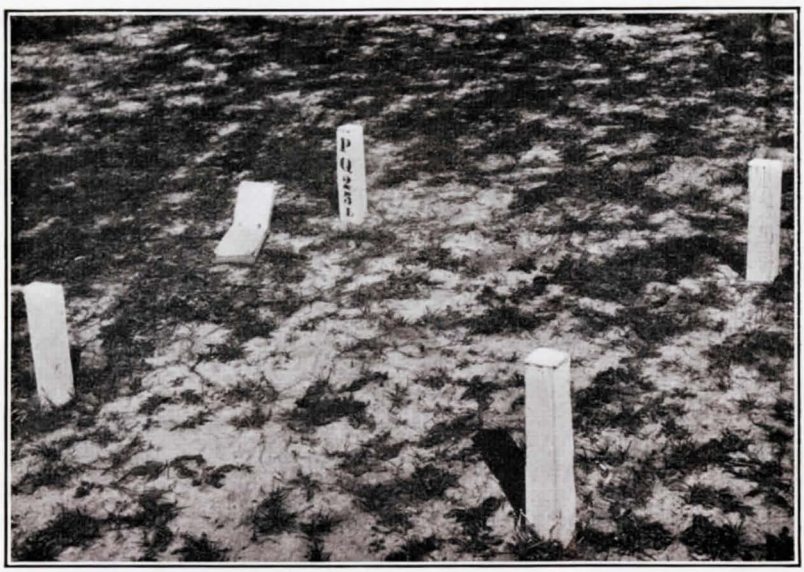

FIG. 1.—AFTER THE ADVENT OF KILLING FROSTS ONLY THE INVADING GRASSES ARE IN EVIDENCE

Small plot or quadrat located on a depleted area revegetating to grass in the spruce-fir type

FIG. 2.—SPARSE, INFERIOR PLANT COVER AFTER THE RANGE HAS IMPROVED SLIGHTLY. JUST OUTSIDE PROTECTED PLOT NO. 2 LOCATED ON PHILADELPHIA FLAT

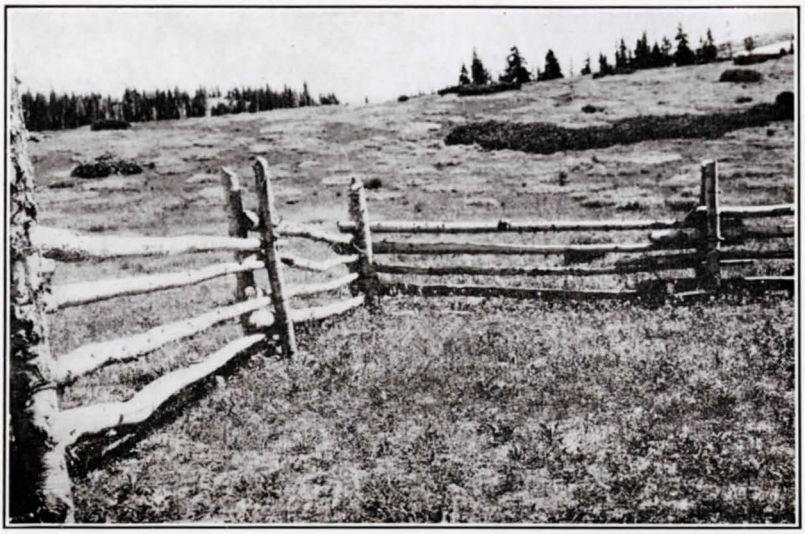

FIG. 1.—PLOT NO. 3, LOCATED AT THE HEAD OF SEELEY CANYON, SHOWING THE WEEDY COVER AFTER THREE YEARS OF PROTECTION AGAINST GRAZING

FIG. 2.—VIEW OF RANGE AND ADJOINING PLOT NO. 3 WHERE DEFERRED GRAZING HAS BEEN PRACTICED

The density and composition of the cover is practically the same as that inside the three-year protected plot

Some of the plots were remapped yearly, others every few years, with a view of noting the changes in the vegetation.

The data have been grouped to show for the first and last mappings (1) the number and names of species, (2) the density of the cover, (3) the average palatability of the cover, and (4) the comparative quantity of the forage.

The true comparative quantity of the forage is expressed by the forage factor, which may be defined as the numerical value, or index figure, obtained by multiplying the density of the cover (expressed in tenths or percentage of a complete cover) by the average palatability (expressed in percentage) of the type concerned. In other words, it is that figure which when multiplied by the surface or gross acres of a type gives the forage acres which the type contains.[10]

In order to apply the forage factor to the plot study it was first necessary to record the palatability of each species that occurred on the selected areas. This was done by careful observation of the actual quantity of each species which was utilized by cattle and sheep on various range types and at different times of the season with a view of determining the average quantity taken by each class when the range as a whole was properly used. The percentages of palatability of the species as given in Table 13 are believed to be reasonable averages for the locality, types, and conditions concerned.

The following compilations aim to show the comparative rate of revegetation and forage increment on plots protected yearlong as compared with those grazed in general according to the deferred plan. Ordinarily the latter plots were grazed more closely than was desirable, and they were not always deferred as late as was advisable. The grazed plots were so selected as to represent, as closely as possible, average conditions on the range adjacent to the inclosed plots.

The most impressive changes are the remarkable increase in number of species, density, and comparative value on all of the plots, regardless of whether they were protected yearlong or grazed.

By reference to Tables 14, 15, and 16, giving conditions in Bear Creek Canyon, it will be noted that in 1921 the density and forage factor of the grazed plot were approximately equal to those of the protected plots. These plots were on an area extremely depleted in 1916, with inferior soil, infertile, and of poor tilth. Nearly all the invading species, therefore, were annuals or short-lived perennials.

The Horseshoe Flat plots, recorded in Tables 17 and 18, are located on range which was less depleted than the Bear Creek Canyon area in 1915 and supported at that time a small number of species, but several valuable grasses fairly high in the successional development. Spiked trisetum, Letterman needle grass, and violet wheat grass were fairly well represented. By 1921 these species had increased appreciably on both the protected and grazed plots, and by far the greater proportion of the vegetation consisted of perennial plants.

[10] A forage acre is represented by a surface acre supporting a complete ground cover of vegetation (10/10 density) within reach of livestock and which is entirely (100 per cent) palatable to livestock.

Tables 19 and 20 represent the vegetation on plots protected and grazed on Philadelphia Flat, where, because of the badly depleted condition and the heavy packing of the soil brought about by many years of excessively close and early cropping, the vegetation was low in its ecological development. (Pl. V, fig. 2.) In 1915 the protected plot contained only one species of grass, and by 1921 no other grass species had come in. The density and forage value of the protected and grazed plots were practically identical by 1921.

Table 21, giving the plant record of protected plot No. 3, located in Seeley Creek (Pl. VI), shows a slower recovery than the other plots. Because of the serious overgrazing that prevailed for many years on the lands which the plot typifies, vegetation was of a transitory type and consisted largely of annuals and short-lived perennials. At the stage of plant development reached in 1921 the area was in a receptive condition for the invasion of desirable long-lived perennial grasses, which, because of their higher palatability, would increase markedly the grazing capacity of the lands.

By referring to the average palatabilities and forage factors on the plots, it will be noted that range in such a serious degree of depletion is generally more valuable for sheep than for cattle. This is largely because the "weeds," which are more readily grazed by sheep, are most abundant.

TABLE 13.—*Palatability list of plants that occur on the natural reseeding plots, Manti National Forest*

Scientific name	Per cent palatable for cattle	Per cent palatable for sheep	Scientific name	Per cent palatable for cattle	Per cent palatable for sheep
Grasses and grasslike plants:			Weeds—Continued.		
Agropyron dasystachyum	85	70	Gayophytum ramosissimum	10	30
Agropyron violaceum	95	85	Gentiana sp	0	0
Bromus inermis	95	95	Geranium viscosissimum	40	70
Bromus polyanthus	95	85	Lactuca sp	50	70
Bromus tectorum (early summer)	60	40	Lathyrus leucanthus	30	60
Carex sp	70	50	Leontodon taraxacum	70	90
Hordeum nodosum	40	25	Lepidium ramosissimum	0	10
Juncus sp	70	50	Lesquerella kingii	0	0
Melica spectabilis	75	60	Ligusticum sp	80	95
Phleum alpinum	95	60	Monolepis nuttalliana	60	80
Phleum pratense	75	90	Orthocarpus luteus	0	0
Poa reflexa	90	80	Oxyria digyna	0	20
Stipa lettermani	80	65	Pachylophus caespitosus	20	60
Trisetum spicatum	80	65	Pentstemon rydbergii	20	50
Weeds:			Plantago tweedyi	0	10
Achillea lanulosa	50	90	Polemonium molle	10	40
Agoseris pumila	80	95	Polygonum aviculare	15	60
Alsine jamesiana	30	60	Polygonum douglasii	15	60
Androsace puberulenta	0	10	Potentilla sp	0	20
Aplopappus clementis	10	20	Potentilla nuttallii	0	20
Artemisia sp	10	40	Pseudocymopterus tidestromii	10	30
Aster frondeus	10	30	Ranunculus inamoenus	10	30
Chaenactis sp	0	0	Rumex mexicanus	10	40
Chenopodium album	25	80	Sophia incisa	10	40
Collomia linearis	0	20	Thalictrum occidentale	0	40
Delphinium menziesii	0	10	Vagnera stellata	10	30
Draba sp	0	0	Vicia americana	90	90
Erigeron ursinus	0	0	Viguiera multiflora	20	50
Erythronium parviflorum	0	20	Viola linguaefolia	15	50

TABLE 14.—*Vegetative record of protected plot No. 5 in Bear Creek Canyon, 1916 and 1921*

Species recorded, 1916:
- Sedge (*Carex* sp.).
- Yarrow (*Achillea lanulosa*).

Species recorded, 1921:
- Androsace (*Androsace puberulenta*).
- Bladderpod (*Lesquerella kingii*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).
- False cymopterus (*Pseudocymopterus tidestromii*).
- Common brome (*Bromus inermis*) (planted).
- Knotweed (*Polygonum aviculare*).
- Lamb's-quarters (*Chenopodium album*).

Species recorded, 1921—Continued.
- Meadow barley (*Hordeum nodosum*).
- Onion grass (*Melica spectabilis*).
- Pachylophus (*Pachylophus caespitosus*).
- Peppergrass (*Lepidium ramosissimum*).
- Potentilla (*Potentilla* sp.).
- Sedge (*Carex* sp.).
- Letterman needle grass (*Stipa lettermani*).
- Timothy (*Phleum pratense*) (planted).
- Tongue-leaf violet (*Viola linguaefolia*).
- Violet wheat grass (*Agropyron violaceum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY OF CHANGES IN VEGETATION AND FORAGE VALUE OF COVER

	1916	1921	Per cent increase or decrease (—) from 1916 to 1921
Number of species	2	19	850
Density	.017	.140	723.5
Palatability percentage:			
Cattle	60	46.328	—22.79
Sheep	90	72.407	—19.55
Forage factor:			
Cattle	.01	.065	550
Sheep	.015	.102	580

TABLE 15.—*Vegetative Record of Protected Plot No. 4 in Bear Creek Canyon, 1916 and 1921*

Species recorded, 1916:
- Dandelion (*Leontodon taraxacum*).
- Violet wheat grass (*Agropyron violaceum*).
- Yarrow (*Achillea lanulosa*).

Species recorded, 1921:
- Androsace (*Androsace puberulenta*).
- Aster (*Aster frondeus*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).
- Downy brome (*Bromus tectorum*).
- False cymopterus (*Pseudocymopterus tidestromii*).

Species recorded, 1921—Continued.
- False yarrow (*Chaenactis* sp.).
- Knotweed (*Polygonum aviculare*).
- Lamb's-quarters (*Chenopodium album*).
- Mountain sorrel (*Oxyria digyna*).
- Pachylophus (*Pachylophus caespitosus*).
- Peppergrass (*Lepidium ramosissimum*).
- Tansy mustard (*Sophia incisa*).
- Violet wheat grass (*Agropyron violaceum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY OF CHANGES IN VEGETATION AND IN FORAGE VALUE OF COVER

	1916	1921	Per cent increase or decrease (—) from 1916 to 1921
Number of species	3	15	400
Density	.01	.13	1,200
Palatability percentage:			
Cattle	60	26.54	—55.8
Sheep	90	49.42	—45.1
Forage factor:			
Cattle	.006	.035	483.3
Sheep	.009	.064	611.1

TABLE 16.—*Vegetative record of grazed plot No. 13 in Bear Creek Canyon, 1921*

Species recorded:
- American vetch (*Vicia americana*).
- Androsace (*Androsace puberulenta*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).
- False cymopterus (*Pseudocymopterus tidestromii*).
- Knotweed (*Polygonum aviculare*).
- Lamb's-quarter (*Chenopodium album*).
- Lettuce (*Lactuca scariola*).
- Meadow barley (*Hordeum nodosum*).
- Mexican dock (*Rumex mexicanus*).
- Monolepis (*Monolepis nuttalliana*).
- Pachylophus (*Pachylophus caespitosus*).
- Peppergrass (*Lepidium ramosissimum*).
- Potentilla (*Potentilla* sp.).
- Small wheat grass (*Agropyron dasystachyum*).
- Tansy mustard (*Sophia incisa*).
- Violet wheat grass (*Agropyron violaceum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY RECORD OF PLANT COVER AND ITS FORAGE VALUE

Number of species	18
Density	.158
Palatability percentage:	
Cattle	40.035
Sheep	80.150
Forage factors:	
Cattle	.063
Sheep	.127

TABLE 17.—*Vegetative record of protected plot No. 1 on Horseshoe Flat, 1915 and 1921*

Species recorded, 1915:
- Beardtongue (*Pentstemon rydbergii*).
- Dandelion (*Leontodon taraxacum*).
- Letterman needle grass (*Stipa lettermani*).
- Meadow rue (*Thalictrum occidentale*).
- Mountain brome (*Bromus polyanthus*).
- Spiked trisetum (*Trisetum spicatum*).
- Sweet sagebrush (*Artemisia* sp.).
- Violet wheat grass (*Agropyron violaceum*).
- Yarrow (*Achillea lanulosa*).

Species recorded, 1921:
- Aster (*Aster frondeus*).
- Beardtongue (*Pentstemon rydbergii*).
- Buttercup (*Ranunculus inamoenus*).
- Chickweed (*Alsine jamesiana*).
- Collomia (*Collomia linearis*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).
- False Solomon's seal (*Vagnera stellata*).
- Gentian (*Gentiana* sp.).
- Lamb's-quarters (*Chenopodium album*).
- Letterman needle grass (*Stipa lettermani*).
- Low larkspur (*Delphinium menziesii*).
- Meadow barley (*Hordeum nodosum*).
- Meadow rue (*Thalictrum occidentale*).
- Mountain brome (*Bromus polyanthus*).
- Mountain dandelion (*Agoscris pumila*).
- Nodding blue grass (*Poa reflexa*).
- Onion grass (*Melica spectabilis*).
- Orthocarpus (*Orthocarpus luteus*).
- Pea vine (*Lathyrus leucanthus*).
- Plantain (*Plantago tweedyi*).
- Potentilla (*Potentilla nuttallii*).
- Rush (*Juncus* sp.).
- Skunk weed (*Polemonium molle*).
- Spiked trisetum (*Trisetum spicatum*).
- Tansy mustard (*Sophia incisa*).
- Sweet sagebrush (*Artemisia* sp.).
- Tongue-leaf violet (*Viola linguæfolia*).
- Viguiera (*Viguiera multiflora*).
- Violet wheat grass (*Agropyron violaceum*).
- Wild geranium (*Geranium viscosissimum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY RECORD OF PLANT COVER AND ITS FORAGE VALUE

	1915	1921	Per cent increase of 1921 over 1915
Number of species	9	0.32	255.55
Density	----------	[1].45	----------
Palatability percentage:			
Cattle	----------	37.733	----------
Sheep	----------	60.040	----------
Forage factor:			
Cattle	----------	.1698	----------
Sheep	----------	.2702	----------

[1] The density in 1915 was so recorded as not to be comparable with that noted in 1921, and hence direct comparisons in the matter of the forage factor can not be made.

TABLE 18.—*Vegetative record of grazed plot No. 14 on Horseshoe Flat, 1921*

Species recorded:
- Androsace (*Androsace puberculenta*).
- Aplopappus (*Aplopappus clementis*).
- Aster (*Aster frondeus*).
- Beardtongue (*Pentstemon rydbergii*).
- Buttercup (*Ranunculus inamoenus*).
- Chickweed (*Alsine jamesiana*).
- Collomia (*Collomia linearis*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).
- Erigeron (*Erigeron ursinus*).
- Gayophytum (*Gayophytum ramosissimum*).
- Lamb's-quarters (*Chenopodium album*).
- Letterman needle grass (*Stipa lettermani*)
- Low larkspur (*Delphinium menziesii*).
- Meadow barley (*Hordeum nodosum*).
- Meadow rue (*Thalictrum occidentale*).
- Mountain brome (*Bromus polyanthus*).

Species recorded—Continued
- Mountain dandelion (*Agoseris pumila*).
- Nodding blue grass (*Poa reflexa*).
- Onion grass (*Melica spectabilis*).
- Orthocarpus (*Orthocarpus luteus*).
- Pachylophus (*Pachylophus caespitosus*).
- Pea vine (*Lathyrus leucanthus*).
- Plantain (*Plantago tweedyi*).
- Potentilla (*Potentilla nuttallii*).
- Spiked trisetum (*Trisetum spicatum*).
- Sweet sagebrush (*Artemisia* sp.).
- Tansy mustard (*Sophia incisa*).
- Tongue-leaf violet (*Viola linguaefolia*).
- Trout lily (*Erythronium parviflorum*).
- Viguiera (*Viguiera multiflora*).
- Violet wheat grass (*Agropyron violaceum*).
- Wild geranium (*Geranium viscosissimum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY RECORD OF PLANT COVER AND ITS FORAGE VALUE

Number of species	34
Density	.40
Palatability percentage:	
Cattle	29.187
Sheep	53.903
Forage factor:	
Cattle	117
Sheep	.216

TABLE 19.—*Vegetative record of protected plot No. 2 on Philadelphia Flat, 1915 and 1921*

Species recorded, 1915:
- Beardtongue (*Pentstemon rydbergii*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).
- Letterman needle grass (*Stipa lettermani*).
- Tansy mustard (*Sophia incisa*).
- Yarrow (*Achillea lanulosa*).

Species recorded, 1921:
- American vetch (*Vicia americana*).
- Androsace (*Androsace puberulenta*).
- Aster (*Aster frondeus*).
- Beardtongue (*Pentstemon rydbergii*).
- Buttercup (*Ranunculus inamoenus*).
- Chickweed (*Alsine jamesiana*).
- Collomia (*Collomia linearis*).
- Dandelion (*Leontodon taraxacum*).
- Douglas knotweed (*Polygonum douglasii*).

Species recorded, 1921—Continued.
- False cymopterus (*Pseudocymopterus tidestromii*).
- Lamb's-quarters (*Chenopodium album*)
- Letterman needle grass (*Stipa lettermani*).
- Ligusticum (*Ligusticum filicinum*).
- Low larkspur (*Delphinium menziesii*).
- Mountain dandelion (*Agoseris pumila*).
- Nodding blue grass (*Poa reflexa*).
- Pachylophus (*Pachylophus caespitosus*).
- Peppergrass (*Lepidium ramosissimum*).
- Plantain (*Plantago tweedyi*).
- Potentilla (*Potentilla* sp.).
- Tansy mustard (*Sophia incisa*).
- Tongue-leaf violet (*Viola linguaefolia*).
- Wild geranium (*Geranium viscosissimum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY OF CHANGES IN VEGETATION AND FORAGE VALUE OF COVER

	1915	1921	Per cent increase or decrease (−) from 1915 to 1921
Number of species	6	24	300
Density	.122	.289	136.9
Palatability percentage:			
Cattle	38.07	37.58	−1.29
Sheep	74.31	76.26	2.62
Forage factor:			
Cattle	.046	.109	137
Sheep	.091	.220	141.8

TABLE 20.—*Vegetative record of grazed plot No. 15 on Philadelphia Flat, 1921*

Species recorded:
- American vetch (*Vicia americana*).
- Androsace (*Androsace puberulenta*).
- Aster (*Aster frondeus*).
- Beardtongue (*Pentstemon rydbergii*).
- Buttercup (*Ranunculus inamoenus*).
- Chickweed (*Alsine jamesiana*).
- Dandelion (*Leontodon taraxacum*).
- Draba (*Draba crassifolia*).
- Knotweed (*Polygonum aviculare*).
- Lamb's-quarters (*Chenopodium album*).
- Letterman needle grass (*Stipa lettermani*).
- Ligusticum (*Ligusticum filicinum*).
- Meadow rue (*Thalictrum fendleri*).

Species recorded—Continued.
- Mountain dandelion (*Agoseris pumila*).
- Pachylophus (*Pachylophus caespitosus*).
- Peppergrass (*Lepidium ramosissimum*).
- Plantain (*Plantago tweedyi*).
- Potentilla (*Potentilla filipes*).
- Tansy mustard (*Sophia incisa*).
- Tongue-leaf violet (*Viola linguaefolia*).
- Trout lily (*Erythronium parviflorum*).
- Violet wheat grass (*Agropyron violaceum*).
- Wild geranium (*Geranium viscosissimum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY OF PLANT COVER RECORD AND ITS FORAGE VALUE

Number of species	24
Density	.287
Palatability percentage:	
Cattle	50.61
Sheep	76.53
Forage factor:	
Cattle	.145
Sheep	.220

TABLE 21.—*Vegetative record of protected plot No. 3 on Seeley Creek 1915 and 1921 (Pl. VI)*

Species recorded, 1915:
- Bedstraw (*Galium boreale*).
- Douglas knotweed (*Polygonum douglasii*).
- Sweet sagebrush (*Artemisia* sp.).
- Tansy mustard (*Sophia incisa*).
- Yarrow (*Achillea lanulosa*).

Species recorded, 1921:
- Androsace (*Androsace puberulenta*).
- American vetch (*Vicia americana*).
- Bladder pod (*Lesquerella kingii*).
- Buttercup (*Ranunculus inamoenus*).
- Chickweed (*Alsine jamesiana*).
- Collomia (*Collomia linearis*).
- Dandelion (*Leontodon taraxacum*).
- Draba (*Draba crassifolia*).
- Douglas knotweed (*Polygonum douglasii*).
- Lamb's-quarters (*Chenopodium album*).

Species recorded, 1921—Continued.
- Ligusticum (*Ligusticum filicinum*).
- Low larkspur (*Delphinium menziesii*).
- Mountain dandelion (*Agoseris pumila*).
- Nodding blue grass (*Poa reflexa*).
- Pachylophus (*Pachylophus caespitosus*).
- Peppergrass (*Lepidium ramosissimum*).
- Plantain (*Plantago tweedyi*).
- Potentilla (*Potentilla nuttallii*).
- Spiked trisetum (*Trisetum spicatum*).
- Sweet sagebrush (*Artemisia* sp.).
- Tansy mustard (*Sophia incisa*).
- Tongue-leaf violet (*Viola linguaefolia*).
- Trout lily (*Erythronium parviflorum*).
- Violet wheat grass (*Agropyron violaceum*).
- Wild geranium (*Geranium viscosissimum*).
- Yarrow (*Achillea lanulosa*).

SUMMARY OF CHANGES IN VEGETATION AND IN FORAGE VALUE OF COVER

	1915	1921	Per cent increase or decrease (−) from 1915 to 1921
Number of species	5	26	420
Density	.133	.286	115
Palatability percentage:			
Cattle	31.67	25.83	−18.4
Sheep	66.86	60.36	−9.7
Forage factor:			
Cattle	.042	.074	76.2
Sheep	.089	.173	94.4

SUMMARY

To maintain the forage productivity of the range it is necessary to be able to determine (1) when the range is ready for grazing, (2) the intensity and frequency of grazing that may be allowed, (3) how to handle the stock, and (4) the natural revegetation of the range that may be relied on. Observations at the Great Basin

Experiment Station and in other parts of the Wasatch Mountains of Utah indicate how this may be done.

In the Wasatch Mountains the forage cover is of three major types, which correspond with rather definite elevational zones—the oak-brush (6,500 to 8,000 feet elevation), the aspen-fir (7,500 to 9,500 feet), and the spruce-fir (above 9,000 feet).

In this region temperature and precipitation are the chief climatic factors influencing the grazing period. During the main growing season from June to September, inclusive, the mean temperature decrease gradient for each 1,000 feet elevation from the oak-brush to the spruce-fir zone is 4.05° F. Growth is delayed approximately 14 days on comparable areas with an increase in elevation of 1,000 feet. Low precipitation in the oak-brush zone is a limiting factor in plant growth. Precipitation is appreciably greater in the more elevated zones. Heavy snow in these zones delays the start of growth.

The proper time for grazing to begin on a range, or the time of "range readiness," may be defined as the date in any one year when the range first reaches the condition in which there is sufficient feed to keep livestock in thrifty condition and when the stock may be admitted without serious impairment of the growth and reproductive processes of the more important forage plants.

Early yield of forage is comparatively small if the herbage is cropped when its average height is 4 inches or less. Grazing when the plants are at this stage stunts the vegetation, and does not satisfy the hunger of the animals because of the low feed value of the short succulent herbage.

It is advisable to use as a guide for range readiness the development of the plant cover as a whole rather than of a few species. The larger the list of plants used as indicators the more reliable the result.

The earliest plants on the range mature early and are exceptionally high in water content and usually of low palatability. When they are in full bloom the main forage species are seldom sufficiently developed for grazing and the soil is soft and often boggy. They therefore indicate range unreadiness.

The proper development of the later-maturing herbaceous and browse species, and especially the important forage plants, may safely be used as a guide for determining range readiness. The proper stage of development may be identified by height, size, or flower stalk, or head production, depending on the species. The grasses, for instance, should in general be about 6 inches in height and the earlier-maturing ones should have flower stalks showing.

The close of the spring grazing period is determined by (1) the development and quantity of forage on the summer range, (2) the grazing capacity of the spring range as compared with the summer range, (3) the palatability of the forage on the early range and the thriftiness of the animals grazed, (4) the water supply, and (5) the need for and value of the forage on the spring range for fall grazing. The close of the summer and fall grazing period is governed largely by (1) proper utilization, (2) weather conditions and the trampling of wet soil, (3) condition of the livestock, (4) availability of forage elsewhere, and (5) water supply. On winter

range the season should close when proper utilization of the old growth has been obtained and soon enough for the forage plants to make a satisfactory new growth.

The grazing seasons giving the best results in the central Wasatch region are: Oak-brush, May 20 to June 9 and October 1 to October 15; aspen-fir, June 10 to July 9 and October 1 to October 15; and spruce-fir, July 10 to September 30.

To insure proper seasonal use a thoroughly sound and practical grazing-management plan should be developed in accordance with the growth and development of the feed. Sheep, being under herd, can readily be confined to seasonal zones during the best period for use. Cattle ranges should be divided into distribution units so as to make practicable the control of the stock. The control, distribution, and movement of the number of cattle which can use each unit to best advantage is obtained by salting in accordance with definite plans, by riding, by drift fences, or by a combination of two or all of these.

Removing the herbage closely four or more times in a season results in a sharp decline in the forage yield and a marked shortage of the life of the vegetation, with the possible exception of sod plants. Very light cropping several times in the season, which leaves each time sufficient leafage for the elaboration of ample plant food, apparently, does not tend to jeopardize the forage yield.

Grazing closely twice or even three times in a season, provided the first grazing is late enough and the intervals are sufficient for the vegetation quite to recover from each cropping, ordinarily does not seriously affect the yield and vigor of the plant cover. Grazing the range satisfactorily at time of vegetative readiness and again in the autumn at the end of the summer grazing period is not a detrimental practice.

Frequent close cropping of the herbage of Nevada blue grass and violet wheat grass following seed maturity each year for three years resulted in excessive declines in yield and a later maturity in the second and third year. Geranium showed no detrimental effect from such treatment.

Close removal of aftermath leaves the crown of the plant exposed to the elements, decreases the humus added to the soil, and exposes the soil to increased run-off and erosion.

Browse species appear to make much the same physiological response to severe cropping as herbaceous vegetation. Plants completely defoliated three or four times in a season are readily killed. The removal of approximately half of the foliage four times each season markedly weakens browse species and lowers their yield. On most browse types, however, sufficient leafage remains when the range has been properly grazed to permit the plants to function normally.

A reasonable amount of succulence in range forage appears to be associated more or less directly with the gains made by the animals grazed. The moisture content of the leafage of several typical grasses averaged 79 per cent when they were cut four times in a season, 41 per cent when they were harvested at the time of seed maturity, and 54 per cent when they were cut twice in a season (6 and 10 weeks, respectively, after growth started).

The high succulence and comparatively low nutritive quality of young herbage sometimes cause serious livestock losses early in the spring. It is of the greatest importance, therfore, that the animals should not be admitted to the range until the forage is sufficiently developed to furnish herbage of good food value.

The crude protein contained in young herbage is largely in the amido stage, so is assimilated by livestock only to a slight degree. In the more developed leafage the protein occurs in the form of amino acids, in which form it is completely assimilated by the animal. Moreover, considerably less digestible nutrients of all kinds are contained in the young leafage than in that more fully developed.

Any cropping which results in the reduction of the aerial growth is reflected in the root development and in the quantity of food stored in the underground parts. Poor development of the root system results in the production of a correspondingly small quantity of herbage the following season.

The grasses are of primary value as forage plants for the reason that they withstand grazing better than most other vegetation. The growing point of the leaf blade is at the base, and if the plant is physiologically strong the leafage can be nipped off without arresting growth. The leafage of a few other herbaceous plants is produced in a similar manner. Where the leaf expansion is uniform throughout the entire area the total consumption of the leafage practically arrests further development of the leaves eaten.

Attempts at artificially reseeding the plains and the drier foothills to cultivated forage plants have given results of no practical value. The possibility of successfully reseeding to valuable cultivated species is considerably greater on mountain meadows and other favorable sites than on drier lands lying at lower elevations.

Cropping a pasture each year to the maximum of its forage production is sure sooner or later to cause a sharp decline in its grazing capacity. The most successful stockmen are now grazing their ranges on the basis of the quantity of forage produced in the average year, rather than on the maximum yield in the best years.

Improvement and maintenance of native pasture lands, the forage on which is composed largely of bunch grasses, is dependent upon the periodical production of a fertile seed crop. To insure seed production of the more palatable forage plants requires prevention of too early grazing, avoidance of overgrazing, and effective control and distribution of stock. Deferred and rotation grazing, which imply the withholding of part of the range from grazing until after seed maturity each year, have given conspicuous results in range reseeding. The results of experimentation showed that revegetation on the range was practically as rapid where deferred grazing was practiced as where the lands were protected yearlong from foraging animals.

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