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Weather and Plant-Development Data as Determinants of Grazing Periods on Mountain Range

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WEATHER AND PLANT-DEVELOPMENT DATA AS DETERMINANTS OF GRAZING PERIODS ON MOUNTAIN RANGE[1]

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INTRODUCTION

Fundamental in economical range-resource management is the determination of proper grazing periods. It is of prime importance to be able to establish a date in the spring when the range has produced sufficient feed to keep livestock in thrifty condition, when it is reasonably safe from excessive trampling and packing of the soil, and when the more important key forage plants have attained sufficient development to withstand grazing use. Such opening dates, as well as the time to defer and rotate grazing and to remove livestock from the range, are dependent in part on the prevailing weather conditions and on the dates when active growth of the forage plants begins and when subsequent developmental stages of the plants are reached.

It is generally recognized that the proper opening date fluctuates from year to year, but the exact magnitude of and reasons for these

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fluctuations are not well known. Although the relation between phenology and cultivated agriculture has been repeatedly pointed out (*7*, *14*)[3] and lists of phenological dates (*9*, *15*) have been compiled, comparatively few quantitative phenological studies on range plants have been reported. Basic information regarding weather fluctuations and the growth and seasonal development from year to year of the important forage plants common to the various mountain range types is needed as a basis to adjust the opening grazing periods with proper range-plant development. The purpose of this bulletin is (1) to outline the normal trend in the seasonal development of some important range forage plants at different altitudinal zones; (2) to indicate the fluctuations in the seasonal development of the plants in these zones from year to year; (3) to indicate the important climatic factors related to these fluctuations; and (4) to outline how this knowledge may be applied in the determination and adjustment of the opening grazing periods on mountain ranges. The study on which the bulletin is based was conducted from the Great Basin branch of the Intermountain Forest and Range Experiment Station and covered the greater part of Ephraim Canyon on the Wasatch Plateau in central Utah.

DESCRIPTION OF EPHRAIM CANYON

The topography of Ephraim Canyon varies from gentle slopes in the foothills to bold relief at the higher altitudes, and altitudes range from 6,500 feet at the lower limits of the oak-brush zone, where the study area began, to more than 10,000 feet. The summit, a comparatively level plateau, is the divide between the Great Basin and the Colorado River drainages. Although the general aspect of the area is westward, the irregular course of Ephraim Creek provides slopes with almost every exposure.

The soil is mainly of limestone origin and is 30 to 50 percent clay. Organic matter varies from less than 2 to more than 10 percent.

PRINCIPAL TYPES OF VEGETATION

As shown by a previous study (*12*), the vegetation in Ephraim Canyon above the elevation of 6,500 feet may be divided into three major types or zones—oak-brush, aspen-fir, and spruce-fir.

The oak-brush zone, which is bordered on the lower side by the piñon-juniper zone, occurs within the elevational limits of 6,500 and 8,000 feet. The zone is characterized by Gambel oak (*Quercus gambelii*), big sagebrush (*Artemisia tridentata*), bigtooth maple (*Acer grandidentatum*), common serviceberry (*Amelanchier alnifolia*), and an understory consisting of various other shrubs, with grasses and weeds[4] occurring in the openings between the shrubby species.

The aspen-fir zone extends from 7,500 to 9,000 feet, depending largely on the exposure. The transition from oak-brush is abrupt. Aspen (*Populus tremuloides aurea*) generally forms even-aged stands occasionally interspersed with Douglas fir (*Pseudotsuga taxifolia*) and white fir (*Abies concolor*). An understory of shrubs, chiefly mountain snowberry (*Symphoricarpos oreophilus*), is usually present. In open parklike areas, characteristic of this zone, are blueberry elder (*Sambucus*

[3] Italic numbers in parenthesis refer to Literature Cited, p. 29.

[4] The term "weed" is here applied to herbaceous nongrasslike plants which, together with browse, grasses, and grasslike plants, constitute the four main groups into which western range plants are customarily divided.

caerulea), squaw currant (*Ribes inebrians*), and various grasses and weeds.

The spruce-fir zone generally occurs above the 9,000-foot elevation. Engelmann spruce (*Picea engelmanni*) and alpine fir (*Abies lasiocarpa*) form dense stands in ravines and on north slopes. On the level plateau summit a great variety of herbaceous species prevails.

The more important species of each zone are as follows:

OAK-BRUSH ZONE

Woody species.—Gambel oak, big sagebrush, bigtooth maple, common serviceberry, true mountain-mahogany (*Cercocarpus montanus*), mountain snowberry, squaw-apple (*Perraphyllum ramosissimum*), bitterbrush (*Purshia tridentata*).

Grasses.—Letterman needlegrass (*Stipa lettermani*), Indian ricegrass (*Oryzopsis hymenoides*), slender wheatgrass (*Agropyron pauciflorum*), bluebunch wheatgrass (*A. spicatum*), bluestem (*A. Smithii*), mutton grass (*Poa fendleriana*), Sandberg bluegrass (*P. secunda*).

Weeds.—Western yarrow (*Achillea lanulosa*), asters (*Aster* spp.), groundsels (*Senecio* spp.), sticky geranium (*Geranium viscosissimum*), pentstemons (*Pentstemon* spp.), lupines (*Lupinus* spp.).

ASPEN-FIR ZONE

Woody species.—Aspen, Douglas fir, white fir, mountain snowberry, common serviceberry, Fendler rose (*Rosa fendleri*), black chokecherry (*Prunus melanocarpa*), squaw currant, blueberry elder, creeping hollygrape (*Odostemon repens*), myrtle boxleaf (*Pachistima myrsinites*).

Grasses.—Mountain brome (*Bromus carinatus*), slender wheatgrass, Porter brome (*Bromus anomalus*), oniongrass (*Melica bulbosa*), Letterman needlegrass, subalpine needlegrass (*Stipa columbiana*).

Weeds.—Sticky geranium, niggerhead (*Rudbeckia occidentalis*), tongueleaf violet (*Viola linguaefolia*), dandelion (*Leontodon taraxacum*), Rydberg pentstemon (*Pentstemon rydbergii*), aspen pea vine (*Lathyrus leucanthus*), western yarrow, lupines, showy goldeneye (*Viguiera multiflora*).

SPRUCE-FIR ZONE

Woody species.—Engelmann spruce (*Picea engelmanni*), alpine fir (*Abies lasiocarpa*), gooseberry currant (*Ribes montigenum*), squaw currant.

Grasses.—Slender wheatgrass, Letterman needlegrass, spike trisetum (*Trisetum spicatum*), nodding bluegrass (*Poa reflexa*), bluegrasses (*Poa* spp.), alpine timothy (*Phleum alpinum*), meadow barley (*Hordeum nodosum*).

Weeds.—Sweet sagebrush (*Artemisia incompta*), paintbrush (*Castilleja* spp.), gilias (*Gilia* spp.), western yarrow, sticky geranium, Barbey larkspur (*Delphinium barbeyi*), dandelion, slimstem cinquefoil (*Potentilla filipes*), false-carrot (*Pseudocymopterus montanus*).

CLIMATE

Recently, Price and Evans (*11*) have completed a 21-year summary of the weather fluctuations in Ephraim Canyon. Some of the important findings of their report follow.

Seasonal maximum temperatures are usually reached in July in all zones; minimum temperatures for the aspen-fir and spruce-fir zones occur in December, and for the oak-brush zone in January. On the average, temperatures decrease approximately 4.1° F. per thousand feet increase in elevation, or about 5° difference between zones for the study area. Table 1 shows the mean temperatures for the area from 1914 to 1934.

TABLE 1.—*Average monthly and annual mean temperatures and average monthly and annual precipitation at center of 3 vegetation zones in Ephraim Canyon, Utah, 1914–34*

Month	Temperature			Precipitation		
	Oak-brush zone (7,655 feet)	Aspen-fir zone (8,850 feet)	Spruce-fir zone (10,100 feet)	Oak-brush zone (7,655 feet)	Aspen-fir zone (8,850 feet)	Spruce-fir zone (10,100 feet)
	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
January	23.8	21.4	16.8	1.27	3.15	3.96
February	28.2	23.3	18.5	1.23	2.85	2.59
March	29.3	23.2	17.7	1.92	4.11	4.35
April	37.8	34.8	24.7	1.63	3.54	3.03
May	46.9	42.8	35.8	1.77	2.44	1.80
June	58.3	53.7	48.1	.69	.85	.74
July	65.4	60.4	55.3	1.54	1.81	1.86
August	63.7	58.1	53.3	1.40	1.80	1.71
September	55.4	50.1	45.5	1.19	1.56	1.34
October	42.8	38.9	34.7	1.39	1.92	1.40
November	33.4	29.0	24.7	1.59	2.19	2.12
December	25.8	20.3	14.7	1.89	3.26	3.11
Total or average	42.6	38.0	32.5	17.51	29.48	28.01

Monthly and annual precipitation averages for the three vegetation zones are shown in table 1. The mean monthly precipitation for all zones is greatest in March and least in June. Annual precipitation, on the average, increases 10 inches per 1,000 feet rise in elevation between the oak-brush and aspen-fir zones and decreases 1.2 inches between the aspen-fir and spruce-fir zones. During the growing period, precipitation falls as rain in the form of thundershowers, with occasional hail. From November 1 to May 1 most of the precipitation occurs as snow.

Average soil temperatures in the aspen-fir zone from 1924 to 1934, inclusive, for the period May 1 to November 1 at the 6-, 12-, and 24-inch levels were 54.8°, 53°, and 50.8° F., respectively. During this period, the soil is warmest in the latter part of July and coldest in May and October. When the ground is snow-covered, soil temperatures remain almost constant. Following snow disappearance in the spring when active growth of the more important range plants begins, the upper layers of soil are warmer than those at greater depths. Greatest variation in temperature between depths occurs in the latter part of June.

The soil-moisture content is highest at the time of snow disappearance, when it averages about 30 percent of the dry weight of the soil. This moisture decreases until a minimum is reached in the latter part of June or July. Throughout the remainder of the summer, soil moisture at the 24-inch depth remains at a minimum, while showers bring a slight increase at the higher levels. Owing to the high moisture content of the soil following snow disappearance, current precipitation has little effect during the early part of the growing season.

Other factors have been reported upon by Sampson (*12*), in an earlier report covering the period 1913–16. Evaporation during the main growing season was greatest in the oak-brush zone, nearly as great in the spruce-fir zone owing to a highwind velocity, and least in the aspen-fir zone because of a luxuriant growth of vegetation and owing to topographic features. Wind movement was greater by about 100 percent in the spruce-fir zone than in the zones immediately below, and it was not uncommon for the wind to exceed 40 miles per hour for several hours in succession. Sunshine duration and intensity were practically the same in all zones; but there is considerable difference in barometric pressure in the three zones.

The average length of the growing season for different elevations in Ephraim Canyon are: 7,000 feet, 175 days; 8,000 feet, 160 days; 9,000 feet, 145 days; 10,000 feet, 125 days. An unusually late spring or an early autumn may reduce by one-half the length of the growing period, and occasional frosts may occur during any month of the year.

METHODS OF OBSERVATION

PLANT DEVELOPMENT

During the 10-year period 1925–34, plant-development observations were made in Ephraim Canyon on important range-forage species protected by six different enclosures, the lowest and highest being separated by an air-line distance of approximately 5 miles and by an elevational difference of 3,000 feet. The surface area of each plant-development station varied with the enclosure in which it was located, averaging about one-fourth of an acre. Exposure, degree of slope, and elevation of each station, as well as the plant species observed, are given in table 2.

TABLE 2.—*Description of 6 plant-development stations in Ephraim Canyon, Utah, and species observed, 1925–34*

Description of station and species observed	Purshia	Wire-grass [1]	Snow-berry	Head-quarters [1]	Bluebell	Alpine [1]
Elevation ... feet	7,150	7,655	8,450	8,850	9,000	10,100
Exposure	W	W	W	SW	NE	S
Slope ... degrees	10	5	8	5	10	6
Species:						
Slender wheatgrass	×	------	×	×	×	×
Mountain brome	------	------	------	×	×	×
Letterman needlegrass	×	×	×	------	×	×
Western yarrow	×	×	×	------	×	×
Sticky geranium	×	×	×	×	×	×
Pentstemon	------	------	------	------	×	×
Niggerhead	------	------	------	×	×	------
Tongueleaf violet [2]	×	×	×	------	×	×
Common serviceberry	×	×	×	------	------	------
Aspen	------	------	×	×	[2] ×	------
Bitterbrush	×	×	------	------	------	------
Gambel oak	------	×	------	------	------	------
Mountain snowberry	------	×	×	×	------	------

[1] Meteorological station.
[2] Record discontinued at end of 1931 growing season.

Plants observed at the three meteorological stations were reasonably close to the recording instruments, so that conditions affecting the instruments were practically the same as those affecting the plants. Observations on both weather and plant development were started at snow disappearance in the spring and continued until the appearance of snow in the late fall in each of the 10 years of the study. The plant-development stages obtained are summarized in table 3. In addition to this record, maximum and average height-growth measurements were taken at intervals of approximately 5 days from the date of active growth inception until elongation of leaves, twigs, or flower stalks had ceased.

TABLE 3.—*Plant-development stages recorded*

Grasses	Weeds	Browse species
Date of snow disappearance.	Date of snow disappearance.	Date of snow disappearance.
Date 6 inches high.	Flower buds evident.	Flower buds bursting.
Flower stalks evident.	In full bloom.	Leaf buds bursting.
Heads beginning to show.	Seed ripe.	In full leaf.
Flowers in bloom.	Seed disseminated.	In full bloom.
Seed ripe.	Plant dried up.	Fruit ripe.
Seed disseminated.		Fruit all dropped. Leaves all dropped.

Observations were confined principally to the more important forage species, as shown in table 2. Absence of plant species at some stations is due to altitudinal limitations of the species, to differences in habitat, or to the size of the enclosure.

WEATHER OBSERVATIONS

Atmospheric temperatures, soil temperatures at depths of 6, 12, and 24 inches, and precipitation records were continued daily during each growing season of the experimental period at a standard-equipped meteorological station located in the approximate center of each zone (fig. 1). In addition, evaporation measurements and relative-humidity readings were recorded daily during the same period in the aspen-fir zone only.

OBSERVATIONS OF PLANT DEVELOPMENT

NORMAL TRENDS AT DIFFERENT ALTITUDES

Average dates at which the developmental stages of important grasses, weeds, and browse species appear at different altitudes are shown in tables 4, 5, and 6. The date at which a particular stage of growth is reached becomes progressively later with increase in altitude. This delay, which agrees in general with the bioclimatic law of Hopkins (*6*), averages about 12 days for each 1,000 feet increase in elevation. It is notable that each species shows its own average rate of delay. Thus, for Letterman needlegrass it is approximately 11 days; for slender wheatgrass, 13 days; and for mountain brome, 14 days. A greater variation between species appears among the weeds and browse species, viz, western yarrow, 7 days; sticky geranium, 13 days; tongueleaf violet, 15 days; mountain snowberry, 10 days; and common serviceberry, 7 days.

Each developmental stage of the various classes of species also has a specific rate of delay. For example, in grasses, flowerstalk development is delayed from 9 to 12 days for each 1,000 feet increase in elevation, while seed dissemination shows a delay of 12 to 17 days. Similarly, the earlier developmental stages of weeds are delayed 9 to 14 days, but in the later stages it is 6 to 15 days.

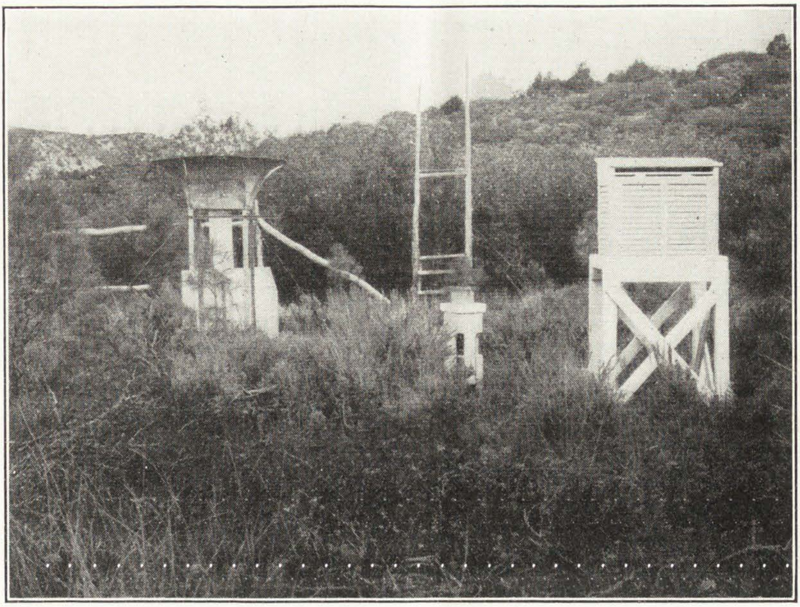

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FIGURE 1.—Meteorological instruments at the wiregrass station located at the center of the oak-brush zone. The ponderosa pines at the extreme right and left have been planted. Big sagebrush is growing in the center; Gambel oak in the background. The principal forage grasses occurring at this station are Letterman needlegrass, slender wheatgrass, bluestem, mutton grass, and Sandberg bluegrass. Western yarrow, in flower, is evident in the foreground.

TABLE 4.—*Forage grasses; average dates of appearance of various growth stages at different elevations, 1925–34* [1]

Species and elevation (feet)	Plant 6 inches high	Flower stalks evident	Flower heads showing	Flowers in bloom	Seeds ripe	Seeds dissem-inated
Letterman needlegrass:						
7,150	May 16	May 25	June 15	July 1	July 28	Aug. 14
7,655	May 21	May 29	June 22	July 5	Aug. 2	Aug. 21
8,450	June 6	June 3	June 23	July 6	Aug. 6	Aug. 26
9,000	June 19	June 19	July 7	July 21	Aug. 23	Sept. 21
10,100	July 12	June 21	July 9	July 25	Aug. 28	Sept. 19
Mountain brome:						
8,850	June 11	June 7	June 27	July 14	Aug. 12	Sept. 8
9,000	June 16	June 19	July 7	July 25	Aug. 26	Sept. 17
10,100	June 30	June 22	July 10	July 27	Sept. 5	Sept. 28
Slender wheatgrass:						
7,150	May 16	May 24	June 16	July 1	July 22	Aug. 8
8,450	June 8	June 2	June 26	July 12	Aug. 12	Sept. 3
8,850	June 23	June 9	July 3	July 19	Aug. 25	Sept. 20
9,000	June 18	June 21	July 13	July 27	Sept. 3	Sept. 22
10,100	July 6	do	July 15	do	Sept. 5	Sept. 27

[1] The magnitude of yearly fluctuations for these and the following data are discussed in later sections.

TABLE 5.—*Forage weeds; average dates of appearance of various growth stages at different elevations, 1925–34*

Species and elevation (feet)	Flower buds evident	Flowers in bloom	Seeds ripe	Seeds dissem-inated	Plant dried up
Western yarrow:					
7,150	May 30	June 29	Sept. 8	Sept. 19	Oct. 10
7,655	June 1	July 5	Aug. 26	Sept. 24	Oct. 13
8,450	June 6	July 10	Sept. 4	do	Sept. 25
9,000	June 18	July 15	Sept. 8	Sept. 29	Oct. 1
10,100	June 25	July 21	Sept. 20	Oct. 8	Oct. 8
Sticky geranium:					
7,150	May 18	June 14	July 18	Aug. 6	Sept. 25
7,655	May 29	June 26	July 26	Aug. 19	Sept. 18
8,450	June 4	do	Aug. 10	Sept. 3	Oct. 5
8,850	June 5	June 28	Aug. 5	do	Sept. 28
9,000	June 13	July 10	Aug. 16	Sept. 5	Sept. 29
10,100	June 19	July 20	Aug. 27	Sept. 19	Do.
Rydberg pentstemon:					
9,000	June 17	July 13	Sept. 5	Sept. 25	Sept. 25
10,100	June 21	July 18	Sept. 11	Sept. 27	Sept. 28
Niggerhead:					
8,850	June 16	July 29	Sept. 2	Sept. 26	Sept. 23
9,000	June 21	Aug. 2	Sept. 8	Oct. 3	Sept. 28
Tongueleaf violet:					
7,150	May 2	May 14	June 10	June 24	July 8
7,655	May 4	May 19	June 20	July 1	July 12
8,450	May 14	May 29	June 30	July 20	July 27
9,000	June 4	June 15	July 15	Aug. 6	Aug. 6
10,100	June 11	June 23	July 29	Aug. 8	Aug. 26

TABLE 6.—*Browse species; average dates of appearance of various growth stages at different elevations, 1925–34*

Species and elevation (feet)	Flower buds bursting	Leaf buds bursting	In full leaf	In full bloom	Fruit all ripe	Fruit dropped	Leaves all dropped
Mountain snowberry:							
7,655	June 17	May 3	June 1	June 26	Aug. 20	Sept. 18	Oct. 6
8,450	June 22	May 8	June 5	June 30	Aug. 17	Sept. 12	Oct. 14
8,850	July 2	May 19	June 15	July 8	Aug. 21	Sept. 26	Oct. 11
Common serviceberry:							
7,150	May 17	Apr. 30	May 26	May 25	Aug. 8	Aug. 21	Oct. 5
7,655	May 24	May 2	May 29	May 29	Aug. 14	Aug. 28	Do.
8,450	May 30	May 7	do	June 5	Aug. 18	do	Oct. 11
True mountain-mahogany:							
7,480	May 23	Apr. 30	May 28	May 28	July 23	Aug. 11	Oct. 14
7,890	June 2	May 3	June 5	June 7	Aug. 2	Aug. 3	Oct. 19
Aspen:							
8,450	May 6	May 19	June 9	May 11			Oct. 14
8,850		May 31	June 18	May 10			Oct. 12
Bitterbrush:							
7,150	May 27	Apr. 27	May 30	June 2	July 26	Aug. 19	Oct. 20
7,655	June 3	Apr. 30	June 4	June 9	Aug. 2	do	Oct. 21
7,890	June 4	May 1	June 6	June 10	Aug. 9	do	Oct. 20
Gambel oak:							
7,655	May 25	May 23	June 17	June 5	Sept. 25	Oct. 10	Do.

In some instances, delay in dates of development are not proportional to increase in elevation. These variations from the general tendency are due in part to differences in slope and exposure at the different stations. Thus, the 9,000-foot elevational station (Bluebell) presents a northeast exposure, which surrounding mountains shade in the morning and in the evening. Snow remains there longer in the spring than is average for that elevation. Consequently, the dates at which developmental stages occur at this station frequently approximate those of the Alpine station, more than 1,000 feet higher. Average total plant height, or length of twigs in the case of browse species, reached on May 1, May 15, June 1, June 15, July 1, and July 15 as determined for each species at different elevations, is given in table 7.

TABLE 7.—*Average heights of important forage plants at various dates and at different altitudes, 1925–34*

Species and elevation (feet)	May 1	May 15	June 1	June 15	July 1	July 15[1]
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Letterman needlegrass:						
7,150	6.6	14.2	21.8	29.9	36.2	38.0
7,655	4.9	12.7	19.5	22.2	29.3	35.4
8,450	5.4	6.8	13.4	19.6	26.4	30.9
8,850		[2] 4.4	8.9	16.2	23.3	31.2
9,000		[2] 9.0	5.7	12.2	20.3	30.1
10,100			2.8	6.8	11.9	18.4
Western yarrow:						
7,150	4.9	9.1	16.2	26.2	30.8	33.9
7,655	3.9	8.0	12.9	20.0	28.4	31.1
8,450	1.4	4.6	7.7	15.8	24.2	29.3
9,000		.5	3.5	7.9	19.0	28.3
10,100				5.7	11.1	19.9
Mountain snowberry:[3]						
7,655		6.0	6.6	9.3	13.1	20.8
8,450		4.0	4.7	8.7	14.9	18.3
8,850		3.2	5.1	11.6	12.1	16.0

[1] Further average height-growth data are not available because plant growth usually ceases soon after July 15.
[2] A single measurement.
[3] 1925 comparison not available.

These data confirm the obvious assumption that height growth at any particular date decreases with increase in elevation. Thus on June 1 average height of western yarrow at the Purshia station (7,150 feet) was 16.2 cm., and at Bluebell (9,000 feet) only 3.5 cm. At Alpine station (10,100 feet) active growth does not ordinarily start until after June 1. Similarly, heights reached by Letterman needlegrass on June 1 were 21.8 cm. at Purshia station and 2.8 cm. at Alpine. This same tendency holds for other dates and for all species observed. Growth is more rapid, however, at the higher than at the lower elevations, once it starts. Shortness of the growing season explains in part the failure of vegetation at high altitudes to reach an ultimate height equal to that attained farther down the mountainside.

The average number of days between successive stages of development has been determined for each species at each elevational zone. Data for three periods are given for the more important grasses and weeds in table 8.

Tendency for growth to catch up during early growth stages at higher elevations is shown by a comparison of the number of days between developmental stages for the same species at different altitudes. For each additional 100 feet of altitude, 0.2 to 1 day less is required after active growth inception for grasses to each "flower stalks in evidence." Sticky geranium requires 38 days at Wiregrass station (7,655 feet) and only 22.5 days after growth inception at Alpine station (10,100 feet) to reach "flower buds in evidence." Catching up tends to decrease in succeeding stages.

The period between "flower buds or flower stalks in evidence" and "flowers in bloom" shows comparatively little variation between different elevations for the same species. A marked difference is apparent, however, between weeds and grasses, and even between weed species themselves. Sticky geranium requires less than 24 days for this period at the 8,850-foot elevation, while slender wheatgrass requires more than 40 days. An examination of table 8 will show that similar differences exist at other elevations.

TABLE 8.—*Average number of days between stages of growth for important forage grasses and weeds, 1925–34*

Growth interval and species	Period required at elevation of—				
	7,655 feet	8,450 feet	8,850 feet	9,000 feet	10,100 feet
Active growth inception to flower stalks or flower buds in evidence:	*Days*	*Days*	*Days*	*Days*	*Days*
Slender wheatgrass	---	40.8	34.2	31.8	24.0
Mountain brome	---	---	29.5	30.6	24.3
Letterman needlegrass	43.1	35.7	---	30.5	29.1
Sticky geranium	38.0	36.8	32.6	24.4	22.5
Western yarrow	41.8	38.3	---	32.1	26.8
Pentstemon	---	---	---	28.7	26.7
Flower buds or flower stalks in evidence to flowers in bloom:					
Slender wheatgrass	---	38.9	40.8	36.5	36.4
Mountain brome	---	---	38.0	35.9	36.5
Letterman needlegrass	36.2	32.8	---	33.5	34.0
Sticky geranium	27.6	22.0	23.4	28.5	31.3
Western yarrow	34.2	34.4	---	27.7	25.8
Pentstemon	---	---	---	26.5	27.0
Flowers in bloom to seeds ripe:					
Slender wheatgrass	---	31.8	35.6	37.4	38.9
Mountain brome	---	---	28.2	32.1	39.1
Letterman needlegrass	29.0	31.3	---	33.0	33.7
Sticky geranium	31.8	45.4	37.8	36.6	37.3
Western yarrow	51.9	56.0	---	54.4	60.9
Pentstemon	---	---	---	52.7	55.1

Grasses show a tendency to lose out in the period between "flowers in bloom" and "seeds ripe." A longer period of time is required to reach "seeds ripe" at Alpine station than at lower elevations, and the catching-up tendency evident in the earlier stages is counteracted to some degree, so that the period from "active growth inception" to "seeds ripe" is but little shorter at Alpine station than at the lower stations. This period varies in length from approximately 95 to 105 days with an average of almost 104 days for all stations.

RECORDS OF NORMAL DEVELOPMENT INDICATE CHARACTER OF GROWING SEASON

By the use of height-growth and development records of key forage plants collected over a period of years, the stage of forage-plant development as of a particular date, may be judged on similar mountain ranges.

For example, the 1935 height-growth measurements for Letterman needlegrass and western yarrow for various dates, when compared with the 10-year averages given in table 7 indicate that height growth of Letterman needlegrass for 1935 was less than average at all elevations except at Purshia station (table 9). On May 1, growth was approximately normal at the lower elevations. By June 1, however, height growth was far behind the 10-year average and continued to drop behind throughout the season. A specific example may be cited: At Wiregrass station (elevation 7,655 feet) western yarrow had attained a height of 8.5 cm. on June 1, and Letterman needlegrass 12.2 cm. These heights are practically identical with the 10-year averages for May 15. Consequently, the condition of the range, as judged by the development of these plants, was at least 2 weeks behind normal on June 1.

TABLE 9.—*Increase or decrease in average heights of 2 important forage plants at various dates in 1935, over the 10-year averages (1925–34), as given in table 7*

Species and elevation (feet)	May 1	May 15	June 1	June 15	July 1	July 15
Letterman needlegrass:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
7,150	−1.1	−2.7	+2.2	+5.1	+5.8	+5.0
7,655	−.3	−4.3	−7.3	−3.9	−7.5	−10.8
8,450		−4.3	−4.4	−6.1	−5.4	−5.9
9,000			−4.2	−4.2	−6.2	−12.6
10,100				−1.4	−.3	−3.5
Western yarrow:						
7,150	+.1	−2.1	−5.7	−10.7	−15.3	−18.4
7,655	+.1	−3.0	−4.4	−9.5	−17.9	−20.6
8,450		−3.6	−2.7	−8.3	−16.7	−21.8
9,000			−1.5	−1.9	−9.5	−13.3
11,000				−1.7	−4.1	−7.9

TABLE 10.—*Schedule of indicators of range readiness for the Wasatch Mountains, based on principal range plants found in 3 vegetation zones of Ephraim Canyon*

Species	Plant height or development	Current twig growth	Flower stalks or buds	Other indicators
OAK-BRUSH ZONE [1]				
Grasses:				
Letterman needlegrass	6–8 inches		In evidence	No heads showing.
Slender wheatgrass	do		Not evident	
Mountain brome	do		In evidence	Do.
Bluebunch wheatgrass	do		do	Do.
Muttongrass			Present	Heads fully out.
Weeds:				
Western yarrow	4 inches		Bursting	
Sticky geranium	do		Showing	
Tongueleaf violet			Full bloom	
Browse:				
Mountain snowberry	½–¾ in leaf	2–3 inches		
Gambel oak	Leaf buds bursting	Starting		
Birchleaf mountain-mahogany.	½ in leaf	None	Bursting	
Common serviceberry	do	Starting	do	
Bitterbrush	do	None	do	
ASPEN-FIR ZONE [2]				
Grasses:				
Mountain brome	6–8 inches		In evidence	No heads showing.
Slender wheatgrass	6 inches		do	Do.
Letterman needlegrass	6–8 inches		do	Heads low in boot.
Weeds:				
Western yarrow	4 inches		Showing	
Sticky geranium	5 inches		Bursting	
Tongueleaf violet				Height of blooming over.
Niggerhead			Showing	
Rydberg penstemon			do	
Browse:				
Aspen	¾ in leaf			
Mountain snowberry	½ in leaf	2 inches		
Common serviceberry	Full bloom and leaf			Young fruit evident.
SPRUCE-FIR ZONE [3]				
Grasses:				
Slender wheatgrass	6–8 inches		In evidence	Flower heads beginning to show.
Letterman needlegrass	6 inches			Do.
Mountain brome	8 inches			Do.
Weeds:				
Western yarrow	6 inches		Bursting	
Sticky geranium	8 inches		do	Some flowers in bloom.
Tongueleaf violet	Height of blooming past.			Seeds ripening.
Rydberg penstemon			Bursting	Some flowers in bloom.

[1] Elevation 6,500 to 8,000 feet. [2] Elevation 7,500 to 9,000 feet. [3] Elevation 9,000 feet and above.

The stage of development attained by the key forage plants is also an important indicator of seasonal advancement of the growing season. For example, flower buds of western yarrow (table 5) and flower stalks of Letterman needlegrass (table 4) are normally in evidence at an elevation of 9,000 feet in Ephraim Canyon between June 15 and June 29, and the 10-year average date is June 19. A comparison of the actual dates of appearance of these developmental stages with the average dates indicates the number of days the growing season is retarded or advanced beyond normal. Thus, reliable averages of height growth and appearance of developmental stages of key forage plants provides a basis for judging current plant development on mountain ranges.

In the light of the longer time record of average plant-development data made available by this study, the schedule of range-readiness stages outlined by Sampson and Malmsten (*13*) for the Wasatch Mountains in Utah can now be revised for greater accuracy, as in table 10. In this revision the major forage plants with their respective stages of development that indicate range readiness have been listed for each of the three vegetative zones characteristic of Ephraim Canyon. This listing makes it possible to detect range readiness more accurately for each vegetative and zonal range.

FLUCTUATIONS IN PLANT DEVELOPMENT FROM YEAR TO YEAR

Marked variations occur in the date of appearance of each stage of plant development between "early" and "late" years, the minimum and maximum variation depending on the species, for example:

	Variation (days)
Grasses:	
Growth begun	20–45
Flower stalks evident	33–39
Flower heads showing	25–35
Flowers in bloom	28–36
Seeds ripe	35–43
Seeds disseminated	41–55
Weeds:	
Growth begun	28–50
Flower buds evident	26–47
Flowers in bloom	26–42
Seed ripe	36–45
Seeds disseminated	35–62
Plant dried	34–100
Browse:	
Leaf buds bursting	27–46
In full leaf	30–35
Flowers in bloom	28–38
Fruit ripe	36–42
Fruit dropped	20–34

Table 11, as an illustration, gives earliest and latest dates at which certain developmental stages for grasses and weeds were reached at Alpine and Bluebell stations.

TABLE 11.—*Extreme variation in the dates of growth stages of important forage grasses and weeds at 2 stations, 1925–34*

Station and species	Snow disappearance	Flower stalks or buds evident	Heads showing	Flowers in bloom	Seeds ripe	Seeds disseminated	Plant dried up
Alpine:							
Slender wheatgrass	May 4–June 14	June 10–July 6	July 8–July 24	July 18–Aug. 16	Aug. 27–Sept. 18	Sept. 20–Oct. 5	
Mountain brome	Apr. 23–June 15	June 9–July 6	June 24–July 21	July 5–Aug. 10	Aug. 8–Sept. 20	Sept. 9–Oct. 11	
Letterman needlegrass	Apr. 1–May 1	May 19–July 7	June 18–July 18	June 24–Aug. 5	July 21–Sept. 10	Aug. 1–Oct. 2	
Bluebell:							
Western yarrow	Apr. 22–June 7	May 25–July 6	----------	July 5–July 25	Aug. 15–Sept. 23	Aug. 25–Oct. 15	Sept. 20–Oct. 15
Sticky geranium	Apr. 23–June 7	May 21–July 6	----------	June 30–July 25	Aug. 5–Aug. 31	Aug. 15–Sept. 16	Sept. 10–Oct. 15
Rydberg pentstemon	Apr. 22–June	May 23–July 6	----------	July 5–July 21	Aug. 20–Sept. 20	Sept. 10–Oct. 5	Sept. 16–Oct. 5
Niggerhead	do.	May 25–July 1	----------	July 20–Aug. 15	Aug. 20–Sept. 25	Sept. 10–Oct. 20	Aug. 31–Oct. 15

The number of days between the earliest and latest date at which a developmental stage occurs varies with the altitudinal zone, being greater in the lower zones. Greatest fluctuation is shown in the date when herbaceous plants become dry. For example, sticky geranium has shown an extreme variation of more than 3 months in the date of drying at Purshia station, while at Alpine station this variation has not exceeded 25 days during the 10-year period of observation. At higher elevations, plants usually dry up soon after seed maturity. At lower elevations, aftermath growth may, with favorable weather conditions, continue into late autumn or even until the vegetation is covered by snow.

Measured growth increments of herbaceous and browse species show considerable fluctuations throughout the growing season and from year to year. Fluctuations in height growth and the extent to which they vary from average depend largely on current temperatures and precipitation and on the time when active growth begins. A comparison of the 1935 height growth of western yarrow at Purshia station (table 7) with the 10-year average shows that on May 1 height growth was slightly ahead of average. Throughout the remainder of the season it fell behind, until on July 1 it had about half of the growth ordinarily attained by that date. In the spring of 1933, active growth inception of practically all species was delayed to the extent that height development remained below average throughout the season. In 1934, the growing season began unusually early and the majority of species showed growth measurements greatly in excess of normal in the early part of the season. The influence of the drought of that year, however, later caused a marked decrease in growth rate with the result that plant heights and twig lengths at the end of the season were the lowest recorded.

The extent of variation in height growth that occurs from year to year at different periods during the growing season is illustrated by the minimum and maximum height growth record of Letterman needlegrass at the different stations, as given in table 12. Variations in height tend, naturally, to become greater as the season advances. Thus, the greatest difference recorded between maximum and minimum height at Purshia station on May 15 was 23 cm; on June 15 it was 26 cm; on July 15 it was 39 cm. Similar tendencies are shown at other stations and for other species.

TABLE 12.—*Range of minimum and maximum average heights attained by Letterman needlegrass at the 6 stations, 1925–34*

Station and elevation (feet)	May 1	May 15	June 1	June 15	July 1	July 15
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Purshia, 7,150	0–19	6–29	14–32	15–41	15–52	15–54
Wiregrass, 7,655	0–13	5–15	13–23	18–34	26–47	28–59
Snowberry, 8,450	0–10	0–14	7–22	14–34	13–37	18–50
Headquarters, 8,850		0– 4	6–12	13–18	20–25	21–42
Bluebell, 9,000		0– 9	0–14	5–18	15–26	24–37
Alpine, 10,100			0– 5	0–13	11–15	13–28

PRINCIPAL CLIMATIC FACTORS AFFECTING PLANT DEVELOPMENT

Sampson (*12*) in an earlier report covering the period 1913 to 1916 indicated that:

1. The rate of maturity of the plants decreases directly as the effective heat units decrease in passing from the oak-brush zone to the spruce-fir zone.
2. The water requirement for the production of a unit weight of dry matter is greatest in the oak-brush zone, lowest in the aspen-fir zone, and intermediate in the spruce-fir zone. These relationships coincide with the intensities of evaporation.
3. The total and average leaf length and total dry weight produced are greatest in the aspen-fir zone and less in the oak-brush and spruce-fir zones alike. The decreased production in the oak-brush and spruce-fir zones is in direct proportion to the evaporation.
4. Stem elongation is greatest in the oak-brush zone, intermediate in the aspen-fir zone, and least in the spruce-fir zone, and appears to be determined largely by temperature.
5. The production of dry matter appears to vary inversely with evaporation, although temperature appears to be important. The largest amount of dry matter per unit of leaf area is produced in the aspen-fir zone and the least in the oak-brush zone.

The present study, conducted over a longer period of time and with special attention to the more readily measured climatic factors, corroborates these findings and yields additional facts on the influence of temperature, rainfall, and snow melt.

TEMPERATURE

Temperature influence is evident during all stages of range-plant development and appears to be more important than other factors in determining the rate of growth, which agrees with the findings of the earlier study.

An inverse relationship exists between temperature and the number of days required by the plant to complete any particular stage of development. Temperatures higher than average are associated with periods of development that are shorter than average and vice versa. The correlation coefficients given below indicate the relationship between deviations from the average mean daily temperature of the first 30 days in a developmental stage and deviations from the average number of days required to complete that stage (*4, pp. 160–*

197; 16). The coefficients are highly significant since the odds that they might occur by chance in uncorrelated data are less than 1 in 100 (*4, p. 196*).

Stage of development	*Correlation coefficient*
Active growth inception to flower stalks (or buds) evident (125 observations)	−0. 500
Flower stalks (or buds) evident to flowers in bloom (124 observations)	−. 531
Flowers in bloom to seeds ripe (117 observations)	−. 445

Although these correlation coefficients, which express the inverse relationship that exists between temperature and the length of time to reach certain developmental stages, measure only about 25 percent of the influences affecting the rate of plant development, they clearly indicate the great importance of temperature as a factor in the rate of mountain range-plant development.

Each species of plant appears to show a specific reaction to temperature. It has been observed that two species growing under apparently identical conditions show different responses. The relationship between temperature and rate of development varies for the same species at different altitudes (table 13), probably because plants at higher elevations are subjected to different weather fluctuations.

TABLE 13.—*Comparison of temperatures experienced at the same stages of plant development at different altitudes, 1925–34*

Species and elevation (feet)	Average mean daily temperatures for 30-day period following—		
	Snow disappearance	Flower stalks evident	Flowers in bloom
	°F.	*°F.*	*°F.*
Slender wheatgrass:			
8,850	47. 1	56. 1	59. 3
10,100	48. 3	54. 2	53. 6
Mountain brome:			
8,850	46. 8	55. 2	60. 0
10,100	48. 9	53. 7	54. 4
Letterman needlegrass:			
7,655	42. 3	56. 4	65. 1
10,100	45. 5	54. 2	54. 8
Western yarrow:			
7,655	43. 8	51. 1	64. 2
10,100	46. 8	54. 7	54. 5
Sticky geranium:			
7,655	43. 9	56. 8	62. 5
8,850	45. 1	55. 4	59. 9
10,100	48. 4	53. 9	55. 5
Mountain snowberry:			
7,655	43. 7		64. 3
8,850	47. 0		60. 4

At lower altitudes growth begins early in the season, when the plant is subjected to unsettled weather conditions and low average temperatures. At higher elevations inception of growth is delayed by the snow cover, with the result that higher temperatures prevail when growth begins. Average mean daily temperature for the first month following growth inception is approximately 3° F. higher at Alpine station than at Wiregrass station. It is likely that this inversion of temperature during early growth stages is partly responsible for the catching-up in growth and development that occurs at higher altitudes.

Following "flower stalks in evidence," temperature inversion disappears and average mean daily temperatures are lower at Alpine station.

This doubtless is one of the factors that slows up the rate of growth and development of plants at higher elevations during the period from "flowers in bloom" to "seeds ripe."

RAINFALL

Influence of rainfall on plant development is not so readily measured as is the influence of temperature, owing to the complex interrelation of precipitation and other climatic factors. However, as already noted, at the time of snow disappearance and during the early part of the growing season, soil moisture is at a maximum; consequently, current rainfall appears to have little influence on rate of plant development early in the season. In the latter part of the growing season a significant relationship appears to exist between current precipitation and rate of plant development.

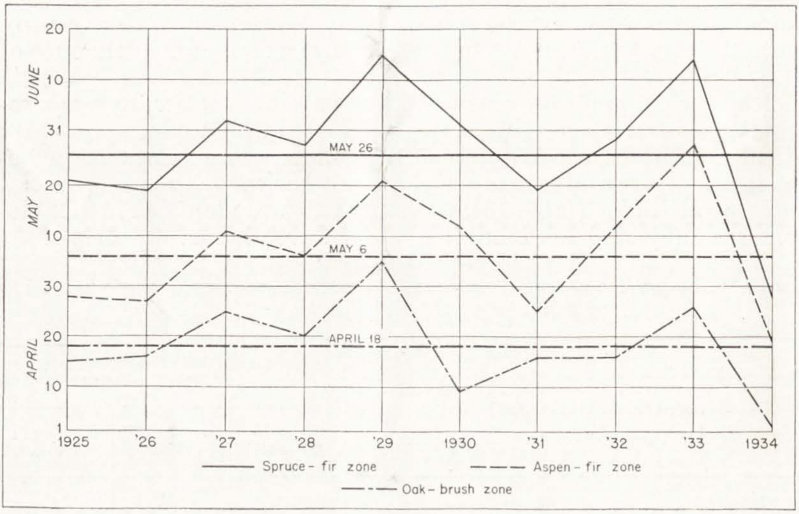

FIGURE 2.—Date of snow disappearance at three elevational zones in Ephraim Canyon, Utah, 1925–34.

The number of days required for seed ripening following "flowers in bloom" is generally less than average when precipitation, which influences current temperatures, is lower than average, and vice versa. In 1925, when rainfall was normal, seeds of slender wheatgrass ripened in 36 days at the 8,850-foot altitude. In 1926 when rainfall was deficient, time of ripening was reduced to 26 days. In 1929 with excessive rainfall, seeds required 47 days to ripen. All other herbaceous species show similar tendencies.

Distribution as well as the amount of precipitation during the period following "flowers in bloom" influences the rate of seed ripening. Excessive rainfall in the early part of the period may have little effect if no rain falls in the latter part. On the other hand, moderate rains distributed evenly over the period preceding seed formation may delay seed maturity for 2 or 3 weeks.

DATE OF SNOW MELT

The date when winter snow disappears, which fluctuates widely from year to year (fig. 2), is determined principally by the depth of snow accumulation during the winter and by wind movement and temperatures during the period of melting (*3*). Since active growth does not begin until the snow cover has disappeared, the growing season is early, late, or normal—depending on the time when snow disappears. Variation in the depth of accumulation at different altitudes may result in an early season at one elevation and a late season at another. The degree of delay in vegetation development caused by increased altitude is governed, to a considerable extent, by the disappearance of snow from the mountainside.

The date of snow disappearance is related not only to the beginning of active growth but also ordinarily reflects the progress of the entire

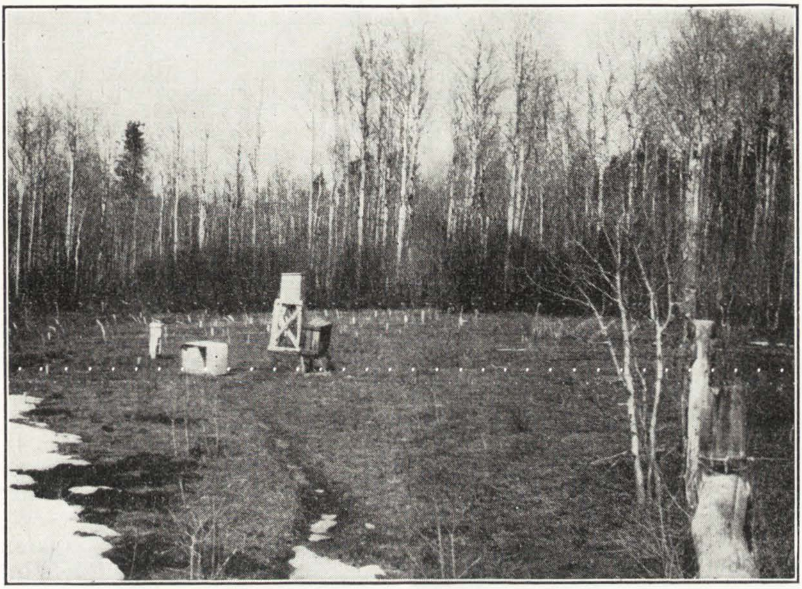

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FIGURE 3.—Snow disappearing at Headquarters station in the aspen-fir zone. Active growth of the important range plants begins almost immediately after winter snow disappears.

growing season (fig. 3). Seasons which begin early, late, or normal tend to remain early, late, or normal throughout the growing period, except as extremes in seasonal temperature and rainfall may exert a counter influence. Plants delayed in early growth may catch up later in the growing season to stages of normal development if above-average temperatures and well distributed precipitation follows. Conversely, unfavorable weather conditions—chiefly low temperatures—may retard the rate of development of vegetation of which the early growth was ahead of normal. The general tendency, however, is for vegetation to maintain the trend of development established early in the growing season.

Figure 4 shows the close relation of the date of snow disappearance to the dates of occurrence of plant-development stages as illustrated by mountain brome at the 8,850-foot elevation. Two important stages, "flower stalks in evidence" and "seeds ripe," have been used for purposes of illustration; "flower stalks in evidence" is a developmental stage useful in determining range readiness; "seed ripe" is a useful criterion for determining the date when deferred grazing may begin. The date of appearance of flower stalks is, on the average, nearly 33 days and the ripening of seeds nearly 99 days later than the date when snow disappears in the spring.

A few exceptions to the general relationship between snow melt and subsequent plant development may be noted in figure 4. The 1925 growing season, for example, began earlier than normal but ended later than normal. This marked divergence from the usual trend was due, in part, to above-normal rainfall received during the latter

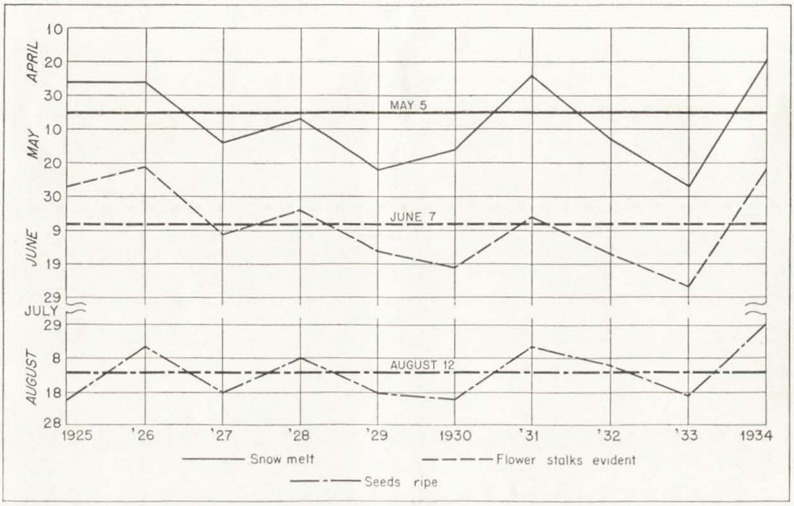

FIGURE 4.—Dates of snow melt and subsequent developmental stages of mountain brome, 1925–34, elevation 8,850 feet. The straight line denotes the 10-year average.

growth stage. High temperatures during the late growing season of 1932 resulted in the growth stage "seeds ripe" being slightly ahead of normal even though the dates of snow melt and active growth were below. In the main, however, the relationship of snow melt to growth stages is sufficiently uniform to emphasize the value of judging later plant development.

The association between the date when winter snow disappears and the date when subsequent developmental stages of grasses and weeds occur may be expressed by correlation coefficients presented in table 14. These correlation coefficients are, in most instances, based on 10 pairs of observations, although occasionally only a 9-year record was available. Although the number of samples is small, the fact that the coefficients are all positive and the odds in nearly all cases are less than 1 in 20 that they are due to chance indicates that the relation is real. Correlation coefficients, calculated for stages other than those given in table 14, show the same relation.

TABLE 14.—*Correlation coefficients expressing the relation between the date of snow disappearance and each of the 3 subsequent growth stages of important forage grasses and weeds*

Species and elevation (feet)	Flower stalks or buds evident	Flowers in bloom	Seed ripe
Slender wheatgrass:			
8,450	[1] +0.722		
8,850	+.791	[2] (+0.580)	[2] +0.815
9,000	+.718	+.792	+.838
10,100	+.883	+.691	[2] +.666
Mountain brome:			
8,850	+.886	+.688	+.820
9,000	+.787	+.919	+.786
10,100 [2]	+.824	+.889	+.868
Letterman needlegrass:			
8,450 [2]	+.690	+.844	(+.615)
9,000	+.840	+.907	+.667
10,100	+.714	+.865	+.832
Western yarrow:			
8,450	+.897	+.765	+.869
9,000 [2]	+.936	+.780	(+.627)
10,100	(+.620)	[2] (+.184)	(+.354)
Sticky geranium:			
7,655	+.792	+.668	+.639
8,850	+.841	+.828	+.638
9,000	[2] +.918	[2] +.650	
10,100	+.859	+.706	+.635
Rydberg pentstemon:			
9,000	+.916	+.760	+.764
10,100	+.963	[2] +.742	[1] +.667
Niggerhead:			
8,850	(+.496)	+.636	+.763
9,000	+.743	+.705	+.744

[1] 8-year record.
[2] 9-year record; parenthesis indicates correlation not significant. Level of significance for $p=0.05$; $n=10$, $r=0.632$; for $n=9$, $r=0.666$; for $n=8$, $r=0.707$.

For the browse species a positive correlation also exists between the date of snow disappearance and the dates at which developmental stages are reached. The correlation coefficient showing this relation with respect to the date when flower buds are swelling is +0.694 for mountain snowberry at Headquarters (8,850 feet) station (the significant value in this case for odds of 1 in 20 that the correlation may be due to chance is 0.602). Common serviceberry shows higher correlations for the same stage of development, +0.824 and +0.868 for Wiregrass (7,655 feet) and Snowberry (8,450 feet) stations, respectively.

FORECASTING RANGE-PLANT DEVELOPMENT FROM DATE OF SNOW MELT

By the use of the original data on which the correlations shown in table 14 are based, mathematical expressions of the snow melt-plant development relationships (regression equations)[4] were determined, as in figure 5 (*4*, *16*). These equations give the mean date of each developmental stage at any date of snow disappearance.

From figure 5 the regression functions appeared to be linear and hence straight-line regressions were fitted. By the use of the regression charts (fig. 5) developed from the regression equations, reliable forecasts of range-plant development may be made.

[4] On the basis of a high relationship existing between two factors, if one factor is known the other may be calculated within a high degree of accuracy. That is, because of the high relationship that exists between the date of snow disappearance on mountain ranges and the subsequent development of mountain-range forage plants, and on the basis of past records, if the date of snow disappearance is known the average date of any subsequent developmental stage of the plants can be calculated.

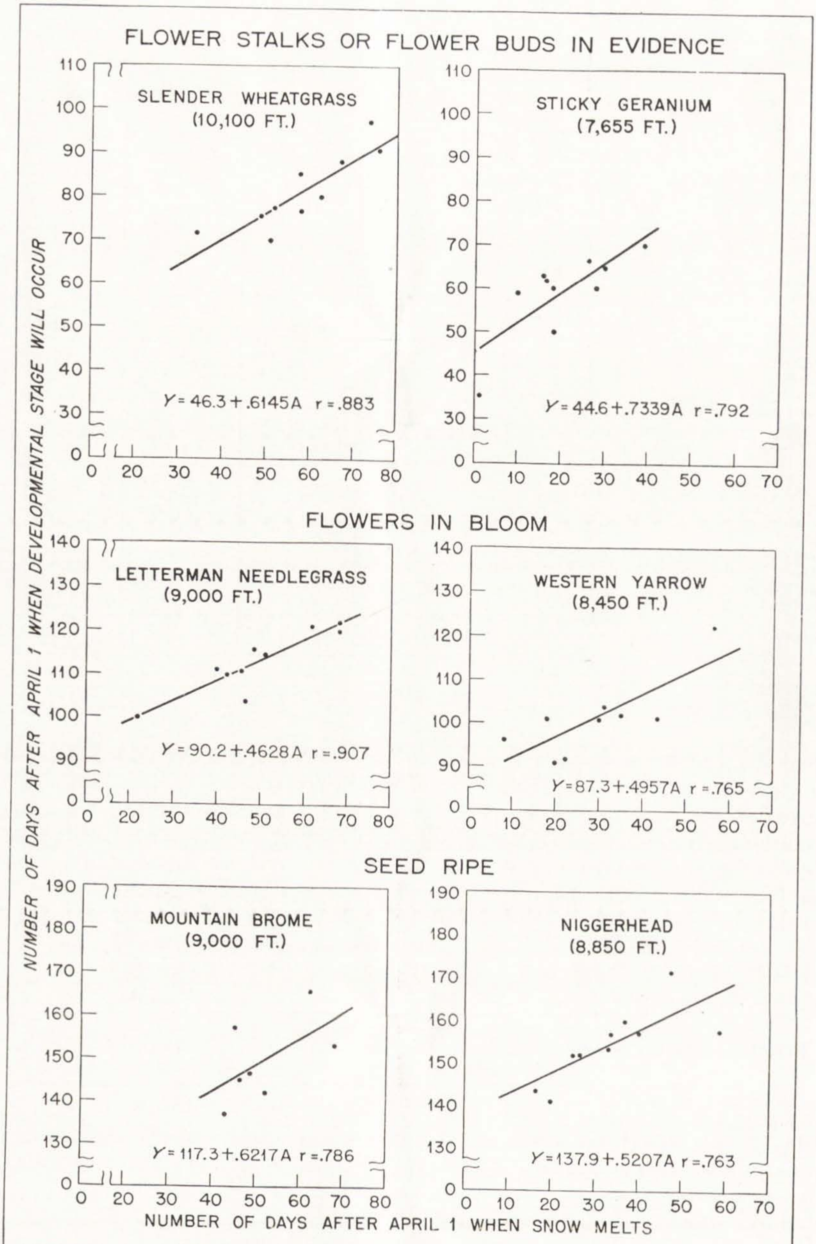

FIGURE 5.—Relationship between the date of snow melt and the dates of occurrence of phenological stages of various forage plants as shown by regression charts. The regression lines show the average relationship. Dots indicate the actual observations noted during the past 10 years. The equations are the equations of the regression lines. When a vertical line is drawn to the regression line from the date of snow melt in terms of the number of days after April 1 on the X axis, a horizontal line from this point will mark on the Y axis the average date when the developmental stage will occur.

TABLE 15.—*Deviations of predicted dates and of 10-year-average dates from actual recorded dates of plant-development stages, 1935 growing season*

Species and station	Date snow disappeared	Date flower stalk evident, actual and predicted		Deviation of—		Date flowers in bloom, actual and predicted		Deviation of—		Date seed ripe, actual and predicted		Deviation of—	
		Actual	Predicted	Regression	10-year average	Actual	Predicted	Regression	10-year average	Actual	Predicted	Regression	10-year average
				Days	*Days*			*Days*	*Days*			*Days*	*Days*
Slender wheatgrass:													
Headquarters	May 22	June 22	June 19	3	13	July 29	July 23	6	10	Sept. 2	Aug. 31	2	8
Bluebell	June 3	June 29	June 28	1	8	do	July 24	5	2	Sept. 12	Sept. 13	1	9
Alpine	June 14	July 1	July 1	0	10	Aug. 5	July 31	5	9	Sept. 15	do	2	10
Mountain brome:													
Headquarters	May 27	June 19	June 23	4	12	July 21	July 21	0	7	Aug. 13	Aug. 21	8	1
Bluebell	June 5	June 29	June 29	0	10	July 28	Aug. 4	7	3	Aug. 31	Sept. 5	5	5
Alpine	June 12	June 30	do	1	8	do	July 27	1	1	Sept. 15	Sept. 16	1	10
Letterman needlegrass:													
Wiregrass [1]	Apr. 17									Aug. 5	Aug. 3	2	3
Snowberry	May 14	June 19	June 10	9	16	July 10	July 11	1	4	do	Aug. 9	4	1
Bluebell	June 3	June 27	June 29	2	8	July 27	July 27	0	6	Aug. 20	Aug. 31	11	3
Alpine	June 6	do	June 27	0	6	do	Aug. 1	5	2	Aug. 22	Sept. 7	16	6
Sticky geranium:													
Wiregrass	Apr. 30	May 30	June 5	6	1	June 29	July 3	4	3	Aug. 3	Aug. 7	4	8
Headquarters	May 22	June 10	June 21	11	5	July 2	July 12	10	4	Aug. 5	Aug. 12	7	0
Bluebell [1]	June 3	June 20	June 24	4	7	July 15	July 16	1	5				
Alpine	June 13	June 23	July 3	10	4	July 18	July 27	9	2	Aug. 26	Sept. 7	12	1
Western yarrow:													
Snowberry	May 8	June 15	June 15	0	9	July 15	July 15	0	5	Sept. 5	Sept. 11	6	1
Bluebell	June 3					July 23	July 22	1	8	Sept. 12	Sept. 19	7	4
Alpine [1]	June 7	July 8	June 29	9	13								
Pentstemon:													
Bluebell	June 3	June 25	do	4	8	July 15	July 18	3	2	Sept. 10	Sept. 17	7	5
Alpine	June 5	June 29	June 30	1	8	July 17	July 22	5	1	Sept. 13	do	4	2
Niggerhead:													
Headquarters [1]	May 21									Sept. 10	Sept. 11	1	8
Bluebell	June 3	June 20	June 30	10	1	Aug. 5	Aug. 10	5	3	Sept. 15	Sept. 16	1	7

[1] Past records not sufficient to make prediction in all stages.

To show the accuracy of this method of forecast, the following example is cited: At Snowberry station (elevation 8,450 feet) snow disappeared in 1935 on May 14. On the basis of the determined regression equation for Letterman needlegrass at that station it was calculated that flowers would bloom for that species on July 11. Observers in the field recorded the actual date as July 10.

To check the reliability of the regression method of forecasting future development of mountain range plants from the date of snow melt, phenological observations were continued in Ephriam Canyon during the 1935 field season. When snow disappeared at each plant-development station, the dates of developmental stages of various forage plants were predicted, and throughout the growing season the actual dates of appearance of the predicted developmental stages were recorded. Deviations of the predicted dates from the actual dates recorded are shown in table 15 The majority of estimates based on the regression method approached the actual recorded dates much more closely than estimates based upon the 10-year average, except in the case of sticky geranium, which has the greatest variability of the plants observed.

As a further test of the reliability of such a forecast, approximately 50 locations at the head of Ephriam Canyon were staked before the beginning of the 1935 growing season. These were scattered over an area 2½ miles long and one-fourth to one-half of a mile wide, within altitudinal limits of 9,000 and 10,000 feet. Date of snow disappearance was recorded for each location. When plants that appeared at each station were large enough to be identified by their vegetative characters, a forecast was made as to the date when various developmental stages would occur. Most of these forecasts were based on regression equations obtained from the Alpine station, since the majority of these areas approximated that degree of slope, exposure, and elevation. Deviations of the predicted dates from actual dates, given in table 16, show that the dates based on the regression method of forecasting agreed favorably with the actual dates recorded.

TABLE 16.—*Average deviations of predicted dates from actual dates for developmental stages of important forage plants, Ephriam Canyon, 1935*

Species	Flower stalks or buds in evidence	Flowers in bloom	Seeds ripe	Species	Flower stalks or buds in evidence	Flowers in bloom	Seeds ripe
	Days	*Days*	*Days*		*Days*	*Days*	*Days*
Slender wheatgrass	0	8	1	Western yarrow	2	2	4
Mountain brome	2	3	7	Sticky geranium	4	10	5
Letterman needlegrass	1	5	2	Pentstemon	8	4	10

Even in "early" or "late" years, developmental stages of forage plants were predicted by the regression method from 3 weeks to more than 3 months in advance with reasonable accuracy.[5] Moreover, developmental stages during the latter part of the growing season were predicted with nearly the same accuracy as were the earlier stages. During the early growth period, extremes in weather fluctuations may cause a deviation, but as the season advances this digression tends to

[5] Standard error, 3 to 8 days.

be compensated by opposite extremes. Thus, the regression method may be considered a practical one for forecasting range-plant development.

DETERMINATION OF GRAZING PERIODS

IMPORTANCE OF PROPER DEVELOPMENT OF KEY FORAGE SPECIES

As demonstrated by the developmental data each individual species of mountain range forage plants has its own peculiar rate of growth and development. This rate of development varies rather widely both within and between each class of vegetation; the greatest variation occurring between the developmental stages of weeds and browse. Moreover, each developmental stage of each vegetation class has its own specific rate of development; the early stages of growth are completed in more rapid order than the later stages. It is therefore necessary not only for practical purposes of grazing management but also for assurance of sustained forage production in future years to base the determination of grazing periods of mountain ranges on the growth and development of the more important key forage species. Inasmuch as the perennial grasses are more stable and superior as forage plants (*13*), are better watershed covers (*2, 5, 10*) and generally furnish the bulk of the feed for livestock on mountain ranges, grazing periods, in the main, should be based on the growth and development of the important more palatable grass species.

The key forage grasses in Ephraim Canyon are Letterman needlegrass, mountain brome, and slender wheatgrass; Letterman needlegrass being more common in the oak-brush zone and mountain brome and slender wheatgrass in the aspen-fir and spruce-fir zones respectively. When the majority of plants of these grasses are 6 to 8 inches high, flower stalks are evident in the two lower zones, and flower heads showing in the upper zone, the associated weed and browse species either because of greater development, lower palatability, or of limited occurrence may also be grazed.

As indicated from the tables of average growth and development of plants (tables 4, 5, and 6), the opening of the grazing season in Ephraim Canyon should be 10 to 14 days later for each 1,000-foot increase in elevation. This average rate varies for each vegetation zone, depending on the rate of development of the key forage grasses, being approximately 10 days for the oak-brush, 14 days for the aspen-fir, and 12 days for the spruce-fir zones. Also, shaded north-facing slopes, especially in the aspen-fir zone, frequently require an additional 10 days to reach similar development of the zone as a whole. In general, however, the rates are in line with the estimate of Sampson and Malmsten (*13*) of 18 days for north exposures, 11 days for south exposures with an average of 14 days per 1,000 feet for the Wasatch Mountains, and J. L. Peterson's [6] estimate of 10 to 14 days for Washington and Oregon contained in an unpublished report. In another unpublished report,[7] Arnold R. Standing gives approximately 10 days per 1,000 feet on the average for the Intermountain region.

The practical application of this knowledge requires adequate control and seasonal distribution of livestock, so as to adjust grazing use to correspond to the proper development of the forage plants within the elevational zones. Too often cattle are permitted to drift to the

[6] Forest Service files.

[7] Covering the national forests of southern Idaho, southwestern Wyoming, Utah, and Nevada.

higher ranges before the forage plants are ready for grazing, causing severe damage to the plant cover. Drift fences to protect elevational ranges from livestock until the forage plants are ready for grazing are useful in preventing cattle from drifting to the higher ranges in the spring. Effective distribution within the vegetational zones, however, requires the placement of salt so as to protect north-facing slopes until they are ready for grazing and to draw cattle from parts of the range where they naturally congregate to those ordinarily less used. Riding to place cattle at new salting places and later to see that they do not excessively concentrate is equally important. Such livestock-management practices, now in rather general use, have been discussed by

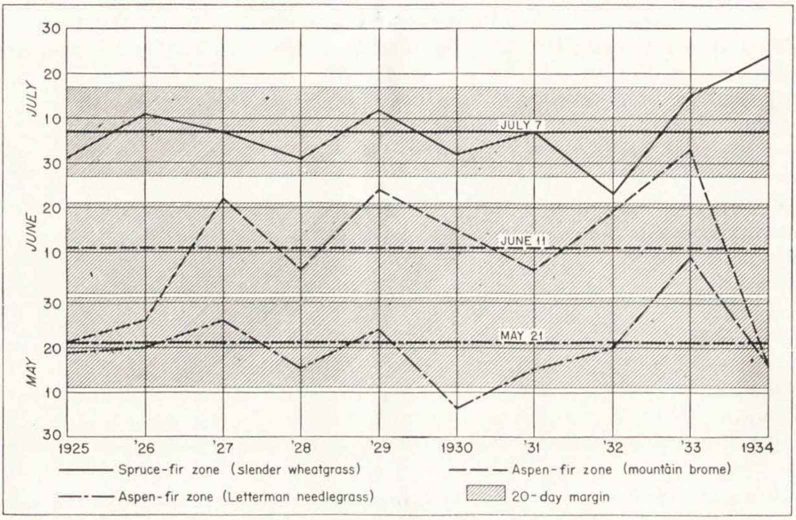

FIGURE 6.—Fluctuation of date of range readiness in three vegetation zones in Ephraim Canyon, Utah, as demonstrated by development of three key forage grasses, 1925–34.

Chapline and Talbot (*1*), Sampson and Malmsten (*13*), Jardine and Anderson (*8*), and others.

Sheep, since they are ordinarily under herd, can more readily be held within vegetational zones during periods when the feed can most effectively be grazed.

Because of the need in livestock-grazing operations for some dependable criteria on which to base the start of grazing periods and to make partial adjustment for the yearly variation in range-plant development, the average date of range readiness has been used as a guide to the opening of the grazing season on many national-forest ranges. Sampson and Malmsten (*13*) on the basis of their study set the average opening dates for the three vegetative zones in Ephraim Canyon as: oak-brush, May 20; aspen-fir, June 10; and spruce-fir, July 10. The results of the present more extended study show the average dates of range readiness for the three vegetative zones, based on the key grass species, to be: oak-brush, May 21; aspen-fir, June 11; and spruce-fir, July 7 (fig. 6), thus closely approximating the earlier findings.

Opening the various elevational ranges to grazing on the average dates of range readiness would have resulted in premature grazing in a number of years. The actual date of range readiness was later than average 3 out of the 10 years in the oak-brush zone; 5 out of 10 in the aspen-fir, and 4 out of 10 in the spruce-fir zone; the delay being more than 15 days later than average in 1 year in all zones (fig. 6). On the other hand, range readiness was markedly earlier than average in an equal number of years in each zone, and in the aspen-fir zone range readiness was reached more than 15 days earlier than average in 3 of the 10 years.

Premature, or too early, grazing not only damages the important forage plants, resulting in a reduction of the grazing capacity of the range (*8*), but also impairs watershed values (*5*), and this, if allowed to continue, will undermine the permanent welfare of the communities or individuals depending upon the range resource. Thus, to prevent the infliction of permanent injury to the important forage plants by premature grazing in late years as well as to permit the utilization of the feed produced in early years, it is advisable to vary the opening of the the grazing periods on mountain ranges from year to year in accordance with the yearly development of the forage plants. However, the benefits of applying this system can be obtained only when proper numbers of livestock are grazed on the range.

PREDICTING OPENING OF GRAZING PERIODS FROM DATE OF SNOW MELT

The date of disappearance of winter snow from the mountain side, which frees the forage plants and allows them to start active growth, offers a practical basis for varying the opening of grazing periods on mountain ranges. This date can be considered a reliable base in similar regions characterized by a permanent winter snow cover and a definite summer growing season. On the basis of the high relationship between the date of snow melt and the subsequent seasonal growth and development of the mountain-range plants as described in the preceding sections, practical predictions of range-plant development can be made.

By the snow-melt, plant-development regression method, the date of range readiness of the key forage plants common to the various mountain vegetative zones can be forecast when the permanent winter snow disappears from the zones, and there is then ample time (an average of 33 days in oak-brush, 36 days in aspen-fir, and 42 days in the spruce-fir zones) for both the livestock operator and range administrator to lay definite plans, or make any adjustments in previously made plans, for the approaching grazing season. Moreover, late stages of plant development, such as seed maturity, can also be forecast with accuracy at the date of snow melt, thereby enabling the range administrator, before the grazing season opens, to set up grazing periods for the entire grazing season, including dates for deferred grazing.

Varying the opening of the grazing season to meet actual range readiness from year to year by the snow-melt, plant-development relationship, however, will make it necessary for the livestock operator to reserve a minimum of 5 to 10 days supply of feed each year, over and above the amount necessary to feed the livestock to the average date of range readiness. This surplus will serve as insurance for the satisfactory condition of the livestock in late years, when, if they entered the range on the "average date of range readiness," they would be short of feed. Feed saved by admitting livestock on the range ahead of the average opening date in early years can be held over and will compensate for the reserve feed necessary in late years.

In the oak-brush and spruce-fir zones the actual dates of range readiness fell within 5 days of the average date in all 10 years of the study except one—the abnormally late year of 1933. The key grasses in the spruce-fir zone in 1934 did not reach normal range-readiness height until a later date, but they were sufficiently developed otherwise, within the 5-day margin. In the aspen-fir zone, the date of range readiness fell within 10 days of the average date of range readiness in all years except two, 1929 and 1933; the year 1929 being only a day or so later. The damage due to a few days early grazing in 1 year out of 10, providing the soil is not so wet as to cause severe trampling and uprooting of the plants by livestock, will not be marked and will be amply compensated by protection in the other years.

Use of the snow-melt-forecast method is also predicated on the availability of plant-development records for the key forage plants on the range. Many national forests have and now maintain such records. These should be continued and analyzed by the regression method for the purpose of forecasting range-plant development. Only the dates of snow melt and of those developmental stages of the plants by which grazing use is regulated need be noted, such as the stages indicating range readiness, time to defer grazing, and the end of the grazing periods. A 10-year record of such data providing they are truly representative and valid will afford reasonably accurate predictions and even fewer may serve. Accurate plant-development records taken on representative vegetational zonal ranges of a national forest will offer a basis for forecasts of forage development for similar zones for the entire forest, even though there may be local changes in topography, vegetation, and climate throughout the forest.

Where it is not practical from the livestock operator's standpoint to vary the opening of the grazing periods from year to year, it will be necessary to establish grazing dates sufficiently late to prevent premature grazing. This necessitates delaying the grazing season on mountain ranges beyond the average date of range readiness. Conservative opening dates, or dates when the important forage plants will actually reach range readiness in most years, for the three vegetative zones in Ephraim Canyon and similar mountain range types are oak-brush zone, May 26; aspen-fir zone, June 21; and spruce-fir zone, July 13. These are 5 days later than the average date of range readiness in the oak-brush and spruce-fir zones, and 10 days later than average in the aspen-fir zone.

Where the three vegetative zones constitute one summer grazing allotment, as is usually the case on most intermountain national-forest ranges, the variation of the date of range readiness in the middle and upper zones, once livestock are admitted to the lower zonal range, may be adjusted by varying the length of the grazing period in the low range. Handling and distribution of livestock to correspond to proper seasonal forage development within a range unit as well as the time for the close of the grazing season in the fall have been discussed by Jardine and Anderson (*8*) and Sampson and Malmsten (*13*). Where the zones are used separately, the opening dates outlined in the preceding paragraph should be adhered to unless weather and plant development records dictate otherwise.

SUMMARY AND RECOMMENDATIONS

To determine proper opening grazing periods of mountain ranges it is important to know (1) the normal growth and development of the principal forage plants at different altitudinal zones, (2) the fluctuation in seasonal growth and development of the plants from year to year, and (3) knowledge of the more readily measured climatic factors related to the growth and development of the plants. Observations and measurements of weather and range plant development in Ephraim Canyon, Utah, by the Great Basin branch of the Intermountain Forest and Range Experiment Station during the 10-year period 1925–34 furnish information on these problems.

The vegetation in Ephraim Canyon within the elevational limits of the study is of three major types or zones: Oak-brush, 6,500 to 8,000 feet; aspen-fir, 7,500 to 9,000 feet; and the spruce-fir, 9,000 feet and above.

Temperature and precipitation vary between zones, average monthly temperatures being 42.6°, 38.0°, and 32.5° F. in the lower, middle, and upper zones respectively. Average annual precipitation for the same zones are 17.51, 29.48 and 28.01 inches.

The average length of the growing season for different elevations in Ephraim Canyon are 7,000 feet, 175 days; 8,000 feet, 160 days; 9,000 feet, 145 days; 10,000 feet, 125 days.

It is notable that each individual species of mountain range forage plants has its own specific rate of growth and development; the rate varying both within and between each class of vegetation. The greatest variation occurs between weeds and browse species. Moreover, each developmental stage of each vegetation class has a specific rate of development, earlier growth stages develop more rapidly than later stages.

The rate of development varies with altitude, being delayed from 10 to 14 days for each 1,000-foot increase in elevation. Height growth at any particular date decreases with increase in elevation largely due to higher average temperatures at the lower altitudes. However, growth is more rapid at higher than at lower elevations, once it starts, owing to more even and favorable temperatures during the early growth stages. On the other hand, a longer period of time is required to reach seeds ripe at the higher than at the lower elevations due in part to lower average temperatures and in part to increased seasonal rainfall during the period of development at the higher elevations.

Marked variation also occurs in the rate of growth and development of the plants from year to year. The start of active growth of grasses from one year to the next, for example, has varied as much as 45 days. Likewise, the date when the key grasses reach range readiness—when they are 6 to 8 inches—varied as much as 47 days from one year to the next in the aspen fir zone. Similar variations occurred for other classes of vegetation and for all stages of development. Such variations are different for each zone; being greater in the lower zones.

Temperature influence is evident during all stages of plant development but especially apparent during the early stages of growth, extending to the time flowers are in bloom. Temperatures higher than average are associated with periods of development that are shorter than average and vice versa.

During the later growth stages, precipitation, soil moisture, and evaporation assume importance, and may become limiting factors. Fewer days are required for seed ripening when rainfall is low, and a longer period when rainfall is excessive and evenly distributed.

Start of active growth in the spring follows immediately after the date of snow melt. When snow melts early, the active growing season is early and vice versa. Moreover, the progress of the entire growing season was found to be related closely to the date of snow melt. Seasons which begin early, late, or normal, depending upon the date of snow melt, tend to remain so throughout the growing period.

Variation in the depth of snow accumulation at different altitudes may result in an early season at one elevation and a late season at another. The degree of delay in vegetation development caused by increased altitude is governed, to a considerable extent, by the rate of disappearance of snow from the mountain side.

On the basis of the significant snow-melt, plant-development relationship within the vegetational zones, practical forecasts of range-plant development were made. Developmental stages of important forage plants were predicted with reasonable accuracy from a few days to more than 3 months in advance from the date of snow melt. The method of forecasting was checked in the field during 1935 and the predicted dates of development agreed favorably with the actual dates recorded.

From these results the following guides to the establishment of opening grazing periods of the Wasatch Mountain ranges in central Utah and similar mountain ranges are obtained, contingent upon proper stocking:

Owing to the sporadic rate of growth and development of mountain-range plants it is necessary, not only for practical purposes of grazing management but also to perpetuate the more important palatable forage plants, to base the determinations of grazing periods on the growth and development of the important key forage species. Inasmuch as perennial grasses are more stable and are superior as forage plants, are better watershed covers, and generally furnish the bulk of the feed for livestock, the grazing periods should in the main be based on the growth and development of the important palatable forage grasses. The key forage grasses in Ephraim Canyon are Letterman needlegrass, mountain brome, and slender wheatgrass. When the majority of these grass plants have reached range readiness, the associated weed and browse species, either because of greater development, lower palatability, or limited occurrence, may also be grazed.

Based on the development of the key forage grasses, the opening of the grazing season in Ephraim Canyon should be on the average 10 to 14 days later for each 1,000-foot increase in elevation. This rate varies for each vegetation zone, or approximately 10 days for the oakbrush, 14 days for the aspen-fir, and 12 days for the spruce-fir zones. Shaded north-facing slopes, especially in the aspen-fir zone, frequently are delayed an additional 10 days. This knowledge makes it necessary to control properly the distribution of livestock so as to protect each elevational range and north-facing slopes within a given elevational zone until the key forage plants have actually reached range readiness. Drift fences are valuable aids in regulating seasonal distribution of livestock. Other practices include herding and the use of an adequate salting plan.

Opening grazing periods should correspond to the yearly development of the key forage plants so as to prevent too early or premature grazing. To admit livestock on the range at the average date of range readiness would have resulted in too early grazing 3 out of 10 years in the oak-brush zone; 5 out of 10 in the aspen-fir, and 4 out of 10 in the spruce-fir zones. Also, the range would have been ready for grazing in an equal number of years prior to the average date of range readiness; amounting to as much as 15 days early in the aspen-fir zone. Thus, in order to utilize the feed in "early" years and to avoid a shortage of feed and prevent permanent damage to the range in "late" years it is advisable to vary the opening of the grazing periods to correspond to the yearly development of the important forage plants. The snow-melt, plant-development relationship described herein offers a practical basis for determining the opening grazing date, the time of snow melt being a reliable base for the prediction of future range-plant development in similar regions characterized by a permanent winter snow cover and a definite summer growing season.

Where it may not be practical to vary the opening date of the grazing season each year, it is necessary to establish grazing dates sufficiently late to prevent premature grazing in many years. This necessitates opening the grazing season on mountain ranges later than the customary average date of range readiness. Conservative opening dates, or dates when the important forage plants will actually reach range readiness in most years, for the three vegetative zones in Ephraim Canyon and similar mountain range types are: Oak-brush, May 26; aspen-fir, June 21; and spruce-fir, July 13, amounting to a delay of 5 days after the average date of range readiness for the oak-brush and spruce-fir zones and 10 days for the aspen-fir zone. Where the three zones constitute one grazing allotment, variation in the date of range readiness in the upper zones may be met by varying the date of grazing in the lower zones. Where the zones are grazed separately, the opening dates outlined herein should be adhered to unless weather and plant-development records dictate otherwise.

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