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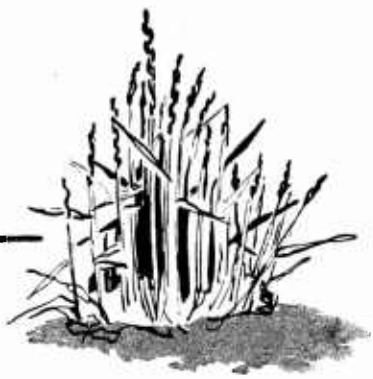
Rangeland Improvement through Seeding and Weed Control on East Slope Sierra Nevada and on Southern Cascade Mountains



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Dr. Cornelius was transferred from the staff of the California Forest and Range Experiment Station to the Agricultural Research Service in 1954.

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Rangeland Improvement Through Seeding and Weed Control on East Slope Sierra Nevada and on Southern Cascade Mountains

By DONALD R. CORNELIUS, *range conservationist*, Agricultural Research Service, and M. W. TALBOT, *associate director*, California Forest and Range Experiment Station,[1] Forest Service

INTRODUCTION

Eight years of research in the plateau region of northeastern California (fig. 1) have shown that seeding and weed control are practical means of quickly restoring productivity and reducing erosion on deteriorated rangelands. These practices are especially applicable where recovery cannot be expected within a reasonable time from improved grazing management alone, that is, where the original perennial grasses have been killed and replaced by undesirable species. This handbook summarizes results and experience indicating how seeding and weed control can be accomplished in this area.

Potentially productive areas on which these improvement practices are needed and are currently feasible amount to at least half a million acres in the plateau region of California. Increasing the productivity of this rangeland would materially benefit the livestock industry and the general economy of the region. The increased forage could also relieve grazing pressure on adjacent ranges and assist in their improvement through grazing management. Soil stabilization, watershed improvement, and increased game forage are other possible benefits from such range improvement practices.

The part of northeastern California to which this report applies most directly has a gross area of about 13 million acres. The findings may also apply to similar ranges in adjacent portions of Oregon and Nevada. Slightly more than one-half of this land in California is in national-forest, grazing-district, and Indian lands. The remainder is privately owned.

Northeastern California is a volcanic plateau ranging in altitude from 3,000 to 8,000 feet. Volcanic and granitic formations are intermixed in the southern fourth of this region. Scattered over the plateau are numerous low buttes and mountains formed from old volcanic cones, but few peaks exceed 7,500 feet in altitude. Abrupt lava rim rocks are common. Over much of the area the terrain is flat or rolling. Large plains and valleys occur throughout the central and eastern parts of the plateau at elevations below 6,000 feet. Smaller flat open-

[1] Maintained at Berkeley, Calif., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California.

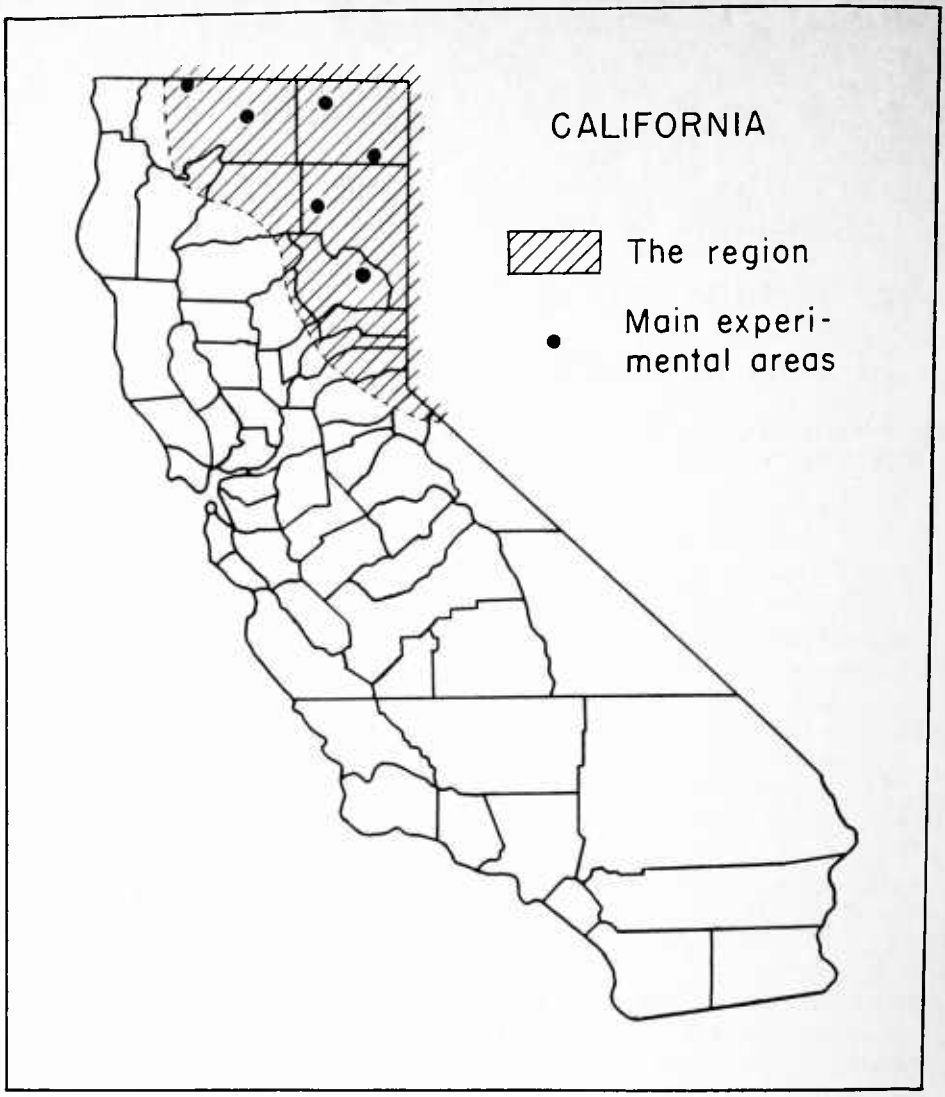

Figure 1.—Plateau region and main experimental areas.

ings are interspersed among the timbered mountains at higher elevations.

The plateau has a semiarid climate with wet winters and springs and dry summers. Precipitation averages about 20 inches a year, but ranges from 10 inches in the lowlands to 40 inches in the higher mountains. Blacks Mountain Experimental Forest in Lassen County is fairly representative of average conditions. At its headquarters only 6 percent of the annual precipitation fell during July, August, and September in the period 1945–53 (table 1). Winter snow and spring rains accounted for about two-thirds of the yearly precipitation. The winters are cold, the summers relatively hot, with maximum temperatures of 90° to 95° F. and relative humidity generally low, occasionally dropping to 10 percent or less. Because of the dry sum-

TABLE 1.—*Monthly precipitation, Blacks Mountain Experimental Forest Headquarters, Lassen County, 1945–53*

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Total
1945–46	0. 03	3. 19	2. 15	2. 67	1. 49	2. 24	1. 91	-------	0. 81	0. 30	0. 63	-------	15. 42
1946–47	. 60	. 57	2. 81	. 80	. 60	. 98	2. 17	1. 85	1. 39	. 76	-------	0. 65	13. 18
1947–48	. 08	3. 15	1. 44	. 55	1. 63	1. 07	5. 07	3. 77	4. 66	2. 39	-------	. 14	23. 95
1948–49	. 38	1. 11	1. 33	2. 67	1. 38	1. 89	3. 10	. 91	2. 26	. 16	. 01	1. 17	16. 37
1949–50	. 47	. 21	1. 45	. 69	4. 17	1. 83	3. 26	1. 99	1. 80	1. 41	-------	-------	17. 28
1950–51	1. 33	2. 49	2. 53	2. 71	3. 36	3. 13	. 55	1. 59	. 52	. 50	-------	. 59	19. 30
1951–52	. 37	2. 06	1. 89	5. 86	6. 65	2. 57	2. 37	. 70	. 63	1. 24	. 52	-------	24. 86
1952–53	1. 67	. 14	2. 02	4. 52	3. 15	. 34	2. 81	1. 45	3. 06	. 72	-------	. 08	19. 96
8-year mean, 1945–53	. 62	1. 62	1. 95	2. 56	2. 80	1. 76	2. 66	1. 53	1. 89	. 94	. 14	. 33	18. 79
18-year mean, 1935–53	. 50	1. 31	1. 81	2. 53	2. 53	2. 71	2. 39	1. 36	1. 49	1. 05	. 24	. 24	18. 16

mer, successful range seeding requires different methods than are used in many other parts of the West.

Grazing and timber production are the two main land uses. The plant cover consists of timbered areas intermingled with open areas of mixed sagebrush and grassland. The pine timber grows in fairly open stands which afford appreciable grazing, and practically all of the sagebrush and grassland areas are grazed. After logging or forest fire, dense pine stands produce higher forage yields until timber reproduction or coarse brush reoccupy the land. Only dense fir stands, patches of dense timber of other types, or small areas of steep, rocky land are of no forage value. Perhaps 80 percent of the total area is grazed by cattle or sheep. Deer graze much of the same area, as well as land too rough for domestic livestock.

The plateau region is an important source of green feed during the summer when forage is dry on most range areas of the State. Forage growth is active mainly from March or April to July. The main summer grazing zone lies between 5,500 and 8,000 feet elevation. Spring grazing occurs between 3,500 and 5,500 feet.

The experimental work reported here was done in 1945 to 1953. The range plant nursery (fig. 2) and a major part of the field plots were on the Lassen National Forest at an elevation of 5,600 feet. Pilot field seeding of forage plants to improve range land was started in 1946, cooperatively by the administrative and research branches of

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Figure 2.—Range plant nursery for preliminary testing for adaptation, Halls Flat, Lassen National Forest.

the Forest Service in California. These pilot fields varied from 50 to 100 acres in size. Small research plots were established along with the pilot fields to test adaptation of grasses, legumes, and a few browse plants on 7 national forests in 6 different counties of northeastern California.

In this area range condition varies from excellent or good in most timbered lands to poor in many mountain meadows and sagebrush flats where grazing animals concentrate. The field plots were established to obtain information on a wide variety of planting sites comprising a total of 10 types of range: Big sagebrush, black sagebrush, silver sagebrush, cheatgrass, tarweed, weedy meadow, rush-sedge, pine understory, aspen understory, and fir-forest openings. Somewhat different methods and species were found to be suitable for the various rangeland types.

IMPROVING SAGEBRUSH RANGE

Sagebrush types occupy about 5 million acres in northeastern California alone. They offer the best opportunity for increasing range production throughout the plateau region. For many years sagebrush has been encroaching on areas formerly dominated by grasses. Open-range livestock grazing weakened the grass stands, and the relatively unpalatable and aggressive sagebrush thickened over extensive areas where it once composed only a minor part of the range vegetation. Today, good possibilities of improving forage production exist on three rather distinct types: Big sagebrush, black sagebrush, and silver sagebrush (fig. 3). All three occur in northern California and adjoining States.

Big sagebrush is mostly associated with deep well-drained soils, a condition usually found on the slopes and knolls. It is most abundant and attains its largest size in a broad irregular zone between the low salty deserts and the high mountain slopes—an extensive zone of great importance to the grazing industry of the West. This zone is generally at elevations of 3,500 to 7,500 feet.

The black sagebrush type, although smaller in acreage than the big sagebrush type, occurs widely throughout the same zone. Occurrence of black sagebrush usually indicates shallow soil underlain by bedrock, claypan, or a cemented layer of iron oxide, at a depth ranging from a few to 20 or 30 inches. The boundaries of this soil type, and of the kind of vegetation characteristically associated with it, are usually abrupt.

The silver sagebrush type in general occurs in flat, saucerlike depressions where drainage is so poor that springtime flooding, sometimes for several weeks, may occur in all but the drought years. When the heavy clay soil dries in late summer, large cracks appear. A sharply defined type line commonly occurs at the margin of the flooded area. Immediately above this line, black sagebrush is usually the dominant species. Occurrence of silver sagebrush is determined more by soil and drainage than by elevation. For example, it occurs on some wet, cold slopes at elevations of 7,000 to 8,000 feet.

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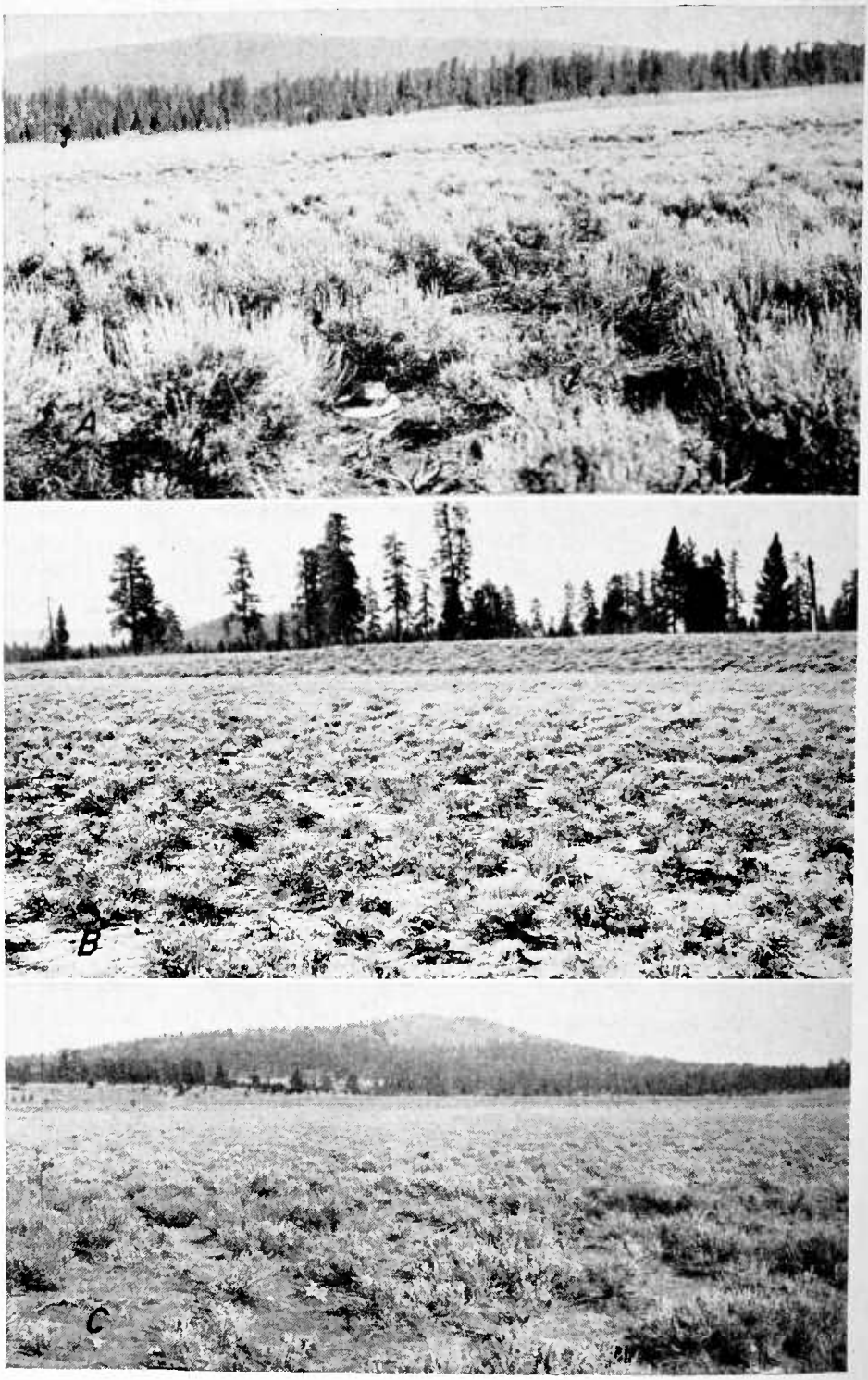

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Figure 3.—Sagebrush types in northeastern California: *A*, Big sagebrush, generally on deep well-drained soils; *B*, black sagebrush, usually on shallow soil where drainage is not o problem; *C*, silver sagebrush, on soil saturated or submerged for several weeks after snow melts.

Big Sagebrush Sites

Site Selection

Steepness of slope, erodibility of soil, occurrence of rocks, and amount of precipitation are the four principal factors to consider in selecting big sagebrush sites for seeding. Slopes greater than about 35 percent are too steep to work safely with tillage implements. Steep slopes with soils easily eroded by water should not be plowed. Loose, sandy soils are susceptible to wind erosion, and consequently recommendations for range improvement will depend upon the amount of plant cover that can be kept on the land or the promptness with which a new cover can be established. Rockiness and roughness of terrain may limit the work that can be done. An average of 9 inches of precipitation per year may be regarded as the minimum under which seeding can be considered practical with presently known techniques and with grasses now available.

Species Adaptation

Nine species of forage plants have been found adapted for seeding on the big sagebrush type. They include intermediate wheatgrass, pubescent wheatgrass, tall wheatgrass, crested wheatgrass,[2] Fairway crested wheatgrass, bluebunch wheatgrass, big bluegrass, Ladak alfalfa, and cicer milkvetch.

Both altitude and annual precipitation affected adaptation. At elevations of 3,500 to 5,000 feet and precipitation of 9 to 15 inches, bluebunch wheatgrass and crested wheatgrass have done best. Above 5,000 feet and where precipitation is more than 15 inches, Fairway crested, intermediate, pubescent, and tall wheatgrasses have proved to be well adapted. These four are less drought resistant than crested wheatgrass, but have produced well with 15 inches of precipitation. Tall wheatgrass does not mature seeds above 7,000 feet in elevation at this latitude; consequently, its persistence over a long period of years may be questioned, and it can be safely recommended for use only below 7,000 feet. Tall wheatgrass also proved well adapted to alkaline soil in flat, poorly drained areas at elevations of 3,000 to 5,500 feet.

Seasonal needs for grazing may influence the selection of a grass for seeding. Crested wheatgrass and Fairway crested wheatgrass provide early spring grazing but dry up 3 to 5 weeks earlier than intermediate, pubescent, or tall wheatgrass. Tall wheatgrass stays green the longest of these three. Leaves of pubescent wheatgrass dry about 10 days earlier than those of intermediate wheatgrass, but both remain green a few weeks longer than those of Fairway crested wheatgrass.

Big bluegrass produces most of its growth in the spring, the foliage remains green throughout the summer and, if cut off, the plant produces good regrowth. The Albion strain of big bluegrass has been

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[2] Refers to *Agropyron desertorum*, commonly called Standard crested wheatgrass, and also called desert wheatgrass in some recent publications. Fairway crested wheatgrass is used here as the common name of *A. cristatum*.

more productive than the Sherman strain at elevations above 5,000 feet, and responds better where night temperatures are characteristically cool (*4*).[3] The Sherman strain has been more widely grown but thrives better in localities where the nights are warmer.

Adapted grasses and legumes can extend the grazing season. Some extension may be attained by sowing grass mixtures, but a better plan would be to use early growing grasses in one grazing unit and later developing species in another unit. If sown in mixture, the different grasses may not be utilized at the best stage for highest yield and perpetuation of the plants.

How yields of different grasses may compare was shown by a range improvement experiment on the Shasta National Forest. This range area, at 4,500 feet elevation and with 13 inches average precipitation, is representative of a large acreage of the drier parts of the big sagebrush type. Perennial native bunchgrasses and sagebrush had been plowed out during early settlement days. But dry-land farming proved submarginal and cultivation was discontinued. Big sagebrush then reinvaded the area and became dominant. Cheatgrass and weedy forbs were common associated species, along with scattered plants of native bunchgrasses such as squirreltail.

The experiment began by plowing the land in the summer of 1945 and drilling seed of 12 forage species before the fall rains. Unfortunately, three desirable wheatgrasses—intermediate, pubescent, and tall wheatgrass—were not available for testing when the plots were seeded.

Crested wheatgrass gave a high and relatively consistent yield over the 7-year period (table 2). Big bluegrass produced the highest yield in the entire test in 1950, and had the highest average yield. However, it was erratic in production, and its yield in 1953 was about one-fourth of that in 1950. Bluebunch and beardless wheatgrasses gave fairly high and consistent yields until 1952, when the vigor of the plants was seriously reduced by snow mold disease. Slender wheatgrass produced the highest yield in 1948, but this relatively short-lived grass failed to reproduce, and its yield declined markedly after the fifth year.

Smooth brome became sodbound and declined in yield after the third year. For optimum yields smooth brome requires higher fertility and soil moisture than this site provided. No fertilizer was tried on this particular area, but a deficiency of nitrogen for best growth of smooth brome was definitely indicated by yellowish color and other symptoms. Density and number of plants of smooth brome did not decrease, but vigor and general productivity did after the fourth year.

Five other species started fairly well, but failed to maintain a stand through the test period. In 1948 their production of forage, in pounds per acre, was: Canada wildrye, 951; mountain brome, 704; orchardgrass, 553; burnet, 427; and Reed canarygrass, 411. The stands declined rapidly after 1948, and by 1953 were very thin. These species therefore are not recommended for use on big sagebrush sites.

While intermediate and tall wheatgrasses (fig. 4) were not included in this trial, results of two tests on the Lassen National Forest show

[3] Italic numbers in parentheses refer to Literature Cited, p. 45.

TABLE 2.—*Forage production of 7 seeded forage species and of the adjacent untreated range, Shasta National Forest, 1947–53* [1]

Species	Yield of forage, ovendry weight							
	1947	1948	1949	1950	1951	1952	1953	Average
	Lbs. per acre	*Lbs. per acre*	*Lbs. per acre*	*Lbs. per acre*	*Lbs. per acre*	*Lbs. per acre*	*Lbs. per acre*	*Lbs. per acre*
Big bluegrass	-----	687	1, 351	2, 596	2, 344	1, 130	595	1, 450
Bluebunch wheatgrass	1, 226	973	1, 039	1, 210	1, 097	-----	-----	1, 109
Beardless wheatgrass	-----	600	970	1, 509	1, 895	233	-----	1, 041
Slender wheatgrass	1, 039	1, 615	645	1, 352	500	-----	-----	1, 030
Crested wheatgrass	1, 446	1, 415	901	1, 020	802	681	759	1, 003
Smooth brome	897	1, 274	590	545	252	494	338	627
Western wheatgrass	-----	465	534	651	668	-----	621	588
Untreated range	126	135	95	127	296	127	-----	151

[1] Seeded in 1945.

the high yielding ability of these species, particularly at higher elevations with more favorable moisture conditions. Both tests were on depleted sagebrush range that had never been cultivated. Elevation was 5,600 feet, average annual precipitation 18 inches. One test, including plots on both big sagebrush and black sagebrush sites, compared 9 different grasses, sown in 1947 and harvested in 1949–53. Yields for the two sites, being closely similar, were averaged (table 3). The second test, in the big sagebrush only, compared 10 different grasses representing 6 species, sown in 1949 and harvested in 1951–53 (table 4).

In both tests, intermediate wheatgrass and tall wheatgrass gave the best yields. One selection of each, intermediate wheatgrass accession No. P–2327,[4] and tall wheatgrass accession No. P–2326, were particularly outstanding in the 1949 trial. The larger form of intermediate wheatgrass (P–2327) also produced much higher yields in this second test than the short form (P–14).

Peak production for tall wheatgrass came 1 year later than for intermediate wheatgrass in the 1949 test. This finding is in accord with results obtained under dryland conditions in Idaho (*10*). The Lassen National Forest site was not suitable for Siberian wheatgrass, bluebunch wheatgrass, and Sherman big bluegrass—plants that have performed better at lower elevations having warmer and even drier conditions.

Western range technicians generally report that the yield of forage reaches a maximum in the second to fourth years after seeding. Then the yield begins to diminish gradually even though basal density of the stand may increase. Vigor is reduced, and hence forage yield per unit area is lowered. Such a decline was noted among the grasses

[4] The Soil Conservation Service nurseries of the Pacific Northwest supplied seed of all of the plants referred to by the P–series accession numbers.

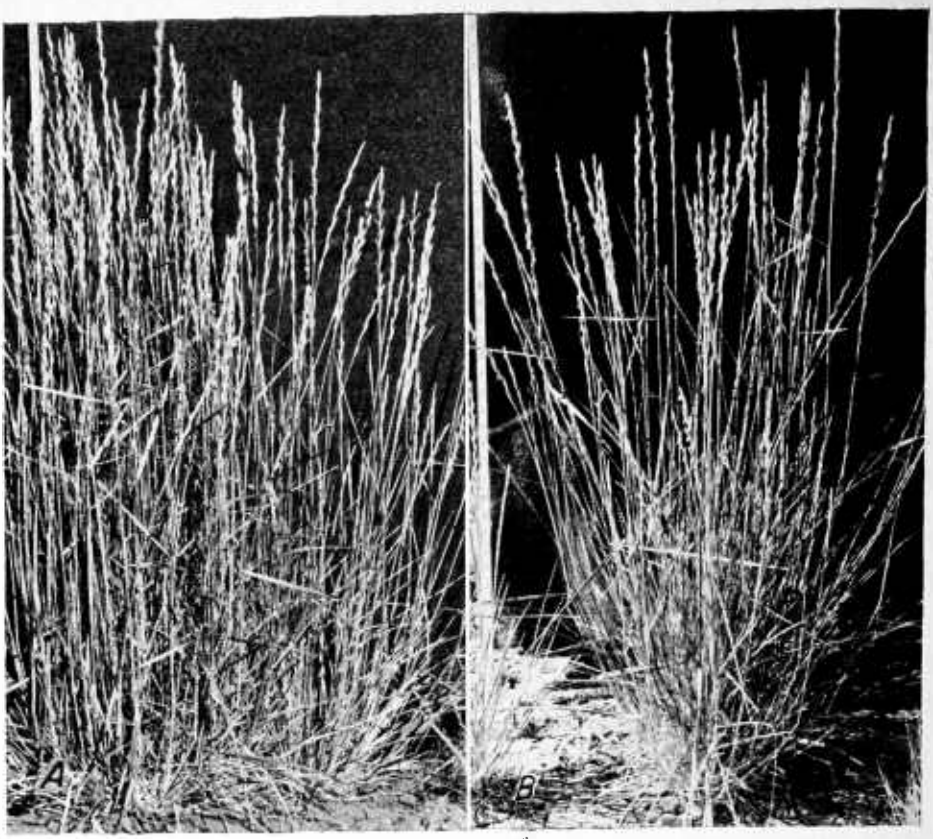

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Figure 4.—Individual plants of two species of wheatgrass. *A*, Intermediate wheatgrass, which spreads by short rhizomes. *B*, Tall wheatgrass, showing its typical bunchgrass habit of growth. This species has no rhizomes.

TABLE 3.—*Forage production by 9 grasses, big sagebrush and black sagebrush sites, Lassen National Forest, 1949–53* [1]

Species	Yield of forage, ovendry weight				
	1949	1950	1951	1953	Average
	Pounds per acre	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
Intermediate wheatgrass	623	1,092	747	1,111	893
Tall wheatgrass	554	978	928	879	835
Western wheatgrass	------	560	697	712	656
Slender wheatgrass	715	772	527	379	598
Crested wheatgrass	302	662	696	693	588
Pubescent wheatgrass	332	843	519	605	575
Beardless wildrye	------	649	569	397	538
Smooth brome	381	583	210	388	390
Timothy	407	418	260	------	362

[1] Seeded in 1947.

TABLE 4.—*Forage produced by 10 grasses, big sagebrush site, Lassen National Forest, 1951–53* [1]

Species	Accession No.	Yield of forage, ovendry weight			
		1951	1952	1953	Average
		Pounds per acre	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
Intermediate wheatgrass	P–2327	1, 547	1, 206	602	1, 118
Tall wheatgrass	P–2326	609	1, 115	1, 026	917
Big bluegrass	P–8903 (Albion)	------	641	539	590
Pubescent wheatgrass	P–41	613	588	246	482
Intermediate wheatgrass	P–14	668	584	186	479
Siberian wheatgrass	P–27	390	657	264	437
Big bluegrass	P–6303	------	376	361	368
Bluebunch wheatgrass	P–7845	------	184	335	260
Big bluegrass	Sherman	------	27	296	162
Bluebunch wheatgrass	P–6409	------	82	197	140

[1] Seeded in 1949.

included in the longer test on the Shasta National Forest (table 2). The decline was most conspicuous in smooth brome, but apparent in all the grasses that maintained a stand throughout the test period.

Despite this leveling off in yield 8 years after sowing, the seeded areas were nevertheless producing 2 to 9 times as much forage as the previously plowed, nonseeded range. The plots were not grazed. Longevity and productivity of grass stands might be somewhat different under use by livestock. But the indications are strong that established stands of these species will persist for a long period of years under good management. Crested wheatgrass especially has demonstrated both persistence and consistently good yields. For example, one of the oldest seedings of this grass at Mandan, N. Dak., has been productive since 1915 (*14*).

Legumes available for testing have not proved as well adapted as grasses for range seeding in Northeastern California. Of some 30 legumes tested in the big sagebrush type, Ladak alfalfa gave best results for elevations between 3,500 to 5,500 feet. Cicer milkvetch was best from 5,500 to 7,500 feet. Although these legumes are adapted to the soil and climatic conditions, rodents and other wild animals often kept them from becoming established. Legumes are needed throughout the range country to build up and maintain soil fertility and to provide better nutrient balance for livestock. Included in a mixture with grasses, legumes usually add to the protein, vitamin, and mineral content of forage. This addition is especially important during the season when grasses are maturing and drying. Continued search and test of native or introduced legumes will be required to meet the need for better adapted plants. But until the rodent and rabbit damage on wild land can be minimized, legumes cannot take their proper place in range seeding mixtures.

Methods of Preparing Land

Experiments in all three sagebrush types show that competing vegetation must be eliminated or reduced to establish grass stands by seeding. Burning, spraying with herbicides, and mechanical clearing will work. Each method has advantages and limitations. A detailed description of methods of controlling sagebrush on western rangelands is given in U. S. Department of Agriculture Farmers' Bulletin No. 2072 (7).

Mechanical clearing.—Plowing with disk-type equipment proved practical on most of the deteriorated range suitable for seeding on big sagebrush sites. Big sagebrush has brittle, easily broken stems, making it rather easy to kill with this equipment. The species does not sprout from the crown or root, and consequently breaking or cutting off the top of the plant results in good control. The disk plow and one-way Wheatland plow gave virtually the same excellent kill of sagebrush, but the disk-plowed plots produced a better stand of sown grass and a higher yield of forage (table 5). The disk plow was more effective than the one-way plow in reducing competition from forbs, sedges, and native grasses because of its deeper penetration and adjustable angle of the disk. In general, the yield of forage increased as density of sagebrush decreased.

Rockiness of the area largely determines the best type of plow to use. One-way Wheatland plows are adapted to moderately rocky land, whereas lighter disk plows are limited to virtually rock-free areas. Big sagebrush averaging about 2 feet tall was fairly well controlled by using a light farm disk or mower. Where sagebrush is reinvading seeded rock-free range, mowing may be used to kill the sagebrush before it attains much size. If the area is protected from

TABLE 5.—*Density of residual sagebrush, and forage production in relation to method of land preparation, on a seeded big sagebrush site*

Method	Density of sagebrush	Forage production [1]	
		Seedlings per square foot	Yield, oven-dry, per acre
	Percent	*Number*	*Pounds*
Untreated	18. 7		287
Mower	2. 1	1. 4	494
One-way plow	. 0	2. 1	644
Light farm disk	1. 5	2. 6	445
Disk plow	. 1	4. 4	1, 294

[1] Plots prepared and forage mixture drilled in autumn, 1947; seedling count made in 1948; yield measured in 1950. The forage mixture sown (in pounds per acre) consisted of: Smooth brome 4, mountain brome 4, western wheatgrass 4, Fairway crested wheatgrass 2½, alfalfa ¾, timothy ¾.

Untreated plot not seeded; yield is from native plants. Yields on treated plots are from seeded and native plants.

grazing for a year to permit production of a hay crop, then a mower can be profitably used to harvest the hay and control the sagebrush in one operation.

Spraying with herbicides.—Spraying with 2,4-dichlorophenoxy acid (2,4-D), carefully planned and applied, can control big sagebrush. The butyl-ester form of 2,4-D, applied at the rate of 2 pounds in an emulsion of ½ gallon diesel oil and 9 gallons of water per acre, gave 85 to 95 percent kill in replicated tests extending over a 6-year period on the Lassen National Forest (fig. 5). The best time to spray big sagebrush was when growth of flower stalks was 3 to 4 inches in length. At this stage the developing flower stalks still appear similar to new twig growth. This stage was reached between May 20 and June 20 at 5,600 feet above sea level—earlier at lower elevations, later at higher elevations.

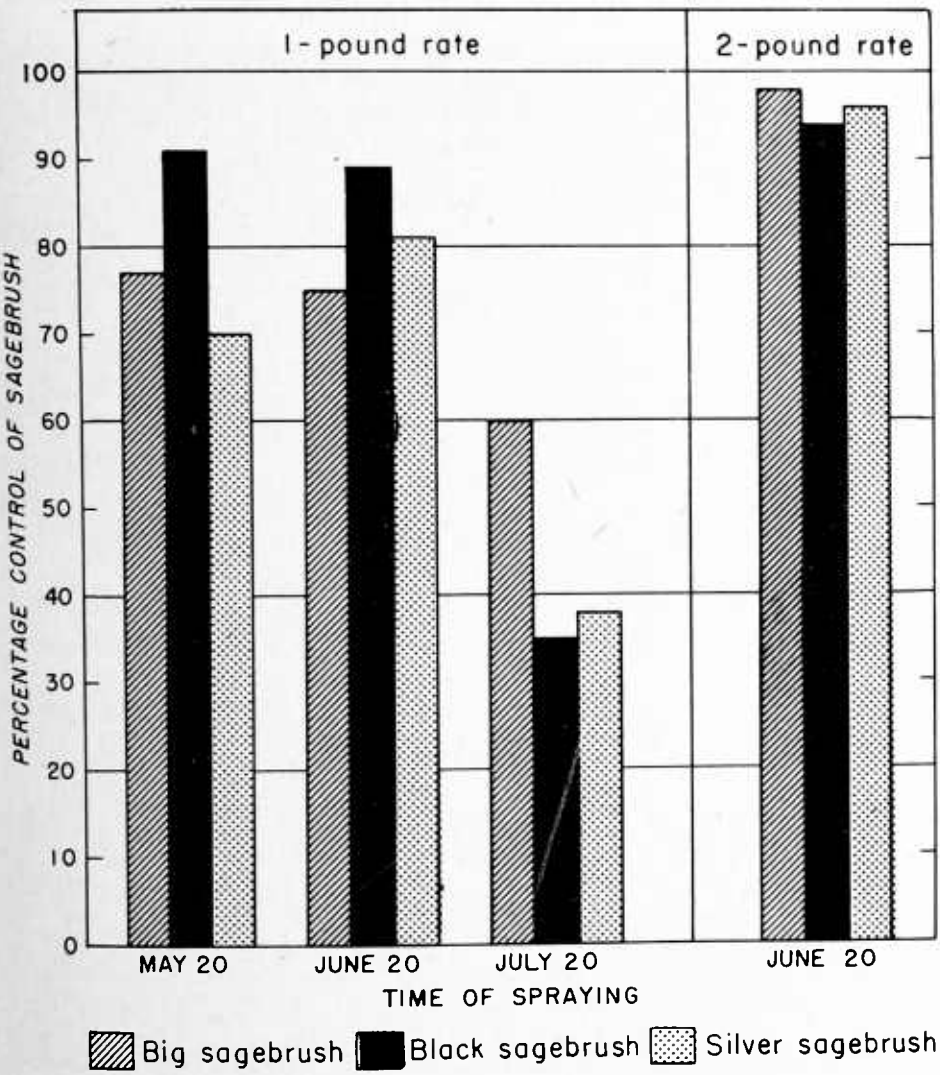

Figure 5.—Control of three species of sagebrush as influenced by time and rate of spraying with butyl ester of 2,4-D.

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Several supplemental field-scale spraying tests at elevations of 4,000 to 7,500 feet in other parts of northeastern California resulted in satisfactory kills of 85 to 95 percent of big sagebrush. Some of the variation in percent kill may result from unrecognized genetic differences in sagebrush. Ward (*13*) has recently reported that two forms of big sagebrush, with different chromosome numbers, occur in northeastern California.

Thorough coverage of the foliage with spray solution was found necessary to obtain a good kill of sagebrush. A method for determining and recording distribution of the spray particles was developed in the course of the experimental spraying (*2*). Bond paper was sensitized with tannic acid solution and placed on the ground across the swath to be sprayed. Iron chloride added to the spray solution during the calibration of the equipment gave a dark gray mark on the sensitized paper showing size and distribution of particles (fig. 6).

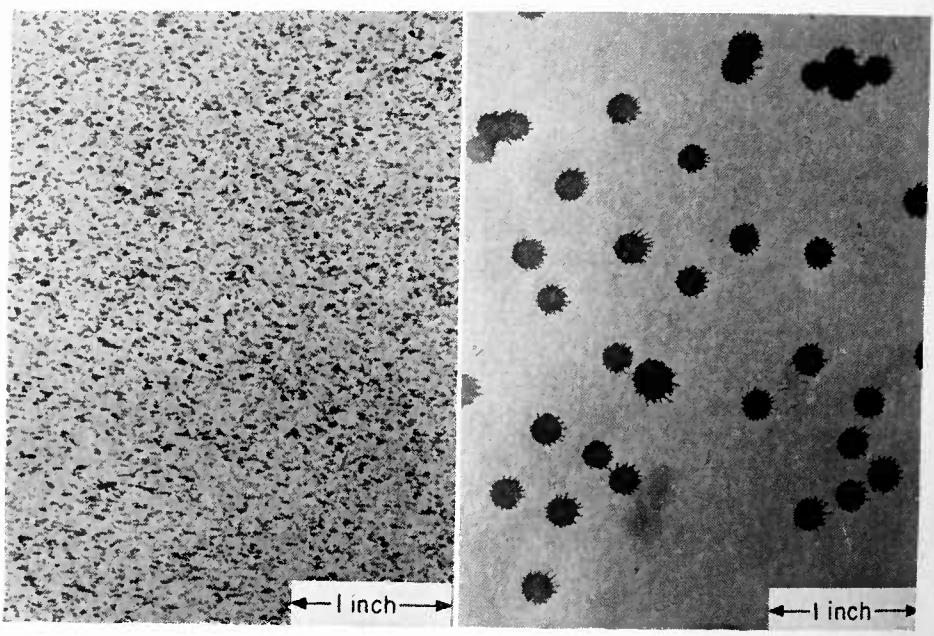

Figure 6.—**At left, spray pattern representing complete coverage with 10 gallons per acre. This is considered to be ideal droplet size and density. At right, spray pattern representing 10 gallons per acre with poor coverage.**

Spraying with 2,4-D increased forage production in the present study either with or without seeding. The test was in a rocky, deteriorated area of big sagebrush, where the stand of good perennial grasses before spraying averaged one plant per square foot. Spraying alone increased forage production to nearly four times that of the untreated range. This improvement occurred in the second year after the competing sagebrush had been killed (table 6). The grass plants increased in density, vigor, and yield.

Spraying and seeding together increased production sixfold, on the average. A mixture of introduced forage grasses was drilled the fall after the spraying. Three years later an average of three grass

TABLE 6.—*Forage production under several combinations of spraying, tillage, and seeding on big sagebrush range, 1950–53* [1]

Treatment	Forage yield, ovendry, per acre				
	1950	1951	1952	1953	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Plowed and drilled	573	1, 007	-------	1, 183	921
Sprayed, disked, and drilled	522	817	1, 086	943	842
Sprayed; not seeded	462	542	427	602	508
No treatment	110	147	141	149	137

[1] Sprayed with 2,4-D in July 1948; seeding done in fall of 1948.

plants per square foot were fully established, even though disking to prepare the seedbed had reduced the native grasses about 50 percent. Introduced grass plants made up three-fourths of the vegetation and native grasses one-fourth.

These results show that introduced grasses can be successfully drilled into sprayed sagebrush areas without plowing. Sowing, however, cannot be done satisfactorily without some tillage to prepare a seedbed. Where disk-harrow equipment can be operated on sprayed sagebrush areas, the tillage will usually be sufficient to prepare a seedbed and to break down the dead brush ahead of the drill. A brushland drill (fig. 7) recently developed by the Forest Service also gave

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Figure 7.—Brushland drill for sowing seed on trashy seedbeds and on uneven soil surfaces.

adequate tillage and performed well where rocks and brush would have stopped ordinary drilling equipment. Because each drill arm is independently hinged, depth of seeding is fairly uniform on rough ground. When this type of drill becomes generally available, it may be possible to use it on sprayed sagebrush areas without disking or plowing.

The principal use for spraying, we believe, will be on land supporting enough perennial grasses to produce an adequate cover of forage after the sagebrush is killed. Spraying is especially adapted to rocky land that cannot be plowed, and also to some sloping land that might erode seriously if plowed. On slopes and easily eroded soils, particular care must be taken not to kill sagebrush by spraying unless the understory of native grasses is adequate to prevent serious erosion or a seeded cover can be rapidly established. Although sagebrush is not desirable as a forage plant, it does help to protect the soil against washing and blowing. If native grasses are not present to revegetate the range, introduced grasses should be sown.

Range managers will want to consider certain other hazards in the use of selective herbicides. First, the sagebrush crowns protect remnants of perennial grasses from grazing, and therefore sagebrush should not be destroyed by spraying unless grazing can be managed to permit the grasses to regain and retain their vigor. Also, 2,4-D can be very detrimental on some sheep ranges by killing many perennial herbs, such as geranium, and scattered legumes. Bitterbrush, snowberry, aspen, and willow, particularly valuable browse plants for sheep and deer, can be damaged by spraying. These hazards can be minimized by careful selection of area, equipment, and time of application.

Burning.—Effectiveness of burning in seedbed preparation was demonstrated along with the species-adaptation testing. One series of drilled plots was established in 1948 on a controlled burn in the big sagebrush type. The burn, on a selected tract in the Modoc National Forest, was clean and provided an excellent seedbed for drilling without tillage.

Crested wheatgrass and four other adapted wheatgrasses were sown within a few weeks after the burn. The area was grazed moderately the first year after sowing, then rested 1 year, and grazed heavily the third year. By 1950 crested wheatgrass had developed a basal density of 4.5 percent, an optimum coverage for the site. Native perennial grasses that survived the fire added 2.0 percent of basal density, making a total of 6.5 percent. On the adjacent unburned range, perennial native grasses—mainly squirreltail, western needlegrass, bluebunch wheatgrass, and Idaho fescue—had a density of 4.2 percent.

Burning reduced the native grasses by more than 50 percent in this experiment. Idaho fescue proved to be especially susceptible to injury by fire. Cheatgrass, an introduced weedy annual, was decreased from 2.3 percent basal density on the unburned range to 1.5 percent on the burned and seeded area. But fire also removed sagebrush, which on the unburned range reduced the yield of the forage. Thus, forage increased in quantity and became more accessible to livestock as a result of the combined use of fire and seeding to improve this kind of range.

New sagebrush seedlings have grown since the burn, and eventually some action will be needed to reduce them. An average of 4,698 seedling sagebrush plants per acre were found in 1950 on the burned area. The unburned range had 2,523 seedlings and 2,958 mature plants, making a total of 5,481 per acre. Burning might have contributed to the abundance of seedlings but did not appear to be entirely responsible; climatic conditions for establishment of sagebrush seedlings apparently were unusually favorable. Observations of nearby sagebrush areas indicate that big crops of sagebrush seedlings have grown in only 1 year in 10 on these rangelands.

Despite the sagebrush seedlings, the grass was vigorous and productive on the area as a whole in the fifth year after sowing. In small enclosures fenced from livestock and rabbit grazing, crested wheatgrass yields were at the rate of 2,194 pounds of forage, dry weight, per acre; intermediate wheatgrass, 1,936 pounds per acre. These yields were comparable to those obtained on another area plowed and seeded at greater expense, and they indicate the possibilities of increased production from seeding burned-over range in the big sagebrush type.

Studies in the Intermountain Region (*6*) have shown that burning big sagebrush to reduce competition with associated grasses can be an effective range improvement practice on selected areas. Risk, difficulty, and expense can be reduced by thorough preparation in advance, by accurate sizeup of the best time to burn, by skillful handling of the burn, and by meeting requirements of local fire-control authorities. Good management of grazing is just as important after burning as after spraying to allow new seedlings to develop and released plants to gain vigor.

To obtain the best forage returns, burns on sagebrush range from both controlled and wild fires should be seeded in autumn of the same year; otherwise, soil becomes compacted and competition from cheatgrass and other range weeds will be increased greatly.

Methods and Rate of Seeding

Covering of seed was found essential for good establishment of grasses. Throughout the 7 years of testing, drilling gave consistently better stands of grass than broadcasting, with two exceptions. Drilling was not necessary on burned-over timberland with heavy ash, nor where needle fall of conifers or leaf fall of aspen was sufficient to cover the seed. On burned-over sagebrush land, however, ash did not cover the seed adequately. There and on plowed seedbeds drilling was necessary.

Consistently better stands of grass were obtained where the soil on plowed seedbeds was firmed before drilling. For example, in one experiment with land roller and disk, used singly and in combination, the comparative results, expressed in number of seedlings per square foot, were: Plowed, 1.2; plowed and disked, 1.3; plowed and rolled, 1.5; and plowed, disked, and rolled, 1.7. In this experiment a cast iron roller was used, but elsewhere log rollers and concrete cylinder rollers proved satisfactory. Usually rolling and drilling can be done in one operation when the roller is pulled ahead of the drill.

Much rangeland, otherwise suitable for seeding, cannot be drilled because of rocks or other obstructions. Broadcasting seed by power equipment or by hand may be the only alternative. For such situations, the pipe harrow (*12*) is an effective tool for covering the seed.

Use of a single-disk drill gave better stands of crested wheatgrass than a deep-furrow drill and proved much better than hand broadcasting without covering the seed on rough plowed land (table 7). Nine pounds of seed per acre proved best with the single-disk drill; 9 pounds gave significantly more plants and higher yield of forage than 6 pounds per acre.

The grass stand that resulted from seeding at the 9-pound rate averaged 2.2 seedlings per square foot. Heavier rates of planting did not increase the yields. Of course, the seeding rate required to produce a desired number of seedlings per unit area will vary as the number of seeds per pound varies, species by species. For example, grasses such as intermediate, tall, and pubescent wheatgrass, which have larger seeds, should be sown at a rate 25 to 50 percent greater than that for crested wheatgrass. (Seeding rates for individual species are in table 14, Appendix.) Also, rates of seeding will gradually be reduced as more efficient machinery and seeding methods are developed for range use.

For most successful results seed should be covered. Optimum depth depends upon texture of the soil. On sandy soil the depth of sowing grasses and legumes should be about 1 inch. Shallow sowing resulted in loss of seedlings at time of emergence. The soil dried too rapidly. Emerging seedlings planted less than ½ inch deep often dried out before they were adequately rooted. On heavy-textured soil ¼ to ½ inch is the best depth.

TABLE 7.—*Establishment and yield of crested wheatgrass, by method and rate of seeding, big sagebrush range*

Method and rate of seeding [1]	Plants established per milacre	Forage yield, ovendry, per acre [2]
	Number	*Pounds*
Broadcast by hand, 6 lbs. per acre	21	162
Deep-furrow drill, 6 lbs. per acre	35	480
Single-disk drill:		
6 lbs. per acre	77	597
9 lbs. per acre	97	857
12 lbs. per acre	89	853
18 lbs. per acre	100	856

[1] Seeded in 1948.
[2] Measured in 1950.

Late fall sowing of grasses generally gave better results than spring sowing. Early fall sowing has been less satisfactory. In 1 of the 7 test years, early September seedings were followed by a rainy period

and a few weeks of warm weather. Seedlings germinated too soon, and losses were heavy during the winter. Plots sown to grass later in the fall of that same year had no germination until spring, and a better stand was obtained. Since the earliness or lateness of storms is unpredictable, it would be desirable to sow in late fall, between October 10 and 30, for elevations of about 5,600 feet. In Nevada at elevations of 4,650 and 5,200 feet, Robertson (*9*) also found that late fall seeding gave better results than early fall seeding.

Early spring proved suitable for sowing areas that are readily accessible. However, if equipment and supplies have to be moved an appreciable distance, muddy roads and fields and early spring storms make spring sowing too difficult and costly. By the time planting can be done in the spring, it is too late for the slow-starting grasses to become sufficiently well developed to survive the summer season without rain. Legumes develop more rapidly than grasses and have responded better to spring sowing than to fall sowing. If a mixture of grasses and legumes is to be sown, early spring would be the preferable time.

Stand Establishment

Grazing by livestock should be withheld until new seedling plants have had an opportunity to become well established. The period of time will vary for different species, seasons, and sites, but as a general rule a full year after seeding is required to avoid pulling up many seedlings which do not become firmly anchored the first growing season. Special situations may justify protection into the second year.

Occasionally a satisfactory stand of grass developed despite early livestock grazing. Such an example occurred with the newly seeded crested wheatgrass on the 1948 controlled burn of big sagebrush. The autumn, winter, and spring proved exceptionally favorable for growth of the crested wheatgrass seedlings. Although grazed the first summer after sowing, they developed into vigorous plants as large at the end of 1 year as would normally be expected in 2 years. Conversely, the big bluegrass sown on plots at the same time and treated in the same manner as the crested wheatgrass germinated well, but the seedlings were pulled up by livestock, and the stand of grass was a failure.

Rodents and rabbits were observed to damage range seedings in varying degree during the test period. The rodents included ground squirrels, mice, and gophers. Rabbits destroyed some new seedings of forage grasses. Rodents and rabbits eliminated legumes from some grass-legume mixture seedings. Rabbits were not controlled successfully on the experimental range areas except by fencing. On one small test area they consumed nearly two-thirds of the forage. Where livestock and rabbits were excluded, the amount of grass at maturity was 2,065 pounds per acre compared to 792 pounds per acre on a small plot fenced against livestock but grazed by rabbits. On this area the grass stand was established before the peak of the rabbit population occurred. If seeding is desired for a large range where the rabbit population is high, the best solution may be to defer seeding until the number of rabbits can be reduced by natural enemies or until more effective control methods are developed.

Black Sagebrush Sites

Site Selection

Since shallow soils characterize the black sagebrush range, special attention should be given to soil depth in selecting areas for seeding. The depth of soil above rock or consolidated substratum should be 2 feet or more for good grass growth. The black sagebrush type is generally found on gentle slopes; so steepness is no problem in most localities. Rockiness, however, prevails through most of the black sagebrush rangeland, and for this reason much of the area cannot be treated with tillage equipment.

Species Adaptation

Grasses found adapted for use in seeding deteriorated black sagebrush range were: Intermediate wheatgrass, tall wheatgrass, western wheatgrass, Standard crested wheatgrass, pubescent wheatgrass, Fairway crested wheatgrass, and smooth brome.

In one comprehensive test for yielding ability of 9 grasses on the Lassen National Forest, intermediate wheatgrass and tall wheatgrass gave the highest and the next highest yields, respectively, and far exceeded 7 other species in relative production (table 3). Nitrogen deficiency accounted for the low production of smooth brome on the test area. On soils of higher fertility, especially at somewhat higher elevation and with better soil-moisture conditions, smooth brome has performed better than it did here. The test was made at 5,600 feet, near the upper limit of adaptation for Standard crested wheatgrass; at higher elevations Fairway crested wheatgrass has persisted and produced better than the Standard strain.

Methods of Preparing Land

Mechanical clearing.—Of the several kinds of tillage equipment tested, a disk plow gave best control of competing vegetation in the black sagebrush type (table 8). Plowing has proved best only on relatively rock-free areas. A light farm disk, which can be operated on some land too rocky for plowing, gave good control of black sagebrush when the land was disked twice and the disk blades were kept sharp. Difficulty was encountered with the one-way Wheatland plow. Many small plants of black sagebrush slipped between the disks; other plants were not killed because the disks merely rolled over them. Mowing was ineffective, since it was impossible to cut low enough to kill many of the plants. This difficulty was partly caused by the rough surface of the soil. Erosion between the black sagebrush plants had left many of them on pinnacles of soil.

Spraying.—Spraying with 2,4-D gave satisfactory control of black sagebrush, equal to that of big sagebrush. Rocky rangeland that cannot be plowed is most suitable for spraying. Desirable native grasses, though limited in amount, are allowed to increase when released from sagebrush competition by spraying with selective herbicides. Comparative yields from sprayed and unsprayed strips of

similar range afford a measure of this stimulus. Sandberg bluegrass and other native grasses produced 273 pounds of forage per acre in 1951 on unsprayed black sagebrush range on the Modoc National Forest. An adjacent area sprayed with 2,4-D by airplane the year before produced 578 pounds of forage per acre. On an area supporting a fair stand of Idaho fescue, a higher producing native grass, the yields per acre were 470 pounds without spraying and 893 pounds with spraying.

TABLE 8.—*Density of residual sagebrush, and forage production in relation to method of land preparation, on a seeded black sagebrush site*

Method	Density of sagebrush	Forage production [1]	
		Seedlings per square foot	Yield, oven-dry, per acre
	Percent	*Number*	*Pounds*
Untreated	26. 4		168
Mower	7. 7	3. 5	311
One-way plow	4. 5	4. 8	483
Light farm disk	1. 1	6. 3	456
Disk plow	. 7	9. 1	1, 638

[1] Plots prepared and forage mixture drilled in autumn, 1947; seedling count made in 1948; yield measured in 1950. Forage mixture as in footnote 1, table 5. Untreated plot not seeded; yield is from native plants. Yields on treated plots are from seeded and native plants.

Rails and pipe harrows (*12*) gave unsatisfactory results in tests on black sagebrush. This rather small shrub is often multiple stemmed and is not easily pulled out or broken off. For example, in one field test of the pipe harrow on Lassen National Forest, black sagebrush plants were reduced only from 12,197 per acre to 5,123—an insufficient kill for successful range improvement.

Method and Rate of Seeding

As on the big sagebrush sites, drilling seed in the fall generally gave best results. After spraying, some tillage is desirable before drilling; this may be done with a light farm disk or the rockland tiller (fig. 8). In a test with the rockland tiller, about half of the native grasses survived and drilling added an average of 2.4 grass seedlings per square foot. Plowing and drilling produced 3.8 seedlings per square foot but eliminated all the native grasses, an undesirable result on erodible areas. In general, however, the best results from the drilling may be expected on a seedbed that has been prepared by plowing and rolling.

In these tests the optimum rate of sowing was 8 to 12 pounds per acre, and the best depth of covering, one-half inch. On land too rocky or rough for either plowing or drilling, yet deficient in forage cover,

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Figure 8.—Rockland tiller used to prepare seedbed for range seeding.

grass seed can be covered by using a pipe harrow in the fall after sagebrush has been killed with a hormone spray applied the preceding spring.

Stand Establishment

To insure establishment of seedlings, the same protection from grazing is necessary on the black sagebrush as on the big sagebrush range. The young grass plants must be given time to become adequately rooted before being grazed.

Silver Sagebrush Sites

Site Selection

In the silver sagebrush type the soil is flooded when the snow melts in the spring. Where water usually stands more than 4 or 5 weeks, seeding is inadvisable unless drainage can be improved. Preparation for seeding is more difficult in this type than in either big sagebrush or black sagebrush.

Soil 2 feet or more in depth has generally produced enough forage to justify the expense of seeding. Loam soils have given best results in revegetation, but clay soils, which are most prevalent in this type, also have given satisfactory stands of grass.

Silver sagebrush is usually found on relatively level land, except at elevations of 7,000 to 8,000 feet. Here the steeper slopes may present an erosion hazard, and special care must be taken in tillage to prepare the land for seeding.

Species Adaptation

Grasses proved adapted for seeding on silver sagebrush sites were: Tall wheatgrass, western wheatgrass, meadow foxtail, beardless wildrye, smooth brome, and thickspike wheatgrass. All of these grasses satisfactorily withstood a few weeks of flooding.

Intermediate wheatgrass, pubescent wheatgrass, and Siberian wheatgrass did not withstand flooding well enough to warrant their use on areas that are likely to be under water or even waterlogged for more than 2 weeks after snow melts in the spring. Reed canarygrass also failed to persist on these sites; although it withstood submergence, it did not survive the dry summers on the heavy clay or loam soils found in the silver sagebrush type. These findings on the relative resistance of forage plants to flooding are in very close agreement with those obtained in Canada (*5*).

Methods of Preparing Land

Mechanical clearing.—Plowing gave excellent results and is recommended for silver sagebrush areas. The disk plow gave the best control of any of the methods tested (table 9). The one-way plow was better than the light farm disk, but neither is to be recommended if a disk plow can be used. The light farm disk was less effective on silver sagebrush than on black sagebrush (tables 8 and 9) because silver sagebrush sprouted from the crown but black sagebrush did not.

Sprouting of the silver sagebrush occurred wherever the plants were not completely cut off a few inches below the soil surface. The most effective depth for plowing was 6 to 8 inches. Mowing proved less successful: practically all of the silver sagebrush stubble sprouted.

Drilling without controlling sagebrush failed to produce forage seedlings; grasses could not be established on bare soil between the

TABLE 9.—*Density of residual sagebrush, and forage production in relation to method of land preparation, on a seeded silver sagebrush site*

Method	Density of sagebrush	Forage production [1]	
		Seedlings per square foot	Yield, oven-dry, per acre
	Percent	*Number*	*Pounds*
Untreated	26. 4	----------	26
Mower	17. 9	0. 7	66
One-way plow	9. 4	. 5	57
Light farm disk	4. 6	1. 4	276
Disk plow	. 1	3. 6	1, 091

[1] Plots prepared and forage mixture drilled in autumn, 1947; seedling count made in 1948; yield measured in 1950. Forage mixture as in footnote 1, table 5.

Untreated plot not seeded; yield is from native plants. Yields on treated plots are from seeded and native plants.

sagebrush plants. The soil was fully occupied by the sagebrush roots even though only about 25 percent of the ground surface was covered by the sagebrush canopy (fig. 3, *C*).

Plows must be weighted and set at the proper angle to eradicate silver sagebrush, a tougher plant than either big sagebrush or black sagebrush. Also, heavy equipment or added weight on the plow usually is necessary to penetrate the heavy-textured soil, especially during the late summer when the soil becomes dry and hard. Notched blades (fig. 9) gave better penetration than smooth disk blades and have been more generally satisfactory in uprooting this tenacious sagebrush species.

Ridging.—Ridging of the soil improved drainage and increased forage yield, and was conveniently done at the time of plowing. A disk plow was used to make ridges (fig. 10). The center strip, which formed the ridge, was double plowed, and the back furrows were thrown to the center. A dead furrow was left open between the ridges to serve as a shallow ditch or swale for drainage (fig. 11). The ridges were laid out in the direction of natural drainage. The gradient has been found to be slight on the floor of the valleys or depressions where this sagebrush type occurs.

Ridges were constructed 12 feet apart in the first experiment, beginning in 1949, to test this method of drainage improvement against regular plowing. Reseeding followed both treatments. Ridged plots averaged 27 percent more forage production than level plots in the years 1951–53, as shown in the tabulation below.

	Forage yield, air dry (pounds)	
	Ridged	*Flat-plowed*
1951	1,355	922
1952	643	554
1953	863	771
Average	954	749

The percentage difference between ridged and level plots was greater in 1951 when the plots were submerged about 8 weeks than in 1952 or 1953 when flooding occurred for only 2 or 3 weeks each spring. It was concluded that differences in growing conditions, rather than a decrease in effectiveness of the ridges, accounted for the lower yields.

Later experiments conducted with ridges spaced 18 feet apart revealed advantages for the wider spacing. The flatter slopes permitted more uniform depth of seeding. Also, in large-scale seeding the 18-foot spacing would fit the larger plows better.

Spraying.—Spraying silver sagebrush with 2,4-D with the same procedure and formulation used for big sagebrush gave a high percentage kill (fig. 5). Forage production was extremely low without treatment (table 10). Where the sagebrush was killed the forage yield increased more than sevenfold, chiefly as a result of increased vigor of native Nevada bluegrass. On most depleted silver sagebrush range areas, however, the thin remnants of native grasses do not warrant the use of chemical sprays alone as an improvement practice. Seeding of adapted grasses is usually required and should follow some tillage treatment to prepare a seedbed. For this purpose, use of a light farm disk ahead of the drill has proved satisfactory.

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Figure 9.—Stubble plow used in preparing silver sagebrush range for reseeding.

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Figure 10.—Disk plow used for plowing ridges to improve drainage on a silver sagebrush site before seeding.

Spraying and seeding gave an average forage yield 13 times greater than that of the untreated range (table 10). Nevada bluegrass, a highly desirable native grass, occurred on the untreated plots at an average rate of 11 plants per milacre, or 1 plant for each 4 square feet. New plants of Nevada bluegrass became established on the sprayed plots; an examination the third year after spraying revealed 44 plants per milacre, or 1 plant per square foot. Virtually the same number of plants, 45 per milacre, were counted on the sprayed and seeded plots; 19 were introduced, and 26 native grass plants. Disking and

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Figure 11.—Silver sagebrush range ridged to improve drainage and prepare area for seeding.

TABLE 10.—*Yield of forage on treated and untreated silver sagebrush range, 1951 and 1953*

Treatment [1]	Yield per acre, ovendry		
	1951	1953	Average
	Pounds	*Pounds*	*Pounds*
None	91	28	60
Sprayed with 2,4-D	562	356	459
Sprayed and drilled [2]	948	631	790
Plowed and drilled [2]	1,036	729	882

[1] Applied in 1948.

[2] Forage mixture seeded per acre included: Smooth brome, 2.5 lbs.; western wheatgrass, 2.5 lbs.; Fairway crested wheat grass, 2.0 lbs.; orchardgrass, timothy, Chewings fescue, and redtop, 1.0 lb. each; Reed canarygrass, 0.5 lb.

drilling had eliminated about half of the native grasses. The increased yield from spraying and seeding, then, resulted from the introduction of higher yielding grasses and more vigorous growth of remaining native plants. Spraying and seeding are especially suited to areas that have scattered rocks sufficiently near the surface to stop plowing but not too near to prevent disking and drilling.

Methods and Rate of Seeding

Drilling seed in September or October before the fall storms arrive proved to be the most satisfactory seeding practice for silver sagebrush range. A suitable mixtnre is: Tall wheatgrass, 5 pounds; westtern wheatgrass or beardless wildrye, 4 pounds; and meadow foxtail, 3 pounds, making a total of 12 pounds per acre. Thickspike wheatgrass can be substituted for western wheatgrass or beardless wildrye. If a single species is desired, then 12 pounds of tall wheatgrass or western wheatgrass is recommended. Seeds should be covered, but not more than one-half inch deep.

Broadcasting seed in the fall resulted in poor stands of grass on the heavy soils. Sowing in spring and early summer is also unsatisfactory, because silver sagebrush areas are then too wet and muddy for the use of machinery. Scattering the seeds in the floodwater in early spring failed to establish a grass stand.

Stands of grass containing ripe seed can be mowed, bunched until fall, and then scattered to seed the plowed area. This method of establishing native grasses succeeded in 3 different years. Advantages were: First, a mulch was provided and this aided seedling establishment, and second, adapted native grasses could be used when their seed was not commercially available. Nevada bluegrass predominated on the areas thus mowed and seeded. Meadow barley and tufted hairgrass were also present and propagated readily by this method. Care must be taken to mow the grasses before too much seed is lost by shattering. Grass should not be mowed from weedy meadows for this type of seeding. Some weeds, though, may be controlled by spraying with selective herbicides a year in advance of mowing. On the experimental area, enough seed and mulch material was mowed from 1 acre to seed 5 acres.

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Figure 12.—Buncher attachment for use on mower in harvesting native hay as seeding material.

A buncher attachment for the mower (fig. 12) was used to bunch the grass at the time of mowing. This not only saved time and labor, in comparison with separate mowing and raking, but also reduced loss from shattering of the seed.

Stand Establishment

Livestock generally should not graze newly seeded silver sagebrush range until the second year after planting in order to allow plants to develop satisfactorily. On clay soil subject to spring flooding, the development of roots at the root crowns of the young seedling plants was slower than in well-drained loam soil. Also, soil temperature during the spring was lower on the flooded area, and growth of new seedlings was retarded. Often crown roots did not develop at all during the first summer. These roots were necessary to anchor the grass plant adequately in the soil. The seedling grass plants with only primary roots were easily pulled up by grazing animals, and a good stand of grass was ruined by grazing before the plants were firmly anchored.

IMPROVING DRY GRASSLAND SITES

Cheatgrass Areas

Cheatgrass, a weedy annual grass from Europe, invaded much of the Great Basin sagebrush zone during the early part of the 20th century. (This plant is known locally as bronco grass and occasionally as downy chess.) On unplowed rangeland at that time, the stand of perennials had been reduced by heavy livestock use, fire, insects, diseases, or drought. Big sagebrush predominated on much of this land until it was removed by wildfire. Then cheatgrass came in to occupy open ground resulting from this reduction in perennials. Large areas of rangeland formerly dominated by perennial grasses and forbs have thus been transformed into a less productive annual-grass range.

At the same time much grassland was cleared for cultivated crops, but farming was discontinued on large acreages that proved to be submarginal for dryland grain production. These fields quickly reverted to rangeland covered by dense stands of cheatgrass.

The chief disadvantages of cheatgrass are its short season of green growth for grazing, great fluctuation in amount of forage from year to year, and high fire hazard presented by the dry mature vegetation through the summer and fall. Opportunity is great for improving rangeland by converting cheatgrass areas to perennial grasses. Where enough native perennials remain, the improvement can be accomplished by managing grazing to restore the desirable grasses. On land that can be worked by tillage equipment, improvement will be quicker and more positive through reseeding of perennial grasses.

Medusa-head, another weedy annual grass of more recent introduction from Europe, has become a further threat to the productivity of some of these cheatgrass areas. Cheatgrass, though inferior to perennial grasses, provides some forage, but medusa-head is unpalatable to livestock. Finding ways to control or replace this later invader has barely been started, and no conclusive recommendations can be made at this time.

Site Selection

Some abandoned submarginal croplands have been damaged by erosion. In general, however, cheatgrass-infested rangeland that was formerly cultivated offers the most favorable soil and topographic conditions for seeding in this region. The fields can be tilled. Seedlings are established rapidly and come into use soon. Often such areas are already fenced. They are located near ranch headquarters, an advantage in supplementing native range. Previously unplowed lands with cheatgrass are not so fortunately situated. Some of their characteristics, such as steep slopes, broken terrain, boulder-strewn surface, and shallow soils, limit or preclude tillage and drilling.

Species Adaptation

Our plot tests and observations of results from field-scale sowings on privately owned ranches show that the following forage species are adapted for use on cheatgrass rangeland: Crested wheatgrass, big bluegrass, intermediate wheatgrass, tall wheatgrass, bluebunch wheatgrass, beardless wheatgrass, and Ladak alfalfa. For cheatgrass areas, as for big sagebrush range, the final choice of grass for seeding will depend upon the season when additional forage is needed most. Crested wheatgrass and big bluegrass reach their peak of production in early spring. Intermediate wheatgrass grows through spring and early summer. Maximum yields of tall wheatgrass, bluebunch wheatgrass, and beardless wheatgrass are not attained until late summer. Where rodents or rabbits do not prevent growth of alfalfa, Ladak alfalfa may be sown in alternate rows with the grass.

Method of Preparing Land

Considerable tillage was found necessary to reduce competition from weeds on cheatgrass areas before seeding grasses. Prompt preparation of seedbed and seeding of grasses or legumes after a cereal crop affords the cheapest and best procedure for establishing a stand of perennial forage plants. The grain stubble needs only to be disked before the forage seed is drilled into the stubble.

Growing a cereal grain or hay crop before seeding grasses or legumes for grazing has two main advantages. First, the cereal crop suppresses many weeds and reduces their seed production. Second, the grain crop repays some of the cost of tillage. The feasibility of this method will depend upon local conditions, including facilities at hand for raising a hay or grain crop. Rye grown as a grain crop before grass establishment resulted in unfavorable competition from volunteer rye plants, but competition from volunteer plants of wheat, barley, or oats was comparatively unimportant. If cereal rye is grown, it should be cut for hay before its seed develops.

Where raising a cereal crop was impractical, plowing was found necessary to prepare cheatgrass land for seeding to perennial grasses. A year of summer fallow was justified if the cheatgrass had been permitted to produce seed before plowing. In such cases, the field should be plowed in the fall and disked the next spring to kill cheat-

grass before it heads out. Then in the fall the area should be rolled before drilling. Good stands of crested wheatgrass have been obtained by this method, but some cheatgrass was present for 2 or 3 years until the crested wheatgrass became well enough established to suppress the cheatgrass.

Poverty weed, wild morning-glory, Jim Hill mustard, and other weeds of cultivated lands also competed with new grass plants in early stages of establishment. These weeds occur much more frequently on land formerly cultivated than on unplowed range. A year of summer fallow did not eradicate them, but was highly beneficial in establishing a grass stand. The perennial weeds were so weakened that their competition with the young grass plants was negligible. Local conditions will determine the number of cultivations needed during summer fallow.

Method and Rate of Seeding

Single disk drills gave excellent results on cheatgrass areas that had been plowed and rolled to give a seedbed of good firmness and tilth. Optimum planting depth was from ½ to 1 inch, depending upon texture of surface soil. Nine pounds of crested wheatgrass per acre has been the optimum rate for seeding; proportionately higher rates are needed for species with larger seeds. A good rate for a legume-grass mixture was Ladak alfalfa, 3 pounds, and crested wheatgrass, 6 pounds per acre. Alternate row seeding of legume and grass has given best results.

Tarweed Areas

Tarweed is a native annual weed growing between 4,000 and 7,000 feet in elevation. It occurs abundantly on small areas of meadow and sagebrush range where the native perennial vegetation is almost completely gone. Tarweed is especially common in valley floors, along livestock driveways, or around watering places. These livestock concentration areas usually have high potential capacity for grazing if desirable forage plants can be reestablished and grazing properly managed.

Site Selection

In the process of range decline, portions of the tarweed areas have developed an erosion pavement. These places are less suited to improvement by seeding than others which still have some surface soil. If 2 feet or more of soil is present and soil fertility is adequate, a satisfactory stand of grass may be established regardless of the presence of an erosion pavement. On badly depleted areas, soil fertility tests should be made before large-scale seeding operations are attempted.

Species Adaptation

In an adaptation test including 40 different grasses and legumes, 5 grasses proved best for seeding on tarweed-infested range: Intermediate wheatgrass, pubescent wheatgrass, Chewings fescue, tall

wheatgrass, and tall fescue. Chewings fescue gave rather short growth and should not be sown alone. In mixture with some of the taller growing grasses, Chewings fescue added to density of the resulting protective sod. A suitable mixture would include 8 pounds of intermediate or pubescent wheatgrass and 2 pounds of Chewings fescue per acre. The need on these critical livestock concentration areas is to restore a dense turf as soon as possible to arrest further erosion and to reduce damage by trampling, which occurs so frequently.

Tall wheatgrass and tall fescue performed best on the more moist and poorly drained sites where tarweed had replaced the original meadow grasses. Intermediate wheatgrass and pubescent wheatgrass proved better adapted to somewhat drier sites with good internal soil drainage.

Methods of Preparing Land

Early to midsummer plowing proved best for preparing land for seeding. The plowing should be done before tarweed matures seed. A light farm disk was tried but did not cut deeply enough to kill all of the tarweed. A disk could be used where the soil is friable; a heavy plow would be needed on hard, compacted soils. The essential requirement is to kill the tarweed before seed is produced. If much surface soil has been lost, plowing and then disking may be needed to provide a satisfactory seedbed.

Method and Rate of Seeding

Tarweed areas generally are too wet for early spring seeding. Fall sowing has given much better results than sowing in late spring, as soon as equipment can be used on the land. Two methods of seeding have given satisfactory results: Drilling seed at a depth of one-half inch, and scattering mature meadow-grass hay containing seed of the native grasses. Using grass hay gave better results than sowing seed on crusted or compacted soils or on erosion pavement. Drilling 10 to 12 pounds of seed per acre has given satisfactory stands of grass on the extensive areas where soil is in reasonably good tilth.

Stand Establishment

Fertility of the soil has been the principal factor in success or failure of stand establishment on tarweed sites. Both phophorus and nitrogen were found to be deficient on one experimental seeding on the Lassen National Forest. A good stand of grass was obtained where fertilizer was applied at a rate to supply 80 pounds of nitrogen and 80 pounds of phosphoric acid equivalent per acre. The average yield of forage, dry weight, on plots seeded to intermediate wheatgrass was 43 pounds without fertilizer and 1,008 pounds with fertilizer. Tall wheatgrass produced 48 and 449 pounds, respectively.

Heaving of small seedling grass plants by frost action was a problem on the tarweed areas. Fertilization reduced this loss. The more

vigorous and larger plants on the fertilized plots were better rooted than the plants on the unfertilized plots. Heaving loss also was lower on the plots seeded with hay from mature native grasses; this indicated that the mulch helped reduce damage from heaving. A direct comparison was not possible because native species were used on these plots and introduced grasses were sown on the drilled plots.

IMPROVING WEEDY MOUNTAIN MEADOWS

Meadows produce much more forage per acre than dry upland range and so are especially important, even though they make up less than 5 percent of the rangeland in the region studied. Livestock tend to concentrate on meadow areas. Through years of season-long grazing, plants of high quality and palatability have declined while coarser vegetation, such as wire rush and other weedy plants, has increased. On many meadows this weedy vegetation now predominates. Some meadow areas have been virtually denuded of any plant cover and can readily be seeded.

Buttercup-Infested Areas

Low palatability of plantainleaf buttercup, western buttercup, biscuitroot, and other meadow weeds has favored an increase in the density of these plants while more desirable grasses and legumes have decreased under grazing pressure. Furthermore, the tops of buttercup and biscuitroot dry up about midsummer and virtually disappear, so that nothing of value remains for the cattle to graze. Yet despite their short period of growth, these weeds greatly suppress growth of grass.

Site Selection

The best areas for improvement with tillage equipment are the more level rock-free areas with soil of good depth, tilth, and fertility. Many of the smaller semiwet meadows in the areas of old lava flows are too rocky for plowing, but can be improved by spraying.

Species Adaptation

Grasses found adapted to seeding on buttercup-infested meadows are: Meadow foxtail, tall wheatgrass, smooth brome, redtop, timothy, tall fescue, and Reed canarygrass (fig. 13). Meadow foxtail proved widely adapted to various soils on which it was tested. Tall wheatgrass and smooth brome required deep, fertile soils for best production. Tall wheatgrass was most tolerant of alkaline soils. Redtop did relatively better on acid soils. Reed canarygrass persisted and yielded well on semiwet or wet meadow sites but did not survive on soils that dry out in the summer. Timothy persisted well on wet meadows but was short-lived on dryland areas.

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Figure 13.—Meadow successfully seeded to mixture of redtop, timothy, and tall oatgrass, Little Shasta Valley, Shasta National Forest.

Methods of Preparing Land

Weedy meadows may be improved by two general methods: Selective herbicides can be used if enough native grasses are left to cover the ground within a year or two after spraying. Or the meadow can be plowed and seeded with adapted grasses.

Spraying with selective herbicides gave excellent results on meadows dominated by weedy plants that are susceptible to 2,4-D, such as plantainleaf buttercup (*1*). Two pounds of alkanolamine form of 2,4-D in 10 gallons of oil-water emulsion per acre was the most efficient spray treatment. The oil-water emulsion included ½ gallon of diesel oil and 9½ gallons of water. Full bloom of plaintainleaf buttercup was the best stage of development for spraying. After spraying, the suppressed native grasses, including Nevada bluegrass, tufted hairgrass, and leafy redtop, increased rapidly in ground cover and in yield. Quality of forage was correspondingly improved.

Spraying not only resulted in higher total production (table 11), but more important, it increased the proportion of grasses. From plots sprayed in 1948, the forage harvested in 1949 was 98 percent grass and 2 percent weedy vegetation; from unsprayed plots, 20 percent grass and 80 percent weeds. Some weeds, such as bistort knotweed, common camas, and squawroot (yampa), were resistant to the 2,4-D spray.

Of the treatments tried, plowing and seeding resulted in the greatest annual production of forage from this weedy meadow. The plowed

plots could not be sown until after a 1-year fallow period, needed to let the heavy chunks of sod weather down. Then a satisfactory seedbed was prepared. The sown grasses not only produced more volume of forage (fig. 14), but also remained green 3 to 4 weeks longer in the summer than the native grasses on either the untreated or on the sprayed meadow plots.

F-478144

Figure 14.—**At left of photo, weedy meadow plot; blossoms of weeds with low forage value and short stature of native grasses are noticeable. At right, a tall growth of grasses with high grazing capacity resulted from plowing and seeding.**

TABLE 11.—*Yield of forage per acre, dry weight, from weedy meadow sprayed with 2,4-D, sprayed and seeded, or plowed and seeded*

Year	Sprayed only [1]	Sprayed and seeded [1]	Plowed and seeded [2]	No treatment
	Pounds	*Pounds*	*Pounds*	*Pounds*
1949	1, 200	----------	----------	[3] 1, 266
1950	467	----------	----------	[3] 145
1951	456	1, 073	1, 142	[3] 166
1952	[4] 1, 180	----------	4, 070	[3] 815
1953	[4] 716	735	998	[4] 695
Average	804	904	2, 070	[3] 617

[1] Treated in 1948.
[2] Plowed in 1948, seeded in 1950.
[3] Half or more in weeds.
[4] Considerable squawroot present.

Method and Rate of Seeding

Drilling seed in the fall gave the best establishment of grass. The meadows were too wet through the spring for satisfactory use of sowing equipment. Broadcast sowing without covering the seed resulted in failure. The mixture of grasses and rate of sowing per acre recommended for meadows are as follows: Smooth brome, 4 pounds; tall wheatgrass, 4 pounds; timothy, 2 pounds; and meadow foxtail, 2 pounds.

Stand Establishment

Reasonable control of grazing until the young grass stands become established is required in the meadow type, as in other types, but the reason is different. In meadows, trampling of young plants when the soil was wet in early spring was the chief cause of injury. Flooding is a special problem in this type. Three grasses, meadow foxtail, Reed canarygrass, and tall wheatgrass, withstood considerable flooding without loss in germination or injury to the established plants.

During the period of grass establishment, poisoning of rodents is advantageous. On the Lassen National Forest, one poisoning helped in reducing damage by ground squirrels and mice on a semiwet meadow that was seeded in the tests. Any rodent poisoning program should be worked out with the local county agricultural commissioner, farm advisor, or representative of the Fish and Wildlife Service because the poisons are toxic to livestock and humans.

Rush-Sedge-Grass Areas

The rush-sedge type occurs in the lower, more level meadows that may be flooded for several weeks each spring. The soil in this type remains moist through the summer. Occasionally this kind of "wet meadow" range is mowed for hay for winter feeding of livestock. Much of the hay is stacked, but some is left in the windrow for fall foraging by the cattle before heavy snowfall. The hay stubble also provides some grazing for livestock after the close of the grazing season on summer ranges at higher elevations.

Site Selection

Natural drainage and the possibilities for bettering it are important considerations in selecting rush-sedge areas for improvement through seeding. The expense and time needed to work the tough sods into a usable seedbed proved to be much greater on these meadows than on dry rangeland types.

Species Adaptation

The grasses adapted to the rush-sedge meadow are: Reed canarygrass, smooth brome, tall wheatgrass, tall fescue, and timothy. Each species has advantages and disadvantages, depending upon local conditions and the objective of management. In northeastern California a moist soil throughout the summer seems necessary for persistence of Reed canarygrass. Smooth brome produced high yields of palatable

forage on fertile soils that remain wet until summer but have good internal drainage. Tall wheatgrass withstood flooding, had tolerance to alkaline soil, and yielded a heavy crop of forage. Tall fescue and timothy may be included as part of a mixture where quick establishment is important. These grasses, however, proved to be less persistent than the other species.

None of our tests to date has found a legume well suited for improvement of these wet meadow sites. Native legumes occur on some meadows, and it seems probable that species from other mountainous areas might be adapted. Broadleaf birdsfoot trefoil has shown some promise of persistence but has been difficult to establish, and only extremely sparse stands have been obtained.

Method of Preparing Land

Plowing was the only completely successful method of preparing these wet meadows for seeding. Coarse rushes and sedges persisted under treatments that included heavy disking and harrowing. Even where the rushes were heavily disked, the sod was only partially broken, and establishment of seedling grasses was very poor. The draft in plowing is heavy; great chunks of sod are turned up by the plow (fig. 15). Fallowing for 1 or 2 years appeared to be necessary before a satisfactory seedbed could be prepared. Disking and rolling were required to make a seedbed sufficiently level and firm for sowing to a uniform depth in soil of good tilth.

F-478135

Figure 15.—Tough sods of plowed rush-sedge require a year or two of weathering before a seedbed can be prepared.

One preliminary test with two selective herbicides, 2,4-D and trichloroacetic acid (TCA), showed promise for control of wire rush. On field plots sprayed with 2,4-D, a reduction of 89 percent in wire rush was obtained. Further study and observation will be needed to determine whether the remaining wire rush will be suppressed by increased growth of native grasses that were resistant to 2,4-D. No procedure has been found entirely satisfactory for seeding grasses into the sprayed sod. Where suitable native grasses exist in sufficient amount, it appears practical to use selective herbicides to reduce the wire rush and thus hasten conversion of these areas to grass without cultivation.

Seeding Method and Stand Establishment

The methods and rates of seeding prescribed earlier for buttercup-infested weedy meadows were found suitable also for the rush-sedge-grass meadows.

The principal precaution to assure stand establishment is to avoid spring grazing while soil is so wet that livestock trampling would destroy many young grass plants.

SEEDING GRASSES IN PINE TYPE

Only on burned or logged areas is improvement of grazing capacity through seeding usually worthwhile on pine ranges in this region. Although grazing is common in open ponderosa pine forests, little of the timbered range is in critical condition. Ordinarily the native plants are either yielding about all the forage the site can produce along with the timber, or are not so seriously depleted that their productivity cannot be restored through grazing management. After wild fires or logging operations, however, grass seeding may be justified for controlling erosion, restoring forage production, or checking invasion of undesirable plants. Overall land-use objectives will determine whether or not grass should be sown.

Where timber production is the primary objective and erosion is not a problem, grass seeding can be undesirable because a dense stand of grass competes with pine seedlings. If only a quick, temporary ground cover is desired to help prevent erosion, short-lived grasses can be used and relatively inexpensive seeding methods may suffice. Where grazing use is an important or a primary consideration, seeding persistent, high-yielding forage species is usually desirable on burns and areas disturbed by logging. In such cases considerable expense for partial clearing of debris is often justified. Reduction in fire hazard is another benefit from sowing perennial grasses that help control cheatgrass, which usually invades burned-over timberland in this area and is highly flammable when dry. Perennial grasses remain green longer, and even after drying burn more slowly than cheatgrass.

Site Selection

Soil depth and fertility are important factors to be considered in selecting areas for seeding in the pine type. For forage production

alone, seeding is usually profitable only on the better soils. However, stabilization of erodible soils and protection of watersheds may justify seeding grass on a wide range of soils.

Species Adaptation

Grasses adapted to seeding in pine areas are smooth brome, intermediate wheatgrass, crested wheatgrass, Fairway crested wheatgrass, timothy, and mountain brome. Smooth brome has grown remarkably well at elevations of 6,000 to 7,500 feet, on deep fertile soils where annual precipitation exceeds 20 inches. This palatable sod grass has also done well in a few tests on timber burns, for example, on the Modoc National Forest. Here in July 1947 a wild fire burned a mixed forest of ponderosa pine and white fir at an elevation of about 6,000 feet. A forage mixture was broadcast by airplane in November. The sowing included: Smooth brome, 3.6 pounds per acre; slender wheatgrass, 0.9; timothy, 0.6; western wheatgrass, 0.1; and yellow sweetclover, 0.4—a total of 5.6 pounds of seed per acre. Smooth brome became well established; only a trace of the other grasses, mainly timothy, appeared. The density and yield of forage was excellent in 1950 (fig. 16). Forage production was 2,332 pounds dry weight per acre as determined from milacre samples cut on August 3, at the time grazing began for that season.

Another highly successful seeding was done on about 6,000 acres of burned-over ponderosa pine timberland on the Modoc National Forest in 1951. This area was somewhat drier, and the soil more shallow and less fertile than the 1947 burn. A mixture of smooth brome, crested wheatgrass, and timothy was sown in early October by airplane. In 1953, the establishment, development, and response of the grasses was determined on a representative area. Smooth brome gave the greatest number of established plants per unit area. The spread of smooth brome by strong rhizomes gave this grass the advantage over the two bunchgrasses in providing ground cover; crested wheatgrass and timothy spread vegetatively only by tillering. Results of this test, and others, show that smooth brome was most suitable in the zone between elevations of 6,000 and 8,000 feet. Crested wheatgrass was best adapted to the lower adjoining zone from 6,000 feet downward to 3,500 feet.

Timothy is a desirable addition to mixtures for use at elevations of 6,000 to 8,000 feet, because it possesses good seedling vigor and establishes a cover quickly, and the seed is relatively inexpensive. Timothy seeds, being small, are more likely than other seeds to go into the ash or small cracks in the soil and be covered; consequently, the chances for germination are improved. Timothy is a comparatively short-lived grass, a desirable characteristic where only a temporary cover is wanted to stabilize erodible soils. But it cannot be depended upon to persist as long as smooth brome or crested wheatgrass.

Intermediate wheatgrass was not sown because at that time the seed was too expensive. Plot tests have shown it to be widely adapted for large-scale planting, and it will be used more extensively as seed

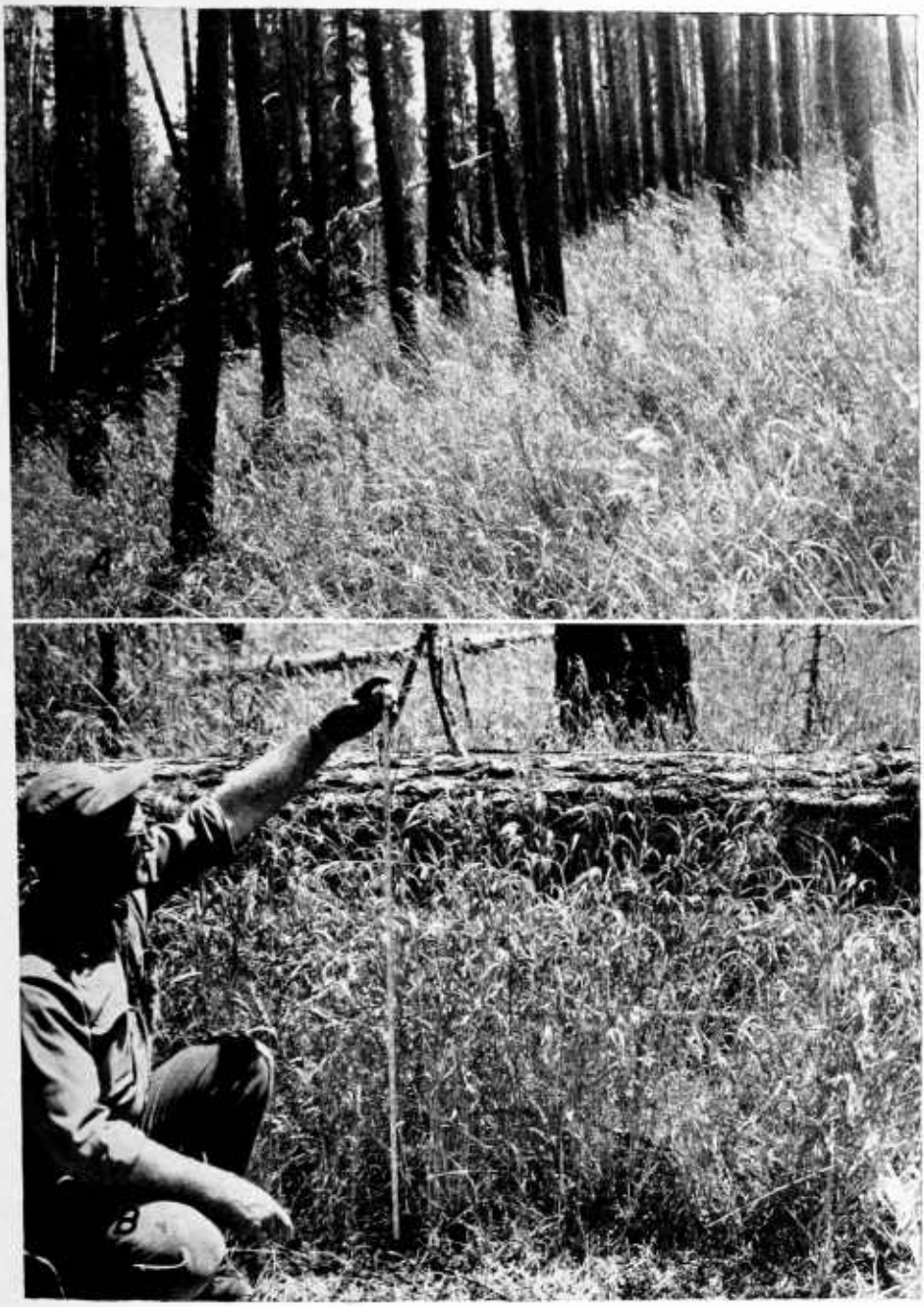

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Figure 16.—Ground cover established on timber burn by airplane seeding of grass mixture. *A*, The slope and the type of timber stand burned; *B*, smooth brome at the same location, photographed at close range.

supplies become generally available. Italian ryegrass, often called annual ryegrass in California, is widely used in seeding burned-over chaparral lands in foothill and coastal areas of the State, but is not sufficiently cold resistant for use in the plateau region.

Methods of Preparing Land

Newly burned timber areas rarely require tillage to prepare a seedbed. Competing vegetation is usually at a minimum, and the surface layer of ash and loose soil provides a favorable condition for seeding. It may be necessary to remove partially burned trees so as to permit easier operation of seeding equipment if ground equipment is used.

Areas left thoroughly disturbed by recent logging also do not ordinarily require tillage for seedbed preparation. The loose soil covers the seed as it settles. Where native plants have not been destroyed but merely crushed or cut off, seeding probably will not be successful because of competition from their resprouting. On steep skid trails or other sloping areas, water diversion devices such as water bars, small dams, and drainage channels usually are needed to help control erosion. These devices should be installed before seeding to insure that seed and young plants are not washed away by snowmelt or heavy rains.

Method and Rate of Seeding

Prompt sowing of burned or disturbed areas is desirable to take advantage of available seedbed conditions. By sowing as soon as feasible, full advantage is taken of the ash, falling pine needles, or loose soil for covering the seed. Seeding before the first rain gives better assurance of obtaining good results than seeding after rainfall. Rain frequently causes a crust to form on the soil surface.

Broadcasting seed by airplane has proved most economical for sowing burned-over timberland. Satisfactory stands have been obtained despite rough topography and surface obstructions. When broadcasting by airplane, flagmen are usually necessary to attain uniform coverage of the area. Clean, heavy grass seed makes for better handling, less cost per unit for seeding, and less danger of spreading undesirable weeds.

Sowing disturbed areas with hand or power broadcasters generally has been satisfactory. When the soil surface has been crusted by rain or snow, harrowing following seeding may be necessary.

Drilling on burned or disturbed areas assures more uniform distribution and coverage of the seed. However, this method is much more expensive than broadcasting and can only be used on relatively smooth land. Fallen trees, brush, or rock on burned areas will usually make drilling difficult—or on many areas, impossible.

For drilling, 8 pounds of crested wheatgrass or 12 pounds of smooth brome of good purity and germination may be considered suitable basic rates, and also a guide to compounding mixtures. Somewhat heavier rates are recommended for broadcasting. However, for sowing by airplane lighter rates are customarily used, because the plane's load limit is a determining factor in deciding upon the rate to seed. Six pounds per acre has given satisfactory results under favorable conditions. Small heavy-seeded grasses such as timothy are better than larger, chaffier seeds such as smooth brome. Since the grasses have different advantages, a mixture (table 12) will often be preferable to a single species.

TABLE 12.—*Forage mixtures suggested for sowing by airplane on burned-over timberland*

Species recommended	Quantity of seed per acre		
	Dry sites, 3,500 to 5,000 feet elevation	Medium sites, 5,000 to 7,000 feet elevation	Moist sites, 7,000 to 8,500 feet elevation
	Pounds	*Pounds*	*Pounds*
Crested wheatgrass or Fairway crested wheatgrass	3. 0	----------	----------
Intermediate wheatgrass	2. 0	2. 0	----------
Smooth brome	----------	2. 0	3. 0
Timothy	1. 0	1. 0	2. 0
Yellow sweetclover	----------	1. 0	1. 0

SEEDING GRASSES IN ASPEN AND RED FIR TYPES

Many scattered openings can be grazed in the aspen and red fir timber types. The openings produce green forage when most ranges at low elevations are dry and green forage supplies are extremely limited. The aspen and fir ranges occur in general above 6,000 feet in elevation. The growing season is short, but soil moisture is ample and forage plant growth is rapid. Precipitation and water yield per unit area are higher than in any of the other types dealt with in this handbook. Consequently, the aspen and red fir types are important producing areas, for both water and forage, out of proportion to their comparatively small acreage of grass.

Site Selection

Two classes of sites offer opportunity for improvement by seeding in the aspen and red-fir types: In aspen, openings plus the ground under tree canopies (fig. 17); in fir, openings only. All the aspen areas studied had suitable soils and growing conditions for range grasses. Openings in the red fir were generally less favorable, primarily because the soil was acid and low in fertility. In both types, steepness of slope and accessibility for livestock use are factors to be considered in selecting sites for seeding.

Species Adaptation

Among the grasses tested, six species proved most suitable for seeding in the aspen type: Smooth brome, orchardgrass, tall oatgrass, timothy, mountain brome, and slender wheatgrass.

In the red fir type, few seedings have been tried and grasses have not persisted as well as in the aspen type. Chewings fescue was the only species that persisted out of 16 grasses sown in a set of test plots in the openings of the red fir forest on the Siskiyou Summit area, Klam-

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Figure 17.—Successful seeding of grass mixture under aspen, Bear Camp area, Long Valley, Modoc National Forest.

ath National Forest. Mountain brome and orchardgrass became established in an earlier test, and these grasses along with blue wildrye, intermediate wheatgrass, and big bluegrass appeared fairly promising the first year but did not survive through the second year. Low soil fertility seemed to cause these grasses to die out.

Method of Preparing Land

Seeding under aspen canopy does not require any tree cutting or other preparation of the land. Openings in both aspen and red fir may require some seedbed treatment. On the Siskiyou Summit area, a sparse stand of pussypaw vegetation was readily reduced by use of a spring-tooth harrow. This harrowing appeared to give all of the preparation necessary before seeding grasses in the openings of the red fir. Both aspen and fir types are relatively free from aggressive competing plants like sagebrush and cheatgrass.

Method and Rate of Seeding

Broadcasting is satisfactory for seeding forage species in the aspen type. Airplane sowing on large areas and hand broadcasting on small ones have been successful on the Modoc National Forest (fig. 17). Grass seed should be sown early in the autumn before aspen leaves fall. Then the aspen leaves provide satisfactory cover for the seed, as earlier Forest Service work in Utah has shown (*8*). A mixture suitable for sowing in the aspen type is: Timothy, 3 pounds; mountain or smooth brome, 3 pounds; tall oatgrass, 3 pounds; and orchardgrass, 3 pounds. A total of 12 pounds per acre is the optimum rate.

In openings in the red fir timber type, a drill may be used on the more level ridge tops or saddles. On steeper areas broadcasting may be the only possible method. Under such circumstances, some covering of the seed would be desirable. This might be done by a spike-tooth harrow or brush drag.

Stand Establishment

No difficulties were encountered in establishing satisfactory stands of grass in the aspen type. The red fir type presents a special problem. In the opening at Siskiyou Summit, Klamath National Forest, some vegetative cover proved beneficial to grass seedling establishment. Seedling grass plants emerged and developed better under rabbitbrush plants than where no vegetative cover was present. These results indicated the desirability of testing a mulch. Small piles of red fir boughs were placed to provide shade and mulch on newly sown areas, but this mulch did not help the grass become established. Serious deficiency in fertility, especially in calcium and phosphorus, was indicated by greenhouse pot-culture tests, conducted by Dr. J. Vlamis, soil chemist, University of California. Although it was not possible to complete fertility tests in the field, results indicate that successful establishment of grasses on open areas in the red fir type may require considerable investment to supply the necessary nutrients and restore organic matter. Specific recommendations for this class of severely depleted rangeland must await results of further research.

On range areas in these two types, because slopes are steep and precipitation high, the joint attainment of maximum forage production and adequate watershed protection depends upon maintaining a good density of vigorous forage plants. Precautions therefore should be taken in grazing to prevent close utilization and excessive trampling that may cause erosion after seeding and damage to the seeded grasses. Otherwise grasses will not persist.

MANAGEMENT OF IMPROVED RANGE AREAS

Improvement of range areas by seeding and weed control will require certain changes in grazing management to realize full benefits of these practices. The first need will usually be to defer grazing, either to allow proper development of new seeded plants or to permit recuperation of desirable plants released from competition through weed control. Unless the desirable plants are allowed to develop good root systems and crowns, they will be weakened and thinned by grazing and undesirable plants will invade the range. In all cases, grazing should be withheld until seed has been set. The required period of deferment will be at least one full season. Under semiarid conditions, however, a good seed crop often does not develop until the second growing season after seeding.

Of special appeal to the livestock operator is the greater flexibility in grazing season obtained by seeding grasses adapted to his specific needs. In this study crested and Fairway crested wheatgrass provided grazing from 3 to 4 weeks earlier in the spring than was available

from native perennial grasses or cheatgrass. Where green forage had been deficient in mid- to late-summer on some of the rangeland in the medium elevation of 5,000 to 6,000 feet, it was possible to use such grasses as smooth brome, intermediate wheatgrass, or tall wheatgrass to meet the need for later summer grazing.

Stocking rates can be materially increased on improved range after the new plants are well established. Carrying capacities 2 to 13 times greater than the former capacity have been obtained by range improvement in the plateau region. No specific figure can be given for an optimum stocking rate because so many factors are involved. A safe rule of thumb has been to stock at a rate that leaves about 50 percent of the year's herbage production on the land at the end of the grazing season. This would be roughly equivalent to a stubble height of 4 inches for most of the grasses and sites considered here. Observations indicate that in comparison with native forage species the recommended introduced grasses tolerate an equal or greater degree of grazing.

Good distribution of grazing animals has been difficult to attain with open grazing when parts of the range were seeded and the remainder left in native forage plants. When given free choice, livestock generally preferred the introduced grasses. Consequently, these grasses have been grazed closer than was desirable, and the native grasses often were underutilized. On most ranches, seeded range areas are grazed as separate units. Therefore, distribution of livestock is a critical problem only on localized portions of range managed under open grazing. On open sheep ranges, herding can be used to distribute grazing pressure. On cattle ranges, additional fencing is required. Extra fencing can be held to a minimum, however, by careful planning before seeding. Moreover, the fencing will aid in putting into effect some form of deferred and rotation grazing, a practice often recommended for range improvement and for obtaining more uniform use of the range.

COSTS OF SEEDING AND WEED CONTROL

No single improvement practice is best for all lands in any one range type. Local conditions of soil, vegetation, and management factors will determine the choice of practice or combination of practices best suited to the individual ranch enterprise. Cost may be a limiting factor.

Initial cost per acre of land preparation, spraying, and seeding will vary from area to area and from year to year. In the period 1951 to 1954 on large-scale public-land projects, cost of equipment operation varied from 35 cents an acre for airplane seeding to $4 an acre for plowing (table 13). Costs are affected by the distance that equipment and materials must be transported, topography and rockiness of area, efficiency of equipment operators, and fluctuations in the price of labor, seed, and materials. The cost of seed and spray materials is not given in table 13. Assuming an average rate of seeding at 10 pounds per acre and a cost of 35 cents per pound for seed, the cost of the total operation would be increased $3.50 per acre. Likewise, in

spraying with 2,4-D the total cost would be increased $2.35 per acre at 1954 prices of spray materials. The materials include 2 pounds of acid equivalent of 2,4-D and one-half gallon of diesel oil to be applied as an oil-water emulsion of 10 gallons per acre.

TABLE 13.—*Sample costs of operating equipment in rangeland improvement, 1951–54*

Job	Equipment	Unit size	Acres per hour	Cost per acre [1]
Plowing	One-way plow	8–10 feet	3	$4.00
Disking	Offset disk	10 feet	4	3.00
Rolling	Log or cast-iron roller.	12 feet	5	[2] 1.00
Drilling	Grain drill	10–12 feet	4	1.50
Broadcasting seed	Whirlwind seeder, hand operated.	10-qt. capacity	1½	2.50
Do	Tractor mounted, bait spreader type.	17-gal. capacity	5	1.25
Do	Airplane [3]	1,200 lb. load, 80 ft. swath	100	0.35
Spraying	Boom type sprayer	20 feet	5	1.00
Do	Turbine type sprayer	60 feet	12	1.25
Do	Airplane [3]	150 gal. load, 40–45 ft. swath	100	1.00

[1] Seed and spraying materials not included.
[2] Rolling and drilling may be done in 1 operation at no more cost per acre than for drilling alone.
[3] Noorduyn Norseman and Stearman airplanes were used.

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APPENDIX

TABLE 14.—*Characteristics of grasses and legumes recommended*

Species	Growth habit [1]	Site adaptation	Purity [2]	Germination [2]	Normal seeding rate per acre
			Percent	*Percent*	*Pounds*
Bluegrass, big	A long-leafed bunchgrass. Produces a high yield of forage in early spring and makes good regrowth after summer grazing. Roots poorly in seedling stage and is easily pulled up by grazing animals.	Moderately dry sites in sagebrush or pine zones on wide range of soils from 3,500 to 7,500 feet. Albion strain best at high elevations; Sherman strain at low elevations.	81	49	6–10
Brome, mountain	Short-lived bunchgrass. Seed large and heavy and seedlings exceptionally vigorous. Similar to slender wheatgrass and timothy in providing quick ground cover.	Sandy or sandy loam soils at 5,000 to 8,000 feet on burned-over timberland.	98	85	8–12
Brome, smooth	Highly palatable sod-forming grass which spreads vigorously by rhizomes. Medium in seedling vigor and ease of establishment. Grows mainly during spring and fall at medium elevations; during summer, at high elevations.	Well-drained, fertile clay loam soils with 20 inches or more precipitation per year. Southern strains such as Lincoln, Achenbach, and Fischer best up to 5,000 feet; Manchar and other northern strains, above 5,000 feet.	92	85	8–12

See footnotes at end of table.

TABLE 14.—*Characteristics of grasses and legumes recommended*—Continued

Species	Growth habit [1]	Site adaptation	Purity [2]	Germination [2]	Normal seeding rate per acre
			Percent	*Percent*	*Pounds*
Canarygrass, Reed	Coarse bunchgrass with short rhizomes; produces high forage yields but palatability is low. Seedling vigor low but vigor of established plants high. Seed shatters badly and therefore is rather expensive.	Wet meadows with deep fertile soil and constant supply of moisture through summer as from subirrigation without stagnation. Thrives from 4,000 to 8,000 feet.	96	80	5–10
Fescue, Chewings	Bunchgrass with tufted growth habit. Foliage remains green throughout summer but production is low.	Acid soil of low fertility in openings of red-fir forest at 6,000 to 9,000 feet elevation.	97	80	5–10
Fescue, tall	Coarse bunchgrass which produces high yields of forage and seed. Remains green through summer but sensitive to summer drought.	Wet or moist meadows with alkaline to slightly acid soils.	96 (3)	90 (3)	6–12
Foxtail, meadow	Bunchgrass with early maturing seed stalks, but foliage stays green throughout summer. Good seedling vigor. Seed chaffy and difficult to drill alone.	Wet meadows or areas submerged up to 2 weeks in spring. Withstands slightly alkaline soil, also moderately drought resistant.	90	80	10–12
Oatgrass, tall	High yielding bunchgrass; medium in palatability.	Moist, deep soils	92 (3)	87 (3)	6–12
Orchardgrass	Bunchgrass which produces moderate yields of high quality forage. Seedling vigor is strong.	Moist, shady conditions under canopy of aspen.	90 (3)	90 (3)	5–10
Redtop	Sod-forming grass of medium production and palatability. Grows throughout most of summer; fairly late in setting seed. Seed is small, but yields are fairly high and seed is readily available.	Wet meadows with medium to fertile soils that may be weakly acid; not suited to alkaline soils. Elevation 4,000 to 8,000 feet.	92	90	5–10
Timothy	Short-lived bunchgrass. Seedlings vigorous and quickly established but stands decline after 2 or 3 years on drier sites. Small, heavy seed is suited to broadcasting on ash.	Light textured soil on burned-over timberlands, or in mixtures for wet meadows at 5,000 to 8,000 feet. Not drought resistant.	99	90	4–8
Wheatgrass, beardless	Similar to bluebunch wheatgrass but absence of awn makes seed easier to drill.	Same as bluebunch wheatgrass. Whitmar strain being most widely used.	92 (3)	90 (3)	6–12

See footnotes at end of table.

TABLE 14.—*Characteristics of grasses and legumes recommended*—Continued

Species	Growth habit [1]	Site adaptation	Purity [2]	Germination [2]	Normal seeding rate per acre
			Percent	*Percent*	*Pounds*
Wheatgrass, bluebunch.	Moderate-yielding bunchgrass, stable in production through favorable and unfavorable seasons. Grows throughout summer and stays green for late summer grazing. Seedling vigor weak.	Dry sites in lower sagebrush zone, 3,500 to 5,000 feet.	94 (3)	90 (3)	6–12
Wheatgrass, crested	Vigorous, well known bunchgrass. (Also called Standard crested wheatgrass and desert wheatgrass.) Grows mainly during spring and provides early spring forage. Highly palatable before seed stalks develop. Strong seed producer. Seedlings moderately vigorous and slow to develop.	Sandy or clay loam soils at 3,500 to 5,600 feet, with 9 to 15 inches annual precipitation. Drought and cold resistant.	95 (14)	85 (14)	8–12
Wheatgrass, Fairway crested.	Very similar to crested wheatgrass but shorter and finer stemmed with more spreading crown, sparsely hairy leaves, and shorter, more wedge-shaped seed heads.	Sandy or clay loam soils, cold dry sites at 5,000 to 7,500 feet. Drought and cold resistant.	95 (14)	85 (14)	6–12
Wheatgrass, intermediate.	Sod-forming grass with short rhizomes which usually appear after plant is 1 year old. High seedling vigor and easily established. Grows during spring and summer at medium elevations.	Wide range of soils at 4,000 to 7,500 feet with precipitation of 15 to 25 inches. Fairly drought resistant. Moderately tolerant to alkaline soils; not to flooding.	89	91	8–12
Wheatgrass, pubescent.	Similar to intermediate wheatgrass but leaves dry from a few days to 2 weeks earlier in summer.	Same as intermediate wheatgrass but slightly more drought resistant and reported to be slightly better on soils of low fertility.	93	85	8–12
Wheatgrass, slender	Short-lived bunchgrass with much the same characteristics as timothy and mountain brome. Good emergence and earlier ground cover than from some longer lived grasses.	Burned-over timberlands at 5,000 to 8,000 feet. Strains with different local adaptation occur.	95	85	8–12
Wheatgrass, tall	Coarse bunchgrass but foliage highly palatable. Remains green throughout summer. Good seedling vigor.	Wide variety of sites; tolerant to alkali and flooding up to 7 or 8 weeks in the spring at snowmelt. Requires annual precipitation 15 to 25 inches. Fails to mature seed above 7,000 feet.	94	90	8–12

See footnotes at end of table.

TABLE 14.—*Characteristics of grasses and legumes recommended*—Continued

Species	Growth habit [1]	Site adaptation	Purity [2]	Germination [2]	Normal seeding rate per acre
Wheatgrass, thickspike	Sod-forming grass, spreading by strong rhizomes.	Areas submerged for a few weeks in the spring; clay or sandy soils.	85 (3)	88 (3)	5–15
Wheatgrass, western	Sod-forming grass, spreading by vigorous rhizomes. Forage production and palatability high. Seed dormancy high when first harvested, but improves with 1 to 2 years' storage. Seedlings weak.	Areas submerged for a few weeks in the spring. Does best on clay loam soil. Tolerant to alkali.	80	80	5–15
Wildrye, beardless	Similar to western wheatgrass. Seed production undependable and seed is frequently unavailable. Slow germination and weak seedling development.	Especially adapted to wet alkaline flats. Occurs on sandy to clay soils and from sea level to 8,000 feet in California.	88	90	5–15
Alfalfa, Ladak	Highly palatable and nutritious legume with deep tap root. Grows most rapidly during spring and more slowly during summer. Responds best to spring seeding.	Well-drained soils. Stand greatly reduced if rodents or rabbits are abundant.	98	90	5–10
Milkvetch, cicer	Sod-forming legume. Summer grower and drought and frost resistant. Contains no harmful alkaloides. May be sown in spring or fall.	Well-drained soils; clay to sandy loam. Suitable at high elevations.	98	90	10–12

[1] Unless otherwise noted, the species are medium- or long-lived. All are perennials.

[2] For average good lots of seed; data are from 1948 U. S. Dept. Agr. Yearbook, pp. 743–752, unless another literature citation is shown in parentheses.

Common and Botanical Names of Species Mentioned

GRASSES AND GRASSLIKE PLANTS

Barley	*Hordeum vulgare*
Barley, meadow	*Hordeum brachyantherum*
Bluegrass, big	*Poa ampla*
Bluegrass, Nevada	*Poa nevadensis*
Bluegrass, Sandberg	*Poa secunda*
Brome, mountain	*Bromus marginatus*
Brome, smooth	*Bromus inermis*
Canarygrass, Reed	*Phalaris arundinacea*
Cheatgrass	*Bromus tectorum*
Fescue, Chewings	*Festuca rubra commutata*
Fescue, Idaho	*Festuca idahoensis*
Fescue, tall	*Festuca arundinacea*

Foxtail, meadow	*Alopecurus pratensis*
Hairgrass, tufted	*Deschampsia caespitosa*
Medusa-head	*Elymus caput-medusa*
Oatgrass, tall	*Arrhenatherum elatius*
Oats	*Avena sativa*
Orchardgrass	*Dactylis glomerata*
Redtop	*Agrostis alba*
Redtop, leafy	*Agrostis diegoensis*
Rye	*Secale cereale*
Ryegrass, Italian (or annual)	*Lolium multiflorum*
Sedges	*Carex* spp.
Squirreltail	*Sitanion hystrix*
Timothy	*Phleum pratense*
Wheat	*Triticum aestivum*
Wheatgrass, beardless	*Agropyron inerme*
Wheatgrass, bluebunch	*Agropyron spicatum*
Wheatgrass, Fairway crested	*Agropyron cristatum*
Wheatgrass, crested	*Agropyron desertorum*
Wheatgrass, intermediate	*Agropyron intermedium*
Wheatgrass, pubescent	*Agropyron trichophorum*
Wheatgrass, Siberian	*Agropyron sibiricum*
Wheatgrass, slender	*Agropyron trachycaulum*
Wheatgrass, tall	*Agropyron elongatum*
Wheatgrass, thickspike	*Agropyron dasystachyum*
Wheatgrass, western	*Agropyron smithii*
Wildrye, beardless (or creeping)	*Elymus triticoides*
Wildrye, Canada	*Elymus canadensis*
Wirerush	*Juncus balticus*

Legumes

Alfalfa, Ladak	*Medicago sativa*
Milkvetch, cicer	*Astragalus cicer*
Sweetclover, yellow	*Melilotus officinalis*
Trefoil, birdsfoot	*Lotus corniculatus*

Other Forbs

Burnet	*Sanguisorba minor*
Buttercup, plantainleaf	*Ranunculus alismaefolius*
Buttercup, western	*Ranunculus occidentalis*
Biscuitroot	*Cogswellia* sp.
Camas, common	*Camassia quamesh*
Knotweed, bistort	*Polygonum bistortoides*
Morning-glory, wild	*Convolvulus arvenis*
Mustard, Jim Hill	*Sisymbrium altissimum*
Poverty weed	*Iva axillaris*
Pussypaw	*Calyptridium umbellatum*
Squawroot (yampa)	*Perideridia gairdneri*
Tarweed	*Madia glomerata*

Shrubs and Trees

Aspen	*Populus tremuloides*
Bitterbrush	*Purshia tridentata*
Fir, red	*Abies magnifica*
Pine, Jeffrey	*Pinus jeffreyi*
Pine, ponderosa	*Pinus ponderosa*
Rabbitbrush	*Chrysothamnus bloomeri*
Sagebrush, big	*Artemisia tridentata*
Sagebrush, black	*Artemisia arbuscula*
Sagebrush, silver	*Artemisia cana*

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