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THE RESEEDING OF DEPLETED GRAZING LANDS TO CULTIVATED FORAGE PLANTS.

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PREFATORY NOTE.

In the investigations planned in 1907 for the improvement of overgrazed lands on the National Forests provision was made for experiments in the artificial seeding of areas in which the natural vegetation had been destroyed or had become relatively unproductive.

In the year 1902 experiments in the reseeding of mountain meadows had been begun by Mr. J. S. Cotton, of the Bureau of Plant Industry. A report on these experiments was published in 1908 as Bulletin 127 of the Bureau of Plant Industry, under the title "The Improvement of Mountain Meadows." The conclusions were that the artificial reseeding of these moist areas was practicable and that timothy and redtop were the most promising grasses for such situations. Continued observation of the original plots, by Mr. Cotton, up to the year 1911, confirmed and extended the earlier conclusions.

The reseeding experiments with cultivated forage plants, begun by the Forest Service in 1907 in cooperation with the Bureau of Plant Industry, are over 500 in number and were located in many kinds of situations. The results are consequently of value as showing not only that reseeding is practicable and profitable but especially as showing in detail to what conditions of soil and moisture it is applicable, under what conditions reseeding is bound to fail, what grasses and clovers have been successful and are best suited to particular situations, the best time of year and the best methods of sowing the seed to secure a good stand, and the extent to which the seeded areas must be protected from stock before the young plants can withstand grazing and trampling.

The percentage of National Forest lands suited to seeding with cultivated grasses is small, but the total area is sufficiently large to make such seeding an important means of increasing the grazing resources of the Forests and to warrant the systematic adoption of the practice of seeding for all the areas to which it is adapted.—FREDRICK V. COVILLE.

THE RANGE PROBLEM.

As anyone familiar with the West knows, unregulated use of the open range has produced a marked deterioration in the forage crop. The most obvious method of providing for range improvement is to close overgrazed areas against stock until the range has regained a normal condition through natural revegetation. This, however, means both a very serious interference with the stockmen who are deprived of use of the range and the waste of the forage which grows during the time that the range is closed. Moreover, in many cases such changes have been produced in the range that betterment takes place very slowly. The most valuable forage plants have either been almost eliminated or had the balance so turned against them and in favor of less desirable plant growth that they can not readily recover the ground they have lost.

The grazing problem is the problem of getting the largest possible use out of the range. This means making the range grow the best possible crop of forage, taking into consideration quality as well as quantity, while making this crop available at the times when the stockman needs it. Evidently the problem has two sides. One side is the study of forage production. The other side is the devising of methods of regulating use of the range by stock so as to utilize the largest possible amount of the forage produced with the least possible reduction of the power to grow forage while conforming to the practical requirements of the stock industry.

In dealing with depleted ranges the first necessity is to learn how the reestablishment of a growth of valuable forage plants can be brought about. Two possibilities are open. The first is that of securing revegetation through natural reseeding. The second is that of replenishing the growing stock through the establishment of a growth of cultivated or introduced forage plants.

INVESTIGATIONS OF THE NATIONAL FOREST RANGE PROBLEM BY THE FOREST SERVICE.

On the National Forests the amount of grazing has been regulated with careful consideration for the condition of the range. Very badly overgrazed areas have in some cases been entirely closed to use. Where conditions are less serious the allotments of stock have been cut down to the point deemed necessary in order to permit the range to recover. Under this system marked improvement in the carrying capacity has taken place. Nevertheless, there is evident need for bringing about improvement more rapidly.

This need has led the Forest Service to undertake, in cooperation with the Bureau of Plant Industry of the Department of Agriculture, a series of grazing studies dealing with the various phases of the whole range problem. Publications setting forth some of the results of these studies have already been issued.[1] One line of experiments has studied the methods of handling stock, with reference especially to the value of inclosed pastures as a means of preventing waste of forage through trampling, of lessening losses, of increasing the number of stock which can be grazed on a given area, and of improving the condition of the range. Another line of studies has sought information concerning the various species of range plants, their forage value, the conditions necessary for their growth and spread, and the nature of the interference produced by grazing use—in other words, the things which must be known in order to understand why and how grazing has reduced the supply of forage and how range regeneration may best be brought about. The third line of studies has consisted in experiments to ascertain to what extent range improvement can be brought about through artificial sowing.

It is a matter of common knowledge that much of the seriously overgrazed range, such as mountain meadows and well-drained parks, have exceedingly fertile soils and originally produced a large native forage crop of high quality, but now support few or no valuable range plants. It is evident that natural revegetation can not be brought about where the original vegetation has been completely destroyed and the land left in a denuded condition. If such land is to be restocked within a reasonable length of time, seed from forage plants adapted to the local conditions must be introduced.

These seriously overgrazed lands differ so widely in soil and growth conditions that before doing any great amount of seeding it was necessary to obtain in much detail, through carefully planned experiments, information concerning the natural factors which limit the successful application of artificial reseeding, the adaptability of various species of plants to the various sets of conditions, the methods which will procure the best results, and the question of cost and returns—in other words, to find out where artificial revegetation can be brought about, what are the most effective means, and whether they will pay.

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[1] The following are the titles of these publications: Jardine, James T., The Pasturage System for Handling Range Sheep, Circ. 178, U. S. Forest Service, 1909. Sampson, Arthur W., The Revegetation of Overgrazed Range Areas, Circ. 158, U. S. Forest Service, 1908. Sampson, Arthur W., Natural Revegetation of Depleted Mountain Grazing Lands, Circ. 169, U. S. Forest Service, 1909.

Both extensive and detailed studies have been carried on during the past five years. As a result it is now possible to give some definite information concerning (1) where reseeding may profitably be undertaken as shown, for example, by the soil and the character of the native vegetation; (2) what species to use; (3) when to sow; and (4) what soil treatment should be applied under the various conditions.

LOCATION AND CHARACTER OF THE REVEGETATION STUDIES.

Since the National Forests extend from the Canadian to the Mexican line and embrace all the important gradations of climate, altitude, moisture, and soil conditions, the investigations were extended over as wide a territory as possible. The location of the experiments is shown in figure 1.

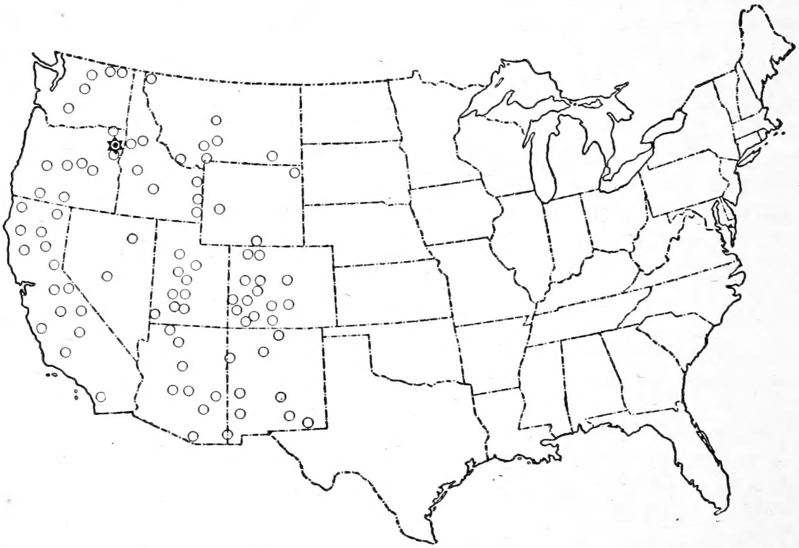


FIG. 1.—Location of the reseeding projects on grazing areas within the National Forests. The star indicates the area where the most intensive study was made.

It will be seen that experimental reseeding has been undertaken in 11 States. Eighty-six important grazing forests out of the 163 National Forests were included in the study, and more than 500 individual experiments were established.

To supplement these extensive experiments conducted by local forest officers, a series of detailed studies was carried out by the writer on the Wallowa National Forest, in northeastern Oregon. These intensive studies were begun in 1907, and were made upon small plots of varying local conditions. Special attention was given to determining the exact causes of failure or success of seeding through careful observations of the potent factors (especially the temperature and soil-moisture conditions during the main growing season) likely to influence the results.

THE GENERAL STUDIES.

These were initiated in 1909 and continued in 1910 and 1911. The tests were confined to plots averaging 4 acres, selected as representative of general conditions. Progress reports on the experiments were submitted at the close of each growing season.

SPECIES SOWN.

The following 14 grasses and 8 species other than grasses were tried in the experiments:

GRASSES.

1. Broom grass (*Andropogon* sp.).
2. Canada blue grass (*Poa compressa*).
3. Slender wheat grass (*Agropyron tenerum*).
4. Blue grama grass (*Bouteloua oligostachya*).
5. Hard fescue (*Festuca duriuscula*).
6. Italian rye grass (*Lolium italicum*).
7. Kentucky blue grass (*Poa pratensis*).
8. Mesquite (*Hilaria cenchroides*).
9. Orchard grass (*Dactylis glomerata*).
10. Perennial rye grass (*Lolium perenne*).
11. Redtop (*Agrostis alba*).
12. Smooth or Hungarian brome (*Broms inermis*).
13. Tall meadow oat grass (*Arrhenatherum elatius*).
14. Timothy (*Phleum pratense*).

NONGRASSES.

1. Alfalfa (*Medicago sativa*).
2. Alfilaria (*Erodium cicutarium*).
3. Alsike clover (*Trifolium hybridum*).
4. Australian saltbush (*Atriplex semibaccata*).
5. Bur clover (*Medicago denticulata*).
6. Japanese clover (*Lespedeza striata*).
7. Red clover (*Trifolium pratense*).
8. White clover (*Trifolium repens*).

In the above list the 10 species most frequently employed in 449 experiments, either sown singly or in mixtures, as reported in the year 1911, were as follows:

	Projects.		Projects.
Timothy	179	Alsike clover	40
Smooth brome grass	96	Australian saltbush	19
Kentucky blue grass	84	Red clover	19
Redtop	81	Canada blue grass	20
Orchard grass	49	Italian rye grass	15

CULTURAL METHODS.

Owing to the difficulty of transportation in many localities, and to the expense involved, the seed was sown broadcast and the soil treatment resorted to in most cases consisted of inexpensive methods which did not require agricultural implements, the use of which often results in serious erosion. In some cases wooden or brush harrows made on the ground were used. In other cases sheep driven in a compact body over the lands after sowing served the purpose of harrowing the seed into the ground.

CHARACTER OF THE LANDS.

The plots were located where the need for range improvement is greatest. The areas seeded vary in altitude from 2,000 to 10,000 feet. This range in elevation was accompanied by a corresponding diversity in the growth conditions and in the character of the native vegetation.

Among the more common and characteristic trees of the higher elevations where studies were carried on may be mentioned: Whitebark pine, foxtail pine, limber pine, subalpine fir, Engelmann spruce, and mountain hemlock. The climatic conditions characteristic of regions in which these trees predominate will be designated by the use of the term "whitebark pine zone." Some of the characteristic trees of the lower seeding stations are: Lodgepole pine, western yellow pine, sugar pine, digger pine, western larch, and various species of willow alder, dogwood, aspen, mountain mahogany, maple, and oak. These species are found in successive zones which may be called the "lodgepole-pine zone," the "yellow-pine zone," and a still lower zone of which no single tree is characteristic, usually known as "Upper Sonoran." The great number of shrub species and herbs characteristic of the places where the extensive studies were conducted will be readily understood by anyone familiar with the great range of plant life found where the various trees just mentioned grow.

In this wide altitudinal and latitudinal range the more important soil as well as climatic conditions were covered. The main soil types were: Sandy loam, clay loam, decomposed pumice, volcanic ash with varying amounts of organic matter, and soils of various textures originating primarily from basaltic, granitic, sandstone, and calcareous rocks.

ESTABLISHMENT OF THE PLOTS.

In all cases the seed was scattered broadcast, either with a machine or by hand. The proportion of seed used in mixed sowings was similar to that employed in the detailed reseeding work. The amount of seed required to produce a full stand, when a single species was sown, will be discussed elsewhere. In most situations the soil was given no culture before the seed was scattered. In general, the areas were closely grazed prior to seeding, and in the main inexpensive methods of planting were employed, namely, harrowing in the seed with a brush or wooden peg harrow, or trampling it in by sheep.

RESULTS.

COMPARATIVE SUCCESS OF THE VARIOUS SPECIES.

Of the 449 experiments observed during the calendar year 1911, 168, or 37.42 per cent, were failures; 112, or 24.95 per cent, were partial successes; 71, or 15.81 per cent, were fully successful; 64, or 14.25 per cent, were undeterminable at the end of the season; and in the case of 34 experiments, or 7.57 per cent of the total, the results were not definitely declared. Grasses were used in most of these experiments. The following table is presented to show the results in the case of single or pure sowings.

TABLE 1.—*Results of seeding to grasses.*

Name of species.	Number of projects.	Failures.		Successes and partial successes.		Undeterminable at end of season.	
		Number.	*Per cent.*	*Number.*	*Per cent.*	*Number.*	*Per cent.*
1. Timothy	87	22	25.29	56	64.37	9	10.34
2. Kentucky blue grass	44	22	50	14	31.82	8	18.18
3. Smooth brome	43	10	23.26	25	58.14	8	18.60
4. Redtop	36	14	38.89	12	33.33	10	27.78
5. Orchard grass	22	11	50	4	18.18	7	31.82
6. Italian rye	8	5	62.5	3	37.50	0	0
7. Tall meadow oat grass	5	2	40	0	0	3	60
8. Canada blue grass	4	3	75	1	25	0	0
9. Perennial rye	4	2	50	2	50	0	0
10. Grama grass	2	2	100	0	0	0	0
11. Canadian wheat	1	1	100	0	0	0	0
12. Hard fescue	1	0	0	0	0	1	100
13. Broom grass	1	1	100	0	0	0	0
Total	258	95		117		46	
Average per cent			36.82		45.35		17.83

Table 1 shows that by far the best results were secured with timothy, 64.37 per cent having been successful or partially successful. It will be observed that this species was employed in 87 projects, from the Canadian to the Mexican boundaries. Despite the fact that the results of a part of these experiments were not declared, over three-fifths gave good returns.

Next in the category of successful results are: Smooth brome grass with 58.14 per cent, perennial rye grass with 50 per cent, Italian rye grass with 37.5 per cent, Kentucky blue grass with 31.82 per cent, and redtop with 33.33 per cent. It is interesting to note that the more drought-resistant species, notably smooth brome grass, perennial rye grass, etc., rank among the first in the successful seeding. The figures given in Table 1 are comparable in each case to the results obtained where these species were seeded in mixtures. As far as the returns show, all trials of meadow oat grass and hard fescue gave negative results.

Very few of the nongrasses yielded satisfactory returns. Those worthy of consideration are white and alsike clovers and alfilaria. Of the trials with white and alsike clover, 41.67 and 14.82 per cent, respectively, gave partly or wholly satisfactory returns. In the case of alfilaria, 28.57 per cent of the experiments gave good results. The alfilaria, however, requires a high temperature during the growing season and therefore it can not be successfully introduced except in the lower elevations. In southern California, where this plant flourishes, it fails to produce much herbage above an altitude of 6,000 feet. In the Northwest it should not be sown above 3,000 feet elevation.

While the locations at which the best results from reseeding have been obtained are not shown in Table 4, it may be stated, allowing for local variations, that the best returns were secured in the Northwest and the poorest in the more arid Southwest. No species yet tried can be economically introduced in the hot, dry foothills of California, Arizona, and New Mexico, where the lands are distinctly arid.

SPRING VERSUS AUTUMN SEEDING.

The most convenient way in which to note the time at which seeding has yielded the best results is by means of curves showing the percentages of successful and partially successful experiments and of failures during the spring, summer, autumn, and winter periods, classifying the months as follows: Spring—March, April, and May; summer—June, July, and August; autumn—September, October, and November; and winter—December, January, and February.

Plate II shows emphatically that autumn is the most satisfactory time to sow, the spring period coming second; the summer and winter periods are the most unsatisfactory. By months, October and May, in the order named, proved the most satisfactory. The reason why fall seeding, and especially the month of October, yields the best results, aside from the more elaborate root development produced, is doubtless primarily the fact that all plant activities have ceased at that time, and thus a weak autumnal growth and subsequent winter killing is avoided. Then, too, during the dormant period the seeds are worked into the ground by physical agencies, and when conditions for germination become favorable the seeds are not only well planted but the seed coats are softened and germination takes place promptly and simultaneously.

CAUSES OF FAILURE.

The causes of failure in the unsuccessful experiments are numerous. Often several factors are operative in bringing about unsatisfactory results, and it is sometimes difficult to determine which is the most potent.

The six chief causes of failure, in the order of importance, are as follows:

1. Lack of soil treatment.
2. Drought.

3. Wrong selection of species.
4. Spring sowing.
5. Excessive competition with native vegetation.
6. Wrong time of sowing (other than spring).

It is interesting to compare the following statement as to the chief reasons for only partial successes:

1. Spring sowing.
2. Lack of soil treatment.
3. Drought.
4. One or more species unadapted.
5. Excessive competition with native vegetation.
6. Wrong time of sowing (other than spring).
7. Overgrazing.
8. Excessive moisture for species sown.

Within the altitudinal limits at which the conditions governing growth are favorable, and on the lands adapted to the growth of cultivated forage plants, the factors which bring about failures are largely preventable. The lack of soil treatment, which, it will be noted, leads as a factor in the causes of failure, is, by the proper handling of the lands, preventable in virtually all cases; the drought factor, except possibly during seasons of unusual weather conditions, may be eliminated by the judicious selection of the lands to be seeded; wrong selection of species is largely avoidable when the soil, moisture conditions, altitude, and the requirements of the species used are known; failure due to spring and summer seeding should be avoidable since it is generally known whether or not enough precipitation is received during the growing period to insure continued vigorous growth.

It will be noted that, in the main, the same causes which were operative in the case of failures were also responsible for only partial successes; and that while the arrangement of the chief causes in the two cases is somewhat different, the lack of soil treatment is of vital importance in both.

Consideration of further results of the extensive experiments will be deferred until an account of the intensive studies has been given, when the conclusions reached as a consequence of both series of studies can be most intelligibly presented.

INVESTIGATIONS IN THE WALLOWA MOUNTAINS.

These investigations, conducted on a series of plots at various elevations, were planned with a view to obtaining precise data upon physical and climatic conditions which might be expected to play an important part in determining the success or failure of each experiment.

The studies were originally confined to 15 main plots having an average area of about 4 acres, of which 10 were in the whitebark pine and 5 in the lodgepole pine zone. Both in the spring and autumn of 1908, 1909, and 1910 several additional small plots were seeded to grasses and clovers at high and medium elevations.

CLIMATIC CONDITIONS.

The amount of precipitation during the growing season was notably greater in the high mountains than at lower levels. In 1909, which was about an average season, the mountain bunch-grass ranges in the whitebark pine zone (elevation about 7,500 feet) received 7.45 inches of precipitation during the main growing season, which, at that altitude, is about three months long, mainly July, August, and September. The lands of medium elevation, about 4,500 feet, in the lodgepole pine zone, a region which enjoys a growing season of about four and one-half months, received during July, August, and September 5.51 inches precipitation. On the ranges of the yellow-pine zone (elevation about 3,000 feet), the precipitation received during the same period was 3.63 inches. In subsequent seasons the relative amounts were about the same.

The temperature in the whitebark pine zone as compared with the two lower zones was found lower by several degrees: the evaporation also was less, and consequently the transpiration demand on the vegetation was less.

DESCRIPTION OF THE PLOTS.

The largest plot, 20 acres in area, was selected on a severely overgrazed tract, on what is known as Stanley Range, lying at an altitude of about 7,300 feet on a ridge which at one place broadens out into a plateau about a mile in width. The area was seeded to a mixture of timothy, redtop, and Kentucky blue grass. The amount of seed sown per acre was as follows: Timothy, 8 pounds; redtop, 3 pounds; and blue grass, 4 pounds. The seed was worked into the ground by driving a band of sheep in a compact body twice over the area.

As shown in figure 2, the topography is smooth, and the whole area slopes westerly from 3° to 6°. The soil is a light clay loam, having a depth of from one to several feet, underlain by a layer of basaltic rock mixed with more or less soil. In places this rocky layer is exposed, forming small "scabs" or "scablands." The water-retentive power of this soil is good, though the surface layer becomes rather dry early in the season.

The whole area was originally covered with mountain bunch grass (*Festuca viridula*), but it is now almost barren. The most abundant perennial plant now is sickle sedge (*Carex umbellata brevi-*

rostris). A number of inconspicuous annuals are scattered over the entire area in more or less profusion. In a number of small patches where moisture is abundant there is a dense growth of alpine redtop (*Agrostis rossæ*), slender hair grass (*Deschampsia elongata*), a number of different species of sedges and rushes, and a small amount of mountain timothy (*Phleum alpinum*). Subalpine fir, Engelmann spruce, and whitebark pine occur in restricted clumps over the area, occupying, as shown in figure 2, less than 5 per cent of the land.

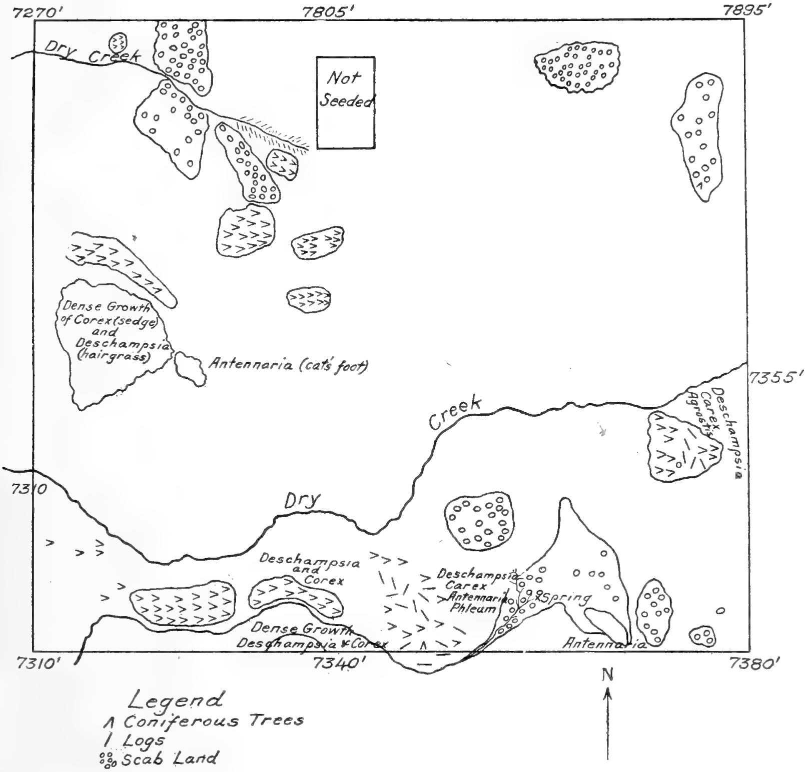


FIG. 2.—Chart of the largest area selected for reseeding experiments, main pasture, Stanley Range.

Three other reseeding plots, one a fourth of an acre and the other two a half acre each in size, were established on Stanley Range, the same species being seeded as on the larger plot, and, in addition, smooth brome grass and alsike and white clovers. The only difference in the physiography of these plots as compared with that of the larger area is in the slope and exposure. The two half-acre areas have a southeastern aspect, one with a gradient of 12° and the other of 15°. The quarter-acre plot has a uniform eastern slope of 6°.

On Sturgill Range, at an altitude of about 7,600 feet and in the same general type as the Stanley Range, 5 acres were seeded. The area selected is an old bed ground lying in a shallow cove. The ground is smooth, except for occasional narrow ruts caused by erosion in the spring. The general aspect is toward the southwest, with a gradient of 5° to 6°. The area formerly bore a heavy growth of mountain bunch grass (*Festuca viridula*), but is now bare of vegetation save for a few scattered tufts of yarrow or wild tansy, sedge, and needle grass (*Stipa minor*) and a small clump of alpine fir and

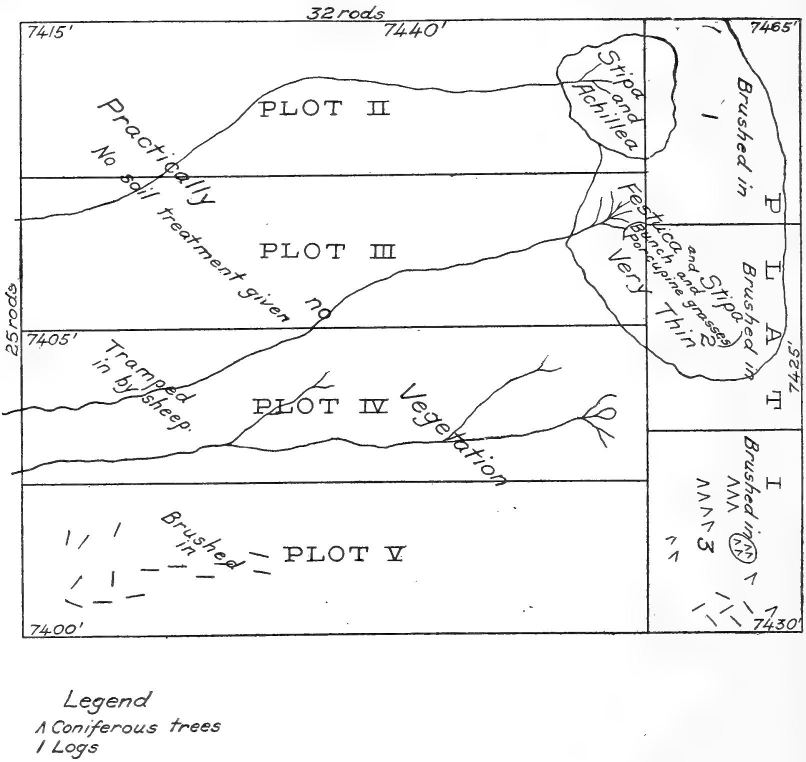


FIG. 3.—Chart of the seeding experiment on the Sturgill Range.

whitebark pine in plot 1. (See fig. 3.) Small portions of plot 1 and plot 5 are covered by logs. The soil is a deep basaltic clay loam similar to that on Stanley Range, but richer in organic matter. Soil samples taken at a depth of 8 inches at various times during the main growing season gave an average moisture content of 27 per cent. Although sheep have been bedded on the ground for several years, the soil has not been packed to a great extent.

Plot 1 contained 1 acre. It was divided into three subplots, each of one-third acre. Subplot 1 was seeded to timothy at the rate of 9 pounds per acre; subplot 2, to redtop at the rate of 15 pounds per acre; and subplot 3, to Kentucky blue grass at the rate of 21 pounds per acre. In each case the seed was planted by the use of a brush harrow. Plots 2, 3, 4, and 5, each 1 acre in area, were seeded to a mixture of timothy 5 pounds, redtop 4 pounds, Kentucky blue grass 5 pounds. No soil treatment was given plots 2 and 3. Plot 4 was trampled by sheep after seeding, and plot 5 was thoroughly brushed with a pine-tree harrow. The arrangement of the plots and the native vegetation are shown in figure 3.

On what is known as the Bear Creek experimental range, an area of 4 acres was seeded to a mixture of 5 pounds timothy, 4 pounds red-

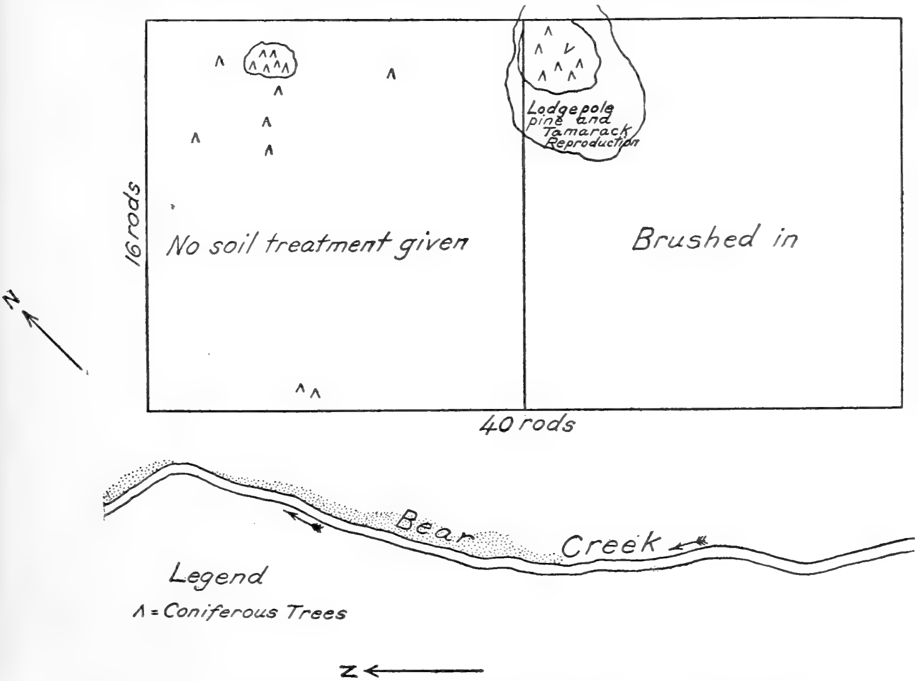


FIG. 4.—Chart of the seeding experiment at Bear Creek Station, altitude 4,800 feet.

top, and 5 pounds Kentucky blue grass. One-half of the area was brushed in and the remaining 2 acres were left untreated.

The area selected, as shown in figure 4, is a strip 16 rods wide by 40 rods long, in the bottom of the Bear Creek Canyon, lying within a few rods of the stream. The elevation of Bear Creek at this point is about 4,800 feet. Ridges rise abruptly on both sides to a height of 2,000 feet above the creek. The seeded area is smooth and practically level. The soil is a deep, black, slightly clayey loam of alluvial character. The minimum water contained in the soil taken at a depth of 8 inches during the summers of 1908, 1909, and 1910 was 16 per cent. The land originally bore a heavy stand of timber, of which western larch, Engelmann spruce, yellow pine, lodgepole pine, lowland fir, Douglas fir, and aspen were the most abundant species. About 20 years ago practically all the timber was killed by fires, leaving the ground strewn with semidecayed logs. Chaparral, which is very dense on adjoining areas, is rapidly invading some of the land. Coniferous reproduction, consisting chiefly of spruce, lowland fir, tamarack, and lodgepole pine, is abundant, and saplings are making an unusually rapid growth, indicating favorable conditions. There is a sparse stand of grasses and grass-like plants, those most abundant being pine grass (*Calamagrostis suksdorfii*), two sedges, and a number of weedy annuals. The herbaceous vegetation had been closely grazed by cattle at the time that the seeding was done.

Additional reseeding plots were established in the less rugged portion of the Wallowa Mountains, near what is called the "Billy Meadow" country. The elevation of this locality (5,000 feet) is slightly greater than that of the Bear Creek area, but in the same vegetation type. The lands selected had been overgrazed to a marked degree, but the soil was still fertile and capable of high carrying capacity. Timothy, Kentucky blue grass, redtop, and alsike clover, were used. Both pure and mixed seeding was done on these plots, the proportion of seed being virtually the same as that given for other plots where the same species were employed. The alsike clover was seeded at the rate of 8 pounds per acre. In some of the plots the seed was harrowed or brushed in; in other cases no soil treatment was given. The viability of the seed of the species used in these studies was determined under controlled conditions in the Seed Testing Laboratory of the United States Department of Agriculture. The results of these tests follow:

TABLE 2.—*Viability of the seeds of the species sown.*

Kind of seed.	Duration of test.	Germination.
	Days.	*Per cent.*
Smooth brome grass	14	72.5
Kentucky blue grass	31	44.5
Redtop	9	88.0
Timothy	13	81.5
Alsike clover	14	90.0
White clover	26	88.0

The germination tests show that with the exception of Kentucky blue grass, which germinated only 44.5 per cent after a test of 31 days, the viability of the seeds sown was as good as might be expected. Owing, however, to the likelihood of "heating" at the time of harvesting, viability of Kentucky blue grass is usually below that of the other species here employed.

In the case of all the plots described the seed was scattered in the autumn. To test the relative merits of spring and autumn planting additional small plots adjacent to those seeded in the autumn were seeded just as the last snow was disappearing in the spring. In all of this work the seed was scattered broadcast, in some cases with a hand seeder and in other cases by hand. Either when sown pure or to a mixture, the hand seeder, shown in Plate I, figure 1, was highly satisfactory in getting an even distribution of the seed. A machine of the kind shown in this plate does not exceed 5 pounds in weight, is easily portable and compact, and can readily be adjusted to regulate the amount of seed to be sown. A 10 to 12 foot swath is covered by a machine of this kind, and one man can sow from 25 to 35 acres per day.

RESULTS OF THE INTENSIVE STUDIES.

In general it may be said that the factors chiefly instrumental in bringing about unsatisfactory results in reseeding are (1) wrong time of sowing; (2) inadequate planting of the seed; (3) use of species unadapted to the conditions; (4) excessive altitude; (5) soil which is either too shallow or of undesirable physical structure and chemical character, or which has too small or too great a supply of moisture.

In presenting in detail the results of the intensive experiments there will be discussed: Spring and autumn sowing; the merits of different methods of soil treatment; growth requirements and characteristics of the forage species in question during the time of establishment; the restriction of reseeding due to altitude; and how to judge, by the native vegetation, lands suitable for reseeding.

SPRING VERSUS AUTUMN SEEDING.

A study of spring-seeded and fall-seeded plots established on contiguous lands in a number of different situations showed the autumn-sown areas far superior to those sown in the spring (1) in the time of germination, (2) in the period required for all the seed to germinate, (3) in the development and vigor of the seedlings, and (4) in the subsequent seedling loss due to adverse conditions, which determines the final stand.

The most striking examples of the advantage of autumn sowing were observed on plots established on well-drained mountain meadow lands where the surface layer of soil is friable and has a tendency to dry out excessively early in the season. A measure of the merits of spring and autumn sowing on such lands is shown in Plate II. Under the same climatic and soil conditions grass seed—timothy, Kentucky blue grass, smooth brome grass, redtop, etc.—sown in the fall germinated from 5 to 12 days earlier than seed sown in the spring on top of the snow or on a saturated soil just as the last snow of the season disappeared. With species having thick, hard, and more impermeable seed coats than grasses, as in the case of clovers, there was much more difference in the time of germination. In some few situations the seed, both of clover and grasses, sown in spring tided over to the following spring, when good germination was secured. With such delayed germination much of the seed is consumed by birds and rodents or removed by the wind and other agencies.

Both the root development and the aerial growth of the plants originating from autumn-sown seed was about double that of plants from seed sown in the spring. The significance of this fact appears in a heavy and relatively early loss of seedlings from spring sowing due to drought. In many situations the difference in the depth of the root system resulting from autumn and spring seeding has resulted in a satisfactory stand on the one hand and complete failure on the other.

It may be definitely stated from the results obtained that in the Wallowa Mountains spring seeding, except possibly in the situations where the soil is well supplied with moisture throughout the season and where the seed may decay if allowed to lie dormant for a long period, has no advantages over autumn seeding. On the other hand, spring sowing has grave disadvantages. The seed germinates late and over a long period; much of it is lost owing to delayed germination; the seedlings are shallowly rooted and are liable to serious injury from drought; and superabundant moisture interferes with cultural methods of planting.

By sowing in the autumn the above difficulties are virtually eliminated. Seed should not be sown so early in the autumn that it will germinate before winter. If it germinates in the fall the little seedlings are likely to succumb to drought, if the season is dry, or their growth is so slight that little reserve food is stored in their roots, and the plants make only a weak growth the following spring. Where winters are severe it is best to sow after vegetative growth ceases and before the heavy winter snows begin. Then the seed will be protected by the snow until the time of germination.

ADVANTAGES OF THOROUGH PLANTING.

In order to know which of the inexpensive methods of soil treatment used will give the most satisfactory results in reseeding it was highly important to secure definite information as to the density of the seedling stands secured on the various plots. The difference in the abundance of seedlings was evident on some of the plots, or on parts of them, by mere observation, but to get definite compari-

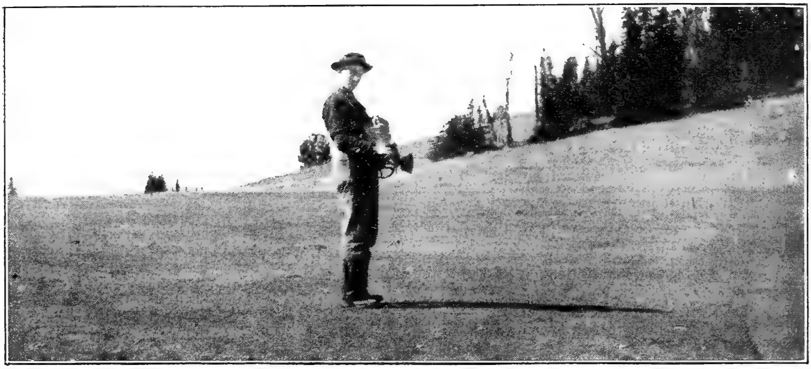


FIG. 1.—A HAND SEEDER IN USE ON AN OVERGRAZED RANGE AREA.

FIG. 2.—A BRUSH HARROW IN USE. WITH MATERIALS AVAILABLE THIS IMPLEMENT CAN BE CONSTRUCTED IN AN HOUR.

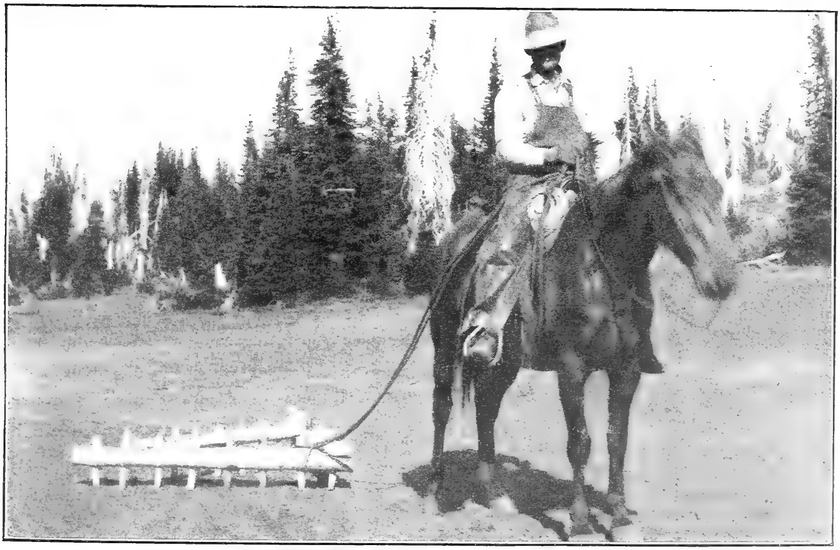
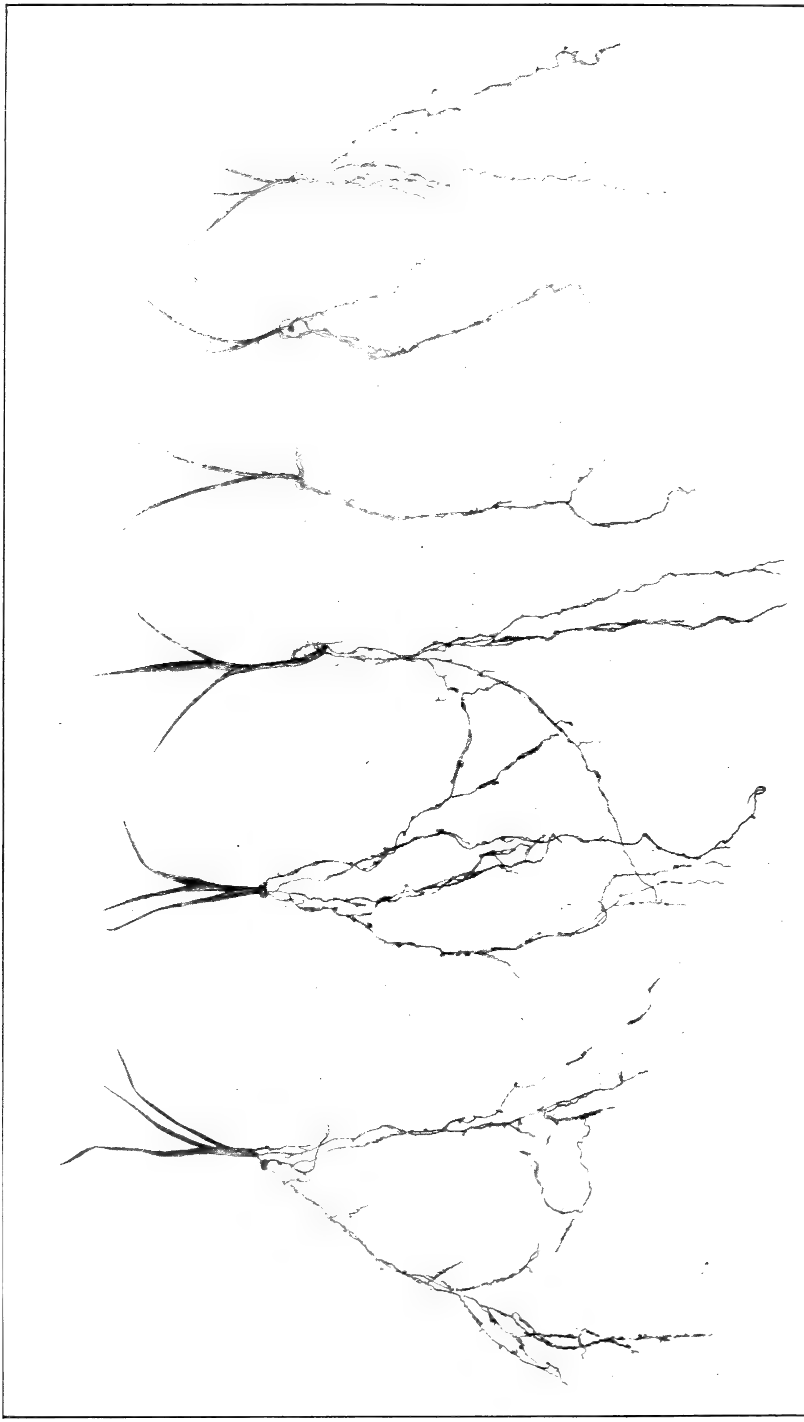


FIG. 3.—A WOODEN PEG "A" HARROW FOR USE IN PACKED SOILS; IT CAN BE CONSTRUCTED BY ONE MAN IN THREE HOURS.



A COMPARISON OF THE ROOT DEVELOPMENT OF TIMOTHY SOWN IN THE FALL AND SOWN IN THE SPRING.

Specimens on the left show average development from fall sowing; those on the right from spring sowing.

sons on the plots as a whole it was necessary to make actual counts. This was done by noting the number of seedlings within a number of sample areas 40 inches square. Table 3, which follows, shows the results.

TABLE 3.—*Seedling stand on the different plots.*

Location.	Plot No.	Treatment.	Number of unit area counts.	Seed sown.									Seeded singly or in mixture.
				Timothy.			Redtop.			Blue grass.			
				Subplot.	Pounds per acre.	Average number seedlings per square meter.	Subplot.	Pounds per acre.	Average number seedlings per square meter.	Subplot.	Pounds per acre.	Average number seedlings per square meter.	
Sturgill Range, elevation 7,600 feet.	I	Brushed in.	32	1	9	15.7	2	15	26.8	3	21	22.0	Singly.
Do.	II	Trampled by sheep.	17	...	5	19.6	...	4	15.4	...	5	3.6	Mixture.
Do.	III	...do.	20	...	5	18.2	...	4	16.0	...	5	4.2	Do.
Do.	IV	Untreated	20	...	5	13.5	...	4	9.2	...	5	2.5	Do.
Do.	V	Brushed in.	15	...	5	43.6	...	4	36.8	...	5	12.4	Do.
Bear Creek station, elevation 4,800 feet.	I	...do.	10	...	5	49.2	...	4	19.8	...	5	15.4	Do.
Do.	II	Untreated.	10	...	5	20.8	...	4	6.4	...	5	4.4	Do.
Stanley Range, elevation 7,300 feet.	I	Trampled by sheep.	31	...	8	16.0	...	3	5.3	...	4	2.1	Do.
				Alsike clover.									
Do.	II	Brushed in.	11	1	8	11.7	...	...	...	...	...	...	Singly.
Do.	II	Trampled by sheep.	9	2	8	6.8	...	...	...	...	...	...	Do.
				White clover.									
Do.	II	Brushed in.	10	3	8	14.4	...	...	...	...	...	...	Do.
Do.	II	Trampled by sheep.	10	4	8	11.2	...	...	...	...	...	...	Do.

The figures show that on the plots sowed to a single species (Plot I, Sturgill Range) the best stand was secured from redtop, the bluegrass plot ranking second in abundance of seedlings. The reason for the sparse stand of timothy, as compared with the other two species on these particular areas, was primarily the superabundance of native vegetation, which prevented much of the seed from coming in contact with the soil.

Comparing the brushed, trampled, and untreated plots, it will be seen that in every case the best stand was secured on the brushed areas, the trampled plots ranking second and the untreated plots having the poorest stand. It will be noted, however, that the plots given no treatment have a correspondingly better stand of timothy seedlings than of any other species. In the case of the untreated plots this may be explained by the greater weight of the timothy seed than that of the other species.

On Stanley Range the plots were all trampled in, and consequently seedling counts were made only in the large pasture. Here the stand was not as good as on the plots just discussed. This area was much drier during the early part of the summer than the area on Sturgill Range, and a notably larger percentage of the seedlings succumbed as a result of insufficient moisture. However, in all situations the loss of seedlings was greater and occurred earlier in the season where the soil was not treated than where the planting was thorough.

The relative merits of the cultural methods used and of no soil treatment, as evinced by the density of the fully established forage stand secured on uniform autumn-sown habitat, are shown in Table 4.

TABLE 4.—*Relation of forage yield to cultural methods.*

Species.	Soil treatment.	Forage cover (10 maximum).
Timothy	Brushed	4 to 6
	Trampled	2 to 7
	No treatment	0 to 4
Redtop	Brushed	1 to 4.5
	Trampled	1 to 4
	No treatment	0 to 2
Kentucky blue grass	Brushed	4 to 7
	Trampled	3 to 4.5
	No treatment	1 to 2

Table 4 shows markedly that in the case of all three species the best stand was secured on the brushed plots, the areas trampled by sheep after sowing being second. (See Pl. III, figs. 1 and 2.) These results are doubtless accounted for by the fact that the seed on the brushed plots is more uniformly and not too deeply covered. On the plots given no soil culture whatever the density of stand secured was very inferior.

Both harrowing or brushing and trampling the seed in by the sharp-cutting hoofs of sheep have special advantages. On densely packed and stiff soils brushing or even running over the surface with the A wooden-peg harrow is not nearly so effective as trampling by sheep. On the other hand, using sheep as harrows will not bring about the good results that brushing will, other things being equal, on denuded areas, where there is no vegetation to bind the surface, and where the soil is friable.

Other conditions being the same, it is evident that better returns from reseeding are ordinarily obtained on denuded lands than on areas where the soil is tightly bound by roots. While lands that support a dense stand of vegetation indicate a fertile soil and usually good conditions for growth, it is often difficult to get cultivated plants started on such areas, first, because of the difficulty of thoroughly working the seed into the ground without thorough cultivation; and, second, because of the inability of the young plants to compete successfully for moisture and light with the hardy, well-established, and deeply rooted native vegetation. On such lands reseeding will usually not pay.

Effective cultural implements.—Owing to the character of the land to be seeded, one instrument may be preferable in one locality and another in a different situation. Accordingly, the means of construction both of the brush and the **A** wooden-peg harrow is here given.

The brush harrow pictured in Plate I, figure 2, consists of five saplings or tops of whitebark pine or any other available stiff-leafed species, pines or spruces being preferable, cut into lengths of about 6 feet and laid parallel to each other at intervals of about a foot, depending upon the spread of the branches. These tops are held together, as in a vise, between two 5-foot crosspieces, the lighter of which is uppermost. The brush ends are usually trimmed a little to insure a tight fit all around. The crosspieces may either be lashed together by wire or rope or secured by wooden pegs inserted through bored holes. The whole can be readily dragged over the ground by a rope attached to the saddle horn. A swath of 5 to 6 feet is covered by this harrow. On denuded areas this crude implement did such effective work that usually only one brushing was necessary to cover the seeds, but where there was more or less grass or other vegetation to bind the soil even repeated brushing was not highly effective. On such lands, where the original vegetation is not so dense as to make reseeding impracticable, an **A** wooden-peg harrow was found more effective.

As shown in Plate I, figure 3, this is a simple device, the framework of which is composed of three small logs, about 5 or 6 inches in diameter, cut into lengths of about 5 feet. These are hewn down with an ax in order to present a flat surface, and are fitted together into the shape of a letter **A**, or of a triangle, and the ends secured by spiking with wooden pegs or by wiring. With a brace and bit holes of about 1 inch in diameter are made through the logs at intervals of about 5 inches, and teeth, made from such branches as may be available, cut into uniform lengths of about 6 or 7 inches, are driven through. This harrow also may be readily dragged over the ground by a rope attached from the apex to the horn of the saddle. An ax and an inch auger are the only tools needed for its construction. This implement takes about a 4-foot swath.

The use of sheep in planting.—Sheep are found even more efficacious in working up partially vegetated and closely packed soils than the **A** wooden-peg harrow. A band of sheep driven in a compact body once or twice over an area after seeding was found to leave no part of the surface soil unstirred. On bunch-grass lands, for example, where many of the tufts had died out, the tussocks were often torn asunder by the sheep passing over them a couple of times. In loose soils, as stated, there is danger of getting the seed planted too deeply by the employment of this scheme. This difficulty may be largely obviated by driving the band over the area before as well as after scattering the seed. By so doing the loose hummocks and elevated points are mostly smoothed down before the seed is scattered, and too deep planting is thereby at least partly eliminated. Even then, however, the forage stand secured on areas of loose soils where the seed was trampled in was not usually as dense as where harrowing or brushing was employed, but much better than where no soil treatment was given subsequent to sowing.

COMPARATIVE MOISTURE REQUIREMENTS AND ROOT DEVELOPMENT OF THE SEEDLINGS.

During the first year of growth—that is, during the seedling period—a rather marked variation was found to exist in the ability of the species in question to become established. This fact does not necessarily mean that one species is more drought resistant or can take more water from a given soil than another, but rather that there is a difference in the depth, spread, and general development of the root system through which the water is secured.

When young, the species of similar growth-form and of the same age produced very nearly the same height growth. It was also found that the species which naturally flourish in the drier habitats produced roots of similar development so far as concerned their depth and spread. It was found, however, that the ratio between the height growth and the depth of the root in the case of species which naturally prefer medium moist soils was different from that developed by species which prefer moist habitats. As a concrete example, four grass species, smooth brome grass, timothy, Kentucky blue grass, and redtop, which are known to have different moisture requirements, were grown in a common habitat, and at the end of the fifth week after germination the respective species were carefully examined to ascertain the average depth of the root development. Smooth brome grass had extended its roots to a depth of 3.1 inches, while timothy, Kentucky blue grass, and redtop had made an average root development of 2.7, 2.5, and 1.9 inches, respectively. The habitat selected was amply moist up to the date that the measurements were made, and during the period in question each species functioned normally at all times.

As the season advanced, the soil, even to the lower depth of the roots, gradually became so dry as to completely eliminate all the seedling plants. Redtop, the plant requiring the greatest amount of moisture in the superficial layer, died from drought at some time or other during the first six weeks of growth. Kentucky blue grass, next

FIG. 1.—THE DIFFERENCE IN DENSITY OF SEEDLINGS FROM DIFFERENT CULTURAL METHODS AT THE END OF THE FIRST YEAR OF GROWTH; PLOTS IV AND V, STURGILL RANGE.

On Plot IV the seed was trampled and on Plot V the seed was brushed in. The dominating species is timothy.

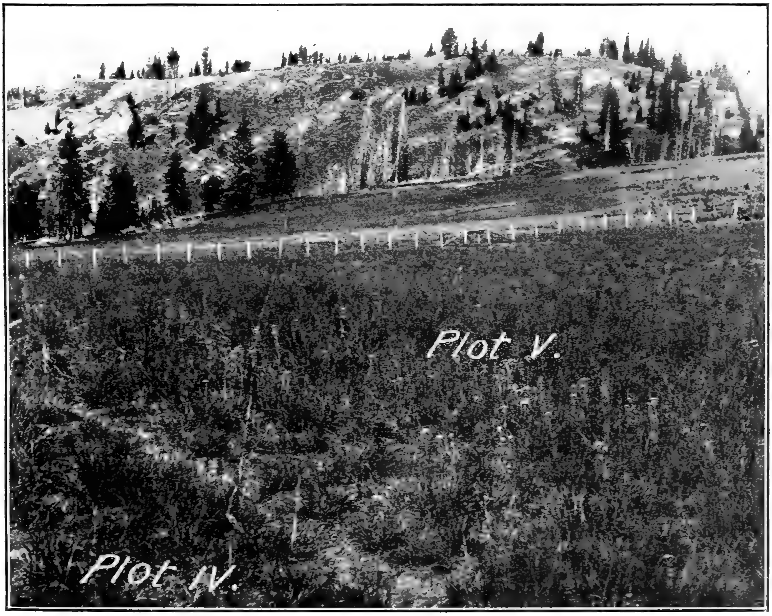
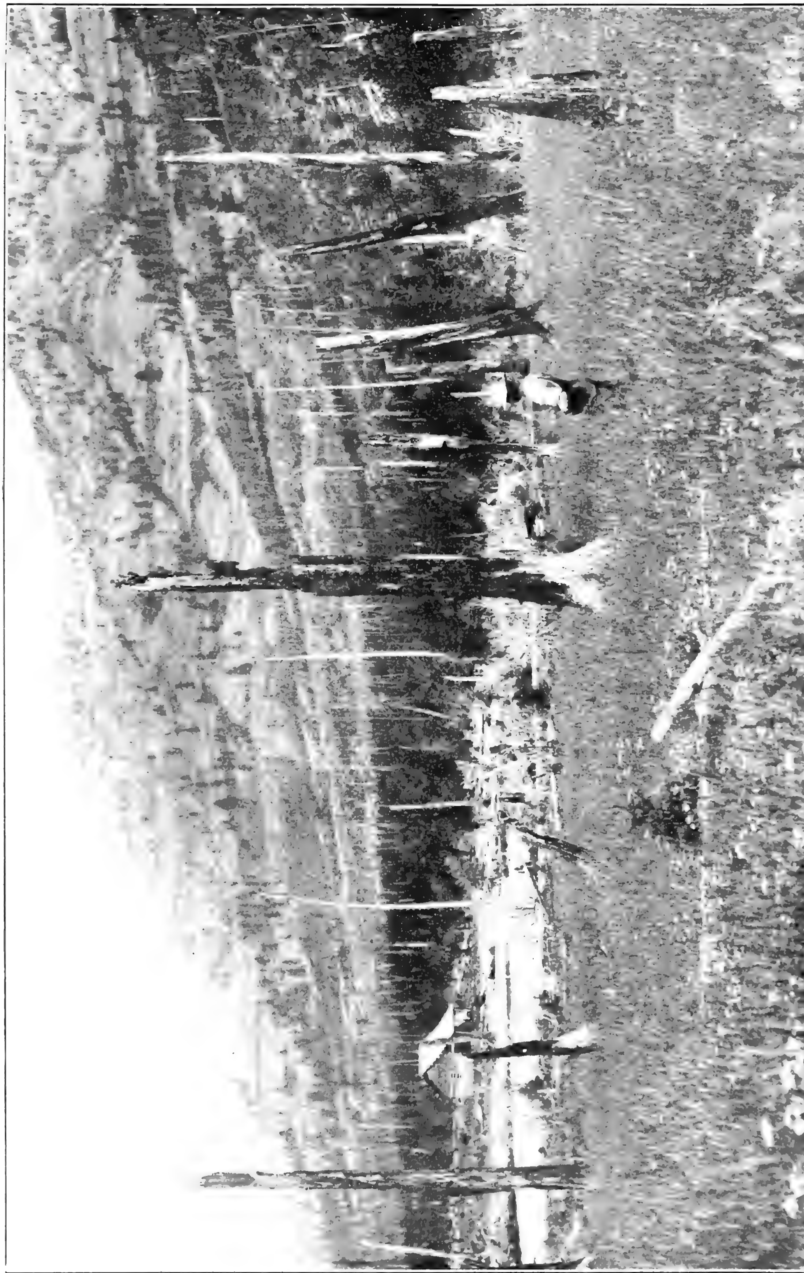


FIG. 2.—ANOTHER VIEW OF PLOTS IV AND V, SHOWING THE GROWTH AT THE END OF THE SECOND YEAR.

On the trampled area 40 per cent of the ground is covered by grass and on the brushed area 60 per cent.

COMPARATIVE MERITS OF DIFFERENT CULTURAL METHODS.



THE RESULT OF RESEEDING.

A burned over area on Bear Creek where pine grass and weeds have been replaced by timothy, redtop, and bluegrass. This area was seeded in the fall of 1907; the picture was taken in the fall of 1909.

to show distress for lack of water, was killed mainly during the seventh week of growth. As evinced by its repeated wilting during the warmer part of the day, timothy showed a more serious condition than brome grass, which, as stated, was more deeply rooted than timothy. During the latter part of the eighth week all the timothy plants were killed, while some few brome-grass seedlings persisted until the end of the tenth week. During this entire 10-week period no precipitation, aside from that accumulated in the form of dew, was received. Meanwhile, the minimum soil water content varied from 4 to 9 per cent. A soil moisture content of 4 per cent marked the lower moisture limits at which these plants could exist in the habitat in question.

A comparison of the time and degree of wilting of the various species and their ability to recover from wilting further substantiates the above classification as to moisture requirements. The species which are able to recover from one wilting to another may tide over the serious drought period, which may be broken at any time by the necessary precipitation. The time of recovery and subsequent vigor varied with the different species. During the fore part of the drought period all species usually began to recuperate between about 4 and 7 o'clock p. m. each day. As the season advanced the time of wilting among the species became notably prolonged and more irregular. The more deeply rooted plants, smooth brome grass and timothy, during the first few weeks varied but slightly in the time during which wilting began, while redtop and Kentucky blue grass would in many cases become limp two hours earlier and would not recover from this condition for several hours after deeper-rooted species had resumed the normal condition.

There is no doubt that the ability of a plant to recover from wilting when in a soil of low water content depends upon the vigor of the species, which, in turn, is largely determined by the depth of the root system by means of which the moisture is secured. Each time during wilting the root hairs in contact with the drier soil particles are doubtless killed, and the gradual elimination of these moisture-absorbing surfaces results in earlier and more severe wilting each day and finally, through the destruction of most of the root hairs, brings death to the plant.

RELATION OF ALTITUDE TO RESEEDING.

The uppermost limits at which seeding was found to yield good returns and the comparative yields at different elevations may best be shown by comparative measurements of the average height growth, density of stand, amount of seed yield, time of the flower stalk production and seed maturity, and the viability of the seed crop of the three closely studied species, timothy, Kentucky blue grass, and redtop. The areas compared are as similar as could be found locally at wide altitudinal range. The lands were seeded simultaneously with seed from the same source, and the soil was given identical treatment. The results are presented in the following table:

TABLE 5.—*Relation of altitude to reseeding.*

Species.	Height growth at—		Density of stand based on scale of 10 at—		Estimated yield at—		Time of— Flower stalk production at—		Time of— Seed maturity at—		Viability of seed crop at—	
	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.	7,800 feet.	4,800 feet.
	In.	*In.*			*Tons.*	*Tons.*					*P. ct.*	*P. ct.*
Timothy...	15	39.0	4	9	½	2	Aug. 5–20	July 1–15	Sept. 1 to end of season.	Aug. 1–15	12.0	86.0
Kentucky blue grass.	9	15.5	3	7	1/10	½	Aug. 1–20	June 20–July 5.	...do....	July 15–Aug. 10.	9.5	36.5
Redtop....	11	23.0	2	5	1/10	½	Aug. 10–28	July 10–30	Sept. 10 to end of season.	Aug. 10–25	8.0	74.0

A glance at Table 5 shows that there is a striking difference in the forage yield in the two situations, the ratio being approximately 4 to 1 for all three species.

This wide contrast in production is due to the difference in the density of the stand and in the height growth. The density bears the relation of 7 to 3 at 4,800 feet and 7,800 feet, respectively, while the height attained by the different species at 7,800 feet is over 100 per cent less than that produced at an elevation of 4,800 feet. This contrast in growth is further shown in Plates V and VI by natural-size photographs of average stands of timothy at 3 years of age, at which time full development has been attained.

Wide differences, of high importance from the standpoint of natural reseeding of the introduced plants, exist in the production and viability of the seed. It will be observed, for example, that the flower-stalk and the seed-maturing periods begin five weeks and five and one-half weeks earlier, respectively, in the situation of lower elevation. The lateness at which the seed crop matures at 7,800 feet makes it impossible, except for the individual plants which put forth the flower stalks unusually early, to produce viable seed. This accounts in part for the fact that the average germination of the three species in the higher elevation is 9.8 per cent, as opposed to 64.8 per cent in the lower habitat.

Owing to the low yield, due to the sparseness of the stand and to the poor height growth made, and the small amount of viable seed produced at an elevation of 7,800 feet, it is evident that this is the maximum elevation at which reseeding should be attempted in the Wallowa region.

RELATION OF SOIL ACIDITY TO RESEEDING.

Throughout the mountains are found areas, usually limited in extent, either so situated that the soil is saturated with water the year round or of such poor drainage that the water accumulated in the spring does not dry out of the soil until late in the growing season. Owing to poor drainage, the rank plant growth usually produced, and the continuous accumulation of organic matter, the soil in such habitats is often acid or sour in varying degrees.

The soil in the densely vegetated grass, sedge, and rush bogs is almost invariably strongly acid. In some such localities more than 30,000 pounds of lime would be required to neutralize an acre a foot in depth.[1] Areas characterized by huckleberries and heaths are also invariably strongly acid. The soils of the willow and alder lands, which are often fairly well drained, are likely to be less sour.

From a number of isolated plantings of the cultivated forage species experimented with, it became evident that in the sour soils clovers (alsike and white clover tested), Kentucky blue grass, and even timothy grew much less luxuriantly than redtop. Where the lime requirement was no more than 4,000 pounds per acre, alsike clover, in spite of the abundant water supply, died early in the first season, and Kentucky blue grass struggled along, making very slow growth. In the more acid soils timothy also showed signs of distress and did not develop nearly to the extent that it did in the better-drained soils less than a hundred yards away. The feature of greatest interest was the behavior of the roots. Except for redtop, each of the species tried made a very meager root development in the sour soils, and instead of penetrating to a normal depth and spreading naturally, the rootlets curved and twisted in a most unusual fashion, as though in search of a different type of soil.

A study of the growth of cultivated forage plants in sour soils shows rather conclusively that alsike and white clovers and Kentucky blue grass are not adapted to such habitats; that timothy does not make its best growth in sour soils; that none of the other species included in this general study, similar in habits to timothy and Kentucky blue grass, succeed; but that redtop makes a prolific aerial and root growth. Such lands are frequently densely vegetated with plants inferior for forage purposes, and owing to the matted surface and the entanglement of long root stocks running under the surface of the ground, it is often difficult to get redtop started. When a stand is once secured, redtop is able to compete successfully with the native plants.

In deciding on the plants that may give the best results in reseeding moist meadows, and more especially marsh lands and bogs, it is

[1] In agricultural practice a soil having a lime requirement of 5,000 pounds for neutrality is considered very acid.

not necessary to determine their acidity by chemical analyses. The acid condition of the soils may be recognized by noting the kind of plants growing on them.

In coves where aeration of the soil is largely prevented by saturated moisture conditions during the greater part of the year, the vegetation is entirely made up of plants that are adapted to living in strongly acid soils. The Wallowa mountain lands of this character support a number of locally well-known grasses such as mountain timothy (*Phleum alpinum*), slender reed grass (*Cinna latifolia*), tufted hair grass (*Deschampsia caespitosa*), marsh pine grass (*Calamagrostis canadensis*), and tall meadow grass (*Panicularia nervata*). (See Pl. VII, fig. 1.) Intermixed with these are a number of sedges, rushes, and weeds, the more common of which are tall swamp sedge (*Carex exsiccata*), water sedge (*Carex festiva*), wood rush (*Juncoides glabratum*), cone flower (*Rudbeckia occidentalis*), and false hellebore (*Veratrum viride*). (Pl. VII, fig. 2.) The genera here mentioned indicate, in a general way, an acid soil, though all the species of a single genus do not necessarily prefer sour soils. Where these plants and those of similar habits are found in abundance, and where the soil remains in a high state of moisture during most of the year, it is relatively certain that clovers, Kentucky blue grass, and even timothy, and indeed all cultivated plants used in this investigation, except redtop, will not succeed. Redtop, on the other hand makes its most luxuriant and prolific growth in these lands.

Even in some of the better drained acid soils where huckleberries and heaths or willows and alders occur in abundance, redtop is often the most satisfactory species. These plant associations, except possibly in the case of dense stands of huckleberries, usually indicate a less strongly acid soil than the grass and sedge marshes. Where lands of these types are so situated that drainage is not seriously obstructed, timothy, which is found to succeed in moderately sour lands, is often a valuable species for reclaiming them. All the experiments indicate that timothy, next to redtop, will give the best returns on such soils. This is one of the instances where a mixed seeding of redtop and timothy is justifiable. If the soil proves too sour for timothy or too dry for redtop, the chances are favorable to the establishment of one or the other of the species.

The intensive studies have therefore established:

(1) That under usual conditions reseeding will be most successful if performed in the fall after vegetative growth has ceased.

(2) That inexpensive soil treatment either in the form of brush or tooth harrowing or by the trampling of sheep is highly important.

(3) That in endurance of drought smooth brome grass, timothy, Kentucky blue grass, and redtop grade in the order named from high to low resisting power.

THE EFFECT OF ELEVATION ON THE DEVELOPMENT OF TIMOTHY.

An average 3-year-old timothy stand grown at an elevation of 4,800 feet. Note the length of the panicle, the rank culm development with its bulb-like base, the many leaf blades, and the deep and spreading root system. (Natural size.)

THE EFFECT OF ELEVATION ON THE DEVELOPMENT OF TIMOTHY.

An average 3-year-old timothy plant grown at an elevation of 7,300 feet. Note the low stature, the small panicle, the slender culm without the bulb-like enlargement at the base, the few and short leaf blades, and the undeveloped root system. (Natural size.)

FIG. 1.—A TYPICAL MOUNTAIN MARSH.

Minam Meadow, altitude 5,000 feet, covered mainly with tall swamp sedge. Redtop is adapted to such a situation, but can be established only with difficulty because of the densely matted soil surface.

FIG. 2.—TIMOTHY AND REDTOP ESTABLISHED.

A moist meadow in the Wallowa Mountains, 5,200 feet elevation, originally covered with various plants of low forage value which have been almost completely supplanted by timothy and redtop.

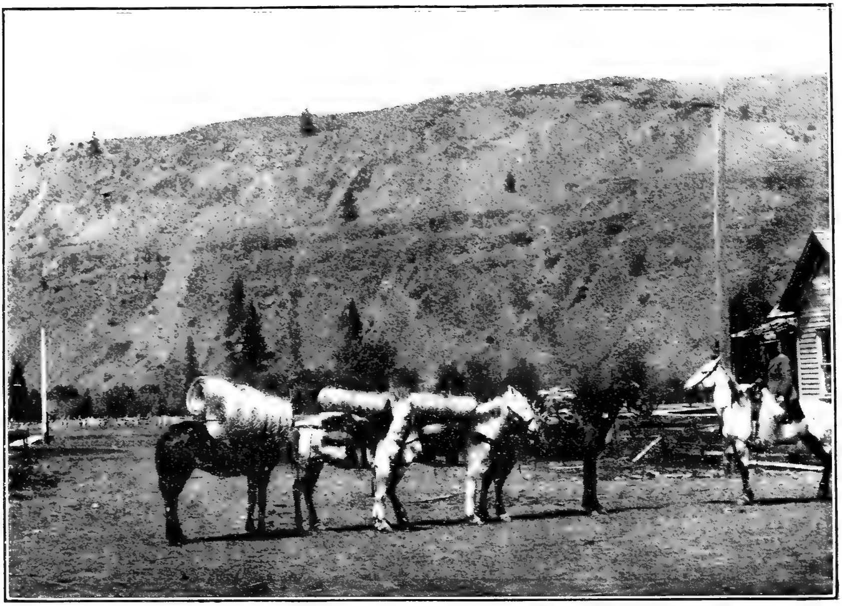


FIG. 1.—A PACK TRAIN STARTING INTO THE WALLOWA MOUNTAINS.

This illustrates the difficulty of transportation, which tends to preclude the use of agricultural implements.

FIG. 2.—A DEPLETED RANGE IN THE WALLOWA MOUNTAINS, 7,600 FEET ELEVATION.

This shows the upper limits at which seeding will pay. The trees have their characteristic open stand, but at slightly higher points, where the trees become dwarfed, reseeding will not pay.

(4) That in the Wallowa Mountains an altitude of 7,800 feet marks the highest limit at which reseeding is likely to pay. This is about 500 feet below timberline.

(5) That on acid soils redtop or redtop and timothy should be sown.

(6) That acid soils may be recognized by the type of vegetation present.

Further conclusions of practical importance, based upon the experience derived from both the intensive and the extensive experiments, will be presented in the following pages.

SELECTION OF SPECIES.

In introducing cultivated forage plants on the range the judicious selection of the species to be sown is a matter of first importance. If species which are not adapted to the local conditions are chosen the cost of seed and labor is to no purpose.

The chief points to be considered are: The particular soil and climatic conditions in their relation to the requirements of the various species; the cost of the amount of seed required to establish a satisfactory forage stand; the time required, and the ability of the species to withstand grazing; and finally, the palatability, nutritiousness, and forage yield of the species.

HABITAT REQUIREMENTS OF THE SPECIES STUDIED.

In the selection of species possibly the most common and most serious mistake is made in not choosing those best adapted to local moisture and soil conditions.

From the standpoint of moisture requirements the species studied may be classed as of high, intermediate, and low requirements. The first group includes the plants that grow luxuriantly in wet meadows and saturated soils, poorly drained and consequently poorly aerated. The second group includes those which do best on well-drained and more porous soils, but which, though requiring a medium amount of moisture for their highest development, may do fairly well both in dry and moist habitats. The third group consists of species which thrive best on lands that are well drained at all times of the year. Table 6 gives the arrangement of the species under these heads.

TABLE 6.—*Water requirements of the species.*

Low.	Intermediate.	High.
Alfilaria.	Alfalfa.	Alsike clover.
Australian saltbush.	Alsike clover.	Orchard grass.
Blue grama grass.	Canada blue grass.	Red clover.
Bur clover.	Italian rye grass.	Redtop.
Hard fescue.	Japan clover.	White clover.
Mesquite.	Kentucky blue grass.	
Slender wheat grass.	Orchard grass.	
Smooth brome grass.	Perennial rye grass.	
Timothy.	Red clover.	
	Tall meadow oat grass.	
	Timothy.	
	White clover.	

It is not to be inferred that the above classification is absolute. Owing to the adaptability of some species to a rather wide diversity in soil-moisture conditions, a single species, as shown in the above table, may fall under two classifications. While the classification is necessarily general, it is believed that it will be helpful to stockmen in the judicious selection of species to be used, since it indicates what species may be used in locations of different moisture conditions. Some will succeed in both the medium and dry situations, and some in both the medium and wet.

As has already been pointed out, the acidity of the soil, as well as its physical structure and the corresponding moisture content, must be considered in selecting a species for a given area. Redtop, for example, makes the best growth and becomes permanently established on moist, poorly drained soils of strongly acid character. Timothy also does well on sour soils, but does not withstand the degree of acidity that redtop does, while clovers fail completely (for all practical purposes) in such habitats. On the other hand, Australian saltbush, aside from being a dry-land plant, is adapted to alkaline soils, which are antagonistic to the other species of low moisture requirements.

RELATIVE AMOUNT AND COST OF SEED PER ACRE.

SEEDING TO ONE SPECIES.

The way in which the seed is sown and the inexpensiveness of the soil treatment makes the cost of the seed itself the heaviest item of expense. The average cost per hundred pounds of choice seed of the various species, and the amount required per acre to secure a full stand on soils of high carrying capacity, follow:

TABLE 7.—*Amount of seed and cost per acre.*

Species.	Pounds per acre.	Cost per hundred-weight.	Cost per acre.
GRASSES.			
Canada blue grass	20	$14.00	$2.80
Slender wheat grass	20	20.00	4.00
Hard fescue	15	15.00	2.25
Italian rye grass	20	6.50	1.30
Kentucky blue grass	20	20.00	4.00
Orchard grass	15	15.00	2.25
Perennial rye grass	20	7.00	1.40
Redtop	15	15.00	2.25
Smooth brome grass	20	15.00	3.00
Tall meadow oat grass	20	15.00	3.00
Timothy	8	8.00	.64
NONGRASSES.			
Alfalfa	8	10.00	.80
Alfilaria	8	80.00	6.40
Alsike clover	8	20.00	1.60
Australian saltbush	20	75.00	15.00
Bur clover	8	10.00	.80
Japanese clover	10	20.00	2.00
Red clover	8	25.00	2.00
White clover	8	25.00	2.00

The other items of expense are transportation, scattering the seed, and soil treatment. The first of these varies so widely, according to the means of transportation, distance, cost of labor, and horse rental, that no figures can be given. Where pack animals must be employed the cost is necessarily higher than if a wagon can be used; and where the stockman does the work the cash outlay is materially lessened, since, by owning his own work animals, wagons, etc., a high rental is eliminated, and in many cases work of this character can be done when other labor is not urgent. In the Wallowa experiments the seed was transported on the backs of pack animals for a distance of about 25 miles at an approximate cost of $2 per hundred pounds. (See Pl. VIII, fig. 1.) This cost is figured on the basis of $2.50 for the day wage of a man and $1 for horse rental.

With the use of a hand seeder a man can sow 25 acres per day, provided the area is in one tract. This makes a cost of 10 cents per acre. Hand sowing is considerably cheaper if an experienced man is available, but it is extremely difficult to get in this way an even distribution of light seed, like redtop and Kentucky blue grass.

If the seed is trampled in by sheep no expense is incurred. Brushing can be done at a cost of 25 cents per acre.

SEEDING TO A MIXTURE.

With species like Kentucky blue grass, the seed of which costs 20 cents per pound and which requires 20 pounds to the acre for a full stand, the cost makes extensive seeding prohibitive, except possibly under the very best soil and growth conditions. It is often a matter of economy to sow such seed in mixture with one or two of the less costly species. For example, a mixture of 9 pounds of Kentucky blue grass and 4 pounds of timothy per acre, which is sufficient seed to produce a full stand, will cost approximately half that of a pure seeding of 20 pounds of Kentucky blue grass. For range purposes generally, even though good returns may be expected, it is not deemed advisable to expend much over $2 per acre for seed and planting. Where growth conditions are favorable the original stand is sure to increase if the lands are not grazed too early and closely each year, and eventually the maximum carrying capacity of the land in question will be secured at a relatively low expense if the $2 per acre limit is adhered to.

Aside from the question of cost, it is sometimes expedient to seed to a mixture because of uncertainty as to what species a given meadow is best adapted, or because with a proper selection the grazing period may be lengthened and at the same time a variety of feed afforded. As a concrete example, where Kentucky blue grass, timothy, and redtop are seeded in mixture and each becomes established, the Kentucky blue grass is the first in the spring to produce a forage crop.

When this plant is at its maximum producing capacity timothy is just beginning to grow vigorously, and no flower stalks are produced until the blue grass begins to mature its seeds. Not until timothy has produced most of its flower stalks, after which it is not eaten with as much gusto as earlier in the season, does redtop come into evidence. It grows late and remains palatable until about the close of the mountain grazing season.

In addition, some species produce a good forage crop much sooner after seeding than others and live much longer. Timothy, for example, usually produces a fair forage crop the second year following seeding, and yields maximum crops up to about 6 years of age, after which its forage production usually decreases year after year.[1] Redtop, on the other hand, does not usually yield good returns until the fourth year after seeding, but when once established it is there to stay and may be depended upon to continue to produce good crops if growth conditions are satisfactory. True, in sowing to a mixture it is possible and entirely probable that the species to which the conditions are best suited may readily predominate and supplant the others, but in some habitats there is such a balance between species that none is forced out until age intervenes. Again, the ability of certain species to withstand adverse winter conditions is variable and one grass may be entirely killed out, possibly by somewhat unusual conditions, while the vitality of another may not be affected in the least. Thus, in artificial reseeding, time may often be saved and additional forage produced by mixture sowing.

In order that the reader may compare the cost of some of the most promising species used, both when sown pure and in mixtures of various proportions, the following summarized table is presented. Timothy, Kentucky blue grass, and redtop were used in these experiments, the cost of the seed being $5, $10, and $15 per hundred pounds, respectively. No cost of transportation is included. The costs of scattering the seed and of a given soil treatment were practically the same throughout.

[1] Records show that in a few cases timothy has yielded good returns for 10 consecutive years.

TABLE 8.—*Kind and amount of seed sown on each plot in fall of 1907, subsequent soil treatment given, and total cost per acre.*

STANLEY RANGE—7,500 FEET.

Area seeded.	Size of area.	Plot No.	Sub-plot No.	Kind of seed.	Pounds sown per acre.	Treatment after seeding.	Total cost per acre.
	Acres.						
Main pasture	20	I	......	Mixture:	8	Trampled in by sheep	$1.40
				Timothy	8		
				Redtop	3		
				Kentucky blue grass	4		
Sedge-catfoot area	¼	II	......	Mixture:	......	....do	1.30
				Timothy	4		
				Redtop	4		
				Kentucky blue grass	4		
Mountain bunch-grass area.	1	III	......	Mixture:	......	....do	1.50
				Timothy	5		
				Redtop	4		
				Kentucky blue grass	5		

STURGILL RANGE—7,800 FEET.

Area seeded.	Size of area.	Plot No.	Sub-plot No.	Kind of seed.	Pounds sown per acre.	Treatment after seeding.	Total cost per acre.
Denuded bed ground	1⅓	I	1	Timothy	9	All brushed in	$0.80
	⅓	......	2	Redtop	15		1.85
	⅓	......	3	Kentucky blue grass	21		3.50
Do	1	II	......	Mixture:	......	Trampled in by sheep	1.50
				Timothy	5		
				Redtop	4		
				Kentucky blue grass	5		
Do	1	III	......	Same as plot 2; same number pounds.	......	....do	1.30
Do	1	IV	......	....do	......	Untreated	1.30
Do	1	V	......	....do	......	Brushed in	1.55

BEAR CREEK RANGE—4,800 FEET.

Area seeded.	Size of area.	Plot No.	Sub-plot No.	Kind of seed.	Pounds sown per acre.	Treatment after seeding.	Total cost per acre.
Burned over	2	I	......	Mixture:	......	Brushed in	$1.75
				Timothy	5		
				Redtop	4		
				Kentucky blue grass	5		
Do	2	II	......	Same as plot 1; same number pounds.	......	Untreated	1.50

The amount of seed per acre given in Table 8, namely, 9 pounds for pure seeding of timothy, 15 for redtop, and 21 for Kentucky blue grass, has proven satisfactory. It is apparent in these sowings that the expense in securing a satisfactory pure stand of Kentucky blue grass and redtop is approximately four times and two times higher, respectively, than in the case of timothy. This is due both to the difference in the cost of the seed and to the amount required to produce a good forage crop; the seeding ratio for blue grass, redtop, and timothy was 5, 3½, and 2. In a mixture the expense is decreased in accordance with the proportion of timothy used.

INCREASE IN FORAGE PRODUCTION.

Timothy when sown at the rate of 8 pounds per acre will cost, for seed, including transportation, not to exceed 10 cents per pound, or 80 cents per acre. To this must be added the cost of 10 cents per acre for scattering the seed and 25 cents for harrowing it in, making a total expenditure of $1.15 per acre.

The production of forage will vary from about one-half to 1½ tons per acre, depending primarily upon the altitude, soil, and climatic conditions. The value of the crop will depend upon local conditions. Even with a minimum of half a ton per acre it is a paying investment to seed. Cotton has shown that where a yield of only half a ton of timothy is secured, an acre of the land upon which his experiments were conducted would carry a 1,200-pound steer a little more than 30 days longer than it previously would. Thus he shows that if pasture is valued at 25 cents a head per month, it would, after the first year, give a return of more than 25 per cent on the cost of seeding. Besides, if the lands are properly handled so that the areas are not prematurely and too closely grazed, an appreciable forage increment of the introduced species may be expected from natural reseeding. This additional increment may often justify reseeding even when a low forage yield is originally obtained.

HOW TO GRAZE THE RANGE DURING THE RESTOCKING PERIOD.

During the period immediately following sowing the young plants ordinarily develop neither a sufficiently elaborate height growth nor strong and deep enough roots to furnish an appreciable increase in the forage and to withstand grazing. In the highest elevations, where the season is short and the temperature low, the seedling plants naturally make slower growth than in lower and warmer localities. Even in the lower elevations grazing is more or less seriously destructive during the first year. The loss from trampling is heaviest early in the season, but even in the autumn moderate grazing results in tearing and uprooting the young growth to a serious degree.

Cropping the plants is not disastrous to their development, unless it is done excessively or prematurely, but the seedlings are often pulled up or the roots are partly exposed when grazed, and as a result the plant suffers the following season. The lands seeded should therefore be wholly protected from stock during the first season subsequent to seeding. In the second year they may be moderately grazed, but stock should not be allowed on them until fall, when the root system has attained its full development for that season.

CONCLUSIONS.

WHERE RESEEDING IS PRACTICABLE.

The reseeding investigations show that the returns secured from sowing suitable cultivated forage plants on certain ranges fully warrant the expense. It is not to be presumed, however, that all overgrazed ranges can be successfully reseeded to cultivated plants. On the contrary, it is unquestionably true that existing conditions in the major portion of the native grazing lands are antagonistic to the establishment of introduced plants. This is due primarily to one or all of three conditions: Excessive elevation, poor soil, coupled with insufficient moisture, or too much and too aggressive native vegetation.

ALTITUDINAL LIMITATIONS.

There are three chief causes of failure at high altitudes: First, only the strongest and best seeds can produce vigorous plants, and even this scanty original stand is often materially thinned out during the first season; second, the plants can ramify or stool out and spread only at a very slow rate; third, the plants produce such a small quantity of viable seed (note Table 5) that the possibility of increasing the stand from seed production is practically eliminated.

The altitude above which seeding to cultivated species should not be undertaken varies with latitude, and is approximately 3,500 feet higher in southern Arizona than in eastern Oregon. Because of this variation the character of the native vegetation is the best criterion for determining the maximum altitude at which reseeding is justifiable. As a concrete example, in the Wallowa Mountains, as previously shown, it has been found that the growing season is so short and the temperature is relatively so low at an altitude slightly exceeding 7,500 feet above the sea that no species thus far tried has made a satisfactory growth.[1] Here is the true timber-line tree—whitebark pine (*Pinus albicaulis*)—mountain bunch grass, heaths, huckleberry, and the lower zonal forms of arctic-alpine species. Where the whitebark pine becomes scrubby—timber line locally usually occurs slightly above 8,500 feet on north slopes—it invariably follows that the altitude exceeds that at which reseeding will pay. (See Pl. VIII, fig. 2.) The same principle applies to high mountain seeding in any locality, and it is safe to say that seeding to cultivated forage plants will not prove economically successful above the altitude at which the true timber-line species attain a good size and grow vigorously. Allowing for the influence of the different slopes and exposures on growth, timber-line trees do not usually make their maximum development when grown within 1,000 to 1,500 feet of timber line, and it may therefore be more specifically stated that seeding should not be attempted within 1,000 or 1,500 feet of timber line.

SOIL AND VEGETATION COVER.

Below 1,000 to 1,500 feet of timber line, then, the only areas suited to artificial seeding are those which have sufficient moisture and a deep soil with considerable organic matter, such as are found in

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[1] At more southerly points, as in California, good stands of timothy have been secured at an altitude of 10,000 feet.

mountain meadows, moist parks meadowlike in character, and moist alluvial bottoms along streams. Soils of coarse physical structure so readily lose their water content through percolation and evaporation that in normal years the introduced seedling plants are almost invariably killed before the end of the first growing season.

In addition to the fertility of the soil the character and density of the native vegetation will help to determine what lands may profitably be seeded. Ordinarily seeding should not be attempted where the perennial native vegetation, such as a grass association, for example, covers about 60 per cent of the surface, for not only is the soil in poor condition to receive the seed, but the introduced species can rarely replace or compete with the more hardy established vegetation. Most of the moister and poorly drained mountain meadows are well vegetated with marsh grasses and succulent sedges, rushes, and weeds. It is often highly desirable to replace this type of vegetation with cultivated forage plants, owing to the low palatability and nutritiousness of the native species. But because of the dense and matted soil surface, a condition often coupled with sour or acid soil, few cultivated species have chances of becoming established in such habitats.

SPECIES RECOMMENDED.

On lands of medium moisture conditions and of average soil fertility no other species has given as uniformly good results as timothy. This plant can be introduced at the lowest cost of any of the highly desirable species; it gives a better yield under a diversity of range conditions than any species experimented with, and when once established it will withstand moderately heavy grazing relatively well.

In habitats of average moisture conditions where timothy flourishes, smooth brome grass, perennial and Italian rye grasses, and Kentucky blue grass, in the order named, are found to give good results. In the moister situations, especially on the poorly drained lands where the soil is inclined to be acid, redtop is far superior to any species so far tried. It will also do well in many situations where timothy thrives, but being less deeply rooted it requires, to attain its highest development, more moisture in the surface layer of soil. Redtop is notably less aggressive than timothy and many other species, but, reproducing as it does, mainly by root stocks, its establishment, while slow, is permanent. It is little liable to injury from trampling, even in wet situations, because of the dense entanglement of roots which bind the soil firmly.

Of the nongrasses, only alsike and white clovers can be recommended. The lands to be seeded to these species should be carefully selected, as neither very dry nor unusually wet soils are adapted to their growth. Saturated and poorly drained soils, which are in consequence badly aerated and sour, are to be avoided or time and money will be wasted. Only the better-drained lands which are well supplied with soil moisture throughout the summer should be seeded to clovers.

WHEN TO SEED.

The climatic conditions, length of the growing season, and the character of the soil in a great measure determine the time that seeding should be done.

Under natural conditions in the mountains the seed crop is disseminated in the autumn and lies dormant until the soil warms up the following spring.

Within the altitudes at which temperature is favorable to growth, a single factor—drought—is instrumental in causing frequent failures. The soils of most mountain lands readily dry out near the surface. This condition results in the serious destruction of shallow-rooted seedlings. The deeper-rooted plants resulting from autumn seeding are less liable to serious thinning out than the seedlings with a shallower and less elaborate root system produced from seed sown in the spring.

Where the winter does not permit of growth, late autumn sowing should, in general, be resorted to. Care must be exercised to sow late enough so that no germination will take place until spring or the seedlings are likely to be heaved out of the ground and killed. The ideal time to seed is just before permanent snows come in the autumn.

If the situation is wet during most of the year, the seed may be dormant for a number of months, and is likely to decay before germination can take place. In such situations spring seeding should be resorted to. Again, in certain situations, especially in parts of the Southwest where the early spring period is habitually followed by dry weather and the inception of summer by heavy precipitation, the seed should not be scattered until late in the spring. In such regions the seed, if sown in the autumn, usually germinates as soon as the temperature is favorable, even though there is a small amount of moisture in the soil, and the tender shallow-rooted plants, being wholly dependent upon the surface soil for moisture, are almost invariably killed before the summer rains come.

METHODS OF SOWING.

The methods of sowing must be practical and inexpensive. The amount of work justified in sowing, preparing, and working the soil will naturally depend on the carrying capacity of the range and on the effectiveness of the operations. In many localities the mountains are so rugged and transportation is so difficult that the use of implements which the farmer relies on for tilling and working the soil is impracticable.

HOW TO SCATTER THE SEED.

Any means of scattering the seed which will distribute it evenly is satisfactory. Ordinarily a compact hand seeder should be used, but an experienced man can broadcast as well by hand; this method is certainly the most convenient, and doubtless the most economical. With either machine or hand method windy days should be avoided for the sowing. It is sometimes desirable to make double sowings, in which half the quantity of seed is sown in passing up and down the area and the other half by crossing at right angles to the first sowing.

SOIL TREATMENT.

It is too often assumed that grasses and other forage plants will grow anywhere and under all circumstances. The writer has no hesitancy in stating that he has yet to see the range conditions under which it will not pay to give some slight treatment to cover the seed, regardless of the kind of seed sown and the character of the soil. Of the various causes for failure the lack of soil treatment, either before or after sowing, was chiefly operative in 61 out of 168 unsatisfactory experiments. More failures were due to not covering the seed after sowing than to drought, wrong selection of species, and wrong time of sowing.

It is neither necessary nor desirable to cover the seed deeply, and expensive operations are rarely warranted. The investigations prove that some seeds, when planted more than half an inch deep, tide over the season or fail to germinate. The plants are more likely to become permanently established when the seeds are merely hidden below the surface of the ground than when covered more deeply.

Where the soil is friable and free from vegetation the brush harrow should be employed, but where compact and supporting vegetation, which binds the soil surface, the A wooden-peg harrow should be used. On such situations sheep driven in a compact body after sowing will plant the seed more thoroughly than any other of the methods tried. There is danger of too deep planting if sheep are used on the loose soils.

PROTECTION AGAINST GRAZING.

Regardless of the species sown, the lands should be protected from grazing animals until the plants have made sufficient development to withstand moderate grazing and trampling. In most places grazing should be entirely restricted during the first season after seeding, because both sheep and cattle destroy the young plants. In the autumn of the second year there is little danger of serious injury from moderate grazing.

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