PACIFIC NORTH WEST

FOREST AND RANGE EXPERIMENT STATION • U.S. DEPARTMENT OF AGRICULTURE • PORTLAND, OREGON

PNW-71 *December 1967*

GRASS-LEGUME MIXTURES FOR ROADSIDE SOIL STABILIZATION

by

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The construction of forest access roads often increases soil erosion and stream sedimentation. In steep terrain, road construction disturbs from 6 to 8 percent of the area, and the bare roadside slopes are especially vulnerable to erosion during the first few months following construction. Fredriksen[1/] reported that although stream sediment content increased 250 times during the first rainstorms after road construction, sediment levels dropped almost to preconstruction levels after only 2 months.

To minimize soil movement, some sort of cover is needed on roadside slopes as soon after construction as possible. Unfortunately, establishment of natural vegetation is extremely slow on these sites because of low soil fertility and unfavorable microclimatic conditions. Realizing the importance of quick stabilization, the Forest Service initiated a roadside grass seeding program in western Oregon and Washington about 12 years ago. Selection of seed mixtures, fertilization treatments, and methods of application have been based on experience and recommendations of county agents and the Soil Conservation Service, U. S. Department of Agriculture. There has been no standardized approach within the Forest Service; rather, methods vary from Forest to Forest and even among Districts. Seeded mixtures often contain a legume--generally white Dutch clover (*Trifolium repens* L.). However, in some areas the legume has been omitted from the mixture because its

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1/ Fredricksen [Fredriksen], R. L. Sedimentation after logging road construction in a small western Oregon watershed. U.S. Dep. Agr. Misc. Pub. 970: 56-59, illus. 1965.

high palatability resulted in deer concentrations on highly erodible slopes. The results of grass or grass-legume seedings are sometimes satisfactory. However, seeded areas are often not stabilized at all or erosion is only slowed temporarily. Some of the difficulties encountered include poor germination of seed, rolling of seed to the bottom of cut-and-fill slopes before germination, and deterioration of good grass stands after 2 or 3 years, all resulting in establishment of sparse stands which do not fully protect the site.

Despite the generally recognized seriousness of the problem, there has been very little formal research on roadside soil stabilization in the Pacific Northwest. Consequently, most available information is derived from experience and casual observation, rather than from controlled experimentation. Bethlahmy,[2/] working on abandoned logging roads in the Cascade Range east of Portland, Oreg., found that application of 450 pounds per acre of a 6-10-4 fertilizer significantly aided establishment of a grass mixture. Raking following seeding also aided grass growth. Wollum[3/] tested grass seeding as a control for roadbank erosion in the H. J. Andrews Experimental Forest. He found that, although a dense grass cover increased the amount of runoff, soil erosion was greatly reduced.

The Soil Conservation Service tests plant species for use in soil conservation planting. Most of the plant materials tested and recommendations issued by the Soil Conservation Service are aimed toward farm use. However, these recommendations include guidelines for planting severely eroded and subsoil areas, such as around dams or on ditch banks. Hafenrichter, Mullen, and Brown[4/] have listed many of the grass and legume species that have been tested in the Pacific Northwest, the characteristics of each species, and the areas best suited for their growth.

The author wishes to acknowledge the splendid cooperation he has received from personnel of the Soil Conservation Service Plant Materials Center at Corvallis, Oreg. Robert S. MacLauchlan of that center provided valuable advice concerning design of the studies, suggested plant species for possible evaluation, and greatly aided in procurement of plant materials.

[2/] Bethlahmy, Nedavia. Fertilizer helps establish grass seedings on abandoned logging roads. J. Forest. 58: 965-966, illus. 1960.

[3/] Wollum, A. G. II. Grass seeding as a control for roadbank erosion. U.S. Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Note 218, 5 pp., illus. 1962.

[4/] Hafenrichter, A. L., Mullen, Lowell A., and Brown, Robert L. Grasses and legumes for soil conservation in the Pacific Northwest. U.S. Dep. Agr. Misc. Pub. 678, 56 pp., illus. 1949.

This study is divided into two sections. The first describes a search for legume species suitable for inclusion in grass-legume mixtures. The second compares the performance of several grass-legume mixtures growing in roadside slope locations.

FIELD EVALUATION OF EIGHT LEGUME SPECIES

One means of improving growth and the stabilizing effects of roadside plantings is through selection of more suitable plant materials. Many species have already been tried, some of which proved to be well adapted. The search, however, should be a continuing one, because environments of the sites to be planted are tremendously varied. Moisture conditions range from wet to dry. Slopes vary in steepness and in the important factor of aspect. Soil fertility levels, dependent on parent material and quantity of surface soil present, are extremely variable.

In addition to the multiplicity of site factors, differing stabilization requirements also add to the complexity. To prevent surface erosion, a fast-growing, sod-forming grass is needed; but, on the other hand, mass movement prevention requires deep-rooted shrubs and trees. Therefore, well-suited plant species are needed which will thrive under a variety of site conditions and meet varied stabilization requirements.

An evaluation of roadside seedings on National Forest lands indicated that perhaps the inclusion of vigorous, fast-spreading legumes in the mixture might result in a denser and longer-lasting stand of vegetation. It was felt that the poor performance of seeded grasses a year or two after seeding might be partially attributed to low soil fertility and, especially, lack of available nitrogen. As previously mentioned, white Dutch clover is the only legume commonly used at the present time. Its performance is often unsatisfactory for several reasons. The clover is often restricted to only the more gentle slopes and, in some areas, its high palatability results in heavy deer use.

An exploratory study of the performance of eight legume species, growing on subsoils at moderate elevations in the Coast Ranges and western Cascades of Oregon, was initiated during the fall of 1964. This initial field screening was necessary because several of the species had never before been planted in comparable locations.

Methods

Legume planting plots are located near Divide Lookout in the Alsea District, Siuslaw National Forest (Coast Ranges), and at the edge of a borrow pit near Cougar Dam in the Blue River District, Willamette National Forest (western Cascades). Elevations are 1,700 feet and 1,200 feet, respectively. Both plot sites are essentially level and comprised solely of subsoil material (figs. 1 and 2). The Alsea plots

Figure 1.--General view of a portion of the fall-seeded legume plot near Divide Lookout, Alsea District, Siuslaw National Forest (2 years after seeding). Rows on the left are big trefoil. Note invading grasses and lupine.

Figure 2.--Spring legume plot immediately after seeding, near Cougar Dam, Blue River District, Willamette National Forest. Note the grass straw mulch.

are on an abandoned log landing where the exposed surface is comprised of subsoil of the Bohannon soil series mixed with large amounts of weathered Tyee sandstone. At the Blue River site, the exposed subsoil is a loamy alluvium mixed with a large quantity of water-worn gravels and cobbles (mostly andesite). At the time of planting, both plot locations had very little vegetation.

Plantings were made September 22 and 23, 1964, and April 27 through 29, 1965, at both locations. Species seeded in the fall included white Dutch clover, New Zealand white clover (*Trifolium repens* L.), wetland deervetch (big trefoil) (*Lotus uliginosus* Schkuhr.), birdsfoot deervetch (trefoil) (*Lotus corniculatus* L.), crownvetch (*Coronilla varia* L., "Emerald"), cicer milkvetch (*Astragalus cicer* L.), and flat peavine (pea) (*Lathyrus sylvestris* L.). Also, 20 transplants each of milkvetch, big trefoil, and bramble (perennial) vetch (*Vicia tenuifolia* L.) were set out at each site. In addition, 20 flat pea seedlings were planted in the Alsea plot. In the spring, the same seven legume species were again seeded, with the addition of perennial vetch. No transplants were set out in the spring.

Seeds were first mixed with a commercial inoculant, then sown in four 25-foot rows which were 30 inches apart. To aid in uniform distribution, the seed for each species was also mixed with 0.3 pound of rice hulls. Seed was sown by a push-type hand seeder (Planet Jr. Seeder). In the fall, transplants of each species were planted in individual rows 1 foot apart.

Soil tests for the two sites indicated the soils were deficient in nitrogen, phosphorus, and to a certain extent, potassium. Accordingly, 25 pounds of single superphosphate (19 percent P_2O_5), 6 pounds of ammonium nitrate (35 percent elemental N), and 5 pounds of muriate of potash were applied to both 25- by 80-foot plots. In addition, 200 pounds of lime was applied to the Alsea plots and one-half cup of lime per species (4 cups total) was applied with the seed at Blue River. Fertilization treatment was the same for both fall and spring plots.

After seeding, plots were mulched with approximately 200 pounds of oat straw for the fall planting and 200 pounds of grass straw in the spring.

Results

Performance of seeded legumes was evaluated 1 to 2 months after planting and in the fall, spring, and midsummer thereafter. Results are summarized in table 1. In most cases, legume growth showed little difference between fall and spring seeding.

1. *Big trefoil (fig. 3).* In all cases, this species germinated very well, and for the first 2 months, rows were extremely dense.

Table 1.--Performance of eight seeded legumes in the Coast Ranges (Alsea District) and western Cascades (Blue River District) of Oregon

Species and time of seeding	Plot location	Germination and establishment	Density	General vigor	Maximum final height	Maximum final spread
					Inches	Inches
Big trefoil						
Fall	Alsea	Excellent	Moderately dense	Very good	10	20
Fall	Blue River	Excellent	Very scattered	Moderate	3	18
Spring	Alsea	Excellent	Moderately dense	Good	10	10
Spring	Blue River	Excellent	Scattered	Good	3	18
White Dutch clover						
Fall	Alsea	Excellent	Moderately dense	Poor	2	(1/)
Fall	Blue River	Excellent	Very scattered	Moderate	2	5
Spring	Alsea	Excellent	Scattered	Good	5	8
Spring	Blue River	Excellent	Very scattered	Poor	2	(1/)
New Zealand white clover						
Fall	Alsea	Excellent	Dense	Poor	2	(1/)
Fall	Blue River	Excellent	Scattered	Good	5	7
Spring	Alsea	Excellent	Scattered	Good	5	8
Spring	Blue River	Excellent	Scattered	Poor	2	5
Crownvetch						
Fall	Alsea	Good	None present	None present	0	0
Fall	Blue River	Excellent	Very scattered	Very poor	1	3
Spring	Alsea	Good	None present	None present	0	0
Spring	Blue River	Very good	None present	None present	0	0
Flat pea						
Fall	Alsea	Poor	Only 12 plants	Moderate	4	12
Fall	Blue River	Very poor	None present	None present	0	0
Spring	Alsea	None present	None present	None present	0	0
Spring	Blue River	Very poor	None present	None present	0	0
Birdsfoot trefoil						
Fall	Alsea	Good	Moderately dense	Good	11	15
Fall	Blue River	Good	Scattered	Good	8	12
Spring	Alsea	Excellent	Scattered	Very good	8	15
Spring	Blue River	Very good	Very scattered	Moderate	8	12
Cicer milkvetch						
Fall	Alsea	Fair	None present	None present	0	0
Fall	Blue River	Fair	Only 3 plants	Poor	--	--
Spring	Alsea	Fair	Only 4 plants	Poor	2-1/2	--
Spring	Blue River	Excellent	Scattered	Moderate	3	10
Perennial vetch						
Spring	Alsea	Good	Scattered	Good	3	3
Spring	Blue River	Excellent	Very scattered	Poor	3	(1/)

1/ Little.

Figure 3.--Fall-seeded big trefoil plants 2 years after seeding (Alsea plot).

The smaller number of surviving plants on the Blue River plots was largely due to extensive winter mortality, probably caused by frost heaving. The remaining plants, however, were at least moderately vigorous, set seed, and showed considerable spread. Big trefoil transplants survived well at both plot sites and showed vigorous growth. Rate of growth was considerably greater at the Alsea plot where, 2 years after transplanting, maximum spread was approximately 3-1/2 feet.

In summary, big trefoil appears well suited to the Coast Ranges site. Its performance near Blue River indicates that once the plants become well established, growth is satisfactory. The principal problem under these climatic conditions is one of high winter mortality.

2. *White Dutch clover.* The species germinated very well in all plantings. With the exception of the fall planting at the Alsea plot, plant density decreased greatly during the first growing season. This was probably caused by decreasing soil nutrient availability coupled with low soil moisture levels. The low vigor of the clover in the fall Alsea plot was perhaps partially due to crowding in the dense rows.

It appears that white Dutch clover is at least moderately well adapted to both plot locations, although it is subject to considerable growing-season mortality and exhibits variable vigor.

3. *New Zealand white clover (fig. 4).* This variety performed in a manner almost identical to white Dutch clover in the Alsea plots. In the Blue River plots, it showed slightly better growth than white Dutch clover. Therefore, New Zealand white clover may prove to be better adapted than white Dutch clover to conditions in the western Cascades.

Figure 4.--Spring-seeded New Zealand white clover plants 1-1/2 years after seeding (Alsea plot).

4. *Crownvetch.* Although this species germinated fairly well, mortality was high during both the winter and growing seasons. As a result, no plants were found after one or two growing seasons on three out of the four plots. Where it did survive, vigor was very low.

Crownvetch does not appear to be suitable for planting in this area.

5. *Flat pea.* This species germinated poorly at all plots. Flat pea seeds have very hard seedcoats and, therefore, are difficult to propagate from seed. However, transplants placed in the Alsea plot did extremely well (fig. 5). After two growing seasons, the plants were thriving and had a maximum spread of about 5 feet.

Apparently flat pea is adapted to our climatic conditions, but transplanting is necessary to gain successful establishment.

6. *Birdsfoot trefoil.* Germination and initial establishment of this species was good to excellent. Considerable thinning of the rows

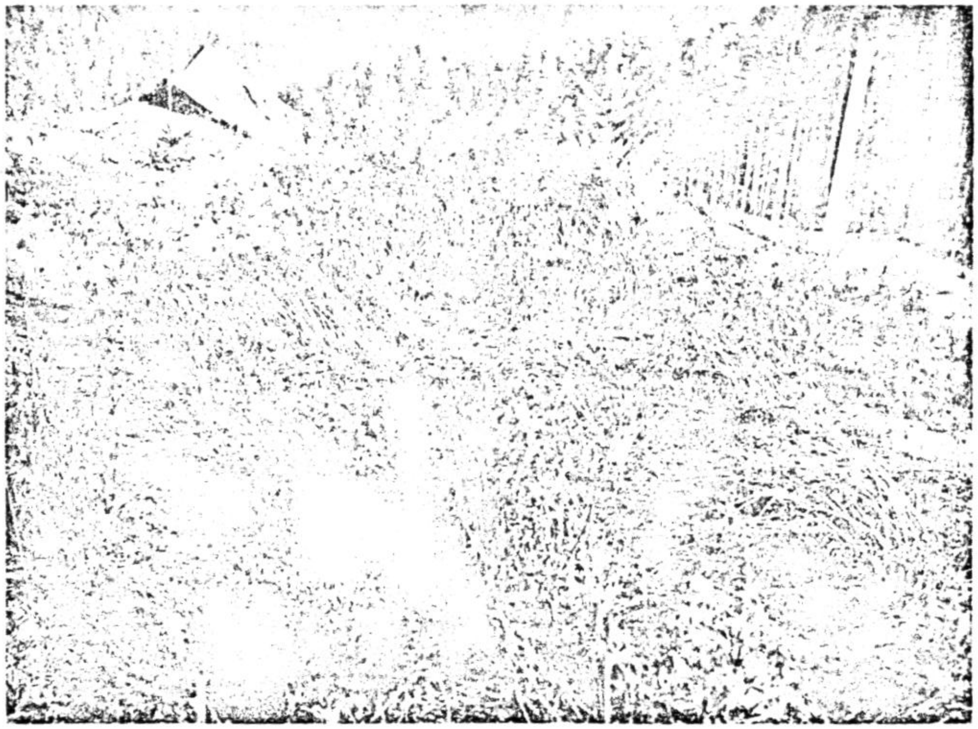

Figure 5.--Transplant area in the Alsea plot 2 years after planting. Note luxuriant growth. Rows, difficult to distinguish because of lateral spread, are from left to right: cicer milkvetch, perennial vetch, big trefoil, and flat pea.

resulted from frost-heaving mortality in the winter. Surviving plants, however, generally showed good vigor, and a large proportion flowered and set seed.

Birdsfoot trefoil appears to be at least moderately well adapted to site conditions at both plot locations.

7. *Cicer milkvetch.* This species grew poorly from seed on all plots except the spring plot at Blue River. Here the seedlings showed moderate vigor and were beginning to spread. Survival of transplanted cicer milkvetch was poor at Blue River but good at the Alsea plot. However, even on the Alsea plot, growth was unsatisfactory and the transplants tended to be spindly and chlorotic.

These results indicate that cicer milkvetch is not suited to the climatic and soil conditions of the Coast Ranges and western Cascades.

8. *Perennial vetch.* This species was seeded only in the spring. Its performance at Blue River was poor. However, it grew fairly well on the Alsea plot and showed good vigor even though the plants tended to be small. Perennial vetch transplants also grew poorly at Blue River despite fairly good survival. Transplants on the Alsea plot generally grew very well to a maximum spread of about 2-1/2 feet (fig. 5).

Perennial vetch shows some promise for use in the Coast Ranges but appears to be poorly adapted to conditions in the western Cascades.

Discussion

This exploratory study demonstrated that field evaluation of individual cover plants is a practical means of screening candidate species. There is a need to expand this approach to include many additional species holding promise for soil stabilization purposes. The search for suitable species must be continuous if the maximum effectiveness in soil stabilization is desired. Woody as well as herbaceous plants should be considered. Certain native species also show considerable promise. For example, at the Alsea site, a native lupine (*Lupinus* sp. L.) invaded the fall-seeded plot and grew well despite low soil fertility. Methods for propagating this species should be worked out and consideration given to including it in some grass-legume mixtures in the Oregon Coast Ranges.

On the basis of these results, big trefoil and New Zealand white clover were selected for inclusion in experimental grass-legume mixtures to be seeded in the western Cascades near the Blue River legume plot. The performance of these mixtures is described in the section which follows.

ROADSIDE PLOT EXPERIMENTS

To evaluate the performance of several grass-legume mixtures, a field plot experiment was initiated in the fall of 1965. Plots were located in the H. J. Andrews Experimental Forest (Blue River District, Willamette National Forest).

Methods

Plots were established at a backslope site (spur road No. L440, 2,450-foot elevation) and on side-cast material just below the road to watershed 1 landing (1,500-foot elevation). At the backslope site, the road was about 5 years old. At the time of planting, the slope was almost devoid of vegetation and obviously was eroding. The soil is a Regosol derived from reddish tuffs and breccias and is classified within the Frissell series. The backslope was approximately 1:1 and had a south aspect.

The side-cast plots were located along a road which was constructed about 4 years prior to this experiment. This steep, west-facing slope had very little vegetation; grasses and herbs present were removed before the plots were installed. The soil at this location is similar to that at the backslope site except for the presence of a considerable number of andesite stones.

A randomized-block experimental design was followed. Five grass-legume mixtures plus a control were replicated twice at both the backslope and side-cast locations for a total of 12 plots at each site. Plots were 6 feet wide, extended up and down slope for the entire length of the backslope, and were 25 feet long on the side-cast slope. Since the plots were contiguous, the total length along the road was 72 feet.

Treatments applied were as follows:

1. Control--bare soil only.

2. Straw mulch only--2 tons per acre.

3. Seeded with Blue River District mixture of:
   colonial bentgrass (*Agrostis tenuis* Sibth.)--6.25 pounds per acre

   creeping red fescue (*Festuca rubra* L.)--5.00 pounds per acre

   perennial rye grass (*Lolium perenne* L.)--3.75 pounds per acre

   alta (tall) fescue (*Festuca arundinacea* (Schreb.) Wimm.)--8.75 pounds per acre

   white Dutch clover--1.25 pounds per acre.

4. Seeded with Oregon Highway Department mixture of:
   creeping red fescue--18 pounds per acre

   chewings fescue (*Festuca rubra* var. *commutata* Gaud.)--12 pounds per acre

   perennial rye grass--4 pounds per acre

   white Dutch clover--6 pounds per acre

   straw mulch--2 tons per acre.

5. Seeded with experimental mixture No. 1 of:
   tall fescue--20 pounds per acre

   Italian rye grass (*Lolium multiflorum* Lam.)--8 pounds per acre

   creeping red fescue--3 pounds per acre

   New Zealand white clover--2 pounds per acre

   big trefoil--2 pounds per acre

   straw mulch--2 tons per acre.

6. Seeded with experimental mixture No. 2 of:
   orchard grass (*Dactylis glomerata* L.)--20 pounds per acre

   Italian rye grass--8 pounds per acre

   creeping red fescue--8 pounds per acre

   colonial bent grass--3 pounds per acre

New Zealand white clover--2 pounds per acre

big trefoil--2 pounds per acre

straw mulch--2 tons per acre.

In addition, all treatments, with the exception of the control, received a blanket application of ammonium phosphate (16-20-0) at the rate of 400 pounds per acre both in the fall and the following spring.

Plot location within each block was randomized. Seeding, fertilization, and mulching were carried out on September 21 and 22, 1965.

Soil movement on the plots was monitored by periodic measurements of the distance between points on a stretched wire cable and the mineral soil surface directly beneath. The measurement was accomplished with a steel tape and attached plumb bob held next to the profile cable at the appropriate point. Three transects, 1 foot apart and extending up and down slope in the central 2-foot strip, were measured in each plot. Fifteen measurements were made along each transect at 1-foot intervals. The first measurement was made 1 foot below the upper boundary of the plot. Therefore, the elevation of the upper 15 feet of slope was measured.

Vegetative cover on each plot was ocularly estimated at frequent intervals. In addition, species composition was noted and recorded for each plot.

Results

A satisfactory grass-legume mixture must provide fast initial growth and quick cover if soil movement is to be minimized. Observations made approximately 3 months after seeding disclosed that three out of the four mixtures seeded in the present study provided satisfactory and equivalent cover during these first critical months (fig. 6). The Oregon Highway Department mixture and experimental mixtures 1 and 2 provided slightly more than 50-percent cover at the end of 3 months on side-cast plots and about 35- to 50-percent cover on the backslope plots. However, after the same period, plots seeded with the Blue River District mixture had only 30-percent cover at the side-cast location and between 15- and 20-percent on the backslope. The difference in cover was apparently caused largely by the lack of straw mulch in the Blue River mixture treatment. The mulch applied with the Oregon Highway Department mixture and the two experimental mixtures appeared to greatly reduce downslope seed movement and thus insure even distribution of vegetation. The distribution of grass cover on the Blue River plots indicated considerable downslope movement of seed; the steepest portions of the slopes were invariably almost devoid of cover. An additional advantage of straw mulch, which may have had some influence here, is its ability to protect newly germinated seedlings from frost-heaving damage.

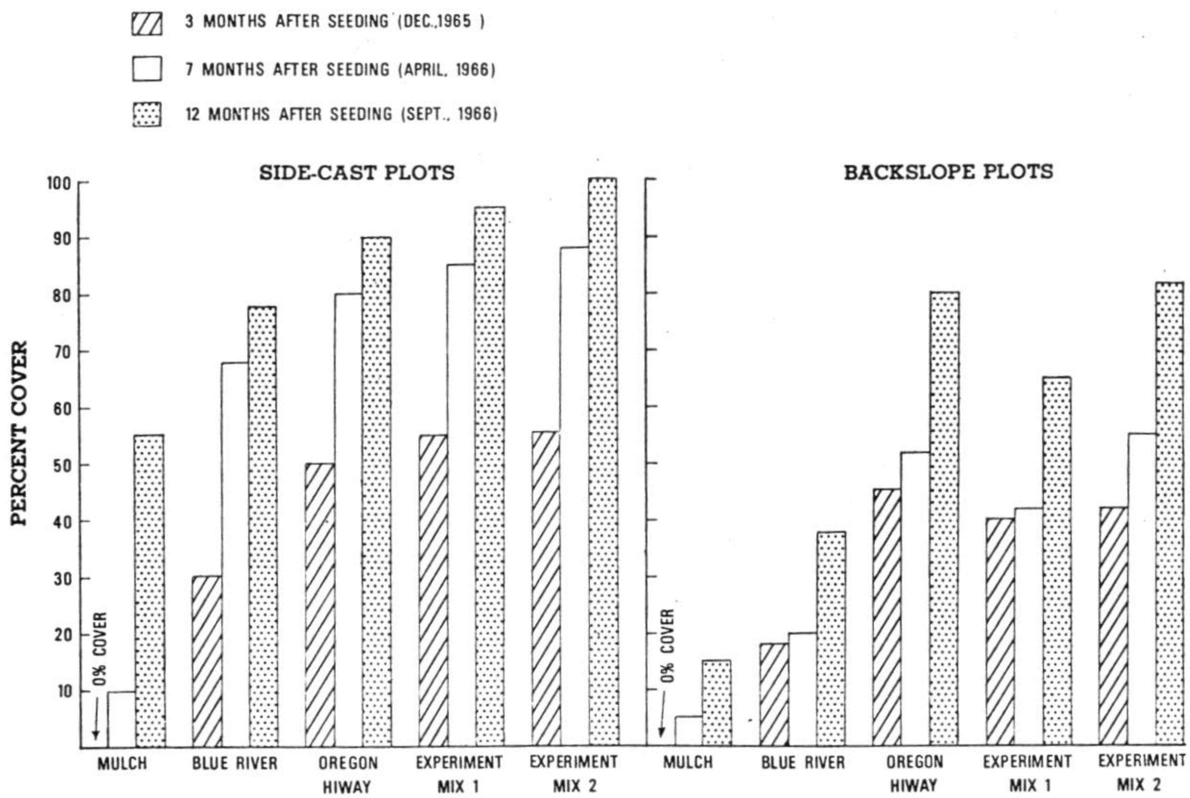

Figure 6.--Vegetative cover on roadside plots 3, 7, and 12 months after seeding.

The Italian rye grass in experimental mixtures 1 and 2 clearly outperformed the perennial rye grass in the Oregon Highway Department and Blue River District mixtures during the first 3 months after seeding. At the end of this period, maximum height of Italian rye grass was 10 inches at the side-cast location and 4 inches at the backslope site. Corresponding figures for perennial rye grass were only 3 and 2 inches. Because of the need for quick cover, the unusually rapid development of Italian rye grass commends it for inclusion in grass-legume mixtures for roadside planting. These results suggest that perhaps it should be substituted for the perennial rye grass which is generally included.

Examination of the plots in April, 7 months after establishment, disclosed a considerable increase in cover on the side-cast plots but a more modest increase on the higher elevation backslope plots (figs. 6, 7, and 8). Gaps on the steeper portions of the Blue River District plots persisted and cover continued to be spotty, especially at the backslope location (fig. 9). Maximum grass height was approximately 11 inches on the Oregon Highway Department and experimental mixture plots (fig. 10), but was only 6 inches on the Blue River mixture plots.

The difference is apparently once again tied to the absence of straw mulch on Blue River mixture plots.

Figure 7.--Side-cast plots 7 months after seeding. The cable for measuring the slope profile is stretched between the channel irons.

Figure 8.--Backslope plots 7 months after seeding.

Figure 9.--Blue River District mixture on backslope 7 months after seeding. Note absence of cover on the steep, middle portion of the slope.

Figure 10.--Experimental mixture No. 2 on backslope 7 months after seeding.

At the end of a full year, all seeded plots at the side-cast location had a very satisfactory grass stand. Total cover ranged from a little less than 80 to 100 percent (fig. 6). Even the plots which were not seeded but only mulched were covered with a moderately dense stand of vegetation--largely grass. Vegetative cover was lower on the backslope plots but generally dense except for small gaps, usually at steep midslope locations (fig. 11). The only exceptions were the Blue River mixture plots, where only about one-third of the total plot area was covered by grass. The other seeded plots were at least two-thirds covered by the end of the year (fig. 6).

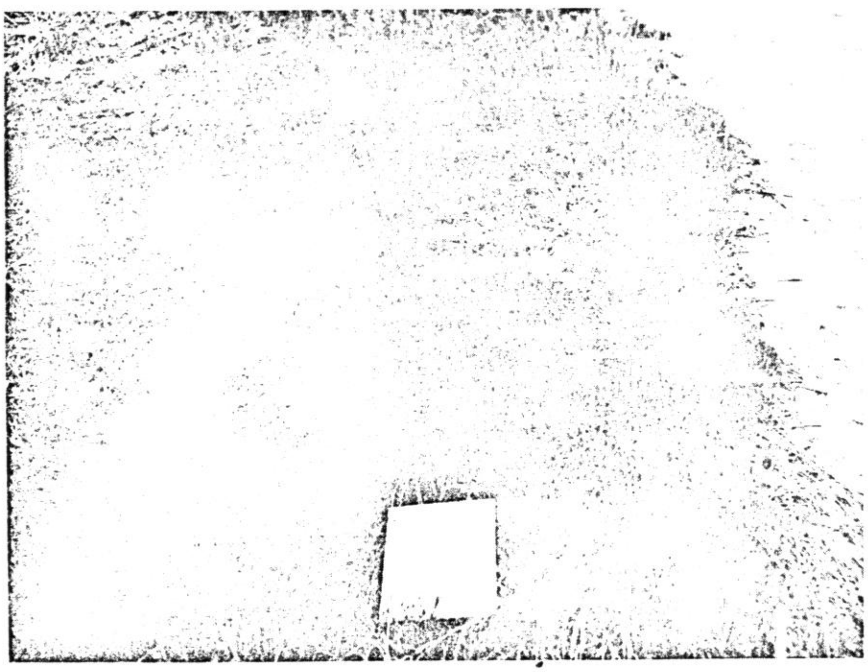

Figure 11.--Experimental mixture No. 2 on backslope 12 months after seeding.

Species present on seeded plots after 3 months were almost exclusively the ryegrasses--either perennial or Italian--and white clover seedlings. Inspection the following spring, 7 months after seeding, revealed that vigorous white clover plants still made up a significant portion of the total stand. However, after another 5 months, it was difficult to find even a single clover plant on most of the plots. Apparently the summer dry period had resulted in virtually 100-percent clover mortality. Big trefoil, included in both experimental mixtures, was never found on either the backslope or side-cast plots.

At the end of 1 year (September 1965 to September 1966), vegetative composition of seeded plots was as follows:

1. *Blue River District mixture.* Dominantly colonial bentgrass, well-distributed perennial ryegrass, and very small amounts of creeping red fescue.

2. *Oregon Highway Department mixture.* Dominantly creeping red and/or chewings fescue, well-distributed perennial ryegrass, and considerable colonial bentgrass, especially on the side-cast plots.

3. *Experimental mixture No. 1.* On most plots, colonial bentgrass and Italian ryegrass were codominant, with only scattered tall fescue and creeping red fescue.

4. *Experimental mixture No. 2.* On side-cast plots, ryegrass was dominant followed by colonial bentgrass; the reverse was true on the backslope plots. At both locations, there were only scattered amounts of orchard grass and creeping red fescue.

First-year soil movement results for the backslope plots are presented in table 2. It was not possible to obtain similar figures for the side-cast plots because several posts necessary for supporting the measuring cable were accidentally destroyed. Analysis of variance

Table 2.--Average soil loss or gain on the backslope plots for the period November 1965 to November 1966

Treatment	Block 1	Block 2	Treatment mean
	-------------	Inches	-------------
Control (bare)	-0.23	-0.44	-0.34
Mulch only	+.13	-.14	.00
Blue River District mixture	+.05	+.14	+.10
Oregon Highway Department mixture	-.13	-.04	-.08
Experimental mixture 1	+.11	+.10	+.10
Experimental mixture 2	+.14	-.01	+.06

of the data in table 2 indicated a significant treatment effect at the 5-percent level. The Duncan multiple range test showed the treatment mean for the control was the only one which differed significantly from the other five means. In other words, it is concluded that the mulch, Blue River District mixture, Oregon Highway Department mixture, and experimental mixtures 1 and 2 treatments are equally effective in curtailing soil movement on these plots.

The apparent slight increase in soil depth measured on Blue River and experimental mixture plots is hard to explain. Perhaps at least a portion of this increase may be due to frost heaving. However, there was reason to believe that there was a small amount of actual deposition of soil on the slope. Undoubtedly, some soil material broke loose from the top of the cut, part of which may have come to rest further down the slope where it was measured.

The contrasting results obtained in the two mulch-only plots (table 2) are also difficult to explain. Throughout the year, the two plots seemed similar with respect to the cover of both mulch and the small amount of volunteer vegetation which appeared. The observed difference in soil movement on the two plots may be partially attributable to plot location.

Discussion

Although all four grass-legume mixtures seeded in this study produced at least moderately dense stands and afforded considerable soil protection, they failed to meet one objective--that of providing a thrifty legume component. The two varieties of white clover apparently succumbed as a result of low soil moisture levels during the summer. Big trefoil, on the other hand, either failed to germinate or the newly germinated seedlings all died during the winter. Even though results of this exploratory study must be considered tentative, they do suggest the need for including better suited legume species in the mixture.

Results reported here have underscored the importance of other cultural practices in addition to the composition of the seed mixture. The consistent superior performance of mulched plots indicates that, on critical slopes, straw mulch may be well worth its rather high cost of application. Newly constructed road slopes may benefit even more from mulch than did the older and more stable slopes used in the present study. Probably a good portion of the success in obtaining dense stands of grass may be credited to ample fertilization both at the time of seeding and the following spring. The question now is, how long will this vegetative cover maintain itself without any further nutrient additions? Research is needed to determine whether periodic refertilization is economically justifiable.

Results for the backslope plots show that all five treatments were about equally effective in curtailing erosion. It is a little surprising that even the Blue River plots with only about 35-percent plant cover showed no erosion and, in fact, showed a slight increase in soil depth. Apparently, some gaps in the grass cover do not substantially decrease its effectiveness in preventing erosion, at least on roadside slopes which are several years old. Rates of erosion along newly constructed roads would be expected to be considerably greater than those measured in the present study.

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