ADAPTATION OF CERTAIN HERBACEOUS MATERIALS FOR HIGHWAY SLOPE CONTROL

P. 43

Presented by*
W. L. Hottenstein, Supervisor of Highway Forestry
Pennsylvania Department of Highways

EFFICIENT and progressive highway engineers have long recognized the desirability and necessity for establishing permanent vegetative cover on roadside areas to control erosion. Such cover substantially reduces maintenance costs and adds safety and pleasure to motor travel.

The rapid increase in the use of grasses and legumes for erosion control during the past ten years is closely linked with the streamlining of highway cross sections. Where topography permits, slopes are no longer left with 1:1 gradients, but are being rolled back and rounded to gradients of 2:1 and flatter. Construction of flatter and liberally rounded slopes has contributed as much as any other factor to the successful use of vegetative materials for slope control.

During the infant years of roadside development, information concerning the use of vegetation on roadside slopes came from trial-and-error plantings established by state highway departments and subsequently from demonstration projects initiated by highway departments in cooperation with the U. S. Soil Conservation Service and other agencies. Although most of these projects were demonstrational in nature, the results contributed valuable information and provided the basis for many present-day erosion-control practices. Little basic research has been conducted on the suitability of specific grasses and legumes for such erosion control. There is, therefore, a serious lack of documented information on the adaptability and best methods of establishing grasses and legumes for slope control within any particular climatic region. Without such basic information, it frequently has been expensive for highway departments to establish and maintain desirable vegetation on cut and fill areas.

In order to assist in the development of a sound body of factual information bearing on this problem, a research project was set up by the Pennsylvania State College Experiment Station, with the Pennsylvania Department of Highways cooperating. The investigations were designed to attempt to evaluate the effectiveness of various grasses and crown vetch as slope erosion-control vegetation. Consideration was also given to date of seeding, slope exposure, and the use of seed-hay mulch (seed in own hay) as compared to prevailing seeding and mulching methods.

Description and Location

Experiments for studying the adaptation of grasses and legumes and rates of applying seed-hay were conducted on an Ashby-shale-loam subsoil. The experimental area is located 1½ mi. west of Port Matilda, Pennsylvania on US 220 in Centre County, and has a southern exposure with a gradient varying from 1:1 to 2:1.

Design of Experiment

Employed in this study was a modified simple split plot design with three replications involving five grasses and crown vetch seeded by two methods. The main plots were 24 by 30 ft. for species, while the sub or individual plots for method of planting were 12 by 30 ft. Metal dividers 6 in. in width were used to separate the individual plots.

---

*This paper is a condensed and paraphrased version of a thesis dissertation by John P. Stanford in partial fulfillment of requirements for a Ph. D. degree.

Establishment and Maintenance

A sufficient quantity of ground limestone was worked into the seedbed to a depth of 2 to 3 in. to adjust the soil reaction to pH 6.5. Two days following the lime application, a fertilizer containing 60 lb. of nitrogen (N), 120 lb. of phosphate (P_2O_5) and 60 lb. of potash (K_2O) per acre was worked into the seedbed. Seedings were made on the rough seedbed two days after applying the fertilizer. The methods used in seeding this area were with seed-hay, and by broadcast seeding under a mulch of wheat straw. Each fall an application of 400 lb. of 5-10-5 fertilizer per acre was made. The grasses and crown vetch were not mowed; however, the weeds were periodically cut from around the area as part of the general maintenance of the roadside.

The plant species used in the study have a wide range of adaptability to soil and climatic conditions, not only in Pennsylvania but throughout the cool humid regions of the United States. They were selected for such characteristics as extensive root systems, ability to withstand droughts, high and low soil and air temperature, low fertility levels, and the ability to produce a desirable ground cover with minimum maintenance. The species studied and the methods and rates of seeding (the seed indicated in each instance represents pure live seed) were as follows:

Poverty oatgrass (Danthia spicata, syn. D. thermalis)--one ton of seed-hay per acre, containing 168 lb. of seed, and by broadcast seeding 100 lb. of seed under one ton of wheat straw mulch.

Alta fescue (Festuca elatior L. var. alta) - one ton of seed-hay per acre, containing 128 lb. of seed, and by broadcasting 60 lb. of seed under one ton of wheat straw mulch.

Orchardgrass (Dactylis glomerta L) - one ton of seed-hay per acre, containing 75 lb. of seed, and by broadcasting 60 lb. of seed under one ton of wheat straw mulch.

Creeping red fescue (Festuca rubra L. var. genuina Hack) - one ton and 2 tons of seed-hay per acre, containing 126 lb. of seed per ton, and by broadcasting 70 lb. of seed under one ton of wheat straw mulch.

Tall oatgrass (Arrhenatherum elatius L) - one ton per acre of seed-hay, containing 90 lb. of seed, and by broadcasting 75 lb. of seed under one ton of wheat straw mulch.

Crown vetch (Coronilla varia L) - one ton per acre of seed-hay, containing 90 lb. of seed, and by broadcasting 20 lb. of seed per acre under one ton of wheat straw mulch.

Methods of Evaluating

Seedling populations and density for the various species and methods of seeding were based on inclined point quadrat counts for the spring and fall of 1948. Owing to the presence of dead vegetation and the height of the species, the point quadrat method could not be used in 1949 and 1950. Evaluation of the percent ground cover and the percent change in ground cover, on the basis of 1 to 100, for the various species and methods of seeding was made by three separate observational ratings.

In the initial stages of the experiment, observational records were taken on the efficiency of various mulch materials as a temporary erosion-control measure. As the tests progressed, frost action and snow cover were observed. Efficiency of the various species in controlling erosion was noted. The relation of weekly precipitation to soil moisture percent at a 3-in. depth under the grasses and crown vetch also was

studied. Bouyoucos gypsum blocks were used and the method reported by Bouyoucos and Mick[1] was employed. Percent soil moisture determinations were made at depths of 3, 8 and 14 in. Precipitation was measured by means of a standard rain gauge located on the test area. During the growing season each year, maximum and minimum weekly temperatures were recorded at a 3-in. depth under the grasses and crown vetch. The penetration and distribution of roots of the grasses and crown vetch were evaluated by taking random samples at 3-in. depth intervals to a depth of 9 in. with a 3-in. plug puller. These samples were taken at random from each replication of the grasses and crown vetch.

Results and Discussion

The suitability of plant species to slope control is dependent upon their ability to develop a persistent ground cover. Data collected from the projects showed definite differences in adaptability among the grass species and between the grasses and crown vetch. The grasses, in general, show a uniform decline in the percent ground cover for both methods of seeding. Although poverty oatgrass gave a slight increase for 1950, it was not sufficient to provide an effective cover. Crown vetch, on the other hand, has shown a continuous increase in ground cover from year to year after it became established.

In the spring of 1948 alta fescue, orchardgrass, red fescue, and tall oatgrass all developed higher percentages of ground cover than were produced by poverty oatgrass and crown vetch. During the first spring poverty oatgrass developed the poorest ground cover of all the grasses while crown vetch produced the sparsest cover of all.

The differences between the percentages of ground cover for poverty oatgrass, alta fescue, red fescue, tall oatgrass, and orchardgrass were highly significant statistically, as were the percentages of ground cover for crown vetch and all the grass species. Crown vetch had developed the highest percentage of ground cover of all the species by the fall of 1950. Red fescue and alta fescue have maintained a better ground cover than orchardgrass, tall oatgrass, and poverty oatgrass. Crown vetch produced the largest increase in total ground cover of all the species for the three-year period. Poverty oatgrass developed a better ground cover in 1950 than 1949; however, the increase did not materially affect the total change. Red fescue and alta fescue maintained lower total changes than poverty oatgrass, orchardgrass, and tall oatgrass. The grasses all showed a decrease in ground-cover percent for the three years, whereas crown vetch showed an increase through each of the three years.

Alta fescue and crown vetch seeded as one ton of seed-hay mulch produced a higher percent ground cover in the spring of 1948 than when seeded broadcast under wheat straw mulch. Orchardgrass and poverty oatgrass developed a somewhat higher percentage of ground cover from seed-hay than when seeded under wheat straw although the differences were not great. Red fescue and tall oatgrass produced comparable results for both methods of seeding.

By the fall of 1950, red fescue, alta fescue, orchardgrass, and poverty oatgrass all showed higher percentages of ground cover from the seed-hay than when seeded under wheat straw. Crown vetch and tall oatgrass, on the other hand, showed lower percentages of ground cover under seed-hay than under wheat straw. The slight differences in ground cover produced from seeding with seed-hay and under wheat straw for the fall of 1950 may be attributed to natural reseeding, rhizome growth and sprouts, or to a decrease of plant competition.

1/ - Bouyoucos, G. J. and Mick, A. H. An electrical resistance method for the continuous measurement of soil moisture under field conditions. Michigan Agr. Exp. Sta. Tech. Bul. 172. 1940.

The results indicate that applications of mulch up to 2 tons had no harmful effect on seedling establishment. Creeping red fescue seeded as 2 tons of seed-hay mulch produced a higher percentage of ground cover in the spring of 1948 and the fall of 1950 than when seeded with one ton of seed-hay, or under one ton of wheat straw mulch. This shows that comparable percentages of ground cover may be expected from seeding with seed-hay or under wheat straw or old hay mulch.

The heaving action of frost was pronounced during the first winter following seeding of the plots. However, the mulch, especially the 2-ton application of seed-hay, was successful in minimizing this effect. Following establishment, the species able to maintain the best ground cover, namely creeping red fescue and crown vetch, suffered the least from frost damage. The effects of frost were more evident on the less densely covered areas of alta fescue, tall oatgrass, orchardgrass, and poverty oatgrass. Observations indicated that soil erosion or soil creeping was more evident under the one ton of wheat straw and the one-ton seed-hay application than under the 2-ton seed-hay mulch. The grass seed-mulches in general were more effective in minimizing slope erosion than was the legume seed-hay or wheat straw. After the establishment of a ground cover, erosion was practically eliminated, but some leaching of the plant nutrients from the top to the base of the slope was indicated on most of the plots by the luxurious growth at the base of the slope.

The data show that the soil moisture percentages at a 3-in. depth under some of the grasses were significantly higher than under crown vetch for certain periods during the growing season. Similar results were also obtained at 8- and 14-in. depths. This may be explained on the basis that crown vetch has a greater transpiring surface, plus the fact that it has a deeper root system and remained in an active growing state even when the soil moisture content was near the wilting point. The grasses tend to go into a dormancy with the advent of droughts and hot weather. The increase in moisture under the grasses may be linked with the reduction in transpiration from the plant as well as a reduction in evaporation as the result of heavy ground cover.

The monthly precipitation was greater in 1948 and 1950 than in 1949. However, the maximum soil temperatures at 3-in. were higher under all the species in 1949 than in 1948 or 1950. Also, the minimum temperatures were higher in 1949 under all the species, except red fescue which showed the lowest minimum of all the species for the three growing seasons. The soil-temperature differences in 1948, 1949, and 1950 agree with the findings of Weaver and Clements[2/], who state that the soil temperatures are affected inversely by the soil moisture content. The maximum temperatures under poverty oatgrass were lower and the minimum temperatures were higher through the three years than under the other grass species. This difference probably resulted from the encroachment of wild white clover which formed about 50 percent of the ground cover in the area where the thermometer was located. Under crown vetch, the soil temperatures were about the same as for the grasses in 1948 and 1949. However, in 1950 both the maximum and minimum temperatures were lower for this species than under the grasses. This was, possibly, due to the dense ground cover developed by this species.

The studies in 1950 showed an increase in total weight of roots per cu. ft. of soil to a depth of 9-in. as compared to 1949 for crown vetch and all the grasses except orchardgrass. The reduction in top growth of orchardgrass which occurred in 1950, apparently, was sufficient to cause a reduction in root growth. Also, it is possible that the lower soil temperatures and more abundant moisture supply in 1950 may have had less effect on the root development of orchardgrass than on the other species.

2/ - Weaver, John E. and Clements, F. E. Plant Ecology. McGraw-Hill Book Co., Inc. New York, 1938.

Weaver and Clements[3/] report that temperatures between 60 and 80 deg. F. are probably most favorable for root development of many crop plants.

Data was collected showing the proportion of roots present at the 0- to 3-, 3- to 6-, and 6- to 9-in. levels, in soil cores 9-in. deep. In 1949, orchardgrass produced 77 percent of its roots in the 0- to 3-in. horizon, crown vetch 73 percent, and other grasses 80 to 85 percent. In 1950 the grasses produced 75 to 79 and crown vetch 65 percent of their roots within 3-in. of the surface. The grasses and crown vetch developed lower percentages of roots at the 3- to 6-in. level — 10 to 18 percent for the grasses and 21 percent for the crown vetch in 1949. In 1950, 15 to 17 percent of the grass roots and 24 percent of the crown vetch roots were in this second zone. At the 6- to 9-in. depth the grasses developed up to 8 percent of their roots in 1949 and 1950. For the same years crown vetch showed 6 and 11 percent respectively. This increase in the percentage of crown vetch roots at the 6- to 9-in. level indicates an ability to anchor the soil at a greater depth than the grasses, and to persist under the drought conditions that often occur on slopes of roadsides. The main root system on crown vetch plants examined showed that they had penetrated the soil to a depth greater than 4 ft. in two years. The lateral root spread was approximately 4 ft. and new plants developed from the underground stems at various points. The extensive root system and dense ground cover produced by crown vetch may be expected to be very effective in minimizing soil movement on slopes of highways.

Date of Seeding and Slope Exposure

A second project was set up in the winter of 1949 to study the effect of dates of seeding and slope exposures on establishment of grasses and crown vetch. This study was conducted on Morrison loamy sand subsoil on Route 047 in Centre County, Pennsylvania, on opposite north and south slopes that have gradients ranging from 1:1 to 2:1. The species used in this test were combinations of one grass and two grasses with crown vetch. The grasses used were creeping red fescue, tall oatgrass, orchardgrass, alta fescue, and domestic ryegrass.

Design of Experiment

The design of the experiment consisted of a modified simple split plot arrangement with four replications. This part of the experiment involves five species of grass seeded with crown vetch at four seeding periods on two slope exposures, and all combinations of two grasses and crown vetch seeded at one period on two slope exposures. The main plots were 480 by 80 ft. on the north exposed slope and 420 by 17 ft. on the southern exposure. The sub-plots for dates of seeding were 40 by 20 ft. on the north exposed slope and 35 by 17 ft. on the south exposed slope. The sub-plots for species were 8 by 20 ft. on the north exposed slope and 7 by 17 ft. on the southern exposure.

Establishment and Maintenance

Seedings were made on both the north and south exposures at four periods: winter of 1949, and in the spring, summer, and fall of 1950. Seedings were made on a seedbed that had sufficient ground limestone worked into the surface 2 or 3 in. to adjust the soil reaction to approximately pH 6.5. Two days later an application of a fertilizer containing 60 lb. of nitrogen (N), 120 lb. of phosphate (P_2O_5) and 60 lb. of potash (K_2O) was made per acre. Seedings on each date were made on the rough seedbed two days after applying the fertilizer. The seeds were sown broadcast raked lightly into the soil, and mulched with old hay at a rate of 2 tons per acre.

3/ - Weaver, John E. and Clements, F. E. Plant Ecology. McGraw-Hill Book Co., Inc., New York, 1938.

Crown vetch was seeded at a rate of 5 lb. per acre with an individual grass and all combinations of two grasses. The rates of seeding (the seed in each instance represents pure live seed) the individual grass species were as follows:

Orchardgrass - 60 lb. of seed per acre; tall oatgrass - 75 lb. per acre; alta fescue - 60 lb. per acre; creeping red fescue - 75 lb. per acre; and domestic ryegrass - 60 lb. per acre.

The rates of seeding combinations of two grass species were as follows:

Orchardgrass - 30 lb. with 37.5 lb. of tall oatgrass, 30 lb. of alta fescue, 37.5 lb. of creeping red fescue, and 30 lb. of domestic ryegrass seed per acre.

Tall oatgrass - 37.5 lb. with 30 lb. of alta fescue, 37.5 lb. of creeping red fescue, and 30 lb. of domestic ryegrass seed per acre.

Alta fescue - 30 lb. with 37.5 lb. of creeping red fescue and 30 lb. of domestic ryegrass seed per acre.

Creeping red fescue - 37.5 lb. with 30 lb. of domestic ryegrass seed per acre.

Methods of Evaluation

The effects of dates of seeding and slope exposures on the seedling population of grasses and crown vetch were evaluated by using a one-foot square list quadrat. Three random counts were taken in each plot of the different species seeded with crown vetch in the winter, spring, summer, and fall. The relation of slope exposures and spring seeding on the seedling population of one grass and all combinations of two grasses seeded with crown vetch were evaluated by the same method. Evaluations were made for each date of seeding 25 days after the first germination was noted. The effects of slope exposures and dates of seeding one grass and all combinations of two grasses on the survival of crown vetch were evaluated by taking three random counts with the aid of a 3-ft. list quadrat. Counts were made at the end of the first growing season. The percent survival was based on the crown vetch seedling population as determined by this same method 25 days after first germination was noted. The percent ground cover formed by the grasses and crown vetch was evaluated visually at the end of the growing season by three independent observers. The ground cover was rated on a one to 100 basis, with 100 representing complete ground cover.

Results and Discussion

The data compiled in this study indicate that the time of seeding had a highly significant effect on the survival of grass and crown vetch seedlings at certain periods. In all cases survival from the winter seedings was lower than from those made in the spring, summer, and fall. Survival from the spring seedings was lower than from those made in the summer and fall for all species except domestic ryegrass. There were no marked differences in seedling survival between summer and fall seeding. The survival of crown vetch seedlings in the various grasses, except domestic ryegrass, was higher from the summer than from the winter, spring, or fall seedings. There was little difference noted in the survival of crown vetch seedlings in the fall and summer seedings when used in combination with domestic ryegrass; however, for both dates there was better survival than from either the spring or winter seedings.

Creeping red fescue developed the largest number of seedlings from the winter, summer, and fall seedings. Orchardgrass, tall oatgrass, alta fescue, creeping red fescue, and domestic ryegrass all showed larger seedling survival from the summer and

The study of date of seeding and slope exposure was conducted on opposite north and south slopes having gradients ranging from 1:1 to 2:1 in Centre County, Pennsylvania. Plant species used were combinations of one grass and two grasses with crown vetch. Included in the grasses were creeping red fescue, tall oatgrass, orchardgrass, alta fescue, and domestic ryegrass (Lolium spp.). A modified simple split plot arrangement with four replications was used. Five grasses were seeded with crown vetch at four seeding periods and on both slope exposures, and all combinations of two grasses and crown vetch were seeded at one period (spring, 1950) on both slope exposures. Seedings were made on a well-prepared seedbed at four different periods, winter 1949 and spring, summer, and fall 1950. Seeds were sown broadcast and mulched with 2 tons of old hay.

Effects of seeding dates and exposure on seedling populations were evaluated by using a 1-ft. square list quadrat. Three random counts were taken in each plot - winter, spring, summer, and fall. The effects of slope exposure and dates of seeding one grass and all combinations of two grasses on grass stands and the survival of crown vetch were evaluated by taking three random counts with a 3-ft. list quadrat at the end of the first growing season. Percent ground cover on a one to 100 basis was evaluated at the end of the growing season by visual observation.

The results of this test showed that the largest number of seedlings developed from the summer and fall seedings, the smallest number from winter seedings and an intermediate number from spring seedings. No species of grass was appreciably superior in ability to establish itself at any particular seeding period. Larger numbers of seedlings of all species survived on the northern exposure than on the slope facing south. The largest survival of crown vetch seedlings for the four seeding periods was with alta fescue.

Survival percentages at the end of the growing season for crown vetch seeded in the spring with individual grasses and all combinations of two grasses were highest with domestic ryegrass on the north and red fescue on the south exposure. The lowest percent survival of spring-seeded crown vetch was with orchardgrass on both slopes. On plots seeded in the summer season the highest survival was recorded with individual seedings of orchardgrass, red fescue, and alta fescue; with domestic ryegrass from winter seeding and with tall oatgrass from spring seeding. Summer seeding gave the highest survival of crown vetch when used in combination with a single species of grass. Orchardgrass seeded in the summer gave the highest percent survival for all grasses at all seasons. Highest survival from winter seeding for all grasses was with domestic ryegrass and from spring seeding with red fescue. Lowest percent survival for the average of all grasses was from winter seeding. Orchardgrass seeded in spring gave the lowest percent survival of any grass at any season. Red fescue gave the lowest percent survival from winter seeding, while tall oatgrass gave the lowest percent survival of all grasses from summer seeding.

A better ground cover was produced on the north exposure than on the south for all individual species and combinations of two species with crown vetch except the combination orchardgrass and alta fescue. The spring and summer seeding of the grasses produced a higher percentage of ground cover than did the winter seeding. All combinations of two grasses with crown vetch produced a higher percent ground cover than did individual grasses.

Conclusions

As a result of these studies, the following conclusions may be drawn for the particular areas and seasonal conditions included in these tests:

(1) Crown vetch, although slow in becoming established from seed, produced an

excellent ground cover in three years.

2. Ground cover produced by individual grasses during the three-year period was in the following order from highest to lowest percent: (1) creeping red fescue, (2) alta fescue, (3) tall oatgrass, (4) orchardgrass, and (5) poverty oatgrass.

3. Crown vetch produced deeper roots with a greater total weight per cu. ft. of soil than did the grasses studied.

4. Grasses showed higher percentages of roots developed in the top 3 in. of soil than did crown vetch.

5. Seed-hay and broadcast seedings under wheat straw mulch did not produce appreciable differences in ground cover.

6. Two tons of seed-hay gave more effective immediate slope protection than one ton of seed-hay or one ton of wheat straw mulch.

7. Crown vetch was not as greatly affected by moisture conditions as were the grasses.

8. After ground-cover establishment, soil temperatures were lower under crown vetch than under the grasses.

9. Dates of seeding affected seedling establishment - summer and fall seedings producing the largest number of seedlings and winter seedings the smallest.

10. North exposed slopes were more favorable to seedling survival and permanent ground-cover establishment than south exposed slopes.

11. Survival of crown vetch seedlings was greatest from summer seedings.

12. Spring and summer seedings of grasses and crown vetch produced higher percentages of ground cover than did the winter seeding.

13. Combinations of two grasses with crown vetch produced higher percentages of ground cover than did individual grasses with crown vetch.

14. Crown vetch at the end of the growing season showed the highest average percentages of survival for all seasons with domestic ryegrass and red fescue on both north and south exposures.

(3) ~~15.~~ Crown vetch with orchardgrass, red fescue, and alta fescue showed highest percent plant survival from summer seedings; with domestic ryegrass from winter seeding; and with tall oatgrass from spring seeding. Summer seeding gave the highest average percent crown vetch plant survival; domestic ryegrass gave the highest average percent plant survival for all three seasons. /AUTHOR/