SEEDING HIGHWAY SLOPES as INFLUENCED by LIME, FERTILIZER, and ADAPTATION of SPECIES

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Successful establishment and maintenance of a suitable turf along roadsides on various slopes through cuts and fills depends upon the adaptation of plant species as associated with all factors that affect plant growth. The performance of any one turf species or variety is associated with soil, climatic, and biotic factors and interrelationships of these factors. A brief categorical outline of the major growth factors to be considered in turf management follows:

Soil factors include physical and chemical properties of the soil environment:

- Fertility
- Acidity
- Compaction and lack of aeration
- Available soil moisture as related to texture, organic matter, and infiltration of water
- Erosion and frost action

Climatic factors:

- Temperature as influenced by slope position; both minimum and maximum temperatures influence species adaptation
- Light intensity and photoperiod

Biotic factors:

- Plant species and variety or genotype as influenced by soil and climatic factors
- Morphology of species (size, rooting depth, method of propagation, and its biological longevity)
- Adaptation of species as related to diseases and insect tolerance
- Rate of seedling emergence and its growth rate
- Date of seeding as interrelated to temperature and moisture

The broad scope of turf management, including all phases of establishment and maintenance, is dependent upon some understanding of these single factors and their interplay and the application of this knowledge. It should be emphasized that species as well as varieties within a species differ in their adaptation. Any one factor but usually an interplay of several of these factors is associated with successful establishment and maintenance of one species and failure of another species.

This paper gives some information on species adaption with different lime and fertilizer practices, mulching practices, seedling competition, and hydro-seeding as related to use of companion crops. Space is not available to give results from all the experiments; hence only some of the more important results from some of the experiments are included in this paper. The experiments have not been under way long enough to draw definite conclusions. A summary statement is included on the usefulness of the research findings.

PROCEDURE

Replicated plot experiments have been established on slopes on cuts in eight locations in Virginia. There are two experiments within each location: (a) lime and fertility variables with a controlled seeding mixture, and (b) plant species and mixtures as variables with lime and fertility as constants. The mixture and fertility treatments vary considerably for these regional experiments as research information from fertility experiments with pasture and forage species was considered in designing the treatment variables.

Geologically, the soil materials where the experiments are located are classified as consolidated sandstones, crystalline gneiss and schist, limestone, and shale. Chemical soil tests show large differences in the availability of essential nutrients for plant growth and in soil pH. The slopes range from shallow to steep 1:1 slopes, and some environments with southern exposures are xeric and hot, whereas other slopes are comparatively humid and cool.

The soil and other environmental factors that affect growth display much variation between the basal and top portion of slopes. Lateral variation along a slope paralleling a highway is meager as compared with vertical variance; hence the experimental plots were laid out across the slopes as shown in Figure 1. This procedure minimized the variation among the plots before imposing the treatments. The plot widths for the experiments in the different locations ranged from 11 to 25 ft and length of the plots or vertical distances of the slopes ranged from 15 to 45 ft.

Steep and long 1:1 slopes were usually staked to help to hold the mulch in place and reduce erosion. Straw mulch with asphalt was applied before making the

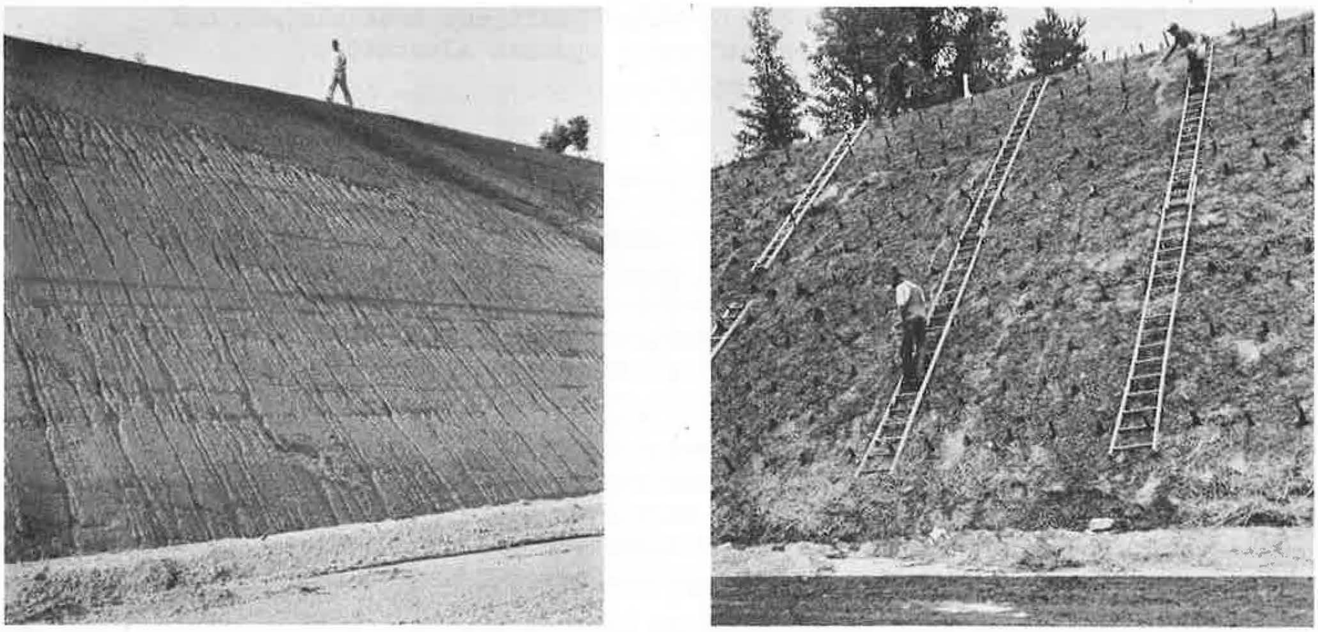

Figure 1. A steep 1:1 slope before and after establishing mixture and fertilizer experiments. Fertilizer treatments are being applied to three experimental plots. The plots were laid out across the slope gradient and are 15 ft wide and 45 ft long. Stakes help to hold the mulch in place. The area was mulched with straw, receiving an asphalt spray as the mulch was blown on the site. It was necessary to apply mulch in advance of seeding and fertilization to prevent these materials from rolling off steep slopes. Normally, the mulch is applied last.

species or fertility variables on long, steep slopes; the mulch was applied after making the seeding or fertility treatments on short or less steep slopes. All lime, fertilizers, and seeds were weighed out for each experimental plot and applied by hand, without incorporation into the soil (Fig. 5). The seeds and fertilizer were usually mixed with moist sawdust to reduce wind movement of seed and fertilizer and to increase the mass to facilitate more even distribution. These techniques are used only for these experimental procedures.

Data were recorded on ground covered with sod (percent ground cover), sod height, color, and species composition. Seedling-growth data are based on actual weights of plants, excluding the roots; soils were sampled before and after applying lime and fertilizers.

RESULTS AND DISCUSSION

Adaptation and Characteristics of Turf Species

Experiments have been conducted in eight locations, but forage experiments conducted for many years at different Research Stations of the Virginia Agricultural Experiment Station have provided much of the information on adaptation given in Table 1. In view of discussing species adaptation, the climate in Virginia may be classified into two regions: (a) mountainous and northern Virginia, and (b) southern piedmont and coastal plains (Fig. 2). Mountainous and northern Virginia is often called the Bluegrass region and is quite similar to the climate in northeastern United States. The climate in southern piedmont and coastal plain regions is not very suitable for bluegrass, but Kentucky 31 fescue is adapted and Bermuda grows well on the warmer, drier slopes.

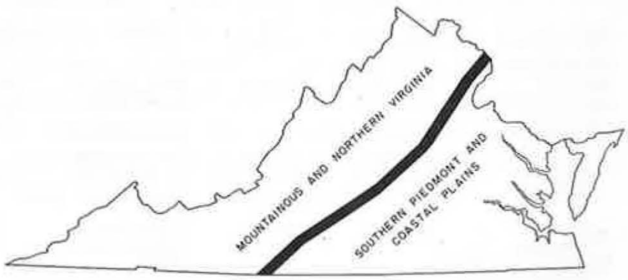

Figure 2. Map approximating (a) mountainous and northern Virginia and (b) southern piedmont and coastal plains regions as related to species adaptation.

Grasses

Kentucky 31 fescue is widely adapted, being suitable for all areas of Virginia; it is long-lived; tolerant of wide ranges in temperature, moisture, and fertility; easy to establish because of good seeding vigor; and not seriously affected by diseases. It is better adapted for summer seedings than the fine-leaved fescues or bluegrass. Its deep roots and dense sod make it especially useful for steep slopes that are subject to erosion. It is a bunchgrass, and so eroded areas "heal over" slowly and the turf is coarse (Table 1). Kentucky 31 and alta are varieties of tall fescue; alta is not as persistent as Kentucky 31. Meadow fescue, a related species, is very poorly adapted; it is susceptible to diseases, and it failed to survive under high temperatures and dry conditions on southern slopes.

The fine-leaved fescues (creeping red and Chewing's) and bluegrass are well adapted to mountainous and northern Virginia, but they tend to be short-lived when seeded on steep slopes through cuts or on difficult environments. The slow seedling development is one of the factors associated with stand problems during establishment. The fine-leaved fescues and bluegrasses require more favorable moisture, fertility, and temperatures than tall fescue. Merion bluegrass is not as suitable for roadside turf as Kentucky bluegrass.

Redtop, though short-lived, is widely adapted and easy to establish because it

TABLE 1

ADAPTATION IN VIRGINIA AND OTHER CHARACTERISTICS OF PLANT SPECIES FOR HIGHWAY SOD

Species	Adaptation in Va. Northern and mountainous region	Southern and eastern region	Turf characteristics	Season of growth	Seeding dates	Establishing a turf as related to seedling vigor	Other characteristics
Kentucky bluegrass[a] Poa pratensis	Suitable	Not suitable	Fine not bunchy	Full season	Cool season in spring or fall	Slow to establish, slow emergence, and slow seedling growth	Not drought-tolerant nor suitable for steep slopes
Redtop Agrostis alba	Suitable (short-lived)	Suitable (short-lived)	Medium coarse	Full season	Cool season fair with summer seeding	Easy to establish, fast emergence, and fair seedling vigor	Often successful when other species fail, especially on infertile soils
Creeping red[b] & Chewing's fescue Festuca rubra	Suitable	Not suitable (short-lived)	Fine, not bunchy in thick stands	Full season	Cool season in spring and fall	Easier to establish than bluegrass; fair seedling vigor	Quite tolerant of drought
Kentucky 31 fescue[c] Festuca arundinacea	Suitable (long-lived)	Suitable (long-lived)	Coarse, not bunchy in thick stands	Longest growing season	Widely adapted; does quite well with summer seedings	Easy to establish, rapid emergence, and aggressive seedling vigor	Very widely adapted; Very deep-rooted & suitable for steep slopes on infertile soils
Bent grasses Agrostis spp.	Adapted, but short-lived	Not adapted	Fine uniform sod	Cool season	Spring or fall	Easy to establish, fair seedling vigor	Too short-lived to be useful in mixture
Perennial ryegrass Lolium perenne	Short-lived	Short-lived	Medium coarse; gets ragged looking	Cool season (summer dormant)	Widely adapted	Very easy to establish, rapid emergence, & very aggressive seedings	Should not be used; crowds out desirable species
Annual ryegrass Lolium multiflorum	Very short-lived	Very short-lived	Crowds out other species & appears ragged	Early spring & fall (summer dormant)	Widely adapted	Very easy to establish, rapid emerence, & very aggressive seedlings	May be used at light rates, 5 lb per acre; crowds out desirable species
Bermuda grass Cynodon spp.	Not suitable	Suitable & long-lived	Fine to coarse (many varieties)	Summer (dormant during cool season)	Spring	Commercial types have poor seedling vigor; improved varieties are planted with sprigs	A good grass to be used with Kentucky 31 fescue; the runners & stolons heal bare spots
Dallis and Bahia grasses Paspalum spp.	Not suitable	Not suitable	Coarse	Summer (winter kills)	Spring	Very slow emergence and difficult to establish	Should not be used; too slow to establish
White and Ladino clover Trifolium repens	Suitable	Suitable	Good, fills in vacant spaces (stoloniferous)	Full season, not tolerant of drought	Cool season spring or fall	Easy to establish, rapid emergence, medium seedling vigor	Adds longevity to the sod, fixes nitrogen and improves grass growth
Red clover Trifolium pratensis	Suitable (short-lived)	Suitable (short-lived)	Does not creep to improve sod	Full season	Cool season spring or fall	Easy to establish, rapid emergence, aggressive seedling vigor	Short-lived, but useful during first two years
Annual lespedeza Lespedeza stipulacea	Adapted	Adapted	A good fill-in species, medium height	Summer annual	Spring	Easy to establish, grown on low fertility	Useful in mixtures; soil erodes easily after the annual plants die
Perennial lespedeza Lespedeza sericea	Adapted	Adapted	Tall coarse plants	Summer; cool season dormant	Spring	Difficult to obtain suitable stands; very slow rate of seedling growth	Best for areas too dry for grasses and other legumes; grasses usually crowd it out

[a] Merion bluegrass is more susceptible to rust than Kentucky bluegrass. It is suitable on very good soils that are high in fertility.
[b] Pennlawn appears to be inferior to red fescue under Virginia conditions.
[c] Alta tall fescue is shorter lived than Kentucky 31 fescue. Meadow fescue is not adapted.

is less demanding in its fertility, pH, temperature, and seeding dates than some other species. The bent grasses, though related to redtop, are not useful for seeding roadside slopes in Virginia. Dallis and Bahia grasses are often injured during low-temperature periods in the winter. Delayed germination and poor seedling vigor of these grasses also make them unsuitable for quick sod development.

Bermuda grass is suitable for southeastern Virginia, especially for the warmer southern slopes. Seedling vigor is poor, but good stands were obtained during the warm and dry spring in 1957, when other species grew slowly. Bermuda grasses grow only during the warm season, but the actively spreading stolons and rhizomes heal eroded spots; also, soils well sodded with stolons and rhizomes resist erosion (Fig. 3). Midland Bermuda would be especially useful for very steep slopes (Fig. 4). The Bermuda grass varieties from best to poorest vigor may be ranked (a) midland, (b) coastal and (c) common or commercial seed. Common or commercial varieties may be established with seed or vegetatively; the other varieties must be established vegetatively.

Figure 3. Left, a Kentucky 31 fescue - commercial Bermuda grass sod on a 1:1 slope on an infertile cut on crystalline gneiss and schist in southern piedmont Virginia. Before seeding in March 1957, a 10-20-10 fertilizer was applied at the rate of 1,000 lb per acre. The photograph was taken in October 1957. Torrential rains caused some of the seed and fertilizer to erode; hence the sparse sod upper left. Right, close-up of sparse sod from upper left. Note that stolons (runners) from Bermuda are encroaching and healing bare spots.

Figure 4. Midland Bermuda grass on a 1:1 southern slope on an infertile cut through crystalline gneiss and schist. Small pieces of rhizomes were planted 18 in. apart in 3-ft rows in March 1957. A 10-20-10 fertilizer at 1,000 lb per acre was applied before seeding. The photograph was taken in October 1957. Many of the stolons were more than 6 ft long.

Legumes

There is divided opinion on the use of legumes in compounding mixtures for roadside seedings. The writer believes that grass-legume mixtures may be used on easy environments, where nitrogen from the legumes may serve as an inexpensive method to maintain growth. Legumes are more vulnerable to injury from adverse climatic, soil, and biotic factors than grasses; hence legume stands are rather difficult to establish and maintain. Difficult environments must be fertilized liberally for establishment and again fertilized to maintain a dense sod cover to resist erosion. Legumes are difficult to establish under such liberal nitrogen fertility practices, as rapid grass growth exterminates leguminous seedlings.

White, ladino, and red clovers are widely adapted; but these species are short-lived, though close mowing and liberal applications of lime, phosphorus, and potassium will usually stimulate legumes. Annual lespedeza varieties are also widely adapted, but annuals are not suitable for slopes, as erosion is often initiated during the winter when these annual plants are dead.

Seedling Competition as Related to Companion Grasses and Compounding Mixtures

The development of a sod in a short time is an essential objective in compounding mixtures for roadside seedings. Seedling development varies with species, as shown in Table 2. The work shows that rate of seedling development is associated with rate of emergence and the subsequent rate of growth. Small grain species sampled 51 days after seeding ranged from 17.21 to 38.56 g in weight per 100 plants as compared with 9.96 g for 100 plants of domestic (Italian) ryegrass. One hundred plants of Kentucky 31 fescue, redtop, red clover, white clover, and *Lespedeza sericea* weighed 1.86, 1.21, 0.86, 0.57, and 0.39 g, respectively. In another experiment, the relative seedling weight of Kentucky 31 fescue was given a relative weight value of 100; the comparative values for other species were: redtop, 27; Kentucky bluegrass, 20; creeping red fescue, 47; perennial ryegrass, 297; and domestic ryegrass, 497.

TABLE 2

SEEDLING GROWTH RATE DURING ESTABLISHMENT OF COMPANION GRASSES AND CERTAIN PERENNIAL GRASSES AND LEGUMES

Plant species	Highway 58, sampled 51 days after seeding. Weight (g) per 100 plants	Relative plant weights[a]
Abruzzi rye	38.56	---
Clinton spring oats	41.13	---
Winter oats	17.21	---
Domestic ryegrass	9.96	497
Kentucky 31 fescue	1.86	100
Redtop	1.21	27
Red clover	0.86	216
White clover	0.57	59
Lespedeza sericea	0.39	---
Kentucky bluegrass		20
Illahee creeping red fescue		47
Perennial ryegrass		279

[a] Data from experiments reported by R. E. Blaser, Timothy Taylor, and Walter Griffeth. Seedling Competition in Establishing Forage Plants, *Agronomy Journal* 48:1-6, 1956.

Ryegrass seedlings develop about 5 times as fast as Kentucky 31 fescue, but Kentucky 31 fescue seedlings developed 5 to 10 times as fast as species like bluegrass, creeping red fescue, and redtop. Small grain crops developed 9 to 22 times as fast as Kentucky 31 fescue, but Kentucky 31 fescue developed 5 times as fast as Lespedeza sericea.

Species with aggressive seedling development such as the small grains and ryegrasses often crowd out the desirable long-lived species with less aggressive seedlings. The companion and aggressive species are especially harmful with seedings made on steep slopes that are not mowed. Immediately after seeding, competition for light, nutrients, and/or moisture among seedlings sets up a dynamic plant community where the aggressive companion grasses become dominant. Coupled with this competition, the tall and erect growth of companion grasses shades out desirable sod-forming plants. Annual ryegrass seeded at 10 lb was as harmful as 30 lb of seed per acre. If companion grasses are used, it appears now that domestic ryegrass should be restricted to about 5 lb and the small grains to less than 20 lb per acre.

The need for companion grasses in new seedings is now reduced for three reasons:

1. Adequate fertilization encourages rapid stands of sod-forming species.
2. Soil mulching where straw and an asphalt spray is applied together is effective in resisting erosion.
3. Kentucky 31 fescue has excellent seedling vigor as compared with bluegrass, redtop, fine-leaved fescue, and bent grasses. Kentucky 31 fescue and redtop are adapted to a wide range of temperatures and may be seeded later in the spring and earlier in the autumn than bluegrass and the fine-leaved fescues.

The climatic, soil, and biotic growth factors as interrelated to differential growth responses among species cannot be exactly predicted; hence the employment of simple mixtures is some insurance against failure. Complex mixtures should be avoided unless information on species and environmental factors is lacking. Some examples on differences in growth among species are given in the succeeding two paragraphs.

It is more difficult to establish and maintain sods on sunny slopes with a southern exposure than for shaded northerly slopes. Sunny slopes are not as favorable for plant growth as shaded slopes because of the greater daily extremes in temperature and inadequate moisture because of high transpo-evaporation rates. In an experiment the soil cover, averaged for 19 mixtures, seven months after seeding, was 59 percent on a southerly exposure as compared with 79 percent on a northerly exposure (Table 3). Likewise, the soil cover for 24 fertilizer treatments averaged

TABLE 3

TURF COVER ON AN INFERTILE CUT OF CRYSTALLINE GNEISS AND SCHIST NEAR TURBEVILLE ON HIGHWAY 58 AS INFLUENCED BY SLOPE EXPOSURE. (THE EXPERIMENT WAS ESTABLISHED IN MARCH 1957.)

Mixture or fertilizer	Ground cover on 1:1 slopes, Nov. 2, 1957			
	Southerly exposure		Northerly exposure	
	Total	Bermuda[a]	Total	Bermuda[a]
Average of 19 mixtures	59	52	79	15
Average of 24 fertilizer treatments	52	Not recorded	81	Not recorded

[a] Commercial seed and sprigs of common, coastal, and midland varieties were planted with various cool-season species.

52 percent on a southerly slope as compared with 81 percent on a northerly slope. Seven of the 19 mixtures mentioned above had Bermuda grass in the mixture. It will be noticed that Bermuda grass made up 52 percent of the ground cover on a southerly slope and only 15 percent of the soil cover on a northerly slope. This points out that Bermuda grass is a useful species on southerly slopes and that mixtures may well be adjusted to slope and its environmental conditions.

A differential response among species to an environmental factor that effects growth is also displayed in Table 4. Liming a red subsoil did not improve the growth of redtop. Conversely, the growth of Kentucky 31 fescue on this same soil was improved 101 percent by lime. Oats also responded more favorably to lime than redtop. Redtop may be considered a desirable component in mixtures because of easy establishment and wide adaptation. Under adverse fertility or moisture, redtop often produces a fair sod when other species fail.

TABLE 4

THE DIFFERENTIAL RESPONSES OF SPECIES TO LIME ON TWO SOILS TAKEN FROM CUTS THROUGH SOILS FORMED FROM CRYSTALLINE GNEISS AND SCHIST (GREENHOUSE EXPERIMENT)

Species	Red subsoil pH 5.2 No Lime	Red subsoil pH 5.2 Lime	Increase due to lime	Grey subsoil pH 5.4 No Lime	Grey subsoil pH 5.4 Lime	Increase due to lime
Redtop	5.27	5.10	-3	4.83	5.79	20
Kentucky 31 fescue	3.86	7.75	101	4.65	7.86	69
Oats	5.52	6.65	20	6.14	8.94	46
Bermuda	5.42	7.66	41	4.69	4.73	1

Type mixtures that are suitable for Virginia follow: (All rates are given as lb per acre.)

I. For mountainous and northern Virginia.

A. For steep 1:1 slopes subject to erosion; for slopes with southern exposures where seasonal variations in temperature and moisture are large; for stoney or drouthy areas; and/or for areas when topsoil is not replaced:

Kentucky 31 fescue, 60 to 80 lb; Redtop, 5 lb.

B. For shallow slopes, especially those with a northern exposure, and for areas with considerable topsoil:

Kentucky 31 fescue	60 lb
Redtop	5 lb
White or ladino clover	5 lb
Red clover	5 lb
or	
Red fescue or Chewing's fescue	30 lb
Kentucky bluegrass	20 lb
Redtop	5 lb
White clover	5 lb
Domestic ryegrass	3 lb

C. Roadside parks where fine-quality turf is desired:

Kentucky bluegrass	50 lb

Redtop	5 lb
White clover	5 lb
or	
Kentucky bluegrass	25 lb
Red or Chewing's fescue	30 lb
White clover	5 lb

D. Roadside Parks with considerable traffic and frequent mowing:

Kentucky 31 fescue	80 lb
Kentucky bluegrass	30 lb
White clover	5 lb

II. For piedmont and coastal plains region.

A. Steep and sunny slopes:

Kentucky 31 fescue	80 lb
Redtop	5 lb
Bermuda grass	10 lb

B. For the more humid cool slopes:

Kentucky 31 fescue	60 lb
Redtop	2 lb
White or ladino clover	5 lb

Liming and Fertilizer Experiments

The physical and chemical characteristics of soils, because of cuts and fills and different geological formations, are extremely variable. It is rather simple to develop good sods on fills as material from top and basal soil horizons is mixed; hence the physical and chemical properties of soils are favorable for growth as compared with soil environments on cuts. The soils through cuts, depending on geological formations, are characteristically of poor soil structure and aeration and very low in one or more of the essential nutrients for plant growth. Because of the compacted subsoils and concurrent steep slopes, water infiltration is poor; hence xeric conditions often exist. To date, all lime and fertilizer experiments in Virginia have been established on shallow to steep slopes on cuts because the Landscape Division of the Virginia Department of Highways has designated these as turf problem areas.

Experiments on Crystalline Gneiss and Schist, Highway 58, Southern Piedmont

The inert characteristics of the subsoils taken from two slopes through adjacent cuts from crystalline gneiss and schist in southern piedmont Virginia is shown by plant-growth responses from a greenhouse experiment (Table 5). The average yield of seedlings of four species in response to liming was increased 45 percent on a red subsoil and 35 percent on a grey subsoil. The relative yield of seedlings when limed and treated with nitrogen, phosphorus, and potassium (1,000 lb per acre of a 12-12-12 fertilizer) was 100 as compared with 87 without potassium; 4, without phosphorus; 30, without nitrogen; and 5, without fertilizer. All three fertilizer nutrients and lime produced increased growth on the grey subsoil, but the magnitude of the responses was smaller than for the fill with the red subsoil. There was a linear increase in seedling weights on the red subsoil as applications of a 12-12-12 fertilizer were increased from 500 to 2,000 lb per acre. This experiment suggests that nitrogen and phosphorus were critically deficient.

TABLE 5

THE GROWTH RESPONSE TO FERTILIZER AND LIME ON A RED AND GREY SUBSOIL FROM CUTS OF CRYSTALLINE GNEISS AND SCHIST TAKEN NEAR TURBEVILLE ON HIGHWAY 58[1/]

Fertilizer	Rate Per Acre	Lime/Tons/Acre	Relative Growth Red Subsoil	Relative Growth Grey Subsoil
None	None	2 tons	5	43
0-12-12	1,000	2 tons	30	38
12-0-12	1,000	2 tons	4	57
12-12-0	1,000	2 tons	87	74
12-12-12	1,000	2 tons	100	100
12-12-12	1,000 plus minor elements	2 tons	115	91
12-12-12	500	2 tons	85	74
12-12-12	2,000	2 tons	160	101
12-12-12	1,000	None	55	65
12-12-12	500	None	14	68

1/ These results were obtained from a greenhouse experiment. The seeding mixture was Kentucky 31 fescue, redtop, red clover, and common lespedeza.

The data from some of the treatments of a lime and fertilizer experiment conducted on slopes through cuts on these red and grey subsoils are given in Table 6. This experiment was established in March 1957. A torrential rain immediately after establishment caused considerable erosion. Moisture during the spring and summer was about half of normal, but autumn moisture was very favorable. By July, the soil covered with sod averaged 36 percent of the total when 500 lb per acre of a 10-20-10 fertilizer was applied as compared with 52 percent and 65 percent ground cover for 1,000 and 2,000 lb of fertilizer, respectively. Lime improved the sod cover slightly.

TABLE 6

TURF COVER ON A 1:1 SLOPE ON AN INFERTILE CUT OF CRYSTALLINE GNEISS AND SCHIST NEAR TURBEVILLE ON HIGHWAY 58 AS INFLUENCED BY LIME AND FERTILIZER (THE EXPERIMENT WAS ESTABLISHED IN MARCH 1957)[1/]

Lime and fertilizer, lb per acre, applied at seeding: 10-20-10	Ground Limestone	Slope covered with turf, %: May 9, 1957	July 12, 1957	November 2, 1957
500	0	42	36	42
1,000	0	51	52	48
2,000	0	59	65	55
1,000	4,000	60	57	54

1/ Seeding mixture in lb per acre: Kentucky 31 fescue, 50; redtop, 5; *Lespedeza sericea*, 10; common Bermuda, 10; red clover, 5; and white clover, 5.

A portion of this experiment, dealing with maintenance fertilizer applications, is shown in Table 7 and Figure 5. All plots received 1,000 lb per acre of a 10-20-10

fertilizer at establishment, in March 1957; maintenance fertilizer applications made in September 1957, were none, 500, and 1,000 lb of fertilizer per acre. A maintenance application of 500 lb of fertilizer per acre increased the soil cover from 53 percent in September to 73 percent cover in November. A 1,000-lb applica-

TABLE 7

TURF COVER ON A 1:1 SLOPE ON AN INFERTILE CUT OF CRYSTALLINE GNEISS AND SCHIST NEAR TURBEVILLE ON HIGHWAY 58 AS INFLUENCED BY MAINTENANCE FERTILIZATION (THE EXPERIMENT WAS ESTABLISHED IN MARCH 1957)1/

10-20-10 fertilizer, lb per acre		Ground limestone lb per acre applied at seeding	Slope covered with turf, %	
March 1957 For establishing	Sept. 1957 For Maintenance		Sept. 11, 1957 Before applying maintenance fertilizer	Nov. 2, 1957 After applying maintenance fertilizer
1,000	0	0	48	48
1,000	500	0	53	73
1,000	1,000	0	40	72
1,000	0	4,000	54	42
1,000	500	4,000	49	65

1/ Seeding mixture in lb per acre: Kentucky 31 fescue, 50; redtop, 5; Lespedeza sericea, 10; common Bermuda, 10; red clover, 5; and white clover, 5.

Figure 5. Maintenance fertilizer treatments are needed. Left, weighing and applying maintenance fertilizer treatments on an experiment on a shaly subsoil in the limestone region on Highway 114. This experiment was established in March 1957, and certain plots are being refertilized during the subsequent August. Right, adjacent plots on crystalline gneiss and schist. Both plots were fertilized with 1,000 lb per acre of a 10-20-10 fertilizer in March 1957. The plot on the right received 1,000 lb of fertilizer again in September 1957, and the photograph was taken in November 1957.

tion for maintenance increased the cover from 40 percent before fertilization to 72 percent 51 days later. Maintenance applications of fertilizer had similar beneficial effects in the presence of lime.

Limestone Soil, Highway 11 in Southwestern Virginia

This experiment was established in September 1954; the data from the lime and fertilizer treatments are given in Tables 8 and 9. Lime applied at 1 ton per acre increased the clover fraction but did not improve the sod cover. Data obtained in April 1957, show a total soil cover of 70 percent for a 10-6-4 fertilizer, 78 percent for a 10-10-10, and 84 percent for a 4-16-8, when all ratios were applied at 800 lb per acre. The 10-6-4 produced a total of 3 percent clover ground cover as

TABLE 8

THE TURF COVER AS INFLUENCED BY LIME ON A SUBSOIL IN THE LIMESTONE REGION ON HIGHWAY 11[1]

Lime, lb applied per acre	Ground cover, percent			
	Total	Grass	Clover	Weeds
	Averaged for 14 fertility plots			
1 ton	84.3	65.9	18.5	0.3
None	78.7	63.9	13.9	.9
	Averaged for 22 mixture plots			
1 ton	79.9	69.7	9.6	1.3
None	79.6	75.0	4.0	1.2

1/ The experiment was established in September 1954; the data were obtained in November 1956.

TABLE 9

SOD COVER AND ITS BOTANICAL COMPOSITION AS INFLUENCED BY FERTILIZATION ON A SHALLOW CUT ON A LIMESTONE REGION, HIGHWAY 11[1]

Fertilizer	lb per acre	Ground Cover: Total %	Grass %	Clover %	Weed %
10-6-4	800	70	62	3	5
10-10-10	400	75	71	4	Trace
10-10-10	800	78	69	8	1
10-10-10	1,200	89	82	7	Trace
4-16-8	400	78	61	11	6
4-16-8	800	84	65	19	Trace
4-16-8	1,200	84	70	14	Trace

1/ The experiment was established in October 1954, and the data were recorded in April 1957.

compared with 8 percent and 19 percent for the 10-10-10 and 4-16-8 fertilizers, respectively. The sod cover was improved linearly as the rates of fertilizer applications were increased from 400 to 800 to 1,200 lb per acre (Table 9). The plots fertilized with a 10-6-4 fertilizer had more weeds than the plots treated with a 10-10-10 or a 4-16-8 fertilizer applied at the same rate per acre.

Consolidated Sandstone

This lime and fertility experiment in the coastal plain region on Highway 360 was established on a shallow 1:4 cut with a soil pH of 6.1, in October 1955. Growth responses to fertilizer show more clover from a 4-16-8 than for 10-6-4 or 12-12-12 fertilizer; it is apparent that the higher applications of phosphorus are associated with increased clover stands. The sod cover was improved as the rate of fertilization was increased from 400 to as high as 1,200 lb per acre. Sod cover was also improved as the amount of nitrogen was increased, but heavy nitrogen fertilization did retard the clover because of competition from the grass seedlings.

Hydrated lime, applied at 1,500 lb per acre, retarded growth during the spring season in 1956 (Fig. 6). It became evident that lime started to stimulate the clover fraction by July, and by the end of the 1956 season and during 1957 the grass and clover sod was much better on the limed than on the unlimed plots. The soil had a 93 percent sod cover when limed as compared with only a 73 percent cover without lime. The clover component covered a total of 52 percent of the soil on limed plots as compared with only 19 percent for the unlimed plots.

Maintenance fertilizer treatments were not included in this experiment. However, by 1956, it was evident that additional fertilizer would have improved the density of the sod. The growth along the basal area of the slopes was retarded and yellowish by fall of 1956, and erosion even on these shallow slopes was evident (Fig. 7).

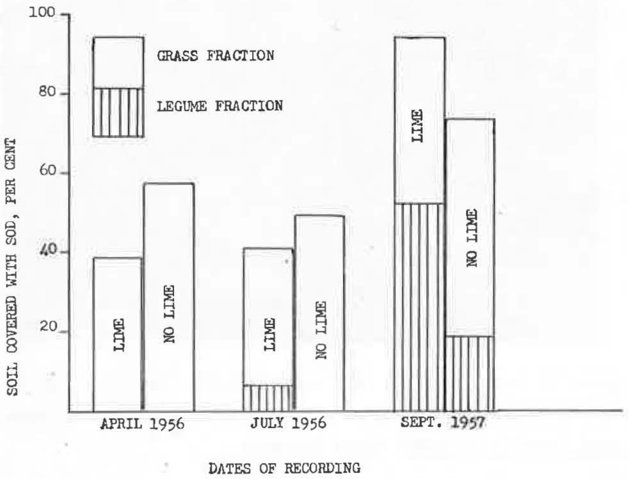

Figure 6. Lime (1,500 lb of hydrated lime per acre) first retarded seedling growth and sod cover, but later legumes were stimulated and the soil cover was better on lime than on unlimed plots. Data from an experiment on a cut in the coastal plain region.

Figure 7. This initial erosion could have been arrested by resorting to maintenance fertilizer practices. This seeding was two years old when photographed. This is a shallow 1:5 slope.

Mulching Trials

Some treatments were included at some of the locations to study plant establishment with and without mulch, rates of applying a given mulch, and comparing

straw mulch with tobacco stems. Proper mulching invariably improved the rate of seedling emergence and the rate of growth after the seedlings emerged. At one location, the seedlings without a mulch failed, but the stand with mulching was satisfactory. Mulching was more beneficial on difficult environments and steep slopes than on easy environments.

Heavy mulching, complete soil cover when it is several inches deep, was very harmful to the experiments and in the general large seeding operations, because the seedlings of the small seeded grasses and legumes could not come through the mulch (Fig. 8). It appears that about 25 to 50 percent of the soil should remain exposed after mulching (Fig. 8). It is better to apply too little rather than too much mulch. On steep slopes, it may be desirable to increase the rate of asphalt application rather than increase the rate of applying straw mulch. Long unchopped straw applied with an asphalt spray sticks to the soil surface and resists erosion much better than short chopped mulching materials.

Figure 8. Left, mulch applied with the asphalt technique at an ideal rate. Note the excellent seedling emergence. Right, a seedling failure occurred on the upper portion of cut where mulch application was too heavy.

Tobacco stems were compared with straw mulch at two locations. Tobacco stems gave harmful results at both locations; the seedlings mulched with tobacco stems produced a poor cover and were yellowish in color as compared with the seedlings mulched with straw (Table 10). There may be some toxic substance in tobacco stems that retards growth. Plant stands have also been sparse when tobacco stems were used; this could be attributed to leaching of soluble minerals, like potassium, into the soil and subsequent seedling plasmolysis due to salt concentration near the soil surface.

It is often difficult to apply straw mulch evenly and lightly because of variable wind currents. Wet straw is very difficult to apply evenly with mechanical blowers.

TABLE 10

THE GROUND COVER, HEIGHT, AND COLOR OF GRASSES 51 DAYS AFTER SEEDING AS INFLUENCED BY MULCHING, HIGHWAY 58, 1957

Mulch	Ground cover, %	Height, in.	Color
Straw mulch	33	3	Normal green
Tobacco stems - heavy	25	3	Very yellowish
Tobacco stems - light	15	2	Very yellowish

Hydro-Seeding Technique and Seed Germination

The seed is mixed with 750 gal. of water and 350 lb of fertilizer and applied as a slurry by the hydro-seeding technique. Normally, the seed is not in contact with the slurry for more than 15 min.

The germination of oats was injured slightly by the slurry; normal germination was 96 percent as compared with 89 to 93 percent after exposure for 15 min. The results for Kentucky 31 fescue and abruzzi rye showed similar trends. Redtop, perennial ryegrass, Hungarian millet white clover, and red clover were not injured in germination by the slurry. The mean germination of eight species for two concentrations and different times of exposure is given in Table 11. It may be concluded that fertilizer slurries were not injurious to seeds when following the conventional procedures for hydro-seeding. The results are based on laboratory experiments.

TABLE 11

THE EFFECT OF FERTILIZER-SLURRY CONCENTRATION AND EXPOSURE TIME ON THE GERMINATION OF EIGHT SPECIES (1956 EXPERIMENT)

Species	Fertilizer slurry		Percent seed germination[a]	
	Concentration lb/750 gal.	Exposure time, min.	Wet germination	Dried and then germinated
Average relative	0	0	--	100
values for all	350	15	95.0	104.6
eight species	350	30	99.4	95.1
	350	60	93.1	100.9
	350	240	92.3	95.7
	350	480	102.2	90.2
	700	30	58.8	92.5

[a] Wet germination: seeds were put in germinator immediately after soaking in slurry. Dry germination: seeds were taken from slurry and allowed to dry thoroughly at room temperature before being placed in the germinator.

SUMMARY AND CONCLUSIONS

This brief research report gives information on some of the soil, climatic, and biotic factors associated with successful turf establishment and its maintenance for roadsides. Experiments were located in eight different locations on different geological formations.

The landscape engineers of the Landscape Section of the Virginia Department of Highways have observed the experiments closely and frequently and some of their

establishing and maintenance procedures have been altered. Fertilizers were altered from a 10-6-4 to a 1-1-1 and later to a 1-2-1 ratio. A 10-20-10 is now commonly used for new seeding, with hydro-seedings and a granulated 14-14-14 fertilizer is now used for dry applications for maintenance.

As a result of these experiments, the amount of ryegrass in new seedings has been reduced to about 3 percent of the mixture or eliminated. Other companion grasses are used at light rates. Kentucky 31 fescue is used in all parts of Virginia with good results.

Mulching techniques are being improved with an endeavor to make applications as light as possible, 50 to 75 percent of ground cover being desirable.

Dates of seeding have been altered to coincide with seasons of favorable environment for seedling establishment.

Reseeding and refertilizing of spots, where poor stands occurred, are being stressed, and funds are being set up to employ maintenance fertilizer and reseeding practices.

ACKNOWLEDGMENT

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DISCUSSION

<u>NEALE</u>: I should like to stress the importance of refertilizing under construction contracts. If the objective is, as it should be, to construct and turn over to the several states "complete highways," we must necessarily make them complete in every respect and detail. It should be borne in mind that the Interstate System of highways is being constructed and financed with 90 percent Federal funds and 10 percent state funds. When these highways are turned over to the states, they immediately become a maintenance burden. This, added to the already heavy maintenance costs, will work a severe hardship on many highway departments.

Pavements, shoulders, gutters or ditches, underdrainage systems, etc., will be constructed complete in every detail and thus not require much maintenance for several years. The roadsides and medians will involve about 35 acres per mile of urban sections, in addition to the wayside or roadside rest areas. Unless these areas are constructed 100 percent complete, with satisfactorily established ground covers, shrubs and trees, and, above all, closely knitted turf or sod, they will create costly maintenance problems from erosion. At present, the average roadside turfing practice is to accept the contract when the area has been graded, fertilized, seeded, and mulched, leaving nature to take over. There is a vast difference between this practice and that of furnishing a weed-free, closely knitted turf or sod.

Now our agronomists tell us that newly seeded turf areas require refertilizing each year, and in many places they will need to be reseeded. Who will refertilize and reseed, and who will pay the bill? Naturally, when the contractor completes his work according to specifications, Federal-fund participation is ended, and the state must take over with 100 percent state funds. As it takes, according to agron-

omists, at least two or more years to establish a satisfactory weed-free sod or turf, I feel very strongly that we are missing a good bet in not changing specifications to require contractors to furnish and turn over to the state a clean, weed-free, closely knitted turf before the project is accepted. Ways and means can be worked out as to how this can be handled. This will contribute to safety, beauty, and economy in the long run. Tomorrow will be too late.

GORDON: Dr. Blaser's paper, as he delivered it, was one of the best and most informative discussions of facts regarding roadside seeding, as disclosed by well planned research, which has been available to members of this committee during the past 20 years. His illustrations showed us beyond any possibility of doubt that:

1. Kentucky 31 fescue is well adapted for control of erosion on the poor clay soils of the piedmont area in Virginia and that this grass can readily be established by seeding at relatively low rates in lb per acre. Slides showed seeding at 50 lb per acre to be successful. His belief that rates may be still further reduced seems well supported by his data.

2. The seeding of redtop and ryegrasses in fine grass-seed mixtures, including bluegrasses and red or Chewing's fescue, is demonstrated by Dr. Blaser's slides to be open to serious question, since ryegrasses, for example, at six weeks after seeding are something like twelve times the height of Kentucky bluegrass plants at the same age. It is evident from these slides that the fine turf grasses should be seeded with very small, if any, percentages of "nurse-grass" seeds.

3. Dr. Blaser also demonstrated in his work that a second application of fertilizer some time after turf has become well established is well worthwhile and may, in fact, be essential, if good turf is to remain in good condition on highway slopes and other seeded areas.

BRANT: I was amazed by the effect of lime on fescue that was reported. We have not considered lime as being particularly necessary with fescue.

Have you abandoned *Lespedeza sericea* as a suitable plant for steep cut slopes, or have you not included it in your experiments so far?

BLASER: *Lespedeza sericea* has been included in some of the mixtures and in the fertility plots in most of our experiments. We have seeded it during the spring season as well as during the autumn season. We attribute its failure to its slow seedling growth; more aggressive species, such as tall fescue, crowd it out during the seedling stage. We believe that it is not generally a useful plant because it would not stabilize the soil quick enough because of its slow rate of seedling growth.

ASTRUP: What do you mean by "heavy mulching"? Can you give the rate? You also state that it appears that about 50 percent of the soil should remain exposed after mulching. I do not agree with this conclusion. Basically, the primary purpose of mulching is to eliminate the puddling action of raindrops on the surface soil. Consequently, if 50 percent of the soil surface is exposed, it would seem that the value of the method was lost. From a practical point of view, how can we instruct crews operating a mechanical mulching machine when and where to restrict their mulch cover?

NICAR: The rate of mulching and the meaning of the terms are as follows: A light mulch is 1 ton per acre; the desirable rate is $1\frac{1}{2}$ tons per acre; and a heavy rate is 2 tons per acre. This refers to dry straw.

GARMHAUSEN: Is the lime referred to agricultural ground limestone or hydrated lime? Was the rate of lime determined by soil tests or by what other method?

What "legume" was used? I am interested because we have been very pleased with the results we have had with legumes in grass mixtures and have not found them hard to establish, which is not what you have experienced.

BLASER: We used ordinary ground limestone (calcium-magnesium carbonate) in all the experiments except one, where hydrated lime was used. Soil tests and plant responses are being used to ascertain the lime requirements.

We have used white clover, Ladino clover, red clover, Korean lespedeza, Lespedeza sericea, birdsfoot trefoil, and hairy vetch in our experiments. With the exception of Lespedeza sericea and birdsfoot trefoil, we have obtained satisfactory stands of legumes on shallow slopes which possess better moisture relationships than the steep slopes. Legume stands have also been better on slopes with a northern exposure than for sunny slopes with a southern exposure. On steep 1:1 slopes it is easiest to develop a quick sod and to stabilize the soil by using tall fescue and 1,000 lb of a 10-20-10 fertilizer. The liberal nitrogen fertilizer and aggressive seedling development of tall fescue does retard legume stands. It is much easier to obtain good stands of legumes on fills than on cuts.

FINN: Was there any soil preparation?

BLASER: All fertilizer treatments and seeds for the various mixtures were sown on the surface followed with an asphalt straw mulch.

OLSON: You mentioned steep 1:1 slopes and that such slopes are usually staked to help to hold the mulch in place and reduce erosion. Why use 1:1 slopes? I thought that by now 1:1 slopes were ruled out as being impractical. If narrow right-of-way is the reason, why not a retaining wall installed to a sufficient height to meet at least a 2:1 or flatter slope?

Also, in regard to legumes, I believe that mention should be made that legumes are very susceptible to chemical weed sprays, such as 2,4D and 2,4,5T which are becoming generally used in maintenance of the roadsides.

NICAR: For economical reasons and because of right-of-way limitations, 1:1 slopes are required in some cases. This is particularly true in mountainous areas. Our latest construction standards have slopes that are much flatter.

HOTTENSTEIN: Why was the seeding rate increased to a maximum of 80 lb (highest for any of the test sites) for the least fertile and most difficult of the test areas? Is it not true that the site least capable of supporting vegetation should be seeded at lower rates in order to encourage the establishment of more thrifty plants, though fewer in number, than could be supported by the more fertile sites?

BLASER: This is a very difficult question. In one of our experiments on a very poor shale site, it appears that the stand of fescue from 30 lb is as good or better than for an application at the rate of 120 lb per acre. In other sites, the seeding rate of 80 lb per acre appears superior to a seeding rate of 40 lb of tall fescue per acre. We believe that high seeding rates of the adapted permanent species are satisfactory, though they may not be necessary. High seeding rates would be very objectionable if companion species such as ryegrass were used liberally.

<u>SLACK</u>: I certainly agree with those who have commented on this paper as to the excellent information it contained as well as Dr. Blaser's fine presentation of it.

As to details, I am interested to know the results obtained by Dr. Blaser with Kentucky 31 fescue, as we have had excellent results in seeding both Kentucky 31 and alta fescues in Louisiana, finding it a good winter grass for erosion control. Also, I am glad to know of certain harmful effects of domestic ryegrass which shades out desirable sod-forming grasses. It has been noted in Louisiana when rye is planted on highways and even on lawns that it retards the growth of Bermuda.

I am glad to know also that heavy mulching of hay or straw is harmful to seeding operations. Again, in Louisiana we have found that about $1\frac{1}{2}$ tons of mulch per acre is about right. More than that lessens the chance of a good stand of grass. Further, Dr. Blaser's statement that seed is not injured in using mixtures of seed and fertilizer in Hydro-seeding operations compares favorably with our experiences. No bad results have been noted.