Turf Establishment and Maintenance Along Highway Cuts

R.E. BLASER, Professor; G.W. THOMAS, Associate Professor; and
C.R. BROOKS, G.J. SHOOP, and J.B. MARTIN, JR., Graduate Assistants,
Agronomy Department, Virginia Polytechanic Institute, Blacksburg

The roadside turf research program in Virginia is restricted to soil environments where sod establishment and maintenance is difficult. The studies are being conducted along highways with steep 1:1 sloping cuts on experimental sites representing the major geological formations in Virginia (consolidated sandstone, gneiss and schist, limestone, and shale). The subsoil materials on the steep sloping cuts are, therefore, usually compacted, infertile, and subject to severe erosion.

It was emphasized by Blaser and Ward in 1958 (1) that successful sod establishment along highways depends on all of the following: (a) adequate lime and fertilizer; (b) choice of seed mixtures with adapted grasses and legumes; (c) elimination of aggressive or low seeding rates of companion grasses such as ryegrasses and cereals; (d) suitable seeding dates, late summer and early spring being the best dates; and (e) light applications of mulch.

The need for fertilizer and lime for a site along US 360, near Amelia, is shown in Figure 1. Good sod establishment depended on the combined use of nitrogen, phosphorous, potassium, and lime; nitrogen and phosphorous were especially necessary.

Five laboratory and field experiments were designed to study sod establishment and maintenance of various grasses and legumes as influenced by lime and fertilization.

LIME AND FERTILIZER FOR SOD ESTABLISHMENT AND MAINTENANCE

A fertilizer and lime experiment was established in March 1957, on an infertile cut of red to greyish subsoil of gneiss and schist on a 1:1.5 slope near Turbeville on US 58. The soil was acid, about pH 5.0; and low in phosphorus, calcium, magnesium, and medium high in potash. Fertilizer, lime, and seeds were mixed together and surface broadcast to simulate the hydroseeding method commonly used by highway departments. The plots with the different lime and fertilizer treatments were arranged to cross the slopes. The lime, fertilizers, and mixtures were replicated twice on northern slopes and also on southern slopes on this east-west highway. An asphalted straw mulch was applied after the fertilizer, lime, and seed mixtures had been applied. A more detailed report on experimental procedures was given in a previous paper (1).

A seed mixture (Ky. 31 fescue 60, redtop 5, red clover 5, white clover 5, common Bermuda grass 10, and 20 lb per acre of Lespedeza sericea) was applied uniformly over all plots with lime and fertilizer treatments. The Bermuda grass and clovers failed. During the first two years the sod cover was mainly

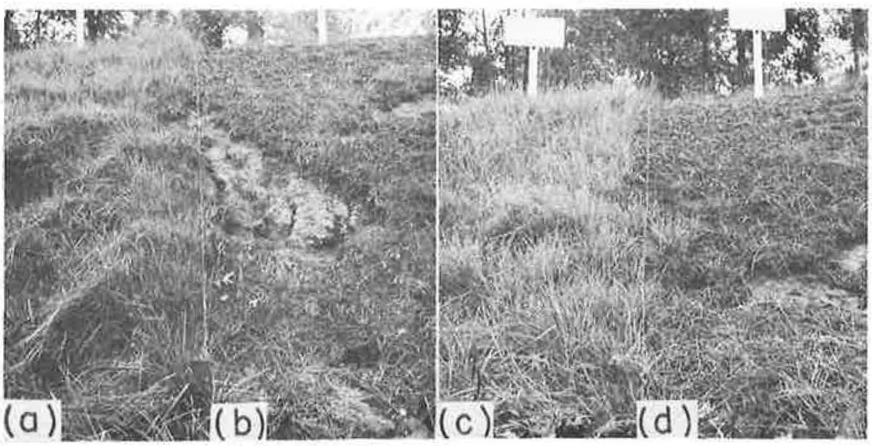

Figure 1. The steep 1:1 roadside cut on a red subsoil was seeded in March 1959; the photo was taken in July 1959. The treatments for the 4 plots from left to right are (a) lime, 2,000 lb and 1,000 lb of a 10-20-10 fertilizer per acre; (b) nitrogen omitted; (c) lime omitted; and (d) phosphorous omitted.

Ky. 31 fescue and redtop. Lespedeza sericea began to add to the sod cover during the third and fourth years after establishment.

The experiment was established in March and a good sod cover developed by May of the same year. The percent soil cover from seeded species in May 1957, ranged from 49 to 59 percent when 1, 000 lb per acre of a 10-20-10 fertilizer was applied at the time of seeding, in March (Fig. 2). The sod began to degenerate the first season as the soil cover was slightly lower in September than for May. The first maintenance applications of 500 or 1, 000 lb of fertilizer per acre in September of the establishing year improved the sod cover to 73 and 72 percent, respectively, by November (Fig. 2). The sod cover without refertilization averaged only 48 percent in November. This improvement of sod cover during the year of establishment shows that low soil fertility limited grass growth and soil cover. Refertilization soon after seeding on infertile and difficult soil environments is essential for turf maintenance.

During the four years of this experiment, sod cover was improved with several maintenance applications of fertilizer (Figs. 3 and 4). When an application of 1, 000 lb of fertilizer was made in March 1957, for establishment (treatment A), there was a very poor sod cover of only 18 percent in 1959 and 1960. Two maintenance applications of a 10-20-10 fertilizer, 500 lb in September 1957 and 1958 (treatment B), improved the sod cover to 56 percent in 1959, but the sod cover dropped to 25 percent by 1960. The use of two tons of lime per acre for establishment and two maintenance applications of fertilizer (treatment C) gave a sod cover of 61 percent in 1959 and 43 percent in 1960. The better sod cover for treatment C than for A is attributed to a better survival of Ky. 31 fescue due to liming.

A total of 2, 000 lb of fertilizer per acre was applied in split applications at different dates (Table 1). The initial sod cover, when a 1, 000-lb application of a 10-20-10 fertilizer was made for establishment, was as good as for the 2, 000-lb rate. Fertilizer at 500 lb per acre for establishing gave a poorer sod cover than the higher rates. The data show that sod cover was better when fertilizer was applied in several split applications as compared with one initial heavy application.

Data on total soil cover and stands of Ky. 31 fescue in October 1960 are shown in Figure 5. The longevity of a suitable sod cover was associated with a stand of Ky. 31 fescue; redtop generally deteriorates after 2 years. The total sod cover at the end of the fourth season was 64 percent with a cover of 39 percent Ky. 31 fescue, when the soil was limed and fertilized at seeding and given two additional applications of fertilizer (Fig. 5). The total sod cover for the fertilizer treatments without lime was 14 percent with a 6 percent ground cover of Ky. 31 fescue. Less than one-fifth of the soil was covered with sod at the end of the fourth season when lime and fertilizers were restricted to establishing treatments. The stands of Ky. 31 fescue deteriorated to a 6 percent ground cover when maintenance fertilization was not used. Although the initial sod cover during 1957 was excellent, there was serious erosion by 1959 and almost complete deterioration by

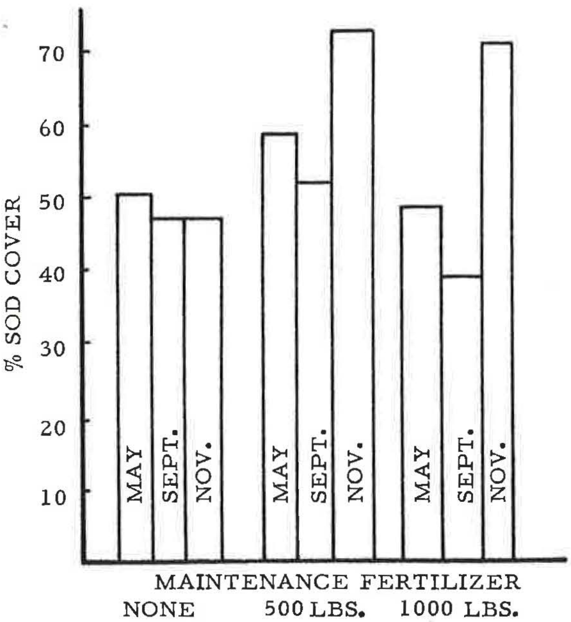

Figure 2. Maintenance fertilizer treatments improve sod cover. The experiment was established in March 1957 when an application of 1,000 lb of a 10-20-10 fertilizer per acre was made on all plots. The maintenance fertilizer application was made in September 1957.

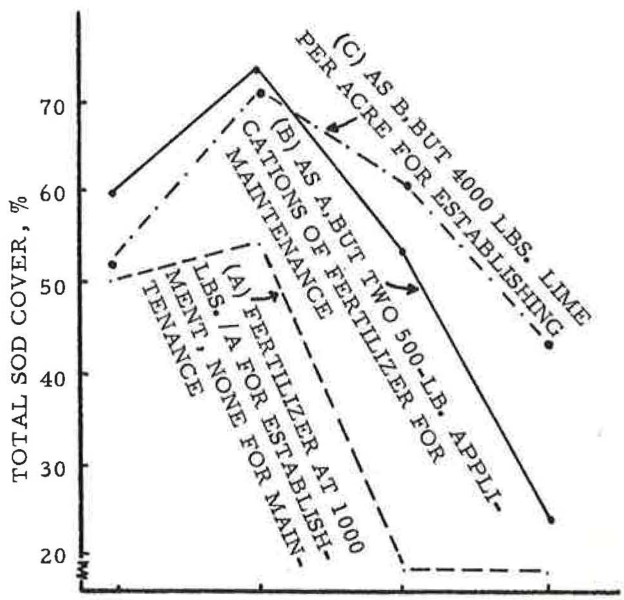

Figure 3. Sod cover as influenced by lime and fertilization. The experiment was established in March 1957; the maintenance fertilizers were applied in Sept. 1957 and 1958.

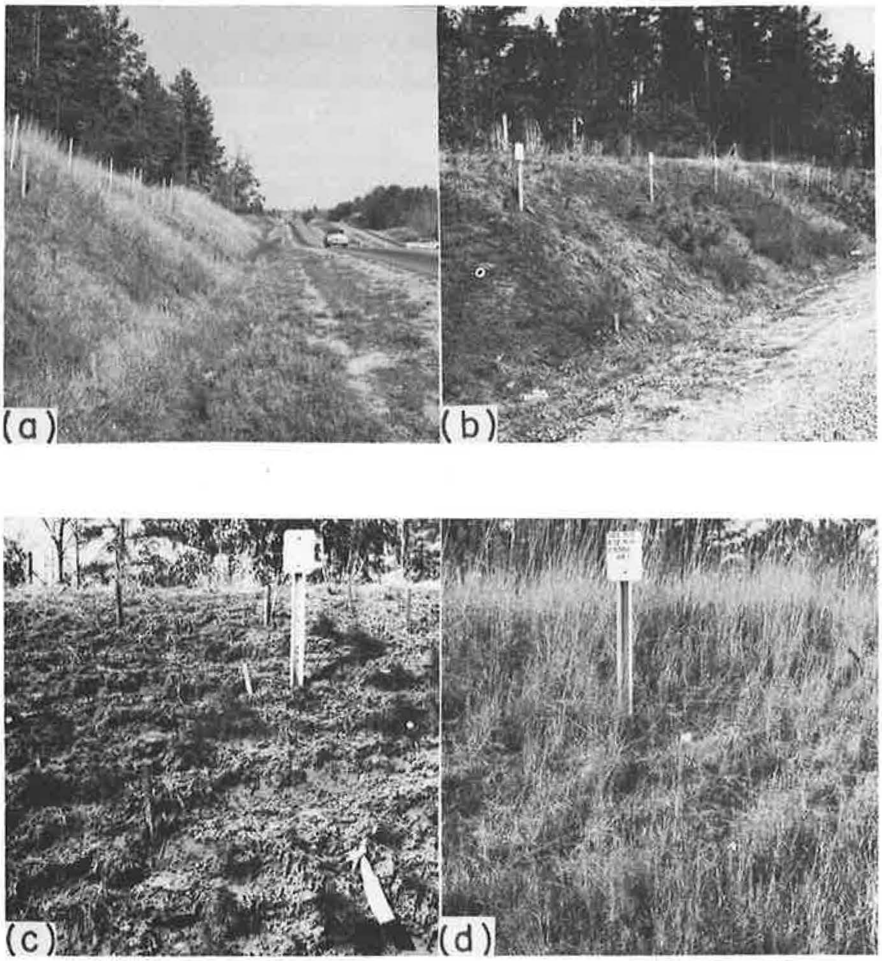

Figure 4. Experiment on cut-slope on US 58 shows suitable sod cover with maintenance fertilization. The experiment established in March 1957 shows (a) poor sod cover on certain treatments in 1959: (b) sod degeneration and soil erosion were very serious by 1960 when maintenance fertilizers were not used. Lower photographs were taken in 1960: (c) 1,000 lb of a 10-20-10 fertilizer for establishment; (d) two maintenance applications of fertilizer at 500 lb per acre.

1960, because maintenance fertilizer applications were not made. Such a degeneration now makes it necessary to begin with the more costly seeding, fertilizing, and liming practices to develop a new sod.

Lespedeza sericea stands were nil during the 1957 establishing season and very poor in 1958. The slow development of stands may be attributed to poor seedling vigor and aggressiveness of other species used in the seeding mixture. The stands improved rapidly during 1959 and 1960 (Fig. 6). Lespedeza sericea cover of 3 percent in 1958 increased to a 16 percent cover by October 1960. Lime improved Lespedeza sericea stands and growth, but maintenance applications of fertilizer were apparently not essential. The improved stands with time are a desirable characteristic of Lespedeza sericea, which survives in difficult soil environments with little refertilization.

Fertilizer for maintenance is also necessary for shallow and more fertile slopes (Fig. 7). The sod on this experiment on a shallow 1:5 slope on a limestone subsoil began to deteriorate in the third year after establishing.

Maintenance applications of fertilizer should be applied only as needed. The amount of fertilizer to apply and the frequency of making applications should be associated with sod cover and color of vegetation (Fig. 8). Applying too much fertilizer is often undesirable because diseases spread rapidly in unmowed, tall, dense sods. Very heavy fertilization makes it necessary to mow more frequently.

GROWTH RESPONSES OF PLANT SPECIES TO LIME AND PHOSPHORUS

The sod cover and its perpetuation on a soil such as the one discussed could now be improved by using less redtop in the seed mixture. Redtop, a short-lived grass, dominated the sod cover in the absence of

TABLE 1

EFFECT OF MAINTENANCE FERTILIZER TREATMENTS AND LIME ON A SOD COVER DURING FOUR YEARS ON A US 58 CUT NEAR TURBEVILLE

Treatment (lb/acre)				Total Sod Cover (%)			
Establishment		Maintenance					
Lime	10-20-10 Fert.	10-20-10 Fert.	Date	1957	1958	1959	1960
0	1,000	0	-	50	54	18	18
4,000	-	0	-	42	48	27	28
0	-	500	Sept. '57, '58	61	74	56	25
4,000	1,000	500	Sept. '57, '58	52	71	61	43
0	1,000	0	-	59	68	44	21
0	1,000	1,000	Sept. '57	51	71	61	23
0	1,000	500	Sept. '57, '58	61	74	56	25
0	500	500	Sept. '57, '58, '59	47	64	51	47

[a]On a greyish-red subsoil (gneiss and schist) in March 1957.

lime and with low rates of fertilizer. This section shows that plant species used in the Virginia highway sod development program respond differentially to lime.

This series of experiments was conducted along US 58 near Turbeville and 360 near Amelia and with soils from cut-slopes placed in pot experiments to interrelate growth of various plants with lime and phosphorus fertilization. The pot experiments with a semi-controlled environment were used with detailed laboratory research techniques to establish basic principles on why species of plants differ in growth responses. Much of the data for the subsequent experiments are reported in detail by Brooks (3) and Shoop (4).

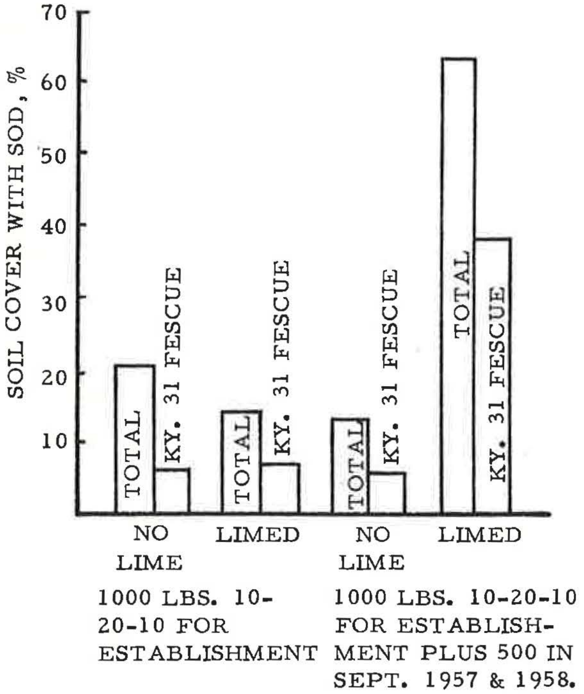

Figure 5. Sod cover and Ky. 31 fescue stands after four growing seasons (data obtained in October 1960). The experiment, on a crystalline gneiss and schist cut-slope along US 58 near Turbeville, was established in March 1957. The seeding mixture was: Ky. 31 fescue 60, redtop 5, red clover 5, white clover 5, Bermuda grass 10, and Lespedeza sericea 20 lb per acre.

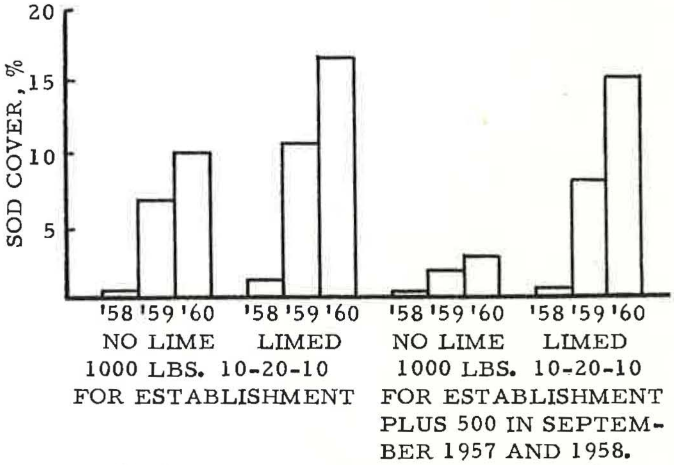

Figure 6. Lespedeza sericea sod cover during three years with lime and fertilizer treatments. (The stand was too low to record in 1957.) The experiment, on a crystalline gneiss and schist cut-slope along US 58 near Turbeville, was established in March 1957. The seeding mixture was as follows: Ky. 31 fescue 60, redtop 5, red clover 5, white clover 5, common Bermuda 10, and Lespedeza sericea 20 lb per acre.

Experiment A

The soil material from a cut-slope of US 58 near Turbeville is typical of sites where turf establishment and maintenance are difficult. The subsoil material contained 70 percent sand, 19 percent silt, and 11 percent clay (mostly kaolinite). The base exchange capacity of the soil was 3.13 me. per 100 grams and the base saturation was 14.7 percent. The soil was infertile: pH, 4.4; and CaO, 20; MgO, 25; K_2O, 50: and 8 lb per acre of P_2O_5 in the surface 6 inches of soil.

Five rates of lime were used with each of four sod species (Table 2). Fertilizer equivalent to 1,000 lb of a 10-20-10 was mixed with the different rates of lime and incorporated with the surface 2 inches of soil in the pots. The fertilizer was made up of compounds that did not supply calcium.

The relative dry matter yield of 14-day old seedling plants with rates of lime show large growth increases with increments of lime for Ky. 31 fescue and Ladino clover; the growth increases for redtop and Lespedeza sericea were small (Table 2). There was a 4- to 6-fold increase in weight of seedlings of Ky. 31 fescue and Ladino clover due to liming as compared with only about a two-fold increase for redtop and Lespedeza sericea. The dry weight yields per pot taken later show even larger differences in lime responses among the four species (Fig. 9). For example, without lime the yield of redtop was almost 10 times higher than for Ky. 31 fescue; however, with 2,000 lb of lime per acre Ky. 31 fescue produced higher yields than redtop.

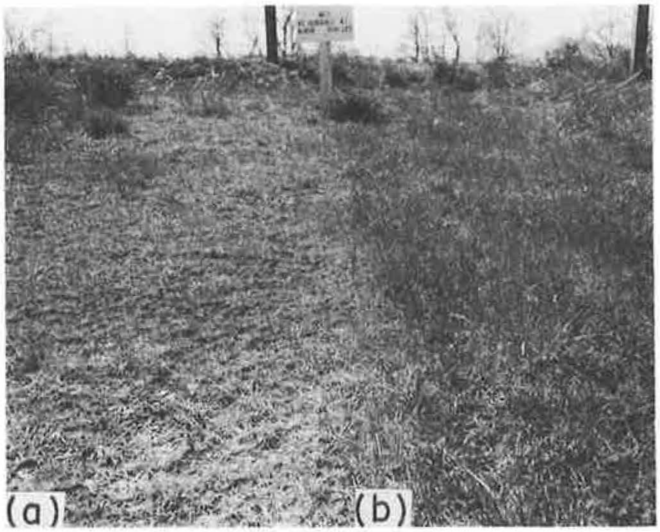

Figure 7. Two plots on a shallow slope on a limestone subsoil on US 11 near Dublin: (a) 10-10-10-fertilizer at 800 lb per acre was applied in 1954 and (b) one-half of this amount was applied again in spring 1957. Sod cover was very poor (a), where only the establishing fertilizer was applied.

TABLE 2

RELATIVE DRY MATTER YIELDS OF SEEDLINGS 14 DAYS AFTER EMERGENCE, GROWN ON A GNEISS AND SCHIST SUBSOIL

Lime (Lb/Acre)	Species			
	Ky. 31 fescue	Redtop	Lesp. sericea	Ladino clover
0	100	100	100	100
250	224	191	117	220
500	431	197	180	260
1,000	534	241	233	427
2,000	630	210	128	278
6,000	573	184	49	98

The relationship between lime, aluminum in the soil, and growth of 4 plant species is also shown in Figure 9. Note the linear decrease in exchangeable aluminum in the soil as rate of lime applications are increased to 1,000 lb. Soluble or exchangeable aluminum in the unlimed soil was about 13 times higher than for an application of 1,000 lb of lime. Lime applied at 2,000 lb per acre and mixed with the surface 2 inches of soil precipitated practically all of the exchangeable aluminum in the soil. The linear increase in growth of Ky. 31 fescue and clover up to the 1,000-lb rate of lime is coincident with the linear decrease in exchangeable aluminum. This relationship shows that soluble soil aluminum is primarily responsible for poor growth of Ky. 31 fescue and Ladino clover. The decrease in exchangeable aluminum, with increasing rates of lime, is attributed to calcium and pH increases in the soil which displaced and precipitated the aluminum.

Although exchangeable soil aluminum was reduced by lime, it is possible that the added calcium, per se, may also have improved the nutritional status for plant growth. Phosphorus availability is also influenced by lime and aluminum. Calcium and phosphorus absorption by plants were generally increased by lime applications. The low exchangeable aluminum in the limed soil, may also improve phosphorus availability and growth of plants.

The cations absorbed by the plants for three of the lime treatments are given in Table 3. Aluminum absorption was decreased as lime rates were increased for all species. These decreases in absorption with

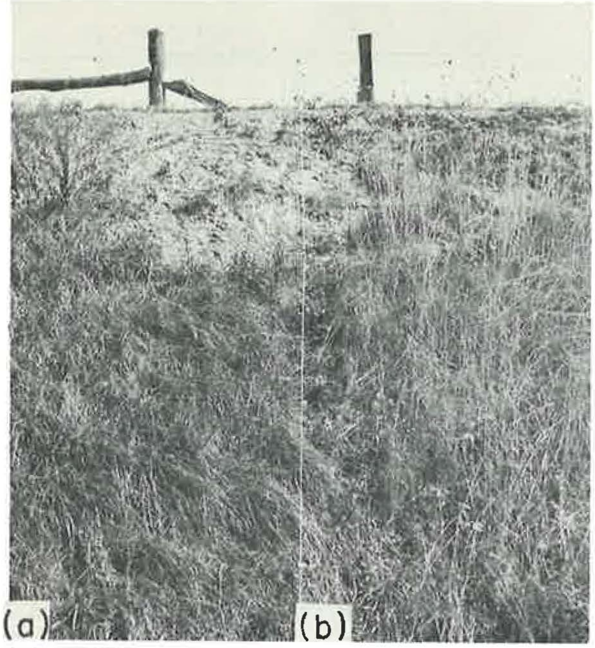

Figure 8. Refertilization should be based on sod cover. The area at top of the slope should be refertilized to stimulate growth and improve sod cover.

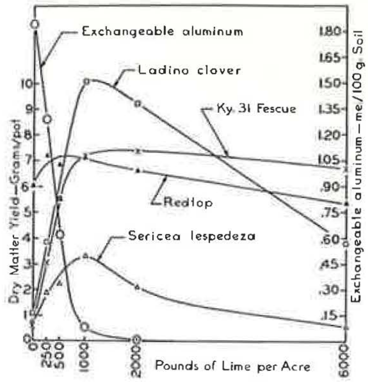

Figure 9. The influence of lime on exchangeable aluminum in soils and yields of four plant species.

added lime are associated with decreases in exchangeable soil aluminum (Fig. 9).

Redtop was much lower in aluminum content than the other three plant species; hence, this species may be tolerant to soluble aluminum because of its low absorption. The legumes absorbed more aluminum than the grasses. Because Lespedeza sericea gave lower responses to lime, it may be more tolerant of aluminum than other plants.

Kentucky 31 fescue and Ladino clover did not develop normal root systems in the unlimed soil high in exchangeable aluminum; the root systems of redtop and Lespedeza sericea in the unlimed soil appeared normal. The inhibited root development is one of the first symptoms of aluminum toxicity. The stunted plant growth without lime may be attributed to low calcium, phosphorus and other nutrient uptake because of the dwarfed root system. Liming soils high in aluminum would improve root growth and drought tolerance of species such as Ky. 31 fescue.

TABLE 3

MINERAL CATION ABSORPTION OF FOUR PLANT SPECIES AS INFLUENCED BY LIMING

Lime[a] (lb/acre)	Me. of Cations per 100 Grams of Plant Material				
	Aluminum	Calcium	Magnesium	Potassium	Total
		(a) Ky. 31 Fescue			
0	27.4	3.5	10.7	48.6	90.2
500	11.7	18.0	9.9	38.9	78.4
2,000	9.7	24.5	14.8	27.6	76.6
		(b) Redtop			
0	7.8	11.0	13.2	45.3	77.2
500	5.8	18.5	14.8	37.3	76.4
2,000	7.5	25.0	15.6	39.1	87.3
		(c) Ladino Clover			
0	46.3	9.0	13.2	53.2	121.7
500	25.7	41.0	17.3	40.7	124.6
2,000	15.4	66.0	15.6	28.9	125.9
		(d) Lespedeza Sericea			
0	41.2	4.0	11.5	31.5	88.2
500	30.6	22.5	10.7	37.6	101.4
2,000	15.4	66.0	15.6	28.9	125.9

[a] A 10-20-10 fertilizer at the rate of 1,000 lb per acre was used with all treatments.

Experiment B

The rate of seedling development and competition among seedling plants in a mixture is very important in establishing a sod of the desired species. Certain plant species are aggressive toward other species because of differences in emergence and subsequent rates of seedling growth (1, 2). The relative aggressiveness of species and the final sod composition can be altered by manipulating the lime and fertilizer treatments. Because plant species respond differently to lime, this experiment was designed to compare growth of 25 plant species with 3 rates of lime (none, 2,000, and 4,000 lb per acre). A 10-20-10 fertilizer at 1,000 lb per acre was used with all treatments. The lime and fertilizer were mixed with the top half of soil in 6-in. plastic pots. This red, friable clay loam subsoil from a cut-slope along US 58 near Turbeville was infertile as shown by the following chemical analyses: CaO, 20: K_2O, 25; and 5 lb per acre of P_2O_5 for the surface 6 inches of soil. The soil was very acid (pH 4.6) and contained 3.5 me. of exchangeable aluminum per 100 grams of soil. The magnesium content was high—440 lb of MgO per acre.

The soil analysis after applying lime and fertilizer is given in Table 4. Lime increased the pH, and available calcium and phosphorus; however, aluminum and potassium contents were decreased.

TABLE 4

EFFECT OF LIMING ON pH, EXCHANGEABLE ALUMINUM AND AVAILABLE CALCIUM, MAGNESIUM AND POTASSIUM IN THE SOIL[a]

Lime rate (lb/acre)	pH	Al (me./100 g)	Available Nutrients (lb/acre)			
			CaO	MgO	K_2O	P_2O_5
0	4.1	2.18	163	373	260	23
2,000	5.6	0.33	2,000	362	146	51
4,000	7.2	0.29	4,500	371	133	57

[a]All values are means of combined data for 25 plant species.

The seedling weights of grasses and legumes 14 days after emergence for three rates of lime are shown in Figures 10 and 11, respectively. The weight of the seedlings harvested at a later date is given in Table 5. Seedling growth in response to lime is also shown in Figures 12, 13, and 14.

The dry weights of four of the 17 grasses (Chewings fescue, redtop, Italian ryegrass, and rye) were not increased by lime (Table 5). Certain grasses such as bluegrass and Russian wildrye almost failed without lime. Lime caused a 3-fold increase in Ky. 31 fescue, a 64-fold increase in bluegrass, and a 3-fold increase in Penncross bent. Seedling plants of barley grown on a limed soil were 14 times heavier than for the unlimed soil. Yields of seedling plants of wheat and oats were almost doubled as a result of liming.

Lime increased the growth of all legumes except Lespedeza sericea, where lime was harmful. The true

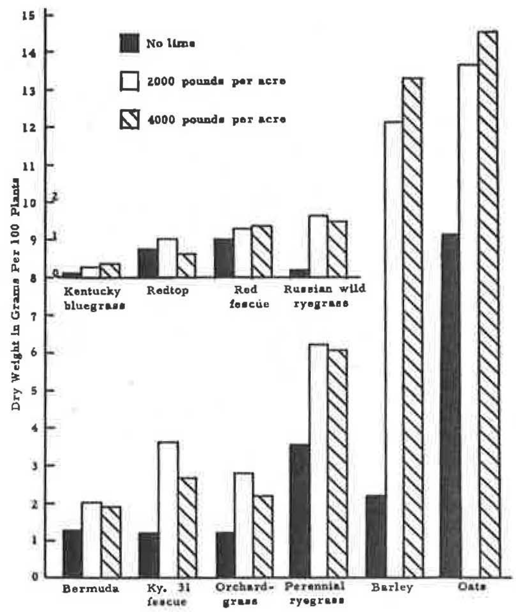

Figure 10. Seedling weights of ten grasses 14 days after emergence, with three rates of lime.

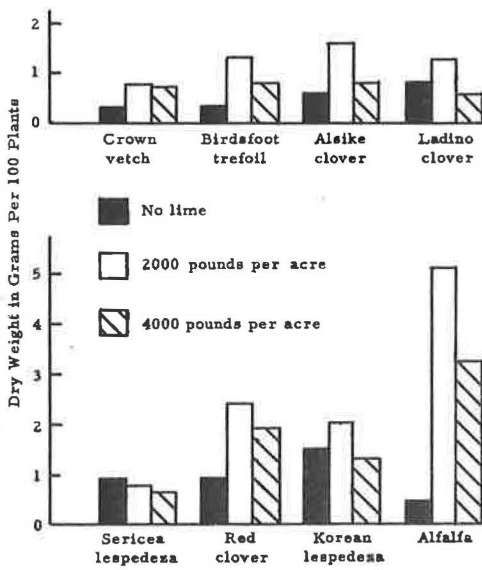

Figure 11. Seedling weights of eight legumes 14 days after emergence, with three rates of lime.

TABLE 5

DRY MATTER YIELD, IN GRAMS, PER POT OF LEGUMES AND GRASSES FOR THE FIRST CUTTING WITH THREE RATES OF LIME[a]

Plant Species	No lime	2,000 lb per acre	4,000 lb per acre
Chewings fescue	1.98	1.97	1.75
Red fescue	2.80	1.20[b]	2.87
Ky. 31 fescue	1.03	2.97[b]	3.28
Redtop	1.80	2.22	1.38
Penncross bent	0.66	1.85[c]	1.42
Bermuda grass	6.58	8.17[b]	5.95
Russian wild ryegrass	0.00	0.67[b]	1.63
Ky. bluegrass	0.03	1.92[b]	1.73
Wheatgrass	0.60	2.52[b]	2.28
Italian ryegrass	3.00	2.88	3.83
Perennial ryegrass	2.67	3.53[c]	4.30
Orchardgrass	2.88	4.17[b]	2.33
Bromegrass	0.55	4.40[b]	4.30
Oats	3.90	5.63[c]	5.30
Barley	0.33	4.70[b]	4.78
Rye	3.17	3.20	4.07
Wheat	2.48	5.77[b]	5.73
Alsike clover	0.14	1.20	0.37
Red clover	0.04	2.55[b]	1.00
Ladino clover	0.73	1.68[c]	0.12
Alfalfa	0.00	2.52[b]	2.68
Crown vetch	0.01	2.82[b]	1.53
Korean lespedeza	3.29	9.71[b]	2.02
Sericea lespedeza	4.58	3.45[b]	0.09
Birdsfoot trefoil	0.07	1.23[b]	0.07

[a]1,000 lb of a 10-10-10 fertilizer applied with all species.
[b]Shows where liming caused a statistically significant difference—1 percent level.
[c]Shows where liming caused a statistically significant difference—5 percent level.

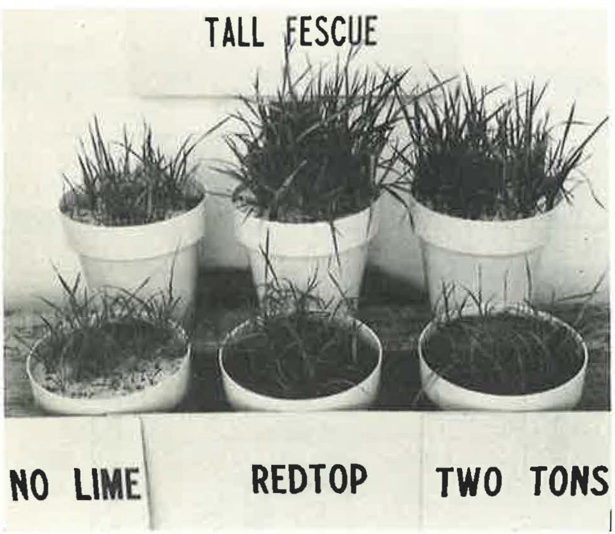

Figure 12. The response of Ky. 31 tall fescue (background) and redtop (foreground) to lime. Lime was applied at 0, 1, and 2 tons per acre, left to right, respectively. Note that redtop showed only a slight response to lime.

Figure 13. The response of six grasses to lime. The soil in the pots in the front row was not limed. Bluegrass, Ky. 31 tall fescue and barley seedlings responded to lime.

clovers—crown vetch, alfalfa, and birdsfoot trefoil—practically failed without liming the soil. Crown vetch produced 282 times more dry matter on the limed as compared with the unlimed soil. Korean lespedeza yields were tripled by using one ton of lime per acre (Table 5).

Yields of many species were lower for the 2-ton rate as compared with the one-ton rate of lime per acre. However, where species responded to lime, the growth was much better with the 2-ton rate of lime as compared with the unlimed soil (Figs. 10 and 11, and Table 5). The reduced growth with 2 tons of lime per acre may be attributed to fixation of trace elements which is associated with the high pH, 7.2. The overliming effects from a 2-ton rate would have been diminished with deep incorporation or by surface application. Other highway experiments in Virginia show that the effects from overliming disappear within a year.

The finely ground agricultural limestone, applied just before seeding, reacted with the soil rather quickly and increased seedling growth. This response of grass and legume seedlings to liming is attributed to reduced exchangeable soil aluminum and improved calcium and phosphorus nutrition as given in Table 4.

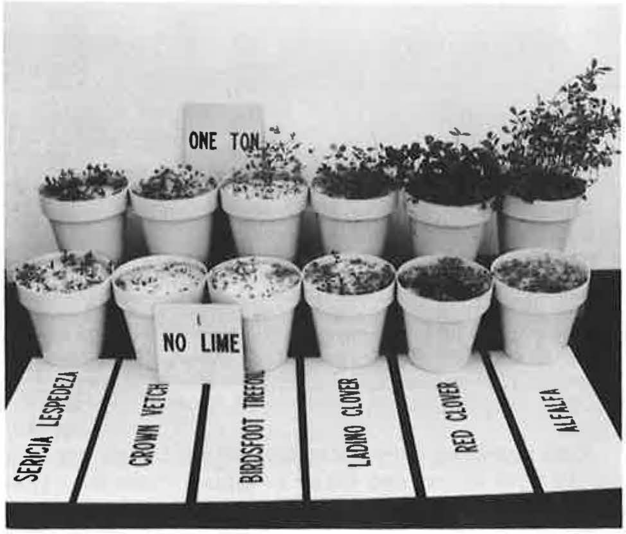

Figure 14. The soil in the six pots in the foreground was not limed. Crown vetch, alfalfa, birdsfoot trefoil, and the clovers made very poor growth without lime.

The comparative rate of seedling development with and without lime (Figs. 10 and 11) should be considered in compounding mixtures. Small grains and the ryegrasses have very aggressive seedlings which crowd out the slow growing seedling such as bluegrass. Bluegrass had the poorest seedling growth rate; hence, it is often difficult to establish this species on difficult soil environments. Light rates of companion grasses, such as ryegrass, should be used in seeding mixtures for quick sodding if species such as red fescue and bluegrass are used. It is not necessary to use companion grasses with Ky. 31 fescue as it has good seedling vigor. Ky. 31 fescue seedlings developed 11 times as fast as bluegrass and about 4 times as fast as red fescue. Crown vetch and Lespedeza sericea have very poor seedling vigor as compared with other perennial grasses and legumes.

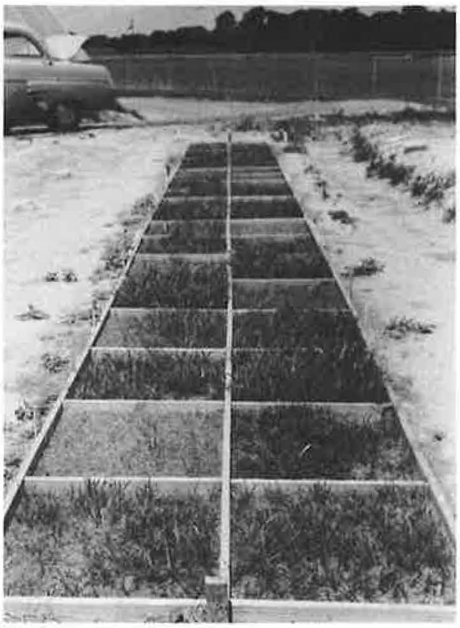

Figure 15. Experiment D.

Experiment C

A third experiment was established on a roadside cut on US 58 near Turbeville to study the growth rate of seedlings of a Ky. 31 fescue-redtop-Ladino white clover mixture as influenced by lime. The lime rates used ranged from none to 8,000 lb per acre as given in Table 6. Two methods of application were used: (a) surface broadcast, and (b) disked into the soil. However, because of the hardness of the soil and steepness of the slopes there was little difference due to the method of applying lime. The data for incorporated and surface applied lime are combined.

The experiment was established in September 1958, but seedling emergence and growth were delayed due to dry weather. The stand of Ladino clover was especially inferior and failed to become established on the drier areas of the slopes. Stands with a north slope face were better than for the slope with a southern exposure. Rate of lime at this date did not influence the degree of sod cover from seedlings; however, the color was greener on the limed plots. It was evident, by 1959, that liming improved growth and stands of plants. The sod cover was made up of 24 percent Ky. 31 fescue for the no-lime treatments as compared with 44 percent of Ky. 31 fescue where 500 lb or more of lime were applied per acre. The higher rates of lime were no better than the low rates.

TABLE 6

SEEDLING WEIGHTS OF KY. 31 FESCUE, LADINO CLOVER, AND REDTOP FROM A FESCUE-REDTOP-CLOVER MIXTURE WITH SIX RATES OF LIME

Lime (lb/acre)	Seedling Weights--Grams per 48 Plants		
	Ladino[a]	Fescue	Redtop
0	2.8	5.6a[b]	5.1[b]
500	6.2	7.1ab	3.3a
1,000	6.0	7.3ab	4.6a
2,000	8.4	8.1 b	3.5a
4,000	7.2	8.5 b	4.3a
8,000	14.0	9.4 b	3.7a

[a] Poor stands of clover prevented complete replication and statistical analysis of the data for clover.
[b] Values in a column not having the same letters differ significantly at 5 percent level.

The seedling weights of the plants in the seeding mixture show a decided increase for Ladino clover plants with increased rates of lime (Table 6). Likewise, there was a gradual and consistent increase in weight of the Ky. 31 fescue seedlings as more lime was applied. However, the size of redtop seedlings was not stimulated nor decreased by lime. These results clearly show that lime favors the stand and growth rate of Ky. 31 fescue seedlings as compared to redtop. It may be expected that redtop will often become dominant over Ky. 31 fescue in the absence of lime. It has been observed that redtop dominates over Ky. 31 fescue in many of the highway sod experiments and it is now apparent that this may be attributed to the high tolerance of redtop to soluble aluminum in the soil.

The results from pot experiments A and B showed that light applications of lime improved growth of many plant species whereas 4,000 to 6,000 lb of lime per acre depressed the growth. Lime applied at the rate of 8,000 lb per acre did not significantly reduce the growth of Ladino clover, Ky. 31 fescue, or redtop in this experiment.

Experiment D

This experiment, established on subsoil material as described in experiment B, was designed to study fertilizer and lime placement on seedling growth and botanical composition of a sod when seeded with a Ky. 31 fescue-redtop mixture. A 36-in. wide wooden frame 30 ft long by 8 in. deep having dividers to form 18- by 18-in. subsections (plots) was placed in a ditch about 6 in. deep (Fig. 15). Red subsoil from a highway slope was placed in a depth of 3 in. in each of the sections, leveled and tamped. An additional 3 in. of the red subsoil was placed on top of the packed soil. The fertilizer and/or lime applications were mixed

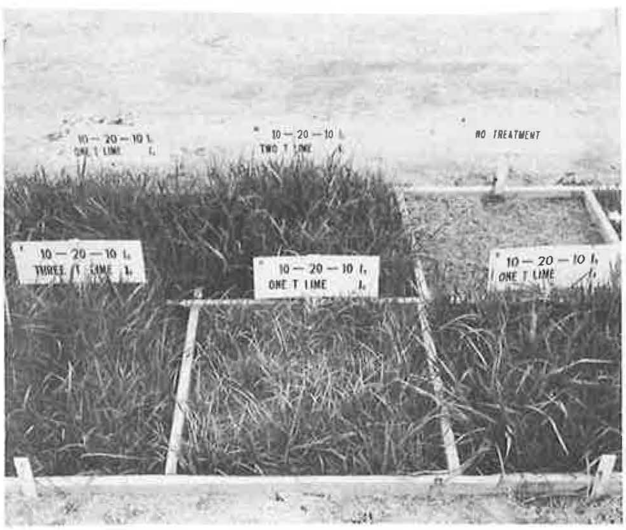

Figure 16. Growth without lime and fertilizer, right background, was nil. Incorporating lime, 1_3 with the surface 3 in. of soil, improved growth. Fertilizer placement was not as important as lime placement. The higher rates of lime were slightly better than the one-ton rate per acre. The mixture was Ky. 31 fescue and redtop.

Figure 17. Growth was poor with a 10-5-10 or a 10-10-10 fertilizer without lime. Stands and growth were better for a 10-20-10 than for a 10-10-10 fertilizer when each was applied at 1,000 lb per acre with lime.

with the top 3 in. of soil or applied on the surface to conform with the plan of the experiment. The plots were seeded at a rate equivalent to 3 lb of redtop and 30 lb of Ky. 31 fescue per acre. A light excelsior mulch was applied and the entire area was shaded with cheesecloth during germination and early seedling development, after which the cloth was removed.

Some of the data with ground limestone at one ton and a 10-20-10 fertilizer at ½ ton per acre on the surface or incorporated with the surface 3 in. of soil are given in Table 7, and Figures 16 and 17.

TABLE 7

LIME AND FERTILIZER PLACEMENT ON SEEDLING WEIGHTS AND YIELD OF A KY. FESCUE-REDTOP MIXTURE[a]

Placement Depth		Seedling Wt Per 75 Plants (grams)		Yield of	Fescue
Lime	Fertilizer	Fescue	Redtop	Mixture	(%)
Surface	Surface	7.3a[b]	3.7a[b]	61	30a[b]
3 in.	3 in.	15.7b	6.2b	82	45a
3 in.	Surface	11.4b	6.4b	83	31a
Surface	3 in.	5.8a	4.7a	54	14b

[a]Lime at 1 ton and a 10-20-10 at 1,000 lb per acre, Ky. 31 fescue, 30 lb and nitrogen 3 lb per acre.
[b]Values in a column not having the same letters differ significantly at 5 percent level.

Incorporating the lime about doubled the rate of Ky. 31 fescue and redtop seedling growth; fertilizer applied on the surface gave as good responses as mixing with 3 in. of soil (Table 7). The best yields of the sod mixture were also obtained where the lime was incorporated. The percent of ground cover made up of Ky. 31 fescue was generally higher when lime was incorporated as compared to surface applications. The best fescue growth, percentage fescue in the mixture, and weight ratio of fescue seedlings to redtop seedlings occurred when both fertilizer and lime were incorporated. Mixing the lime with soil apparently improves root growth of Ky. 31 fescue much more than for redtop.

In another phase of this experiment (Table 8), concentrated super-phosphate was applied at rates of 50, 100 and 200 lb of P_2O_5 per acre to soil treated with no lime and one ton of lime per acre. Nitrogen and potassium were applied with all treatments at the rate of 100 lb of N and K_2O per acre.

TABLE 8

EFFECT OF PHOSPHORUS AND LIME ON KY. 31 FESCUE AND REDTOP SEEDLINGS GROWN IN A MIXTURE[a]

Treatment (lb/acre)		Wt. for 75 Seedlings (grams)		Ky. 31 Fescue: Redtop Seedling Weight
Lime	P_2O_5	Ky. 31 Fescue	Redtop	Ratio
0	50	2.88	2.06	1.40
2,000	50	10.85	3.97	2.73
0	100	2.74	1.63	1.68
2,000	100	11.04	4.91	2.25
0	200	7.56	5.06	1.49
2,000	200	15.68	6.23	2.52
4,000	200	17.57	8.50	2.07
6,000	200	14.25	4.33	3.29

[a]The soil was a red, friable clay loam of a cut-slope on US 58 near Turbeville.

Lime stimulated Ky. 31 fescue seedling weights with all 3 rates of phosphate; 1 ton of lime per acre tripled the size of Ky. 31 fescue seedlings, when averaging all treatments. A comparison of 1, 2, and 3 tons of ground limestone with 200 lb of P_2O_5 shows that seedling weights were increased as lime was applied up to the 2-ton rate per acre; the 3-ton rate of lime caused slight decreases in seedling weights. When P_2O_5 was used without lime, the seedling weights for both fescue and redtop were higher with the 200-lb rate than with the 50-lb rate of P_2O_5.

A very important consideration in establishing sod on roadside cuts is the effect of lime and fertilization on the desired botanical components in the sod. The Ky. 31 fescue: redtop seedling weight ratio was increased by liming with all rates of phosphate fertilization. This occurred because Ky. 31 fescue seedlings responded more to lime than redtop seedlings. The data from this experiment point out that the stand, growth, and longevity of Ky. 31 fescue with a redtop mixture was improved by lime. Better results may be expected when lime is mixed with the soil as compared with surface applications.

Field Experiment at Amelia

An experiment on a cut-slope on US 360 near Amelia was established in March 1959. This steep red subsoil cut-slope with a northern exposure was more fertile than soils reported in the other experiments. The soil acidity before liming and fertilizing averaged about pH, 5.0. A 10-20-10 fertilizer at the rate of 1,000 lb per acre was applied uniformly with and without ground agricultural limestone applied at the rate of 1 ton per acre. Lime at 1 ton per acre and fertilizer at 500 lb per acre was again applied in September 1959. The seeding mixtures, Ky. 31 fescue at two rates with several rates of redtop, were studied with each of the fertilizer and lime combinations given in Table 9.

TABLE 9

TOTAL SOD COVER AND KY. 31 FESCUE AND REDTOP STANDS FOR SEED MIXTURES WITH AND WITHOUT LIME, US 360 NEAR AMELIA, APRIL 1960[a]

Seeds (lb/acre)		Sod Cover, Fescue, and Redtop Stand, 1960					
		Lime Applied			No Lime		
Ky. 31 Fescue	Redtop	Total (%)	Ky. 31 Fescue (%)	Redtop (%)	Total (%)	Ky. 31 Fescue (%)	Redtop (%)
45	0	68	68	0	58	58	0
45	5	80	50	30	59	18	41
60	0	79	79	0	60	60	0
60	5	72	56	17	63	14	49
60	10	68	41	27	73	9	64
Average without redtop		74	74	0	59	59	0
Average with redtop		73	49	24	65	14	51
120	0	79	79	0	45	45	0
0	5	45	0	45	55	0	55

[a]Established on a red Cecil subsoil slope in March of 1959—lime: one ton per acre in March and September 1959; fertilizer: 1,000 lb of a 10-20-10 per acre in March and September 1959.

This steep 1:1 cut-slope was so erosive that it was necessary to first apply an asphalted straw mulch to keep friable areas of the soil and the seed and fertilizer materials from eroding. In spite of the adverse conditions and a torrential rain after the experiment was established, good sod cover was obtained during the first season (Fig. 18).

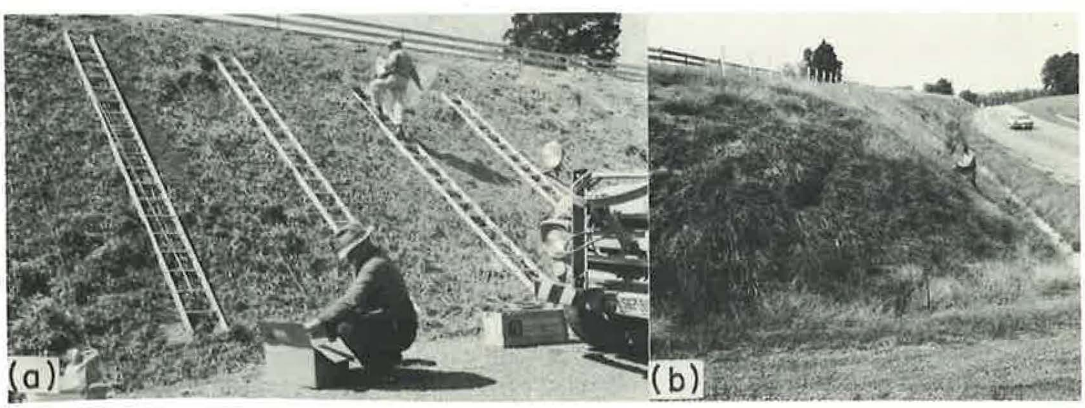

Figure 18. A steep 1:1 cut-slope along US 360 near Amelia showing (a) seeding over asphalted straw mulch to protect erosion, and (b) growth of sod cover during following summer.

Data when using redtop with Ky. 31 fescue in a mixture are shown in Figure 19. When Ky. 31 fescue was seeded at the rate of 60 lb per acre, the use of 5 and 10 lb of redtop per acre reduced the fescue stand and growth. Redtop reduced the fescue sod cover from 79 to 41 percent when limed. The use of 10 lb per acre of redtop with 60 lb of Ky. 31 fescue on the unlimed plots reduced the stand of fescue from 60 percent sod cover to 9 percent sod cover. Ky. 31 fescue seeded at the rate of 45 lb per acre produced a 68 percent ground cover on the limed plots as compared with 58 percent ground cover on the unlimed plots (Table 9). A mixture of 45 lb of Ky. 31 fescue and 5 lb of redtop gave an 80 percent ground cover on the plots as compared with 59 percent on the unlimed plots. Fescue in the redtop mixture made up 50 percent of the ground cover on the limed plots, but only 18 percent of the ground cover on the unlimed plots. Increasing the seeding rate of Ky. 31 fescue to 120 lb per acre did not improve sod cover as compared with the lighter rates of fescue. Redtop is aggressive; a seeding rate of 5 lb produced a good sod cover.

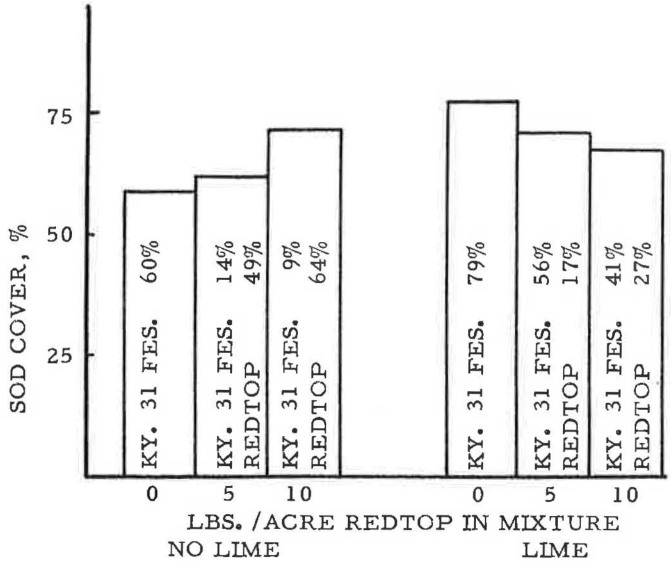

Figure 19. Ky. 31 fescue was seeded at the rate of 60 lb per acre. Redtop reduced the stand of fescue; without lime redtop was very aggressive. Redtop tended to reduce sod cover when limed and to improve sod cover without lime.

The use of redtop in mixtures may be questioned because of its aggressiveness. Its use is justified by the Virginia landscape engineers because, if all other plant species fail, redtop often survives. Survival of redtop may often be associated with adverse chemical properties of soils such as high soluble aluminum, low available calcium, and perhaps low fertility. This grass makes better root and top growth than many other species under such adverse environments. It appears that redtop would not be aggressive toward Ky. 31 fescue, when lime is applied.

RECOMMENDATIONS FOR ORIGINAL SEEDINGS

The specifications for original seedings by the landscape engineers of the Virginia Department of Highways are given in Table 10. Lime is recommended at 2 tons with 1,500 lb of a 10-20-10 fertilizer

TABLE 10

LIME, FERTILIZER, AND SEEDING MIXTURES FOR ORIGINAL SEEDINGS ALONG VIRGINIA HIGHWAYS[a]

Species	Pounds per Acre	Seeding Date
Ky. 31 fescue	76	Spring
Redtop grass	1.5	or
White dutch clover	2.5	Fall
	80	
Hulled Bermuda	40	Spring
Ky. 31 fescue	15	
Redtop grass	1	
White dutch clover	4	
	60	
Unhulled Bermuda	20	Fall
Ky. 31 fescue	55	
Redtop grass	1	
White dutch clover	4	
	80	
Ky. bluegrass	40	Spring
Creeping red fescue	15	or
Redtop grass	2	Fall
White dutch clover	3	
	60	

[a]Fertilizer applied at rate of 1,500 lb of 10-20-10 or its equivalent per acre. Two tons agricultural ground limestone applied per acre.

per acre. Rate of sowing redtop ranges from 1 to 2 lb per acre for the mixture. The low rate of seeding redtop with adequate lime should prevent this species from dominating the sod. Companion grasses are excluded because the unthreshed seed in straw serves as a companion grass, if needed.

SUMMARY AND CONCLUSIONS

An experiment on steep 1:1 sloping cuts without top soil along US 58 in southern Piedmont Virginia was established in March 1957. A sod cover of 54 percent within three months was obtained with 1,000 lb of a 10-20-10 fertilizer applied at seeding. The sod cover was made up primarily of Kentucky 31 fescue and redtop. Red clover, white clover and Bermuda grass failed to produce stands and Lespedeza sericea started contributing to the sod cover during the second year. Although the experiment was established in March 1957 with 1,000 lb of a 10-20-10 fertilizer, an additional application at one-half the original rate in November of the same year, improved the sod cover during the fall season and gave an excellent cover during the winter season and the next year to control erosion. The sod cover without maintenance fertilization degenerated to an 18 percent cover during the third year as compared with a 60 percent cover when an application of 500 lb of a 10-20-10 fertilizer was made in September 1957 and 1958. The results show that it is imperative to apply maintenance fertilizer treatments for sod maintenance. The amount and frequency of applying fertilizer depends on the growth and appearance of the grass as interrelated to the soil conditions. Redtop dominated in the sod during the first two years with low fertility rates in the absence of lime. Lime improved the stand and sod cover of Kentucky 31 fescue. This was especially evident during the third and fourth growing seasons. Although Lespedeza sericea was seeded in March 1957 at the rate of 20 lb per acre, it did not contribute but a 16 percent sod cover in 1960. Maintenance fertilizer applications did not aid the growth of Lespedeza sericea.

The red subsoil material from this experiment was used for a greenhouse pot experiment to study growth as related to liming. There were large increases in weight of seedlings of Kentucky 31 fescue and Ladino clover as the rates of applying lime were increased; Lespedeza sericea and redtop seedlings were not increased by liming. Redtop produced almost 10 times as much growth as Kentucky 31 fescue on unlimed soils, but when 2,000 lb per acre of lime were added, Kentucky 31 fescue produced more growth than redtop. The unlimed soil contained about 13 times more aluminum than the limed soil, the differential species response may be attributed to susceptibility of Kentucky 31 fescue and Ladino clover to aluminum toxicity but also to the low calcium level in the unlimed soil. Kentucky 31 fescue and clover failed to develop normal root systems in the unlimed, high aluminum soil, but redtop and Lespedeza sericea grew normally without lime. The aluminum absorbed by the seedling plants was decreased for all species as lime was added. Calcium also improved the calcium uptake.

A second pot experiment was set up to test the growth of 25 plant species with three rates of lime (0, 2,000, and 4,000 lb per acre). The growth of all legumes, except Lespedeza, was increased with lime. Growth of plants with lime at 2 tons per acre was lower than for the one-ton rate. Only four grasses (Chewings fescue, redtop, Italian ryegrass and rye) of 17 grasses tested did not respond to lime. A three-fold yield increase was obtained on limed soil with Kentucky 31 fescue and there was a 64-fold increase due to liming with Kentucky bluegrass.

Another experiment along US 58 was designed to study the influence of rates of lime on the botanical compostion of a Ky. 31 fescue-redtop-Ladino clover mixture on a sloping cut. When 500 lb or more of lime were applied, the sod cover consisted of 44 percent fescue; on the unlimed slope, Ky. 31 fescue sod cover was 24 percent. Seedling weights of both Ky. 31 fescue and Ladino clover increased with added amounts of lime, but lime had no effect on the weight of redtop seedlings. These results under field conditions are in agreement with conclusions from the greenhouse pot experiment previously mentioned.

An experiment was conducted in 18- by 18-in. plots to study the influence of fertilizer and lime placement on seedling growth and botanical compostion of a Ky. 31 fescue-redtop mixture. The best growth of Ky. 31 fescue was obtained when lime and fertilizer were incorporated into the soil. It was especially desirable to incorporate lime.

A mixture-fertility experiment was established on a steep sloping cut without topsoil along US 360 near Amelia in 1959. Forty-five pounds of Ky. 31 fescue per acre produced a ground cover of 68 percent on limed soil and 58 percent on unlimed soil. An addition of 5 lb of redtop per acre added with the fescue increased ground cover to 80 percent on the limed soil, but showed no difference on the unlimed soil when compared with fescue alone. Increasing the amount of redtop to 10 lb per acre reduced the total ground cover when added to 60 lb of Ky. 31 fescue per acre. Redtop is very aggressive toward other species and for that reason its use in mixtures should be restricted to low rates as shown in recommendations by the landscape engineers of the Virginia Department of Highways.

ACKNOWLEDGMENTS

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Discussion

Simonson:—Did you say that lime should be mixed into the soil, rather than just applied to the surface?

Blaser:—Our and other experiments show that it is better to incorporate the lime than to apply it on the surface. If mechanized equipment can be used, the lime should be incorporated with the surface 3 to 5 in. of soil. Although lime is not used as efficiently when applied on the surface, it is much better to apply lime than to omit it on acid soils. On certain very steep slopes or cuts, it is not possible to incorporate the lime, hence, it is applied on the surface.

Hottenstein:—You said that fertilizer and lime are put on together. Don't you lose the nitrogen that way?

Blaser:—Many fertilizer companies use dolomitic limestone as a filler in mixed fertilizers. Ordinary ground agricultural limestone does not generally cause nitrogen losses. Nitrogen losses with hydrated lime would be high with certain sources of nitrogen fertilizer.

Slack:—What are the soluble fertilizers?

Blaser:—This is a very difficult question and would take much time for answering. Fertilizers that are soluble in water may or may not remain soluble when they are applied to the soil. A portion of the phosphate fertilizer is water soluble, but when applied to the soil, it becomes insoluble and does not move to the lower levels of soil. Other fertilizer materials, especially some sources of nitrogen and potassium are soluble in water, and they may leach with the water through the soil.

Slack:—What is proper pH for fescue?

Blaser:—The proper pH range for Kentucky 31 fescue is 5.8 to 6.8.

Brant:—Lime is always in suspension when applied, isn't it?

Blaser:—Ordinary ground agricultural limestone, when applied with water in a hydroseeder, is in suspension because its solubility is very low.

DeMont:—Is most of the growth improvement as a result of liming and fertilization in the root or the tops of a grass?

Blaser:—It is now known that lime and fertilizers improve the root as well as the top growth. Heavy nitrogen fertilizer increases top growth more than root growth.