MULCH EVALUATION AND MANAGING VEGETATION IN MEDIANS

by

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ABSTRACT

Experiments show best erosion control and vegetation with straw mulch, all wood or paperfiber mulches being suitable tacking agents at rates of 750 lb/A. When used alone, standard woodfiber generally gave better vegetative cover than paperfiber; however, all fiber mulches are acceptable when applied at 1500 or 2500 lb/A.

Sparse grass stands in medians were improved before and after one spring mowing when applying readily available N at 50 or 100 lb/A; during late winter, responses from urea formaldehyde (slow release nitrogen) were nil. Grass canopies along mowed areas often become thin and weedy because of low soil fertility; such grass canopies may be improved by N fertilization or permanently by seeding persistent perennial legumes, crownvetch (Coronilla varia), flatpea (Lathyrus sylvestris) and/or sweetpea (Lathyrus latifolius). Legumes may be successfully established when broadcast seeded in late winter-early spring into existing sod with a loose, roughened soil surface or by no-till sod seeding when legumes are placed in the soil. In dense grass sods, herbicides banded over the rows usually improve stands and growth of legumes.

With dense stands of temperate grasses, as tall fescue, it is practical to mow once during the season when delaying the first mowing until about 50% of the seedheads emerge. Sparse grass canopies with weedy annual and perennial species need to be mowed a second or third time to maintain a "groomed" appearance. Principles of mowing temperate grasses and grass-legume mixtures are given.

Sampling soil in areas in need of renovation is strongly recommended to ascertain the lime, phosphorus and potassium needs. Sampling studies show large variations in the mineral nutrient status among and within cut and fill slopes and medians. Soil analyses reduce renovation costs by applying only needed fertilizers.

Four legumes, crownvetch, flatpea, sweetpea, and sericea lespedeza, are persistent perennials for cut and fill slopes in the Piedmont, Coastal Plain and Mountainous regions of Virginia when not mowed. These legumes persist indefinitely after applying lime, phosphorus and potassium liberally for establishment.

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I. INTRODUCTION AND RESEARCH APPROACH

The project proposal with four primary research objectives was accepted but some members of the Review Committee objected to the broadness of the research to be undertaken. The project proposal was initially written as a three year proposal. However, because of a shortage of funds and an anticipated change in personnel, the proposal was funded for only one year. Thus, the Review Panel accepted the proposal with the understanding that all of the research objectives could not be fulfilled unless funds would be made available to extend the project for two additional years.

Research on the evaluation of various paper mulch materials for their suitability to establish vegetation and to control erosion were investigated under favorable and stress conditions in highway corridors in different physiographic regions. Laboratory studies to evaluate mulches were also undertaken. Purchasing procedures and locating paper mulch materials by highway personnel caused delays allowing less than nine months for the research investigations. Locating suitably uniform freshly graded cut slopes made by highway personnel or construction contracts for mulch evaluation experiments in highway corridors was a deterrant. It was difficult to find suitable cut slopes because of limited work on highway construction. To minimize variance for evaluating mulches, it is necessary to use rather uniform slope environments (soil, slope degree and aspect, moisture and other environmental conditions). Ideally, the environment on a slope for a given plot before establishing each mulch should be identical so that germination, seedling growth, canopy cover and degree of erosion are unquestionably associated with the properties of the various mulch materials. Variable slope environments among mulch materials even with the mulch materials replicated, confounds and makes it difficult to interpret and apply the results.

Experiments in medians to improve sparse vegetation include the following three categories: 1) nitrogen and other fertilizers to stimulate tillering to improve grass densities, 2) fertilization and reseeding in medians where grass stands are not sufficiently good to develop dense canopies by fertilization and 3) introducing perennial legumes that persist without mowing or with one or two annual mowings. Because of the short duration of the project and very wet late winter-spring season during 1980, only a few experiments to renovate grassy vegetation could be established. However, many experiments for introducing legumes into medians were established in the various physiographic regions of Virginia.

Experiments with persistent perennial legumes were designed to investigate methods of establishment, competition with associate companion species, seasons of seeding, mowing management and fertility and lime requirements. Also, some experiments for objective D (legumes in medians) were established at the close of the previous project (Adams and Blaser, 1979). Results during 1980 for these experiments are included in this report, but detailed diagrams were omitted.

In biological research arenas, several stages of plant succession occur before a reasonably stable and persistent vegetation as persistent legumes develop. Plant succession occurs because of differential responses of plants to interplaying climatic, soil and biotic factors. Thus, data and observations from old experiments allied to the research objectives are included to augment and reinforce the findings on legume adaptation and culture for various physiographic regions of Virginia.

The June 1980 data on the performance of legumes on cut and fill slopes were obtained while collecting data from the specific objectives of the research proposal; hence, costs for obtaining the additional data were low. It seemed desirable to include a history and pertinent summaries on developing vegetation for many of the old experiments. The collecting, summarizing and interpreting a broad array of information should increase data for implementation to improve specifications and results for establishing and maintaining persistent vegetation to abate pollution from soil materials and provide desirable aesthetic values for highway travelers. Diagrams and treatment details of old experiments already reported for past projects (Woodruff and Blaser 1969; Green et al., 1973; Wright et al., 1976; and Adams and Blaser, 1979) are excluded.

Because degenerating of vegetation is associated with soil fertility and acidity, soil sampling for diagnosing lime and fertilizer needs was conducted for sections on several interstate highways. The soil analyses point out that costs of renovating vegetation in medians can be reduced by applying lime and mineral nutrients only when soils are deficient in any mineral nutrient or lime.

Mowing specifications have been established by personnel of the Virginia Department of Highways and Transportation in cooperation with personnel of the Agronomy Department at Virginia Polytechnic Institute and State University. Thus, recommendations are based on observations of mowing management along highways by highway personnel and from data from several mowing experiments. Based on the principles that cool season grasses form seedheads only once yearly during the mid-spring season and maintaining dense canopies to exclude weeds by competition, a "groomed" appearance can be maintained by mowing once or twice during the growing season.

The data in tables are mean values of two to four replications that improve the validity of the results. Where differences are small, statistical analyses would not likely show significant differences because of variance in slope environments; also, where differences among treatments are large, mean differences among replicated treatments are obviously significant.

II. EXPERIMENTS WITH RESULTS

A. The Value of Paper and Woodfiber Mulches

The primary objective was to obtain information on the suitability of various wood and paperfiber mulches for establishing vegetation and controlling erosion in view of approving or rejecting such mulches for contract seedings. The mulches were compared with Conwed, a standard woodfiber that has been used for many years. The mulch materials that were evaluated may be placed in the following categories: paperfiber - Cellin, Turfiber and Spittles; delignified woodfiber - Original; and a combination of wood and paperfiber - Fib-R-Green. Four experiments were initiated under varying climatic conditions encountered during autumn, winter, spring, and late spring.

1. Experiments along highways

a. Mulch evaluation during autumn

This mulch experiment on Route 764 in Carroll County near Dugspur was established on October 5, 1979, during a period when moisture and temperature conditions are usually favorable for establishing vegetation. The mulches were applied at 1500 and 2500 lbs/A on a 45 degree cut slope with a southern exposure. The soil material was an erosive micaceous material derived from underlying mica-schist parent material. The entire area was uniformly seeded (Kentucky 31 tall fescue @ 60 and Penngift crownvetch @ 20, Crimson clover @ 5 and annual ryegrass @ 5 lbs/A), limed @ 2 T/A and fertilized with a 10-15-10 fertilizer at 650 lbs/A. The diagram showing treatments is given in Figure 1. Data were collected on erosion control, vegetation establishment and mulch surface characteristics.

Data in Table 1 are mean values of three replications. The cut slope prepared by highway personnel was not satisfactory for an experiment nor for making a seeding to establish a protective vegetative cover. The steep slope about 1.5:1 or steeper had been tracked with a dozer with tracks paralleling the cut slope. Such tracking along with the compaction inhibits water infiltration causing downward movement of water and soil which deters the establishment and maintenance of a vegetative cover. However, the slope was used for the experiment because another site was not available. The frequent mild rains and cool temperatures were condusive to seedling establishment of grasses. The responses to erosion control and seedling establishment were similar for the various mulch materials. About 40 days after seeding there was a 50% vegetative cover with Conwed applied at 1500 lb/A, the cover for the other mulch materials being similar. By January 28, 115 days after seeding and applying the mulch materials, the vegetative covers for the various mulch materials were similar ranging from 30 to 41% cover. Increasing the rate of application from 1500 to 2500 lb/A did not improve the vegetative cover significantly.

By late spring, 1980, the vegetative covers degenerated. There was severe sheet and gully erosion, irrespective of the initial mulch material. This cut slope was vulnerable to erosion because of the faulty grading and tracking by highway personnel in preparing this freshly graded cut for seeding. Stairstep grading or roughened loose surfaces as stated in the specifications were ignored. Including cereal rye and a companion species to obtain large plants would likely have deterred erosion.

The soil cover with mulch materials ranged from 70 to 80% on November 15 and declined to values ranging from 27 to 43% by January 28 (Table 1). The variations among mulch materials were not large enough to differ significantly. Applying mulches at 2500 vs 1500 lbs/A did not improve soil protection appreciably. Unfortunately, a check (no mulch)

Figure 1.

Carroll County - Route 764
Mulch Evaluation Experiment

Seeded and mulched October 5, 1979

Wind →

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I	D	J	E	A	C	G	B	F	H	G	I	C	E	H	D	B	F	J	A	C	E	I	A	D	G	J	B	H	F	I

← Route 753 | Plot Size 8′ x 20′ | Route 221 →

A - Conwed @ 1500
B - Conwed @ 2500
C - Fib-R-Green @ 1500
D - Fib-R-Green @ 2500
E - Original @ 1500
F - Original @ 2500
G - Turfiber @ 1500
H - Turfiber @ 2500
I - Cellin @ 1500
J - Cellin @ 2500

Notes:

Wind caused overspray on 1/8-1/4 of plots. Plot 17-B overspray covered 1/2 the plot.

2500# rate - globbed and splashed once the ground was saturated.

Conwed + Original mulches applied easily for a nice uniform coating. Original was packaged nicely for easy loading.

Seeded over entire experiment:

Ky-31 @ 60 lbs/A
Crownvetch @ 20 lbs/A
Annual ryegrass @ 5 lbs/A
Crimson clover @ 5 lbs/A
Lime @ 2 tons/A
Fertilizer 10-15-10 @ 650 lbs/A

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Table 1. Vegetation establishment and soil protection values for a fall season mulch experiment, Route 764, Carroll County, VA.

	Mulch materials and rates per acre, lbs.									
	Conwed		Fib-R-Green		Original		Turfiber		Cellin	
Date	1500	2500	1500	2500	1500	2500	1500	2500	1500	2500
	Vegetative cover, %									
Nov 15	20	25	25	20	24	26	25	26	19	24
Jan 28	33	33	37	35	37	30	32	32	41	38
	Soil cover with mulch materials, %									
Nov 15	72	75	72	80	76	74	72	73	74	72
Jan 28	33	47	27	43	42	40	43	45	33	43

Values are means of three replications.

treatment could not be included because of inadequate slope space.

b. Mulch evaluation during the winter season

This experiment along Prices Fork Road, Blacksburg, was established on December 21, 1979, to investigate the value of mulches during the unfavorable season for erosion control and establishing a vegetative cover. The paper and woodfiber mulch materials were each applied alone at 2000 lbs/A and at 750 lbs/A as tacking agents for straw. A mixture of cereal rye at 60, creeping red fescue at 40, Kentucky 31 tall fescue at 40, and flatpea at 20 lbs/A was uniformly applied to all plots in the experiment, along with finely ground agricultural lime at 1 T/A and a 15-30-15 fertilizer at 650 lbs/A. All treatments were applied with a 600 gallon Bowie hydroseeder.

The 4:1 cut slope with a westerly exposure had a rather smooth and hard soil surface. The subsoil material was from a limestone formation. Figure 2 shows the plot diagram of all mulch treatments in the experiment.

Data were collected for erosion control during the winter. The mulches endured rain, snow and ice storms with little erosion occurring during the winter months. April rains and rising temperatures stimulated seed germination and growth of the grass and legume species. Vegetative cover estimates were recorded and tabulated in Table 2 along with erosion control data. There was considerable variance from plot to plot making it impossible to measure small differences due to mulch treatments. Uncontrolled water from the slope apex flowed over certain plots which added to the variance to nullify small differences among mulch materials.

Because of the variance among plots on this slope environment, the mean differences among the wood and paperfiber did not differ significantly. However, the vegetation cover and soil protection was better with straw than for wood or paperfiber alone. Water flowing over the apex of the slope

Figure 2.

Title: Mulch evaluation experiment, winter season, Prices Fork Road, Blacksburg, Virginia
Established: December 21, 1979
Site Description: The experimental site is located on Prices Fork Road in Blacksburg, Virginia where VPI commuter parking lot entrance is. The site is a 60° north facing cut slope exposing B horizon orange-red clay. The pH is 6.0; P - medium; K - medium; Ca - medium; Mg - medium.
Plot Size: 10' x 30'

← To Main Street — To 460 Bypass →

Rep I													Rep II										Rep III									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
FRG	✓	TF	✓	O	CW	C	✓	C	FRG	TF	CW	O	O	C	TF	FRG	CW	C	TF	CW	O	FRG	CW	FRG	TF	O	C	CW	C	TF	FRG	O
20		20		20	20	20		S	S	S	S	S	S	S	S	S	S	20	20	20	20	20	20	20	20	20	20	S	S	S	S	S

S ↑, E ←, → W, ↓ N

Treatments:

TF = Turfiber, a newsprint paper fiber mulch
FRG = Fib-R-Green, a mixture of woodfiber and newsprint paper fiber mulch
O = Original, a woodfiber mulch
CW = Conwed, a woodfiber mulch
C = Cellin, a newsprint paper fiber mulch
✓ = No mulch
S = 4000 lbs/A of straw + 750 lbs/A mulch
20 = 2000 lbs/A of mulch

The entire experiment was uniformly seeded, fertilized and limes with the following: lime @ 2000 lbs/A, 15-30-15 fertilizer @ 650 lbs/A, cereal rye @ 60 lbs/A, creeping red fescue @ 40 lbs/A, and Kentucky 31 fescue @ 40 lbs/A and flatpea @ 20 lbs/A.

Table 2. Vegetation establishment and soil protection values for a winter season mulch experiment, Prices Fork Road, near Blacksburg.

Parameters	Mulch materials, lb/A										
	Cellin		Original		Turfiber		Fib-R-Green		Conwed		No Mulch
	2000	Straw[1]	2000	Straw	2000	Straw	2000	Straw	2000	Straw	
January 15											
% mulch cover	91	95	91	93	88	95	90	95	92	95	0
% soil exposed	8	5	8	6	12	5	10	5	8	5	100
April 14											
% mulch cover	47	40	33	42	51	40	53	40	37	42	0
% soil exposed	33	0	52	0	28	0	37	0	50	0	95
% vegetative cover	20	60	15	58	21	60	10	60	13	58	5
April 21											
% mulch cover	55	15	44	20	48	10	53	10	59	15	35
% soil exposed	17	2	28	0	17	2	20	0	18	2	53
% vegetative cover	28	83	28	80	35	88	17	90	23	83	12
April 30											
% vegetative cover	42	83	37	60	45	82	30	80	23	75	43

[1] Straw at 3000 lb was tacked with 750 lb/A of paper or woodfiber.

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inhibited vegetative cover for some plots.

c. Mulch experiment during the early spring season

This experiment on Route 610 near Forks of Buffalo was established during mid-spring on April 17, 1980, usually a favorable season for establishing vegetation. The 1:1 slope with an east-facing aspect was of variable sandy-clay subsoil material that is very unfavorable for establishing seedlings. High temperatures from absorbing radiant energy on such red colored subsoils cause high evaporation and water stress. Also, the high expansion and contraction with changes in temperature and moisture lift seedlings to sever root contact with moist firm soil; hence, slow developing seedlings or death. Soil analyses before liming and fertilization showed phosphorus to be low, calcium and potassium as moderate and magnesium to be high in availability in the soil.

The woodfiber mulches were applied alone at 2500 and 1500 lbs/A and at 750 lbs/A as a straw tacking agent. The following mulches were applied with a hydromulcher: Conwed 2000, Cellin, Turfiber, Original, Fib-R-Green and Spittle. All treatments were replicated four times as shown in Figure 3. The area was uniformly seeded with a mixture of creeping red fescue at 30, Kentucky 31 tall fescue at 30, annual ryegrass at 5, flatpea at 25, sweetpea at 10 and crownvetch at 20 lbs/A. A 15-30-15 fertilizer at 650 lbs/A and hydrated lime at 1 T/A were applied evenly with a hydromulcher over all treatments.

The weather following the establishment of this experiment was very dry. The first rain occurred two weeks after establishment with less than an inch of rain during the first month and a critically low rainfall through June which prevented successful seedling development and the growing of a protective vegetative cover. Data were collected on erosion control, seedling stands, vegetative vigor and water infiltration rates.

Assessment of the mulch treatments is illustrated in Table 3. Estimates of surface crust penetration, vegetative cover, erosion and water absorption are given. Surface crust penetration was measured by estimating differential forces needed to penetrate the crusty dry mulch surface. The force required to break the mulch crusts was evaluated by pressure from one finger and also from a pointed tool. Six measurements were made per plot treatment. The forces to penetrate the mulches were scaled from 1 to 5; the latter requiring the least force to break the mulch crust. Results ranking each mulch used with straw and alone are as follows:

1. 750 lbs/A for tacking straw - Spittle > Cellin > Fib-R-Green > Turfiber > Original > Conwed.
2. 1500 lbs/A of wood or fiber mulch alone - Spittle > Fib-R-Green > Cellin = Original = Turfiber > Conwed.
3. 2500 lbs/A of fiber mulch materials - Spittle > Fib-R-Green = Turfiber > Cellin > Original > Conwed.

The best vegetative cover occurred with the straw-fiber combinations ranging from 38 to 48% cover 36 days after seeding and 58 to 74% cover 13 days later. The tacking agents did not cause different responses.

The highest values in vegetative cover for wood and paperfiber mulches ranged from around 1 to 15%, being inferior to the straw-fiber combinations. With the wood and paperfiber materials, seed germination and seedling growth were much slower than for straw mulch. However, the data are confounded as much of the rapid germination and vegetative cover in straw plots is attributed to the rapid germination and seedling growth of rye seeds in the straw. The large fast developing rye seedlings tended to form a protective canopy. Rye seedlings established and maintained root contact with the subsoil which reduced surface soil expansion to improve moisture availability of seedlings. However, straw mulch per se moderates temperatures which reduce water loss more than for woodfiber (Barkley et al., 1965).

Because the wood and paperfiber materials generally developed poor vegetative covers (less than 15% soil cover) the replicated plots were ranked from a scale of 1 to 10, the latter having the lowest vegetative cover. The rating of 6.2 and 4.0 for Conwed woodfiber applied at 1500 and 2500 lbs/A, respectively, were generally better than for the other mulch materials. However, the soil cover was low for all wood and paperfiber mulches as compared to straw. The soil cover from small seedlings was less than 1% on May 1 and ranged from 1.3 to 7% soil cover on May 23 among the paper and woodfiber mulches. These values were much lower than for straw mulch. The germination and stands of seedlings with the wood and paperfiber mulch were generally good enough to develop a dense vegetative cover, however, the seedlings remained very small and many died because of water stress. The largest and best color of seedlings occurred with Conwed woodfiber.

Because of the low rainfall and no torrential showers, erosion on all plots with all mulches including straw was low, being nearly nil. The paper and woodfiber mulches generally formed surface crusts. It was postulated that these crusts would repel water, therefore, a water absorption test was conducted. A controlled volume of water was applied during a controlled time period. Data recorded in Table 3 show large differences among mulch materials, Conwed being lowest in "immediate" water absorption. These parameters did not evaluate the mulches satisfactorily because the

Figure 3.

Title: Mulch evaluation experiment, spring season, Route 610, Forks of Buffalo VA

Objectives: To evaluate woodfiber and paper fiber mulches applied at 2500 lbs/A, 1500 lbs/A, and at 750 lbs/A tacked to straw for erosion control and vegetation establishment.

Location: 1 mile south on Route 610 from Route 60 near Forks of Buffaloe, VA.

Plot Size: 10' x 30'

North on Rt. 610 to Rt. 60 →

Rep I

15	25	15	25	25	25	S	S	S	S	S	S	S		15	15	15	XXX	25	25
NC	C	O	FRG	CW	NC	TF	C	CW	O	FRG	NC	✓	✓	O	FRG	NC	XXX	O	C
19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	XXX	2	1

Rep II

S	S	S	S	S	S	25	15	15	15	15	25	25	25	25	15	15	15	25
CW	NC	TF	C	O	FRG	TF	CW	C	FRG	TF	CW	FRG	O	NC	TF	C	CW	TF
38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20

Reps I and II are separated from III and IV by 1/4 mile.

Rep III

15	15	25	25	15	15	15	15	15	15	25	25	25	S	S	S	S	S	S
NC	O	TF	NC	CW	O	FRG	C	TF	NC	CW	NC	O	TF	C	CW	FRG	O	NC
57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39

Rep IV

← South on 610

S	S	S	S	S	S	25	15	25		15	25	25	15	25	25	15		25	→ Mulch rate
TF	C	CW	O	FRG	NC	FRG	CW	C	✓	FRG	TF	FRG	C	CW	O	TF	✓	C	→ Mulch type
76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	→ Plot number

Treatments:

TF = Turfiber
CN = Conwed
C = Cellin
O = Original

FRG = Fib-R-Green
NC = Spittles
S = Straw tacked with 750 lbs/A mulch
25 = 2500 lbs/A mulch
15 = 1500 lbs/A mulch
✓ = No mulch

Table 3. Assessment of spring season application of mulch materials applied at 2500 lbs/A, 1500 lbs/A, and at 750 lbs/A tacked to straw. Established April 17, 1980. Values are the mean of four replications.

	Mulch Treatments																		
	Conwed [1]			Cellin			Turfiber			Original			Spittle's			Fib-R-Green			No Mulch
	15	25	S	15	25	S	15	25	S	15	25	S	15	25	S	15	25	S	
April 22 penetration scale (1-5) hard-soft	4.6	4.5	4.6	2.1	1.6	1.8	2.1	1.3	2.3	2.1	2.6	3.1	1.0	1.0	1.3	1.8	1.3	2.1	---
May 1 vegetative cover,%	0.3	0.6	1.3	0.3	1.0	1.0	0.6	0.6	0.6	0.3	0.3	1.0	0.3	0.6	1.0	0.6	1.0	1.6	0.6
May 23 vegetative cover,%	3.8	7.0	43	3.0	1.3	48	4.0	4.0	41	2.0	4.2	43	2.0	2.8	38	1.5	2.3	40	2.0
Degree of erosion (1-10) good-severe	1.3	1.3	2.0	1.8	1.5	1.8	1.8	1.5	2.0	1.5	1.8	1.5	1.0	1.0	1.5	1.3	1.5	1.5	3.5
June 5 vegetative cover (1-10) good-poor	6.2	4.0	71 [2]	8.0	8.0	74	7.0	6.8	65	7.5	6.0	73	9.8	8.8	58	9.3	8.8	70	7.7
Water absorption (1-10) good-poor	8.5	9.5	---	3.0	3.0	---	3.0	4.5	---	2.0	1.5	---	5.5	7.5	---	2.0	2.0	---	6.5

[1] Each mulch was applied alone at 1500 and 2500 lbs/A and at 750 lbs/A for tacking straw applied at 3000 lbs/A.

[2] Vegetative cover on straw plots was based on actual percentage of soil cover.

application rates were unrealistically high. However, this technique, when applying water at around 2 inches per hour, might evaluate differential infiltration rates among mulches.

d. Mulch experiment during late spring

This experiment on the Mt. Tabor Road near Blacksburg was established during mid-spring on May 15, 1980, on a 60° southern exposed slope. The subsoil, mainly B with some C horizon, is of limestone origin and of an erosive clay material. The soil material was slightly acid having a pH of 5.8.

Cellin, Turfiber, Conwed, Original and Spittle mulches were applied alone at 1500 and 2500 lbs/A. The entire slope was limed at 2 T/A, fertilized with a 15-30-15 fertilizer at 650 lbs/A and seeded with a mixture of Kentucky 31 tall fescue at 30, annual ryegrass at 5, crownvetch at 15, deertongue grass at 8, and birdsfoot trefoil at 6 lbs/A. All treatments were applied with a hydromulcher. There were 3 replications of all treatments as shown in Figure 4.

Rainfall was favorable during a few weeks after establishing the experiment, later there was a shortage of water because of low rainfall and high temperature conditions. By the end of June, the soil cover with vegetation had reached a maximum of about 25% cover. The lateness of seeding, low rainfall and high temperatures withheld rapid seedling growth. Data in Table 4 rank the mulch treatments for vegetative cover; the ratings ranging from 5.0 to 6.3 among the paper and woodfiber materials applied at 1500 lbs/A. The differences are not large enough to be significant. Applying paper or woodfiber mulches at 2500 lbs/A rate generally improved vegetative cover over the 1500 lbs/A rate.

When applying the paper and woodfiber mulches at 1500 lbs/A, the ratings on seedling vigor ranged from 5.6 for Conwed to 7.3 (lowest) for Original but the differences were not high enough to be significant. At the 2500 lb/A rate, the values ranged from 4.0 for Spittle to 5.3 for Original; the values for vigor tended to be better for the high as compared to the low rate of mulch application.

An endeavor was made to assess the soil cover from the muclh materials and rates of application. Soil exposure data in Table 4 indicate soil surface not covered by mulch materials before seedlings appeared. These data were taken after a rainstorm. Soil exposure of mulches applied at 1500 lbs/A ranged from 9.6 to 18.3% of the soil not covered; for 2500 lbs/A applications, the values ranged from 9 to 13.3% soil exposure. Values on soil cover are difficult to estimate; hence, the values encounter variance due to errors in judgment. The brownish color of woodfiber is more difficult to distinguish from soil material than the grey color of paperfiber. Also, woodfiber tends to become embedded in soil material. Thus, values for soil exposure among mulches do not correlate with vegetative cover.

Results collected on July 14, 1980, are listed in Table 4 giving the low, high and mean values for the three replications of each mulch treatment. The low and high values are given to illustrate the large variations among replicated plots of a given mulch treatment. The large differences among the mulch treatments show why the mean values among the mulch treatments were not statistically significant. For example, the extreme ranges in values for soil cover with vegetation from mulches applied at 1500 lbs/A were: Conwed, 1500 , 5 to 18%; Turfiber, 3 to 20%, and Cellin, 8 to 15%. The very low and inconsistent precipitation during May and June inhibited differential vegetative establishment. Severe droughts after rainfall caused a severe soil expansion lifting a one-half inch surface

Figure 4.

Title: Mt. Tabor mulch evaluation experiment, Blacksburg, VA
Objective: To evaluate wood and paper fiber mulches applied at 2500 and 1500 lbs/A for erosion control and vegetation establishment.
Location: 10 miles east of Route 460 (North Main Street) on Mt. Tabor Road.
Site Description: The site is a 60° southern cut slope exposing B horizon orange-red clay and some C horizon with shale parent material. Soil pH is 5.8.
Plot Size: 8' x 20' except check plots 1 and 33; they are 16' x 10'.
Established 5/15/80.

N / W ← → E / S

← Rt. 460 (Main St.) ← Wind

Rep I

1	2	3	4	5	6	7	8	9	10	11
	TF	O	CW	NC	CW	O	C	C	NC	TF
√	25	25	25	15	15	15	25	15	25	15

Rep II

12	13	14	15	16	17	18	19	20	21	22
NC	CW	NC	C	O	TF	C		TF	O	CW
15	15	25	25	15	25	15	√	15	25	25

Rep III

23	24	25	26	27	28	29	30	31	32	33
NC	NC	O	C	TF	CW	O	C	TF	CW	
25	15	25	15	15	25	15	25	25	15	√

Treatments:

TF 25 = Turfiber @ 2500 lbs/A
TF 15 = Turfiber @ 1500 lbs/A
C 25 = Cellin @ 2500 lbs/A
C 15 = Cellin @ 1500 lbs/A
CW 25 = Conwed @ 2500 lbs/A
CW 15 = Conwed @ 1500 lbs/A
O 25 = Original @ 2500 lbs/A
O 15 = Original @ 1500 lbs/A
NC 25 = Spittle's @ 2500 lbs/A
NC 15 = Spittle's @ 1500 lbs/A
√ = no mulch

The entire experiment was uniformly seeded, fertilized and limed with Kentucky 31 fescue @ 30 lbs/A, annual ryegrass @ 5 lbs/A, crownvetch @ 15 lbs/A, deertongue grass @ 8 lbs/A, and birdsfoot trefoil @ 6 lbs/A, and 15-30-15 @ 650 lbs/A and lime @ 2 T/A.

Table 4. Mean values for estimating vegetation and erosion control for vegetation estimates and erosion control values for a mid-spring mulch experiment, established May 15, 1980.

	Conwed		Original		Cellin		Turfiber		Spittles		No Mulch
	15	25	15	25	15	25	15	25	15	25	
					May 22, 1980						
Soil exposed, %	18.3	13.3	17.3	12.6	13.3	9.3	13.0	9.3	9.6	9.0	100
					June 9, 1980						
Vegetative cover,[1]	5.6	4.3	6.3	4.6	5.0	3.5	6.0	4.3	5.3	3.6	10
Vigor[1]	5.6	4.6	7.3	5.3	6.6	4.5	6.3	5.0	6.0	4.0	7
Range of values					July 14, 1980 Soil cover with vegetation, %						
Low	5.0	19.0	5.0	10.0	8.0	10.0	3.0	6.0	6.0	10.0	3.0
High	18.0	11.0	8.0	15.0	15.0	12.0	20.0	10.0	12.0	18.0	3.0
Mean	12.0	14.0	6.0	12.0	12.0	11.0	10.0	8.0	9.0	14.0	3.0
					Height, inches						
Low	1.5	2.0	2.0	1.8	1.8	2.5	1.8	2.5	1.5	1.8	1.5
High	4.5	3.0	2.0	3.0	2.0	3.0	2.5	2.5	3.5	3.0	1.5
Mean	3.0	2.5	2.0	2.4	2.0	2.8	2.3	2.5	2.3	2.3	1.5
					Legume stand and vigor rating[2]						
Low	1.0	2.0	3.0	2.0	2.0	2.0	1.0	3.0	3.0	2.0	5.0
High	4.0	3.0	4.0	4.0	3.0	3.0	5.0	4.0	4.0	3.0	5.0
Mean	2.0	2.3	3.7	3.0	2.7	2.5	3.0	3.7	3.0	2.3	5.0
					Erosion rating[3]						
Low	2.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	7.0
High	2.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	10.0
Mean	2.0	1.0	2.0	1.5	2.0	1.7	1.7	1.0	1.4	2.0	9.0

[1] Ranked from 1-10, 1 being the best cover or vigor.

[2] Ranked 1-5, 1 having the best stand and vigor.

[3] 1 rating = little or no erosion; 10 rating = severe sheet and rill erosion.

layer of soil and roots which severed roots of young seedlings from moist soil material.

Conwed and Cellin mulches at 1500 lb/A generally had the vegetative cover; Turfiber, Spittle and Original mulches at 1500 lb/A had somewhat less vegetative cover in July. Conwed mulch tended to have more vigorous grass and legume vegetation than Cellin, Spittle, Turfiber and Original. Erosion control ratings in July were similar and very good for all of the mulches; the erosion control vegetative cover and vigor of seedlings being very poor without mulch.

2. Laboratory experiments with mulches

The mulch materials evaluated in this project were paper or woodfiber products. Conwed, a ground natural woodfiber, is made from select hardwoods. Original, a wood cellulose fiber, is manufactured from a blend of virgin hardwood and pine fibers. It is fiberized, screened, cooked, washed, and dried to produce a hollow fiber with no resins. Fib-R-Green is a blend of wood cellulose and paper fiber particles. Turfiber and Cellin are ground newsprint.

The pH values of the mulch materials ranged from 5 for Conwed to 8.5 for Original, the ash contents were generally associated with the pH values of the mulch materials, being 0.6 for Conwed, and 7.2 for Original. The high ash content was apparently high in ionizable cations in Original mulch. The mulches were not evaluated for ash content, but the data suggest that the ash components should be identified by manufactures as certain components in the ash could be toxic (Table 5).

Values for water-holding capacity were obtained by the following procedure: Ten grams of each mulch were submerged until completely saturated in 100 grams of water on filter paper, then suspended for 5 minutes to loosen gravitational water. Containers were covered to minimize evaporation. All samples were weighed and mean values for three replications are presented in Table 4. Results show that similar amounts of water were held by Cellin, Fib-R-Green, Turfiber; the values for Conwed and Original being intermediate and lowest, respectively.

The implication of water holding capacity of mulches is not known; however, an experiment was designed to measure rate of water loss or moisture retention of a soil mulched with two rates, 1500 and 2500 lbs/A of the paper and woodfiber mulches. Straw at 1.5 T/A was tacked with each of the fiber mulch materials (Table 5). The mulch treatments were applied to a clay soil 1 inch deep in pots 4.5 x 3 inches. Water-holding capacity of the mulch and soil were calculated. The mulch treatments and soil received 125 ml of water and were placed in a growth chamber set at 78F and 60% relative humidity. Each pot was weighed every 4 hours until 75% of the water added had evaporated. All treatments lost 4 to 5 grams of water every 4 hours. The values in Table 5 are summations of total water lost in a 48-hour period for three replications. At 2500 lb/A of mulch, 59 grams of water were lost with Conwed as compared to 67 to 73 grams for the other mulch materials; water loss at 1500 lbs/A of mulch ranged from 66.5 to 73 grams. Water losses were lowest for the straw mulch treatments, ranging from 54 to 61.7 grams per 48 hours. Water loss was highest for the unmulched soil; 80 grams. The data indicate that this technique for measuring water loss may not be satisfactory as there was an interaction between mulch material and rate of application. Water loss tended to be lowest with Conwed applied at 2500 lb/A and with straw at 750 lb/A; however, at 1500 lb/A water loss tened to the be lowest with Turfiber.

Particle size analyses of the wood and paperfiber mulches were determined by separating 20 grams of each dry mulch with a series of sieves. Sieve sizes were 8 mm, 4 mm, 2 mm, .75 mm and a collection pan for particles less than .75 mm. Twenty grams of dry mulch were separated by placing the mulch in sieves on a shaker machine until particles separated as shown in Table 5. Original mulch does not have 12.9 grams of 8 mm size particles, being a fibrous mulch, much like cotton, it remained clumped together after the shaker treatment. The particle sizes of mulch materials differed but it is difficult to interpret that data in terms of suitable mulching properties .

A given number of grass and legume seeds were embedded in a given mass of each mulch for germination and seedling growth. This was done to ascertain if any of the mulch materials were toxic to seed. The seed and mulches in separate containers were moistened with distilled water and placed in an incubator to allow germination of seed. The experiment was repeated on four dates giving similar data for each date. The data in Table 5 are summaries of four trials. Germination of seeds in Conwed or Original were generally lower than for other mulches except for Fib-R-Green where the legume failed to germinate.

Laboratory data are difficult to interpret and may or may not be associated with good mulching properties of augmenting germination, seedling development and developing vegetative cover on harsh environments encountered in highway corridors. The laboratory data as reported herein may become useful along with improved techniques and additional research.

Table 5. Data from laboratory experiments with mulches.

Mulch	Conwed	Cellin	Turfiber	Original	Fib-R-Green	No mulch
pH	5.0	5.6	5.3	8.5	6.5	---
Ash, %	0.6	1.5	1.4	7.2	1.5	---
Particle size		Separates from 20 grams of dry mulch				
≥ 8 mm	0.0	0.0	0.0	12.90	0.0	---
≥ 4 mm	1.52	7.89	9.56	1.00	4.28	---
≥ 2 mm	1.38	7.16	6.06	1.02	7.01	---
≥ .75 mm	6.86	2.21	1.67	1.49	4.05	---
≤ .75 mm	10.14	2.64	2.66	3.37	4.66	---
		Seed placed in mulch, germination				
Grasses, %	55	82	71	31	67	---
Legumes, %	26	49	51	30	0	---
		Water content at saturation, %				
Water holding capacity	94	99	98	85	99	---
Mulching rates		Soil water lost in 48 hours, grams				
2500 lbs/A	59	67	70	73	69	80
1500 lbs/A	69	73	67	73	70	80
750 lbs/A/straw	54	60	56	61	62	80

B. Renovating Grasses in Mowed Areas

1. Nitrogen fertilization and mowing experiments

Two nitrogen and mowing experiments with grasses in medians were established to investigate the interplay of these factors. The objectives were to assess the effects of slow release and readily released nitrogen fertilizers at rates of application improving the vegetative cover in medians. Mowing treatments at early and late spring dates were imposed as strip effects over nitrogen applications. Phosphorus and potassium with nitrogen and nitrogen alone were treatments in blocks.

a. Two experiments, one in a median along U. S. 460 near Shawsville and one in a median along I-81 near Christiansburg, were established during March, 1980. Three types of nitrogen fertilizer were applied with phosphorus and potassium at 100 lbs/A and alone on a grassy median. The nitrogen treatments include ammonium nitrate (33.5% N) at 50 lb and 100 lb N/A, a slow release nitrogen from sulfur-coated urea (38% N) at 100 lb N/A, and very slow release nitrogen urea formaldehyde (32% N) at 100 lb N/A. The two mowing treatments were May 15 and June 10 at a 3-inch stubble.

Data on color, height, ground cover, seedhead emergence and tillering were obtained. The data and interpretation of the results are given in Section D entitled, "Mowing Management."

2. Reseeding grasses in medians with sparse canopies

A cooperative experiment in the Lynchburg district was planned and established with highway personnel during spring, 1980. (Figure 5). Seedbed preparation, herbicide kill, fertilization were all variables to be assessed with a seeding mixture applied at a constant rate.

The seedbed treatments were made with an aerator furnished by highway personnel from the Lynchburg district. An aerator is a tool used

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Figure 5. Early spring reseeding grasses into sparse canopies and methods of median renovation; Route 460 x 608, Lynchburg, VA.

Objective: To assess methods of reestablishing vegetation in medians by seedbed preparation, herbicide kill fertilization and reseeding treatments.

Soil Properties: pH - 8.0; Ca, high; Mg, high; P, low; K, low.

Location: .125 mile east of Route 608 on Route 460 near Lynchburg, VA.

Rep I						Rep II					
W	V	T	U	X	V	V	X	U	T	V	W
BCA	BAC	CAB	ACB	ABC	CBA	ABC	CBA	BCA	BAC	CAB	ACB

Plot Size: main plot - 24' x 20'
subplot - 8' x 20'

Treatments:

Main plots

T - one pass with aerator + round-up @ 2 qts/A

U - one pass with aerator

V - two passes with aerator + round-up @ 2 qts/A

W - two passes with aerator

X - no seedbed preparation + round-up @ 2 qts/A

Y - no seedbed preparation

Subplots

A - red fescue @ 20 lbs/A

B - Ky 31 tall fescue @ 80 lbs/A

C - 50:50 mix of red fescue and Ky 31

Fertilizer @ 400 lbs/A (15-30-50) and flatpea and sweetpea @ 30 lbs/A were broadcast over entire experiment.

by the turfgrass industry. It is mounted on a tractor with a three point hitch. When pulled by a tractor, the weight and rotating perpendicular tubular tines on a roller remove plugs of soil about 1 inch deep and 0.75 inch or larger in diameter. The holes or perforations in the soil surface increase with the number of passes over soil with the aerator.

A heavy application of Round-up herbicide at 2 qts/A was applied to the existing vegetation. This herbicide weakened and partially killed the vegetation. The partially killed vegetation regrew by tillering.

Grass species seeded were Kentucky 31 tall fescue at 80 and creeping red fescue at 80 lb/A, each seeded alone and a 50:50 mix of the two grasses was a third seeding mixture. The grasses were slow to germinate and original grasses developed canopies much faster than the seeded grasses. Sweetpea and flatpea legumes were seeded over the entire experiment to evaluate the effectiveness of the aerator on developing stands of legumes in medians.

The results are inconclusive. Grass stands from new seedlings were very poor with and without aerifying due to the unfavorable rainfall and lateness of the spring seeding. At the date of ending this project, the legume stands were poor.

3. Sampling soil materials

During highway construction, infertile subsoil and topsoil materials often cause poor seedling growth and vegetative cover or vegetative covers that degenerate soon after establishment unless persistent legumes are present. Cut, fill and median slopes with degenerating sparse vegetation should be improved by applying needed lime and fertilizer nutrients to improve grass canopies or to establish legumes. Thus, soil materials with degenerating vegetation should be sampled and analyzed to diagnose lime and fertilizer needs. It is known that the acidity and fertility of soil materials in highway corridors differ due to the geological materials, mixture of soil materials and liming and fertilizer history. Thus, soil materials in medians, cut and fill slopes along several highways in Virginia were sampled at 0.5 to 1 mile intervals to ascertain variations in soil fertility and acidity for making soil sampling recommendations for diagnosing lime and fertilizer needs.

Soil materials were sampled and analyzed from sections of highways I-81, U. S. 460, and I-77.

a. Soil analyses, I-81

The medians along I-81 in parts of Botetourt and Roanoke Counties were sampled at 1 mile intervals. Three to four subsamples at a 3-inch depth were combined from the median area to make one composite sample. The mineral nutrient status for calcium, magnesium, phosphorus and potassium are given in pounds per acre (lb/A) in Table 6. The mineral nutrients can be converted from pounds per acre of the oxide form to the elemental form or to PPM by consulting a chart on page 36.

Values for pH range from 6.0 to 7.8, a pH a little below neutral (pH7) seems to promote a good balance and high availability of plant nutrients (Brady, 1974). Test results for calcium and magnesium were generally high. Values in lb/A for calcium ranged from 1781 to 3360 with most values at or near 3360. Values for magnesium were also high except those at the lower pH values of 6.1 which had 102 to 109 lb/A. With the exception of these two low values, magnesium tests were very high at about 396 lb/A.

Values for phosphorus ranged from low to high, 32 to 276 lb/A with most values falling in the medium range. Potassium values ranged from 55 to 250 lb/A with most values in the moderate range between 91 and 211 lb/A.

Table 6:

Soil analysis for mineral nutrients and pH for samples in medians along I-81 through Botetourt and Roanoke Counties.

Mile post	Pounds per acre				
	pH	CaO	MgO	P_2O_5	K_2O
173	7.5	3360	396	133	187
172	7.8	3360	396	60	67
171	7.3	3360	396	115	96
169	6.1	2284	109	152	250
168	7.2	2486	396	41	161
167	7.1	3360	396	37	180
166	6.9	2284	363	64	74
165	7.0	2789	396	207	166
164	7.8	3360	396	276	70
163	7.8	3360	396	115	100
162	6.8	2117	396	32	134
161	7.5	3360	396	165	122
160	7.8	3360	396	87	161
159	6.4	2184	396	46	154
158	7.1	3360	396	230	152
157	7.7	3360	396	276	142
156	6.4	2722	396	41	250
155	6.7	2822	396	37	159
154	7.7	3360	396	87	132
153	7.5	3192	396	60	197
151	7.8	3360	396	115	108
150	7.8	3360	396	46	134
149	7.3	3360	396	147	108
148	7.5	3360	396	276	108
147	6.5	3360	396	87	120
146	7.1	3360	396	156	216
145	6.3	1814	287	55	55
144	6.7	2822	396	97	151
143	6.0	2352	396	28	168
142	7.6	3360	396	32	142
140	7.8	3360	396	46	86
139	7.1	3360	396	276	154
138	6.1	2352	102	161	288
137	7.8	3360	396	276	134
136	7.0	3360	396	276	204
135	7.1	3360	396	276	185
134	7.2	3293	396	179	187
133	6.2	1781	396	87	134
132	7.0	3259	396	253	154
131	7.3	3360	396	276	199
130	7.6	3360	396	276	94

The analyses show the general trend of soil mineral nutrients in the soil to be high for calcium and magnesium and moderate in concentration for phosphorus and potassium. The high values for pH, calcium and magnesium indicate that soils for this section of the highway do not need lime. Although the availability of phosphorus is maximized when the soil pH is between 6.0 and 7.0, other factors also influence its availability. Fixation of phosphorus by hydrous oxides of iron, aluminum and magnesium and by calcium phosphates and reactions with silicate minerals in the soil will render phosphorus unavailable to plants and inhibit movementof phosphorus into soil. Phosphate fixation can be kept at a minimum when the pH values of soils are maintained between 6.0 and 7.0 (Brady, 1974). Adequate availability of phosphorus in soils can be maintained by applying phosphorus-containing fertilizers; the moderate concentrations indicated by the soil analyses suggest that phosphorus is needed to maintain established vegetation. Values of about 253 lb/A should be maintained to insure adequate phosphorus availability to plants. Potassium availability, like phosphorus, is also influenced by pH. Around 90 to 98% of the potassium in soils is relatively unavailable, 1 to 10% being slowly available and 1 to 2% being readily available (Brady, 1974). Potassium in a given soil declines due to removal by plants and leaching. The moderate values of soil potassium availability suggest that light rates (50 to 100 lb K_2O/A) of potassium fertilizer be applied. Desirable concentrations in the area of 240 to 264 lb/A of potassium should be maintained for optimum mineral nutrient availability.

b. Soil analyses, I-77

The soil analyses for median, cut and fill slopes for an area of I-77 are given in Tables 7 & 8. Soils were sampled at 0.5 mile intervals.

Table 7. Soil analysis for mineral nutrients and pH for samples along medians at a given location and at .5 mile intervals near Wytheville, I-77.

Mile[1]	Location in median	pH	Pounds per acre CaO	MgO	P_2O_5	K_2O
15.5	S[2]	3.9	101	36	103	71
	M[3]	3.9	168	60	82	146
	N[4]	5.1	134	92	50	161
16.0	S	5.0	67	24	39	86
	M	6.4	2015	398+	42	173
	N	5.3	134	60	44	123
16.5	S	5.5	1175	123	51	142
	M	8.5	3358+	187	28	150
	N	6.4	638	195	33	67
17.0	S	8.0	873	147	150	200
	M	7.4	1108	295	95	376+
	N	6.6	437	72	59	105
17.5	S	7.0	302	84	125	30
	M	6.8	839	235	61	376+
	N	7.5	1007	386	73	376+
18.0	S	5.1	235	48	110	200
	M	6.3	604	227	123	116
	N	5.6	269	84	53	200
18.5	S	6.4	235	32	39	71
	M	6.5	537	96	40	108
	N	7.1	302	24	44	71
19.0	S	5.4	369	44	40	131
	M	5.2	269	52	29	86
	N	7.0	3358+	84	250+	75
19.5	N	8.2	3358+	183	61	208
20.0	N	6.7	336	32	42	120
20.5	S	5.3	336	147	31	243
	N	6.3	235	84	86	45
21.0	S	3.2	772	203	150	9
	N	3.3	839	219	214	37
21.5	S	4.2	504	111	194	37
	N	5.7	1712	398+	250+	48

[1] Mile post 15.0 . . . refers to mile posts along I-77.

[2] Sample located in median below shoulder along south right of way.

[3] Sample located in mid-area of the median.

[4] Sample located in median below shoulder along north right of way.

Table 8 . Soil analysis for mineral nutrients and pH for samples along cut and fill slopes at a given location and at 0.5 mile intervals near Wytheville, I-77.

Mile post[1]	Location of slope	Pounds per acre				
		pH	CaO	MgO	P_2O_5	K_2O
				Cut Slopes		
15.5	Nc[2]	5.8	873	314	250+	223
	Sc[3]	6.1	235	127	110	131
16.0	Nc	5.1	101	119	42	169
	Sc	8.0	3358+	259	29	196
16.5	Nc	—	—	—	—	—
	Sc	6.0	772	330	104	169
17.0	Nc	7.0	638	191	187	150
	Sc	—	—	—	—	—
17.5	Nc	5.8	537	151	39	231
	Sc	6.7	437	135	250	112
18.0	Nc	6.2	336	135	93	101
	Sc	5.5	202	52	55	101
18.5	Nc	6.6	806	203	48	127
	Sc	7.1	470	68	40	142
19.0	Nc	7.1	403	16	114	71
	Sc	7.6	403	131	39	93
19.5	Nc	7.8	3358+	52	250+	204
	Sc	7.1	369	28	75	56
20.0	Nc	5.4	134	4	46	78
	Sc	5.5	202	100	24	86
20.5	Nc	5.3	168	40	79	34
	Sc	6.5	302	104	62	52
21.0	Nc	3.4	336	44	150	56
	Sc	2.8	638	127	148	8
21.5	Nc	2.8	437	215	250	4
	Sc	5.1	739	223	250	12
22.0	Nc	7.1	672	139	73	93
	Sc	2.7	504	64	250+	4
22.5	Nc	3.5	336	68	250+	63
	Sc	—	—	—	—	—
23.0	Nc	6.7	2182	398	250+	376
	Sc	6.8	873	340	191	274
23.5	Nc	6.4	907	398	250+	231
	Sc	7.1	1511	398	250+	169
24.0	Nc	6.3	504	263	51	274
	Sc	6.6	2216	398	250+	310
				Fill Slopes		
15.0	Sf[4]	5.8	134	48	68	105
16.5	Nf	6.8	537	263	227	376+
17.0	Sf	8.1	1377	163	202	86
22.5	Sf	6.5	739	267	238	262

[1] Mile post 15.5, etc. designates mile posts along I-77 where a soil sample was collected.

[2] Nc identifies sampling site on cut slopes. Samples were taken mid-way on slopes along the north bound lane.

[3] Sc identified sample sites midway on cut slopes along the south bound lane.

[4] Sf or Nf refer to fill slopes along south or north bound lane.

Medians at each 0.5 mile interval were generally sampled at three locations, e.g., adjacent to each of two shoulders and in the mid section (Table 7). The values for pH and mineral nutrients differed sharply in the median for a given location and among locations. For example, at mile 16.5, I-77, the pH values ranged from 5.5 to 8.5; calcium 638 to 3358 lb/A; magnesium 123 to 195 lb/A; phosphorus 25 to 51 lb/A and potassium 67 to 157 lb/A (Table 7). The analyses show very large differences among the 0.5 mile samplings. For example, the pH in the median was 3.2 to 3.3 at mile 21 as compared to 6.7 to 8.2 at mile 19.5. The various mineral nutrients for soils sampled in medians also show large differences for the samples taken at 0.5 intervals.

Cut slopes were sampled mid way on the slope. There were large variations in soil acidity and fertility for slopes at 0.5 mile intervals and at given intervals. The largest variations between slopes at a 0.5 mile interval occurred at mile 21.5 where pH values ranged from 2.8 to 5.1 and at mile 16.0 with pH ranges from 5.1 to 8.0. The soil acidity among slopes ranged from very alkaline as shown by pH values of 8.0 at mile 16.0 to very acid soil pH values of 2.8 at mile 21.0 and 21.5. Mineral nutrients differed sharply among slopes at intervals and between slopes at different intervals. Values for mineral nutrients are given in pounds per acre of CaO, MgO, P_2O_5, and K_2O for cut and fill slopes and medians (Table 8).

c. Soil analyses, U. S. 460

The soil analyses for samples taken along U. S. 460 medians cut and fill slopes are given in Table 9 . Soils were sampled at 0.5 mile intervals. Medians at each 0.5 mile interval were sampled at two locations (below shoulders along east and west right of ways). Cut and fill slopes were sampled near the middle of the slopes. The values for pH in medians

Table 9 . Soil analysis for mineral nutrients and pH for soil samples in medians, cut slopes and fill slopes at a given location and at 0.5 mile intervals along U.S. 460 Bypass, Blacksburg.

Mile[1]	Location in median	pH	Pounds per acre			
			CaO	MgO	P_2O_5	K_2O
			Medians			
0	W[2]	7.0	2350	279	48	173
	E[3]	7.8	2720	330	86	105
.5	W	7.6	1712	346	61	165
	E	7.6	2048	318	44	101
1.0	W	7.8	3358+	398+	79	108
	E	7.6	2149	398+	103	105
1.5	W	7.9	1645	398+	75	75
	E	7.6	2250	398+	64	93
2.0	W	8.3	2182	398	44	258
	E	7.9	2182	350	73	37
2.5	W	7.4	2283	398+	62	26
	E	7.7	2250	398+	121	67
3.0	W	7.8	3358+	398+	24	105
	E	8.2	3358+	398+	26	78
3.5	W	7.7	1310	398+	61	181
	E	6.0	1142	263	55	48
4.0	W	6.9	1780	362	68	112
	E	7.5	2252	386	108	161
			Cut Slopes			
0	Ec[4]	5.4	571	310	48	184
	Wc[4]	7.2	2015	398	28	376+
.5	Ec	6.9	1142	326	48	376+
	Wc	7.7	2216	398+	50	278
1.0	Ec	7.9	1545	398+	61	204
	Wc	7.6	1142	370	88	173
2.0	Ec	7.1	2149	398+	132	204
	Wc	4.9	437	239	48	116
2.5	Ec	7.5	1074	259	82	173
	Wc	6.1	772	275	46	90
3.0	Ec	7.5	3358+	398+	79	286
	Wc	7.7	3358+	398+	123	302
3.5	Ec	7.7	1679	314	71	135
	Wc	4.7	437	151	42	298
4.0	Ec	---	---	---	---	---
	Wc	8.1	3358+	398+	145	274
			Fill Slopes			
1.5	Ef[5]	7.7	1847	398+	53	105
	Wf[5]	8.1	3358+	398+	53	239

[1] Distance from N. Main St. heading east on U.S. 460 Bypass.

[2] Sample located in the median below shoulder along west right of way.

[3] Sample located below shoulder along east right of way in median.

[4] Sampling sites midway on cut slopes along east or west bound lanes.

[5] Sampling sites midway on fill slopes along east or west bound lanes.

and fill slopes were generally good. The ranges in pH values were 6.8 to 8.3 and CaO and MgO also showed larger differences. The variation of CaO in pounds per acre in medians and fill slopes ranged from 1310 (M-) to 3358 lb/A (VH). The values for MgO were variable in medians but similar for fill slopes. For fill slopes values for MgO were 398+ lb/A. In median sites, values for MgO ranged from 263 (H-) to 398+ lb/A (VH). Phosphorus tests in pounds per acre of P_2O_5 ranged from 24 (L+) to 121 (H-) in medians. For the two fill slopes, the values of MgO were 53 lb/A. Potassium (K_2O) in medians varied from 26 (L) to 258 (H) pounds per acre and 105 (M-) to 239 lb/A (H-) in fill slopes.

Soils for different cut slopes showed large differences in pH along U. S. 460; values ranged from 4.7 to 8.1. Calcium (CaO) in soil along cut slopes ranged from 437 (L) to 3358+ lb/A (VH). Magnesium (MgO) along cut slopes had low sampling variance; it ranged from 151 (M) to 398+ (VH) pounds per acre. Phosphorus (P_2O_5) ranged from 28 (M-) to 145 (H) pounds per acre and potassium (K_2O) ranged from 90 (L) to 376+ (VH) pounds per acre in soils for cut slopes along U. S. 460 bypass, Blacksburg.

The variation in soil fertility and pH along medians, cut and fill slopes illustrates the need to sample soil materials to diagnose lime and fertilizer needs before renovating degenerated vegetative covers and to reduce costs in routine fertilizing programs. Sampling soils on specific medians and cut and fill slopes for soil analyses can reduce labor and transportation costs and save funds by purchasing and applying only needed lime and fertilizer materials.

Calibration of Phosphorus(P), Potassium(K), Calcium(Ca), and Magnesium(Mg) Tests
VPI&SU Soil Testing Laboratory

EXT. P	P - LB/A	P - PPM	P2O5 - LB/A
L-	0-3	0-2	0-7
L	4-8	2-4	9-18
L+	9-11	5-6	21-25
M-	12-20	6-10	28-46
M	21-30	11-15	48-69
M+	31-35	16-18	71-80
H-	36-55	18-28	82-126
H	56-85	28-43	128-195
H+	86-110	43-55	197-252
VH	110+	55+	252+

EXT. K	K - LB/A	K - PPM	K2O - LB/A
L-	0-15	0-8	0-18
L	16-55	8-28	19-66
L+	56-75	28-38	68-90
M-	76-100	38-50	92-121
M	101-150	51-75	122-181
M+	151-175	76-88	182-211
H-	176-210	88-105	212-253
H	211-280	106-140	254-337
H+	281-310	141-155	339-373
VH	310+	155+	373+

EXT. CA	CA- LB/A	CA - PPM	CAO - LB/A
L-	0-240	0-120	0-336
L	241-480	121-240	337-672
L+	481-720	241-360	673-1007
M-	721-960	361-480	1009-1343
M	961-1200	481-600	1344-1679
M+	1201-1440	601-720	1680-2015
H-	1441-1680	721-840	2016-2350
H	1681-1920	841-960	2352-2686
H+	1921-2160	961-1080	2688-3022
VH	2161-2400+	1081-1200+	3023-3358+

EXT. MG	MG - LB/A	MG - PPM	MGO - LB/A
L-	0-24	0-12	0-40
L	25-48	13-24	42-80
L+	49-72	25-36	81-119
M-	73-96	37-48	121-159
M	97-120	49-60	161-199
M+	121-144	61-72	201-239
H-	145-168	73-84	240-279
H	169-192	85-96	280-318
H+	193-216	97-108	320-358
VH	217-240	109-120+	360-398+

C. Legumes in Medians

Persistent perennial legumes such as crownvetch, perennial sweetpea and flatpea have not generally been used or seeded in medians. Predicated on the principles that legumes could reduce maintenance costs by recyling nitrogen from clipping and nitrogen fixation by nodules to form dense canopies to exclude weeds by competition rather than by herbicide application and require only one mowing during the growing season, experiments on establishing legumes in medians were initiated.

Experiments, established in two physiographic regions (Piedmont and Mountainous), were seeded in medians with sparse to dense vegetation. Variables such as lime and fertilizer rate, seeding rates and dates, seeding methods (surface seeding with sod not disturbed, sod tillage, row sod seeding with and without a herbicide) and tillage methods were investigated. Diagrams and experimental procedures of experiments established during this project are given. Diagrams are omitted for experiments with preliminary results reported by Adams and Blaser, 1979.

1. Mountainous region

a. Sod seeding flatpea

The objective of this experiment was to sod seed flatpea (Lathyrus sylvestris) into mowed grass medians and to evaluate the treatment effects on the spread and growth of this legume. The experiment was established in a median on U. S. 460 bypass near Blacksburg in July, 1979 (Figure 6). A modified Allis-Chalmers sod seeder was used to seed flatpea in 3-foot rows @ 10 lb/A into a grassy median. The composition of the sod in the median was 75% ground cover as creeping red fescue; red clover, 15%, and weeds making up 10% of the cover.

A sod seeder, also called a conservation planter, is built to reduce seedling competition from sod when seeding into it. This is also called minimum tillage planting, which saves time and fuel and conserves moisture and soil. It is similar to a row planter but is built much heavier to tear through sod. A ripple coulter that cuts 1-inch wide or fluted coulters that cut 2.5 inches wide effectively slice through trash and soil ahead of a double disk opener that opens a V-shaped trench for seed placement. A consistent depth of planting is obtained by a depth-gauging wheel. Seed is released through either a finger pick-up, feed cup, or plate type mechanisms. The Allis-Chalmers model used had a plate type mechanism. A press wheel follows behind the seed placement mechanism to compact the soil for soil-seed contact.

To kill the species in the sod, Round-up herbicide at 2 qt/A was sprayed in 10-inch bands from nozzles attached to the coulter brackets. Four rows of flatpea were planted on each side of the median sloping into a mid ditch in rows 30 feet long parallel to the road. The herbicide effectively killed the vegetation in 8-inch bands.

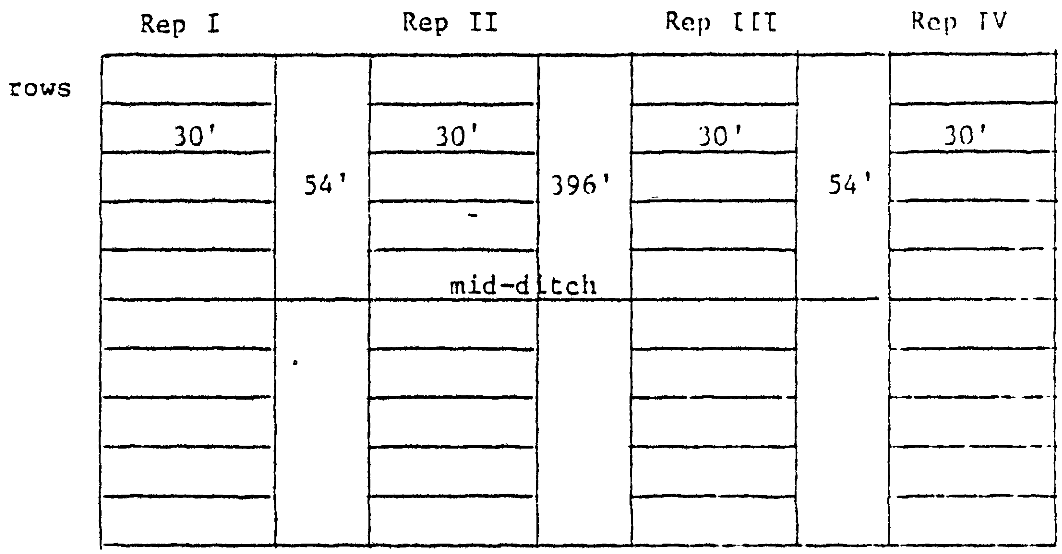
Flatpea seedlings began to emerge on August 2. Seedling counts were made four days later in each replication. The average number of seedlings was 30 at a 1-inch height per 30-foot row. Plants grew vigorously throughout August, September and October. New tiller shoots (6-7 per plant) rhizome formation (1-2 inches long) and apical growth flourished. Tap roots were 0.25 to 0.67 inch in diameter and were well nodulated. Grass bands killed by herbicides were regenerating slowly. With the onset of winter, the grass vegetation began dying with each successive frost. Flatpea withstood early heavy frosts, but by late November the foliage became nectrotic and turned brown like the grass.

Rising temperatures during spring stimulated the grasses; growth being about a week earlier than flatpea. Flatpea also regenerated quickly fr

Figure 6. Establishing legumes in medians, flatpea sodseeding; Route 460 Bypass, Blacksburg.

Objective: To evaluate the effects of establishment and spread of growth of flatpea (Lathyrus sylvestris) sod seeded into a grassy median.
Soil Properties: pH - 7.7; Ca, very high; Mg, very high; P, high; K, medium.
Plot Size: Median width x 30'
Date Established: July 17, 1979

About .5 mile to Toms Creek Rd. exit
← Route 460 E



Space left for other seeding dates

Route 460 W →
about .25 miles to N Main St.

tiller and rhizome formations.

On June 1 plots were divided for mowing at 4 and 8 inch heights. Plant heights were estimated at 9 inches before mowing treatments were imposed. The 4-inch cut suffered more damage as half the canopy was removed. Observations on June 27 showed canopy regrowth of plants mowed at 4 inches to be prostrate with lateral growth of tillers and auxiliary buds persisting in the grass canopy. The 8 inch height of mowing caused minimal damage to flatpea plants. Tillers grew vigorously, both laterally and vertically, and rhizomes of flatpea were invading into the grass canopy.

Plant stands were somewhat better on the cool eastern slope of the median although both hot and cool slopes had generally good stands. Sod strips, killed by herbicides, are slowly regenerating, but vigorous stands of flatpea spaced throughout the rows are spreading among the thatched strips and out into the grass canopy.

b. Birdsfoot trefoil and crownvetch

The objective of this experiment was to investigate the establishment of two legumes (birdsfoot trefoil and crownvetch) by sod seeding on August 24, 1979. The experiment was established in a grassy median along U. S. 460 bypass near Blacksburg. Seeding rates were 10 lb/A each for birdsfoot trefoil and crownvetch seeded together and on separate plots replicated four times (Figure 7). Phosphorus at 100 lb/A of P_2O_5 was applied with all seeding treatments. The legumes were seeded in rows where Round-up herbicide had been sprayed in 10 inch strips to kill the sod, mainly grass.

Seedlings were slow to germinate. On September 23 birdsfoot trefoil began to germinate but no crownvetch seedlings appeared. The herbicide was 100% successful in killing the vegetation in strips; however, in replication II some plots received little or no herbicide due to malfunctioning of equipment; hence, the sod kill was spotted.

Observations on October 22 showed sparse stands of crownvetch and birdsfoot trefoil seedlings in the rows. Seedling development ranged from the two primary leaves (cotyledons) to true leaves. Plant heights ranged from 0.75 inch to 1.75 inches for both species. Plants emerging in rows not killed by herbicide were similar in size and vigor to plants in rows killed with herbicide.

November 5 observations showed that many additional new seedlings had emerged of both species. Several heavy frosts did not damage the seedlings but severely damaged the grass vegetation. Observations on December 5 showed some seedling damage by the cold temperatures. At this date, crownvetch and birdsfoot trefoil plants had four more true leaves. The frost had damaged only the cotyledons (first leaves); the true leaves suffered no observable damage. January 10 observations showed that both birdsfoot trefoil and crownvetch seedlings were surviving the extremely cold temperatures. The leaves were constricted, succulent, deep green in color, having survived snow, freezing and thawing. Stress conditions incurred throughout the winter reduced stands by an estimated 80%.

In May, most birdsfoot trefoil and crownvetch plants that survived were an average height of 4 inches and more seedlings were emerging. Birdsfoot trefoil is tolerant of acid, infertile, poorly drained soils, but its small seed needs to be scarified for quick germination. It has 90% hard seed that inhibits germination (Heath, Metcalfe and Barnes, 1951). Many plants that survived winter stress conditions were producing tillers. Crownvetch was not as abundant as birdsfoot trefoil, but more plants are emerging and old plants are proliferating. Grass strips killed by herbicides are slowly regenerating with grasses as competition by legumes is meager.

Figure 7. Establishing legumes in medians with birdsfoot trefoil and crownvetch; Route 460 Bypass, Blacksburg.

Objective: To evaluate the effects on establishment and spread of growth of birdsfoot trefoil (*Lotus corniculatus*) and crownvetch (*Coronilla varia*).

Plot Size: 15' x median width

Description: Each plot has four 15' rows 30" apart on each side of the median running parallel to the road and mid-ditch.

← Route 460 E By-pass (entrance to Va. Tech .1 mile to Southgate Dr.)

Rep I			Rep II			Rep III			Rep IV		
CV	50:50	BFT	50:50	CV	BFT	BFT	CV	50:50	BFT	50:50	CV

Route 460 W →

CV = crownvetch at 10 lbs/A

BFT = birdsfoot trefoil @ 10 lbs/A

50:50 = two rows of each species per side of median

Seeded with a modified Allis-Chalmers sod-seeder and sprayed in rows with Round-up @ 2 qts/A.

Establishment of competitive legume stands in grass sod by machine planting is possible,but additional research is essential to determine optimum depths and seasons of seeding into sods, usage of herbicides and mineral nutrients.

c. Legume adaptation experiment - I-81 near Exit 40 and Salem

The objective was to evaluate the legumes birdsfoot trefoil, milkvetch, crownvetch, sweetpea, flatpea, and sericea in a median in August, 1976. Each legume was seeded in untilled and tilled sod with and without paraquat (Adams and Blaser, 1979). There were no differences in legume stands due to tillage. Legume stands are developing with perennial sweetpea, flatpea and crownvetch, with perennial sweetpea having the best stands and growth and flatpea giving the best lateral spread. Crownvetch stands are poor but plants are healthy and it is expected that crownvetch will continue to spread and to invade.

The generally sparse stands of all three legumes are attributed to severe competition from the dense grass cover; the area is heavily thatched, especially with red fescue. The two perennial peas gave better stands than crownvetch because the large seedlings of the pea species endure considerable competition. Late summer seeding dates as for this August seeding, have low probabilities of success because of low moisture availability in grass competition at this season. Also, legume seedlings may not develop a cold tolerance with such late seedings (Woodruff and Blaser, 1969).

During June 1980, perennial sweetpea was severely infested with aphid, whereas the infestation was minor on flatpea and nil with crownvetch. Near the shoulder, there was severe injury to legumes from the use of herbicides. Damage from herbicides was especially evident with perennial sweetpea and flatpea.

d. Legume experiment near Salem

This experiment on I-81 in a median is about a mile north of Exit 40 near Salem. The objective was to study crownvetch establishment on a north and south slope aspect with inoculated legume seed where seeds with inoculant were coated and not coated with lime (Adams and Blaser, 1979). There were several rates of applying phosphorus, potassium and nitrogen. The sod treatments were row seedings with and without paraquat and broadcast seeding (with and without disking).

The erratic stands of crownvetch may be attributed primarily to the very dry autumn and spring seasons causing moisture competition by the grass sod during seedling establishment in 1977 and 1978. Because of severe grass competition, fair stands of crownvetch were developing where paraquat reduced grass stands.

There was evidence that nitrogen fertilization retarded crownvetch. This is attributed to improved grass growth and severe canopy competition toward slow-growing crownvetch seedlings. It was postulated that nitrogen might stimulate crownvetch seedlings but this did not occur. One plot on a southern exposure had a good stand of crownvetch; however, the yellowish seedlings indicate a nitrogen shortage due to poor nodulation or inefficient nitrogen fixation. It would be desirable to apply an inoculant and study its effect on rate of growth and spread of crownvetch seedlings.

Crownvetch plants were damaged from herbicides. Also, herbicides did not give good weed control; certain weeds such as milkweed were unaffected by the herbicide treatment applied by highway personnel. Areas of white clover almost completely killed by herbicides are being invaded by ragweed. Ragweeds are around 6 inches high because there is no competition as compared to very spindly, dwarfed ragweed plants in competition in grass sods. This shows that a good way to inhibit weeds is to develop a dense canopy of grass.

2. Piedmont region

a. Two legumes with rates of lime and phosphorus

This experiment was established in a median along U. S. 29 near Hurt on April 1, 1977, as reported by Adams and Blaser (1979). The two legumes (crownvetch and flatpea each inoculated and seeded @ 20 lb/A) along with the lime and phosphorus rates are given in Table 10).

By the spring season 1979, crownvetch had a better cover than did flatpea (Adams and Blaser, 1979). During June, 1980, the crownvetch soil cover ranged from 63 to 88% among the lime and phosphorus treatments as compared to 29 to 63% cover for flatpea (Table 10). The responses of the two legumes to lime and phosphorus are erratic, there being no significant differences for ground cover among treatments. However, the legumes appear the most vigorous with the lime and phosphate treatments. A lack of responses to lime and phosphorus may be attributed to the residual carry-over of lime and fertilizer applied when the median was initially seeded by a highway contractor.

The inoculated legume seeds with lime and phosphate treatments were applied over the poor vegetative cover in the median composed of mainly volunteer annual and biennial species. The exceptionally good growths of both legumes have developed into suitably dense covers during a 3-year period to stop erosion, eliminate weedy growths and provide a colorful vegetation in medians. Crownvetch is invading into flatpea, being the more aggressive legume. The good stands of legumes have improved consistently

Table 10. Legume, percent ground cover, as influenced by lime and phosphorus, June 1980. (Experiment in U.S. 29 median near Hurt.)

	No Lime				1.5 T lime				3.0 T lime				
	P_2O_5, lb/A				P_2O_5, lb/A				P_2O_5, lb/A				Grand
Legumes	0	100	200	Avg.	0	100	200	Avg.	0	100	200	Avg.	Avg.
Crownvetch	89	85	80	85	69	63	77	70	88	73	84	82	79
Flatpea	41	44	46	44	29	31	50	37	48	32	63	48	43
Average	65	65	63	64.5	49	47	64	53.5	68	53	74	65	

each year and generally subdued the grasses and weedy species. It would be very desirable to impose mowing managements on this experiment next spring before the grasses are completely dominated by the legumes. Based on this and other experiments, the chances of obtaining persistent vegetative cover by seeding perennial legumes in medians is infinitely better with spring sowing as in April, 1977, for this experiment as compared to late summer seedings as for other experiments reported herein.

b. Experiment with three legumes on U. S. 360 near Greenbay

This experiment was established on March 6, 1979, in a median of U. S. 360, 3 miles east of Greenbay, west of the industrial intersection to Union Camp Lumber Company (Adams and Blaser, 1979). The median site was tilled twice with a field cultivator. Crownvetch @ 20 lbs/A and a mixture of 15 lbs/A each of flatpea and sweetpea were seeded on separate plots replicated three times. The entire area was then treated with a slurry of cereal rye @ 30, P_2O_5 @ 200, K_2O @ 100 and woodfiber @ 1500 lbs/A. The area was also limed @ 3000 lbs/A.

The three legumes developed an unusually good vegetative cover for erosion control during 14 months. The soil cover with crownvetch among the replicated plots ranged from 25 to 75%, averaging 52% in soil cover. The soil cover with the mixture of flatpea and perennial sweetpea averaged 37%.

The excellent cover from the three legumes may be attributed to the early March seeding; cultivation to form a rough surface that aided in covering the seed, lime and phosphorus was also beneficial because moisture and light competition from established sod was depressed thereby encouraging seedling establishment. These factors stimulated early germination and augmented seedling development.

c. Legume experiment along U. S. 460 bypass, Farmville

This experiment was established in March 1979 with flatpea and crownvetch seeded along a median of U. S. 460. The treatments were field cultivation, paraquat and no treatment (surface seeding and sod not disturbed) with a mixture of crownvetch and flatpea seeded on all plots. During mid spring, part of each legume plot was mowed.

Seeding on the hard soil surface resulted in a very sparse stand of legumes due to competition from the established sod. Reducing competition by killing vegetation with paraquat gave better stands of legumes than no treatment. The best growth and stands of legumes occurred when the soil had been cultivated. However, the cover in June, 1980, is classified as fair. It is apparent that flatpea stands are best where the mower missed the plants. It is evident that the growth of the legumes would have been substantially improved if the area had not been mowed.

Along this bypass across from the median experiment just described, there are good developing canopies of flatpea on the cut slope facing to the north. This was apparently seeded by highway personnel.

d. Legume adaptation in Charlotte County

Two experiments appear on U. S. 360 east of Route 92 intersection and near Route 685. Legumes were established with different sod treatments: disking, no disking and seeding in rows with paraquat sprayed in bands over the row to kill the vegetation. The pH and fertility status were favorable when the experiment was established (Adams and Blaser, 1979).

This experiment, based on June 1980 observations, is a failure as there were only scattered plants of flatpea and sweetpea; there were no crownvetch plants.

The second experiment at this location with hard compacted soil material had the following treatments: a) tillage with a field cultivator and b) no tillage (seeding on a hard surface). A mixture of perennial sweetpea and flatpea (15 lbs/A of each) and 0-20-10 at 1000 lbs/A was applied on March 30, 1978.

Previous to June 1980, this area had been mowed; there was a poor stand of the two perennial peas. The semi-failure of this seeding may be attributed to the prolonged drought during the spring of 1978, the late spring seeding date, and the hard compacted soil, all contributing to a severe moisture competition from established vegetation with legume seedlings.

e. Legume experiment in a median, Farmville

This experiment along U. S. 460, 0.7 miles west of intersection U. S. 15 and about 100 yards west of a yellow shed,was seeded March 9, 1977. Strips in the median were disked and limed @ 1 T/A and fertilized with a 5-20-5 @ 1000 lbs/A. The legumes were seeded separately in plots replicated three times (Adams and Blaser, 1979).

This experiment shows fantastic legume cover. Crownvetch with a 100% cover is invading into adjacent seedings of sweetpea and into flatpea. The perennial sweetpea is the least aggressive when seeded next to crownvetch; there was only about 2% cover of sweetpea due to invasion by crownvetch. Flatpea is not as aggressive as crownvetch but stands are satisfactory.

f. Legume adaptation in Pittsylvania County

This experiment,located on U. S. 29 in a median just north of Route 903 in Pittsylvania County approximately 3 miles from Gretna, was established on March 31, 1977 to study the effect of lime applications on growth of legumes for improving medians. After seeding, there were scarcely any legumes because of a prolonged dry spell. In March 1979, after tillage with a field cultivator, crownvetch was reseeded right over the other legumes in replicates I and II.

In June 1980, there were good stands of perennial sweetpea and crownvetch on many plots; flatpea also developed satisfactory stands on some plots but stands were not as good as the other two legumes. There were severe encroachments of little and big hop clovers and red clover. These legumes were deterring the growths of seedling plants of crownvetch, flatpea and perennial sweetpea. Red clover plants, being more than 2 feet high, were aggressive, causing severe light competition. It is expected that plant success during the next two years will result in a dense canopy of legumes.

D. Mowing Management

Personnel of the Virginia Department of Highways and Transportation have already adopted the concept of minimum mowing to save fuel, labor and machinery costs and to reduce the incidence of accidents. Money saved by reducing the number of mowings per year has already been allocated to maintenance divisions for improving vegetation for desirable aesthetic values and to reduce the possibilities of erosion.

This proposal was initially written to investigate mowings during a three year period. However, because the proposal was approved for only one year, June 1979-June 1980, it was impossible to obtain specific results on mowing for various regions of Virginia for implementation. Mowings made during the mid to late spring season of 1980 could not be fully evaluated by June 30, 1980, the termination date of this project.

Two experiments with mowing grasses and one with legumes have furnished inconclusive findings. Information reported herein for making recommendations was obtained from specific mowing experiments and from observations of mowing practices by highway personnel in various physiographic and climatic regions of Virginia.

1. Mowing and fertilization experiments with grasses

a. Two experiments in mountainous regions

In mowing management, it is desirable to obtain reasonably rapid regrowths after mowing to exclude annual weedy seedlings such as crabgrass, ragweed, and lambsquarter by light and moisture competition from rapidly developing dense canopies. Thus, the objective of two experiments in mowed medians was to investigate two mowing dates with rates and sources of nitrogen. Sources of nitrogen were: water soluble urea or ammonium nitrate that are readily available; primarily water insoluble nitrogen as urea formaldehyde, and sulfur-coated urea which is water insoluble but becomes available at a moderate rate as the sulfur becomes degenerated by soil microbes. The sources and rates of nitrogen were also used with and without phosphorus and potassium. The fertilizer and nitrogen were applied in late winter, 1980. One half of each nitrogen and fertilizer combination plot treatment was mowed on May 15 and the other half was mowed on June 10 @ a height of 3 inches.

For the experiment located near Shawsville along U. S. 460 (Figure 8), data recorded in Table gave canopy height, ground cover, seedhead emergence and tiller density. Data for these parameters were obtained before and after mowing. The canopy growth before and after mowing was excessive for sulfur-coated urea and ammonium nitrate when applying these sources of nitrogen at 100 lbs/A of N. After mowing, grasses with these two nitrogen treatments had better tillering, foliage color and ground cover than for the other nitrogen treatments (Table 11). When applying ammonium nitrate @ 50 lb/A, there was moderate regrowth, tillering and foliage color; the values for these parameters were very poor for without and with urea formaldehyde nitrogen. This shows that there were positive responses to readily available sources of nitrogen applications of 50 lb of N/A being a satisfactory rate.

Excellent control of seedheads was obtained by mowing on May 15; only a few seedheads appeared in the regrowth after mowing. Although data collection had to terminate by late June, it is assumed that 100% of the seedheads were controlled by mowing during mid June.

Comparative weed invasion, rates of regrowth and canopy density could not be ascertained for May 15 as compared to June 10 mowing dates

Figure 8:

Title: Nitrogen fertilization and mowing, Spring 1980
Location: Route 460, Shawsville median
Date Established: March 26, 1980
Experiment Size: 20' x 300'; Plot Size: 10' x 20'

← Route 460 W

Rep I										Rep II									
N alone					N + P + K					N alone					N + P + K				
E 1	A 1	D 1	B 1	C 1	D 2	A 2	E 2	C 2	B 2	E 1	D 1	A 1	B 1	C 1	B 2	E 2	A 2	C 2	D 2
F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G	F G

Rep III									
N alone				N + P + K					N Alone
A 1	C 1	D 1	E 1	D 2	E 2	B 2	A 2	C 2	B 1
F G	F G	F G	F G	F G	F G	F G	F G	F G	F G

Route 460 E →

A - No nitrogen
B - 50 lbs/A NH_4NO_3
C - 100 lbs/A NH_4NO_3
D - 100 lbs/A UF
E - 100 lbs/A SCU

1 - no P + K
2 - 100 lbs/A P + K

F - June 10 mowing at 3" height
G - May 15 mowing at 3" height

Table 11. The influence of spring applications of sources of nitrogen with and with[…] phosphorus and potassium and mowing on characteristics of Kentucky 31 tal[…] fescue in a highway median.

	No Nitrogen		Ammonium nitrate 50 lbs/A		Ammonium nitrate 100 lbs/A		Urea Formal. 100 lbs/A		Sulfur-coat[…] urea, 100 lb[…]	
	No Fert	P+K	No Fert	P+K	No Fert	P+K	No Fert	P+K	No Fert	P-
April 18, before mowing										
Color[1]	5.0	5.0	1.0	1.0	1.0	1.0	4.0	3.0	2.0	1.
Height, in.	8.0	8.0	16.0	16.0	16.0	16.0	8.0	8.3	10.6	1[illegible]
April 30, before mowing										
Ground cover, %	65.0	65.0	81.6	78.3	90.0	88.3	68.3	68.3	78.3	76.
Color	5.0	5.0	2.3	2.3	1.0	1.3	4.0	4.0	2.3	2.
Height, in.	8.0	8.0	17.0	17.0	18.0	17.0	8.6	9.3	10.6	[illegible]
May 15, before mowing										
Color	5.0	5.0	1.3	2.3	1.0	1.0	4.3	4.6	2.0	2.
Height, in.	13.3	14.3	19.3	22.0	22.6	23.3	12.3	18.0	20.0	21.
Seedhead emergence, %	21.6	9.0	35.0	46.6	56.6	48.3	18.3	20.0	55.0	[illegible]
June 17: first row, after mowing on May 15; second row, after mowing on June 10										
Canopy height, in.	8.3	10.0	11.0	13.0	15.6	14.6	10.3	10.0	13.0	14.
	4.0	4.0	4.0	4.3	5.6	3.0	4.6	4.6	5.6	5.
June 30: first row, after mowing on May 15; second row, after mowing on June 10										
Ground cover, %	55.0	63.3	81.6	85.0	86.6	88.3	65.0	78.3	90.0	93.
	45.0	43.3	45.0	45.0	43.3	53.3	43.3	47.3	48.3	50.
June 30: first row, after mowing on May 15; second row, after mowing on June 10										
Canopy height, in.	6.0	6.3	9.3	9.0	11.3	12.6	7.0	8.6	11.3	12.
	3.6	4.0	5.5	5.0	5.8	6.2	3.6	4.2	6.0	6.
June 30: first row, after mowing on May 15; second row, after mowing on June 10										
Color	3.8	3.6	3.0	2.3	1.5	1.5	3.6	3.3	1.3	1.
	2.8	3.3	2.6	2.5	2.8	1.5	3.0	3.1	2.0	[illegible]
June 30: first row, after mowing on May 15; second row, after mowing on June 10										
Tillers[2]	6.6	5.3	3.3	3.0	3.0	2.6	6.3	4.6	2.3	2.
	5.3	5.6	7.0	5.6	6.6	4.6	6.0	5.6	4.6	4.
June 30: first row, after mowing on May 15; second row, after mowing on June 10										
Seedheads,[3]	2.3	2.3	1.3	1.3	1.5	1.0	1.6	1.3	1.0	1[illegible]
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.

[1] Color was rated on a 1-5 scale (dark green to yellow green).

[2] Tiller densities were estimated on a 1-10 scale (dense to sparse population).

[3] Seedheads - 1 = no seedheads, pleasing leafy regrowth; 10 = objectionable growth with many seedheads.

because of the termination date of the project. However, it appears that regrowth and formation of dense canopies was more rapid with May 15 than for June 10 mowing. It is postulated that slower rates of regrowth and canopy development may be expected with the late mowing date for the following reasons: a) prolonged shading of basal vegetative tillers with late as compared to early mowing would cause elongated and etiolated tillers, b) late mowing usually causes sparse open canopies causing temperature elevations and a xeric environment as compared to early mowing and c) late mowing is usually associated with moisture and temperature stress as compared to early mowing.

A second similar experiment with mowing and fertilizer treatments (Figure 9) was established near Christiansburg on I-81. Because of mower breakdown, there was only one mowing date, May 15. Data on various parameters before and after mowing are given in Table 12. There were marked improvements in greeness of foliage color with added increments of ammonium nitrate during April, foliage color being similar for a given rate of ammonium nitrate and sulfur-coated urea. Foliage color was yellowish green without nitrogen and with slow release urea formaldehyde nitrogen. As the grasses developed seedheads by late May, the responses in foliage color to nitrogen were not evident. Using phosphorus and potassium with the nitrogen treatments did not improve color of foliage as compared to nitrogen applied alone.

The ground cover responses resulting from nitrogen applications paralled those for color. For example, ground cover averaged 76.6% for no nitrogen as compared to 95.8% when applying ammonium nitrate at 100 lbs/A of N. Legumes, mainly red clover making up 20 to 36% of the vegetation,

Figure 9:

Title: Nitrogen fertilization and mowing, Spring 1980
Location: I-81 median between the two Christiansburg exits
Date Established: March 19, 1980
Experiment Size: 20' x 300'; Plot Size: 10' x 20'

← I-81 S

Rep I

N alone										N + P + K									
E	1	B	1	D	1	C	1	A	1	B	2	D	2	A	2	C	2	E	2
F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G

Rep II

N alone										N + P + K									
C	1	E	1	A	1	B	1	D	1	E	2	D	2	A	2	C	2	B	2
F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G

Rep III

N + P + K										N alone									
C	2	B	2	E	2	D	2	A	2	D	1	C	1	A	1	E	1	B	1
F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G

I-81 N →

A - No nitrogen
B - 50 lbs/A NH_4NO_3
C - 100 lbs/A NH_4NO_3
D - 100 lbs/A UF
E - 100 lbs/A SCU

1 - no P + K
2 - P + K

F - June 10 mowing at 3" height
G - May 15 mowing at 3" height

Table 12: The influence of applying rates and sources of nitrogen on March 19, 1980 on canopy characteristics before and after mowing on May 15 (I-81 median, near Christiansburg).

	No Nitrogen		Ammonium nitrate 50 lbs/A		Ammonium nitrate 100 lbs/A		Urea Formal. 100 lbs/A		Sulfur-coated urea, 100 lbs/A	
Date	No Fert	P+K	No Fert	P+K	No Fert	P+K	No Fert	P+K	No Fert	P+K
					Color[1]					
4/21	4.3	5.0	2.3	3.0	1.6	1.0	4.0	4.3	1.6	1.3
4/30	4.0	5.0	2.3	2.3	1.0	1.6	3.6	4.3	1.0	1.3
5/26	3.4	3.0	3.0	3.0	2.4	3.0	3.0	3.0	3.0	3.0
6/30	3.7	2.6	2.8	2.6	2.3	2.1	1.8	2.5	1.8	1.8
					Ground cover, %					
4/30	76.6	76.6	83.3	91.6	96.6	95.0	80.0	76.6	95.0	95.0
6/30	80.0	81.6	78.3	86.6	85.0	90.0	86.6	78.3	83.3	91.6
					Legume cover, %					
4/30	26.6	28.3	36.6	23.3	28.3	23.3	33.3	31.6	31.6	20.0
6/30	6.6	16.6	15.0	16.6	15.0	10.3	15.0	14.0	6.6	11.3
					Canopy height, inches					
4/30	8.0	8.0	16.0	16.0	17.3	17.0	8.6	9.3	10.6	14.3

[1] Color ratings - 1 = dark green; 5 = yellowish green

were not influenced by nitrogen treatments. The heights of the grass canopy on April 30 for unmowed grass ranged from 8 to 17 inches for no nitrogen and 100 lb N/A (ammonium nitrate), respectively. Sulfur-coated urea was less effective than soluble N in improving canopy heights of grasses.

After mowing on May 15, percent ground cover ranged from 78 to 90, the best cover was associated with the highest rates of N; likewise, color of foliage after mowing was generally best with the highest rate of N. Also, by June 30 the foliage color with slow release urea-formaldehyde was similar to values with high rates of soluble nitrogen.

It would be desirable to study grass canopy growth during another year without applying additional nitrogen on these two experiments. Increases in protein yields (total yield and percent protein in foliage) resulting from nitrogen fertilizer should recycle nitrogen to improve growth and canopy density the next year.

It may be concluded that nitrogen fertilization with readily available sources of nitrogen improved the height and density of grass canopies. This occurred before and after mowing; hence, nitrogen fertilization improves competition from grass canopies which should reduce invasion of annual weeds. Dense and tall canopies are known to depress seedlings and invasion of weedy species. It would be highly desirable to study nitrogen fertilization and weed invasion as compared to herbicides and growth inhibitors in practical economic management of vegetation in highway corridors over several years.

2. Mowed grass areas by highway personnel

Mowing practices for primary and interstate highways by highway personnel vary widely for different regions and within regions in Virginia. During late June, interstate highways in some regions had not been mowed during mid May. Mowing practices, supervised by different personnel of the Virginia Department of Highways and Transportation, differ for areas in Virginia ranging from stubble heights of around 2 to 8 inches after mowing. Mowing with rotary mowers is invariably closer than with sicklebar mowers. In most regions, highway personnel are restricting mowing operations to medians and shoulders, however, in one area, entire or mowable parts of cut slopes were mowed. In many areas where crownvetch has been used, it has spread from the cut slopes into shoulders under a once-a-year mowing management. Highway personnel could encourage the encroachment of this species, thereby, eliminating the need of frequent mowing, refertilization and the applying of herbicides for weed control.

The mowing practices along U. S. 360 in the vicinity of Tappahannock were excellent. One mower swath was made on each side of the east and west bound highway. It was estimated that mowing occurred earlier than mid May; there was excellent regrowth of the mowed tall fescue and no accumulation of unsightly mowed herbage. Mowing was properly timed as there was nearly 100% control of seedheads.

Conversely, an area along U. S. 29 between Charlottesville and Amherst showed bad mowing management. Entire cut slopes on both sides of the highway were mowed. Mowers traversed the apex of cut slopes (bars reaching downward) to mow all of the vegetation. The entire areas of wide medians were unnecessarily mowed. Also, the mowing operations were started too late as by early June regrowth was nil. The stubble residue of mowed areas had few leaves due to the late date of mowing and mowing too closely. Close and late mowing caused excessive bareness (leaf removal) and slow regrowth was also allied with high temperatures and low moisture. Lack of a leafy regrowth may also be attributed to the tall canopy which shaded the basal area causing the shoots to be very small and etiolated. It is likely that rapid changes in temperature and humidity before and after close mowing caused death of many shoots. The sun was penetrating to the soil in the closely mowed stubble causing high temperature conditions and it is likely that the regrowth of grass will continue to be poor allowing invasion of weeds. The stubble was "open" because there was no leafy regrowth. Mowing in late May also caused an accumulation of straw-colored tall fescue seedheads.

Traveling on U. S. 29 it is estimated that mowing was completed before mid May as there was no accumulation of mowed material. Leafy tall fescue growth after mowing was 6 to 8 inches high giving an attractive groomed appearance which excluded weeds. However, later we saw close mowing of entire cuts rather than mowing one strip. Late mowing caused a straw colored appearance due to the apex of the stubble because of no regrowth; also, mature seedhead mowed herbage lying on the surface was brown. The medians were mowed much earlier and were of an attractive green color.

3. Legumes in mowed areas

a. Mowing experiments with flatpea, sweetpea and crownvetch

A mowing experiment was imposed over a demonstration seeding of perennial legumes established in late winter of 1979. Perennial sweetpea at 40 lb/A and flatpea at 20 lb/A were seeded into a large interchange where Prices Fork Road and Route 460 bypass intersect near Blacksburg. A seedbed was prepared with a field cultivator leaving the soil surface in an extremely rough condition. The soil materials were of heavy clay subsoil with pH 7.8, Ca - very high, Mg, very high, P-medium, and K-medium. Soil amendments made at time of seeding were N at 50 lb/A as NH_4NO_3, P_2O_5

at 200 lb/A, and K_2O at 50 lb/A. Kentucky 31 tall fescue at 25 and annual ryegrass at 5 lb/A were used as companion species.

A mowing experiment was imposed 3 months after establishment when flatpea seedlings were about 5 inches high and made up 20% of the vegetation. Annual ryegrass was in the seedhead stage of growth; it made up 30% of the vegetation. White clover and weeds at various heights made up 50% of the vegetation. Total ground cover was about 60%, leaving 40% of the soil exposed. Eleven mowing treatments (different heights and dates, Figure 10), were imposed over the area seeded to flatpea.

July mowing at a 6-inch height caused minimal damage to the legumes but ryegrass seedheads and the weeds were reduced. Abnormal August weather stimulated growth of all species. It was cool, overcast and rained frequently throughout the month. These climatic conditions aided regrowth of the legumes mowed in mid-August. Mowing in mid-August, especially at a 3-inch height, appeared to damage the flatpea plants. However, a remarkable regrowth of flatpea began about a week after mowing; axillary buds grew 4 to 6 inches, tillering was induced (3-4 per plant) and rhizomatus growth occurred.

Flatpea plants showed adaptive characteristics, mowed plants developed prostrate tillers but had lower leaf areas than unmowed plants. After September mowing, tillering continued, reaching about 10 tillers per plant. Regrowth after October's mowing was minimal.

Data in Table 13 show the accumulative effects of various mowing treatments during August and September in 1979 and the 1980 residual effects resulting from the July-October, 1979 mowing treatment. The October 10 data are difficult to interpret because the ground cover and heights of plants are confounded with mowed and unmowed growth. However, the

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Figure 10:

Title: Mowing management of newly seeded, mixed, tall fescue - Lathyrus spp. sod.

Objectives: To determine optimal mowing regimes for establishment of mixed tall fescue - Lathyrus spp. sods.

Location: Large infield at interchange at the Blacksburg 460 bypass and Prices Fork Road, NE of the overpass.

Established: Lathyrus spp. were drilled in mid-April 1979 into the infield area which had been tilled with a field cultivator. Flat pea was seeded @ 20 lbs/A; perennial sweet pea @ Mowing treatments applied in 1979.

A = mow July 3 @ 6"
B = mow July 3 @ 6"; Aug 15 @ 6"
C = mow July 3 @ 6"; Sep 15 @ 6"
D = mow July 3 @ 6"; Oct 15 @ 6"
E = mow July 3 @ 6"; Aug 15 @ 6"; Sep 15 @ 6"
F = mow July 3 @ 6"; Aug 15 @ 6"; Sep 15 @ 6"; Oct 15 @ 6"
G = mow July 3 @ 6"; Aug 15 @ 3"; Sep 15 @ 3"; Oct 15 @ 3"
H = mow July 3 @ 6"; Aug 15 @ 3"
I = mow July 3 @ 6"; Sep 16 @ 3"
J = mow July 3 @ 6"; Aug 15 @ 3"; Sep 15 @ 6"
K = mow July 3 @ 6"; Oct 15 @ 3"

← To Blacksburg

Rep I | Rep II →

A	K	E	H	C	B	I	D	G	J	F	H	B	G	C	K	J	I	A	D	F	I
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

Rep III — To Prices Fork →

E	C	J	K	E	A	G	F	D	H	B
23	24	25	26	27	28	29	30	31	32	33

Plot size - 5' x 100'

Table 13: The canopy characteristics of flatpea in response to various heights and dates of mowing.

	Mowing treatments[1] giving month and height in inches										
Parameters	None	Aug @ 6	Sept @ 6	Oct @ 6	Aug Sept @ 6	Aug Sept Oct @ 6	Aug Sept Oct @ 3	Aug @ 3	Sept @ 3	Aug @ 3 Sept @ 6	Oct @ 3
October 10, 1979											
Soil cover, %	36.4	30.0	29.0	45.0	28.0	29.6	18.0	23.0	7.3	27.0	30.6
Height, in.	9.0	7.0	7.0	10.6	6.6	6.6	4.3	5.0	3.6	5.0	8.3
June 17, 1980											
Soil cover, %	58.3	45.0	36.6	50.0	30.0	43.3	20.0	48.3	25.0	25.0	26.6
Height, in.	16.6	12.0	11.6	16.0	10.6	14.0	8.3	14.0	10.6	11.3	8.0

[1] The entire area was mowed on July 3, leaving a 6-inch stubble; subsequent mowing dates were on the 15th day of the indicated month.

June 17, 1980 data show the best soil cover occurred without mowing after July 15 the previous year; however, canopy development as indicated by soil cover was similar when mowed in August or on October 15 at a 6-inch height. Mowing several times during 1979 depressed growth of flatpea (soil cover and height) the 3-inch mowing heights in October being especially harmful.

It may be concluded that flatpea seedling plants were tolerant of frequent mowing under favorable rainfall and temperature environments. This legume appears suitable for seedings in medians with one annual mowing.

An area surrounding the flatpea mowing experiment was seeded to sweetpea and companion species as mentioned for flatpea. This area was mowed once on July 3 at 6 inches to reduce competition from weeds and to remove annual ryegrass seedheads. Without additional mowing after seeding, sweetpeas had 80% vegetative cover with prolific blooming with red, white and pink blossoms. This good canopy of sweetpea subdued most of the Kentucky 31 tall fescue and annual ryegrass seeded with it and controlled volunteer legumes and weeds.

Fescue growing among legumes is more vigorous and much darker green than fescue seeded with annual ryegrass and redtop without a legume. Grasses seeded in the absence of legumes had a 30% vegetative cover with 15% of that being weeds. The grasses appear nitrogen deficient, being pale green in color and lacking in vigor.

Across the Prices Fork exit ramp, in another section of the interchange area, crownvetch was seeded with Kentucky 31 tall fescue in soil that had been field cultivated in March, 1979. The area had been mowed once on July 3, 1979, at 6 inch height during establishment to remove seedheads of annual ryegrass and to reduce competition by weeds. The area was mowed again in mid-May, 1980, by personnel of the highway department. Crownvetch at 45% ground cover was persisting with Kentucky 31 tall fescue in the heavy day subsoil. The ground cover of crownvetch ranged from 1% to 90% intermingled with Kentucky 31 tall fescue and white clover plants. The mowed crownvetch was short and blooming prolifically. Cover by Kentucky 31 fescue appeared more vigorous and darker green in color in close vicinity to the leguminous cover as compared to areas dominated by grass. Tall fescue, crownvetch and white clover are growing in harmony with one mowing per year. It is expected that crownvetch will subdue the other species.

b. Mowed grass-legume areas by highway personnel

General observations along highways show that persistent perennial cool season legumes tolerate one or two annual mowings on cut slopes and medians. Such legumes would improve the density of canopies <u>per se</u> and augment grass growth by recycling nitrogen, thereby reducing weeds by canopy competition. It is known that crownvetch forms dense canopies that deter weeds when not mowed. Mowing once yearly as a basal swath on cut slopes has maintained a near 50-50 legume-grass balance. With such a once-a-year mowing management, crownvetch has persisted in all three physiographic regions and often invades mowed shoulders.

4. Herbicides and growth inhibitors

Observations along Virginia highways indicate that an annual practice of applying herbicides and growth regulators along highways may cause undesirable effects, does not give consistent control of seedheads and may not be economic. Repeated annual applications of herbicides and certain growth regulators may depress grass growth; poor grass stands and vigor, leaving open canopies may cause severe invasion of weeds and annual legumes.[1] A sparse cover and yellowish color of grasses and the presence of annual weeds and legumes (little and big hop clovers, rabbit clover and annual lespedeza) indicate a nitrogen deficiency. Spring applications of herbicides are not giving suitably good weed control because canopies are not sufficiently dense. Also, growth inhibitors undoubtedly reduce the density of grass canopies due to depressed seedhead development, thereby allowing more light penetration and weed survival or regeneration when compared with uninhibited grass growth. Since one mowing, delayed until flower buds appear above the mowing height, gives complete control of seedheads it appears that delaying herbicide application to several weeks after mowing would be a practical and economic alternative. Money spent for late winter herbicides and inhibitors might be used to apply nitrogen or pursue other treatments to give a dense canopy to inhibit weeds. The first principle for weed control is to employ cultural practices to grow and maintain a dense canopy all year. This will exclude almost all annual weeds and legumes. Applying herbicides should serve as a secondary emergency tool to control annual and perennial weeds by spot spraying.

5. Woody vegetation

Various woody species invade naturally in the various environments along Virginia highways. With seed sources and non-woody vegetation as controls, woody species usually invade more rapidly on slopes with cool than for warm aspects, moisture and temperature environments being more favorable on slopes with cool aspects. We repeatedly observed that crownvetch canopies deter invasion of woody species as compared to grass canopies

[1] Based on discussions with Dr. R. E. Schmidt, Associate Professor of Agronomy, VPI & SU

in agreement with Sharp, 1978. Canopies of cool season legumes, crownvetch, flatpea and perennial sweetpea, inhibited invasion of woody species more than sericea lespedeza. The latter legume, growing during summer seasons, causes less competition than the other legumes that grow actively during a long season. Thus, where woody growths are undesirable, their invasion may be delayed or depressed by canopies of the cool season legumes.

E. Legumes Adapted for Cut and Fill Slopes

Many experiments in highway corridors on cut and fill slopes were established in three physiographic regions of Virginia to investigate legume establishment and maintenance (Woodruff and Blaser, 1969; Green et al., 1973; Wright et al., 1976; Adams and Blaser, 1979). These and other investigations have shown that perennial legumes such as crownvetch and sericea develop long lasting vegetative covers for erosion control that require little or no maintenance. Designated perennial legumes are adapted to many environments along Virginia highways. Persistent legumes become established rather slowly through a series of changes in plant succession (Blaser et al., 1979) usually requiring two or more years. While obtaining final data for writing the final report on the four objectives of this project, information was obtained on the performance of legumes such as crownvetch, flatpea, perennial sweetpea, sericea, birdsfoot trefoil, milkvetch and other legumes. Observations from these experiments established with other projects should aid in updating recommendations for seeding specifications to obtain low cost vegetative covers for erosion control in various environments along Virginia highways. Only those legume experiments on cut and fill slopes close to or on the route of specific research objectives of this project were inspected. Detailed information on soil characteristics and experimental diagrams are intentionally omitted as such information can be obtained from the final reports cited earlier. It would have been desirable to obtain data from all experiments.

1. Mountainous region

    a. Crownvetch experiment, 460 bypass near Christiansburg

The basal part of a cut slope with a good canopy of crownvetch had been seeded by highway personnel. Soil tests showed pH ranges of 6.3 to 8.1, phosphorus high and potassium low to medium (Adams and Blaser, 1979). Thus, it was postulated that boron and/or bacterial inoculant might stimulate crownvetch invasion in an upward direction on the slope. Combinations of these two variables applied just above the crownvetch growth did not stimulate the upward spread of crownvetch as compared to no treatment. Through proliferating roots, crownvetch had invaded about 4 feet into the sparse grass cover on this steep cut during 1979 and early 1980.

Crownvetch had encroached into and stabilized the soil in rills as deep as 18 inches where erosion had occurred previous to seeding crownvetch on the basal slope section. There was a 100% soil cover with crownvetch on the basal half of this cut that had crownvetch included in the mixture; the grassy and weedy vegetative cover ranged from 50 to 60% on the upper half of the slope where crownvetch had not been seeded.

It would be desirable to study other variables such as potassium to augment the spread of crownvetch.

b. Crownvetch and sericea, I-81 near Christiansburg

This fill slope with a warm southern aspect was predominately sericea previous to 1977. During early spring 1977, we observed that most of the sericea had died during winter, apparently due to low temperatures. Crownvetch has invaded rapidly, developing an 80 to 100% vegetative cover. A few remaining sericea plants are weak and are making meager regrowth.

c. Perennial flatpea and sweetpea along U. S. 460 bypass

The experiment on cut slopes on each side of U. S. 460 bypass near Blacksburg was treated uniformly with phosphate; lime was not needed according to soil tests. Two legumes were seeded separately in established sod, each with and without paraquat to control grass competition during 1974 (Wright et al., 1976). It is difficult to interpret the results because the diagram does not agree with the legume treatments. However, the canopy covers of both flatpea and perennial sweetpea are very satisfactory, both legumes having a 50 to 100% cover. There is intermixing of sweetpea and flatpea; e.g., both legumes are spreading beyond plot borders where they were seeded and encroaching into each other. Perennial sweetpea is blooming prolifically, giving a colorful appearance. Flowers of flatpea are not conspicuous, but the dark green foliage is attractive as viewed while traveling on the bypass.

d. Crownvetch seeded with companion grasses

On a cut slope along 460 bypass just north of Prices Fork Road near Blacksburg, crownvetch was seeded with each of two companion crops, buckwheat and German millet in late July, 1978. Two years later, the crownvetch canopy cover is near perfect having more than an 80% ground cover with plants being healthy and vigorous.

Adjacent to the experiment, a bare slope was seeded with crownvetch and companion species in August 1978 using a paperfiber mulch which gave a very poor stand. The poor results are associated with moisture stress caused by a poor paper mulch (large pieces) and high summer temperatures causing high rates of evapotranspiration. These and other results show that the best chances for successful establishment of crownvetch are obtained from late winter-early spring seedings.

e. Legumes with companion species and mulches

This experiment established with three legumes (sericea, flatpea, and crownvetch), various companion grasses and mulch treatments, was established in 1974 along Route 617 near Route 8 in Floyd County. Crownvetch and flatpea continue to give a 100% canopy cover on the respective plots where these legumes were sown. These unmowed legumes have completely dominated over grasses on most of the plots. However, stands of sericea are very poor; the plants may die this year (1980). At this cool slope site with an unfavorable soil environment, flatpea is more aggressive than crownvetch; however, both species are very well adapted. There is yellowing of some leaves of crownvetch and flatpea which may be associated with drought, especially on the rocky areas where there is little fine subsoil or other soil material. There is very little encroachment of woody vegetation whereever either of the two legumes, flatpea or crownvetch, have dense canopies. Encroachment of blackberry and locust was noted across the top of the slope; however, the plants were very small, locust generally being 3 feet high. Adjacent to the site where there are no legumes, good stands of woody vegetation appear; the height of the plants being twice that of those with legume associations. The suppression of woody vegetation agreed with other published information (Sharp, 1978; Blaser et al., 1979).

For another seeding on a warm cut slope on Route 617 seeded in May 1974, crownvetch and flatpea have dominated over sericea. One plot had a 15% cover of sericea and all other plots seeded to sericea had been subdued by crownvetch and flatpea. Flatpea was more aggressive than crownvetch but both species have invaded into each other. A 100% ground cover occurs in plots seeded to the respective legumes. When investigating the spread of the legumes over the apex of the cut slope (not seeded or fertilized), crownvetch spread up to 6 feet under the fence and into a red clover-orchardgrass field. Crownvetch also invaded across apex sections (40 feet) of plots seeded with sericea or flatpea. On the other hand, flatpea did not encroach perceptively over the apex of the cut slope. Thus, flatpea invaded laterally but not over the top of the slope. Flatpea and crownvetch are very well adapted to this environment and should be used on state roads to control erosion and inhibit woody vegetation invasion.

Woody vegetation is encroaching rapidly where the two persistent perennial legumes were not used. There is also considerable red clover encroaching on some of the cut slopes seeded to grass; the grass lacks vigor due to low nitrogen. There was some soil erosion with grassy vegetation as compared to no erosion for the cover with the two legumes. It is predicted that woody vegetation and legumes such as red clover may encroach to avoid the severe deterioration of the grassy vegetation.

f. Crownvetch with grass associates in Floyd County

This experiment on Route 8 near Route 810 intersection had crownvetch seeded with companion species and grass associates in June 1978. The perennial grasses were weeping lovegrass and Ky 31 tall fescue, and the annual companion grasses were German millet and buckwheat. Crownvetch stands were equally good with the annual companion species. Generally, there was better encroachment of crownvetch into weeping lovegrass than into Ky 31 tall fescue. This was more evident on the warm than on the cool slope. The more rapid spread of crownvetch into lovegrass than Ky 31 tall fescue is attributed to less competition from lovegrass because its growth is restricted to a short season by cool temperatures during spring and fall. The plots seeded with crownvetch had a legume cover ranging from around 30% to nearly 100%, an excellent vegetative cover during two years.

On Route 729 near Route 8 in Floyd County, the cuts had been stair-step graded and seeded to grasses. The grass mixture gave an excellent initial vegetative cover, however, much of the vegetative cover is sparse due to low nitrogen fertility. Including sericea, crownvetch or flatpea would have developed a stable vegetative cover.

g. Legume experiment in Floyd County, Route 729

This experiment on a sunny cut slope along Route 729 had three legumes seeded with three lime rates each with two rates of P_2O_5 and K_2O. Sericea lespedeza had been subdued by other vegetation and legumes. Crownvetch had made the most spread giving a 100% cover on many plots and had invaded laterally into other legume seedings. Crownvetch also invaded over the shoulder of the road. Stands of flatpea were fair to excellent. It appeared that flatpea was adapted to the low lime (low pH) plots but depressed by low phosphorus. Crownvetch appeared to be more vigorous with low phosphorus than the other legumes. Sweetpea seedings gave poor to good cover; it has spread less than flatpea and crownvetch.

h. Legume experiment in Franklin County

This is an experiment that was established in September 1974 in Franklin County along Route 785. This area showed a degeneration of legumes when data were taken in 1978 (Adams and Blaser, 1979). Data taken in April 1978 were likely too early in the season for the legumes to express growth potentials, also, this was a dry year.

Presently, in June 1980, there is a beautiful cover of crownvetch and flatpea. For replication II with rough soil surfaces before seeding, flatpea is dominating over crownvetch. However, crownvetch is spreading further beyond the borders of its original seeding than flatpea and has encroached into the entire shoulder, having a good stand next to the highway. In replication I with smooth and hard soil surfaces as treatments for seeding the two legumes, crownvetch is dominating over flatpea for the rough soil preparation. However, the legumes are in good balance giving a 100% cover. The good response of flatpea with roughened soil surfaces is attributed to seed coverage and better germination and root development for legumes with large seeds. This is the most vigorous stand of crownvetch and flatpea among all experiments in Virginia.

i. Legume experiments in Floyd County, Route 644

Several experiments were planned to investigate the establishment of persistent perennial legumes on steep cut slopes as influenced by annual and perennial companion species (Adams and Blaser, 1979). The entire area of the cut slope was treated with lime @ 2 T/A, 15-30-15 @ 667 lbs and 1500 lbs/A of woodfiber. Flatpea was seeded with various perennial grasses in June 1977. Observations in June 1980 showed that the westerly faced cut slope had erosion across the mid section; however, there was a good stand of flatpea across the basal part of the slope the band of flatpea being 4 to 6 feet wide. This band is wide enough to prevent most of the falling soil material from becoming a stream pollutant. However, a few plots had a good flatpea cover over the entire slope, the best stands of flatpea generally occurring in association with lovegrass. Summer growth of lovegrass apparently gave a protective cover which held seed and fertilizer in place to encourage the establishment of slow developing legumes such as flatpea. When considering that the seeding was made during the summer season on a hard slope surface with many rills, it is remarkable that this large seeded legume, flatpea, developed a reasonably good protective canopy. With an additional lime and phosphate application (no seed), it is predicted that this slope will become covered with a dense canopy of flatpea.

In a second experiment for establishing crownvetch, Lehmann and weeping lovegrass and velvet bentgrass were tried as grass associates. Crownvetch was seeded over all of the plots @ 20 lbs with woodfiber at 1500 lbs and a 15-30-15 fertilizer at 667 lbs/A. All treatments were applied in May 1977. There were also three rates of lime, none, 1.5 and 3 T/A. In general, the crownvetch cover was very satisfactory, covering from 70 to nearly 100% of the slope of each seeded plot. The crownvetch cover was good on the plots without lime; however, the best crownvetch occurred when lime was applied. There were no differences in crownvetch establishment due to the companion grass species. This very satisfactory cover of crownvetch should continue to stabilize the cut slope indefinitely.

2. Piedmont region

a. Crownvetch on a stair-step graded cut

A 1.5:1 cut slope with a 60 foot slope aspect was stair-step graded and fertilized with 1000 lbs/A of a 10-20-10 fertilizer after liming at 2 T/A. The seeding mixture of lovegrass, Ky 31 tall fescue, sericea and crownvetch was applied in June 1977 on this east facing slope on U. S. 29 near Hurt. The 1977-78 seasons were rather unfavorable for establishing vegetation because of prolonged periods of drought. However, the initial stands of lovegrass with some legumes, through plant succession, have developed into a 100% vegetative cover with 70% of the soil cover being crownvetch by June 1980. The spotted cover of sericea is being subdued by crownvetch; it is predicted that this will be entirely crownvetch by 1981.

This is an excellent exhibit of the desirability of using stair-step grading. A persistent leguminous vegetative cover with zero erosion has been obtained with one seeding during unfavorable moisture conditions on this infertile subsoil material (high aluminum-low calcium-low phosphorus complex).

Flatpea, space planted across the B horizon along the apex of the slope, displayed good stands but poor spread (invasion) into other vegetation.

b. Companion grasses and crownvetch establishment

This experiment on a steep cut slope on Route 640 Pittsylvania County was established in July 1977 (Adams and Blaser, 1979). The initial stands of 5 to 13 crownvetch plants degenerated to 0.09 and 0.24 plants during 1978 because of seedling damage from moisture stress.

Presently in 1980, crownvetch has developed into an excellent protective canopy ranging from a 30 to a 100% soil cover. The best crownvetch cover occurred where Ky 31 tall fescue was used as the companion species. The Lehmann lovegrass was not a good associate. There is still some velvet bentgrass present. With lime treatments, the best cover of crownvetch occurred with the 3T/A rate, the best cover being across the base of the slope. To develop a 100% cover on the entire slope, the area should be treated with lime and phosphate across the bottom of the cut slope during the autumn or late winter seasons so that crownvetch will invade upward on the slope. The slope across the road from this experiment, seeded without legumes, had less than a 50% soil cover. This area will likely need to be reseeded and refertilized to avoid erosion.

c. Perennial sweetpea-crownvetch experiment, Pittsylvania County

The objective of this experiment on Route 640 in Pittsylvania County was to study Lehmann lovegrass and velvet bentgrass as companion grasses for establishing perennial sweetpea and crownvetch (Adams and Blaser, 1979). Lime rates at 0, 1.5 and 3 tons of lime were used. The fertilizer rate was 667 lb/A of a 15-30-15. The crownvetch had been seeded across the plots on the upper portion of the slope, and perennial sweetpea was seeded across the basal half of the cut slope. The two legumes were intermixing, showing the desirability of using a perennial sweetpea with crownvetch for highway beautification. The perennial sweetpea had colorful reddish flowers distinctly conspicuous and differing from the color of crownvetch flowers. The color and growth of the legumes was best where lime had been applied, however, the cover was surprisingly good without liming.

Across the road crownvetch was seeded with two grass associates. A near 100% crownvetch cover had developed except in small areas where irrigating waters from a field flowed over the cut slopes causing seed, mulch and fertilizer to erode away.

d. Legume experiment along U. S. 360

This experiment with perennial legumes and weeping lovegrass as an associate was seeded on a northern cut slope aspect just east of Greenbay (Woodruff et al., 1969). Many years after seeding, excellent vegetative covers of crownvetch seeded alone and for a perennial sweetpea-flatpea mixture have persisted without maintenance treatments. The sparse lovegrass cover was attributed to the vigorous legumes causing competition for light and moisture. Lovegrass, grown alone without legumes, had around a 50% ground cover; it had deteriorated from a complete cover due to low soil nitrogen.

In a second experiment across U. S. 360 on a south slope aspect, various legumes had been seeded with different amounts of lime and phosphate. The diagram of this experiment established more than ten years ago could not be located. On some plots, flatpea is invading into crownvetch; with other plots, the reverse is occurring with flatpea cover lacking vigor. Except for several plots, flatpea is very vigorous having a canopy of about 40 inches in height.

e. Legume experiment on a cut slope along Route 628

This experiment established in 1977 had legumes seeded with companion grasses and potassium, lime and phosphorus applied uniformly. The cut slope with a 5 to 8 foot slope aspect had a good stand of flatpea, perennial sweetpea or crownvetch across the base of the (plot) slope with good stands over the entire slope for some plots seeded with flatpea. The growth and stands were best for flatpea and poorest for perennial sweetpea.

f. Legume experiment on 460 bypass near Lynchburg

This experiment established on a cool cut slope aspect in October 1976 included a uniform treatment of 150 lbs P_2O_5 and 2000 lb/A of limestone. Flatpea has spread laterally more than any other legume and it is the most vigorous, showing the best ground cover and spread in June 1980. Crownvetch cover is very satisfactory, but growth and cover of sweetpea is unsatisfactory. Milkvetch was a failure. Crownvetch is spreading more rapidly than flatpea. A natural invasion of perennial sweetpea on a cut slope was noticed near this site.

g. Sericea degeneration

Along I-64 approaching Charlottesville from Richmond, there is a serious degeneration of sericea causing various weeds and briars such as blackberry and polkweed and woody species as sumac to invade. The sericea is not completely dead, but many of the plants have only a few tillers, a canopy of tillers per plant being desirable and normal.

This degeneration of sericea suggests that varieties of perennial lespedeza should be investigated for longevity and persistence. It is not known why sericea lespedeza is degenerating as there is no information on how many years a plant normally survives. Young stands of sericea often appear more vigorous than old stands. It would be desirable to conduct research on the life history of sericea and the adaptation and longevity of different cultivars in different environments in Virginia.

h. Experiment with legumes, Route 29

An experiment on a sunny cut slope facing east on U. S. 29 South near Route 760 intersection was seeded in early June 1974 to test woodfiber mulches and tacking agents. The area was seeded with two legumes, flatpea and crownvetch, on the upper and lower half of the cut slope. This is a beautiful exhibit stabilizing a sunny cut slope with two cool season legumes. There is a near 100% legume cover.

The basal part of the slope for all treatments had been mowed to an 8 inch height perhaps once each year. Crownvetch appears more tolerant of mowing than flatpea; however, both species are persisting under the mowing but both legumes would have been much more vigorous without mowing. Crownvetch is invading into the flatpea plots, where flatpea invasion into crownvetch is relatively mild. Crownvetch has invaded over the top of the slope back 4 to 6 feet from the original seedings. Flatpea invasion has been nil.

i. Legume-lovegrass associations in Nelson County

This is a large cut slope on U. S. 29 about nine miles from Lovingston. This slope was seeded to weeping lovegrass and legumes. Much of the slope has flatpea in small to huge islands; also, crownvetch appears in large islands (dense canopies in pure stands). It is anticipated that this entire cut slope will eventually be dominated by crownvetch and flatpea. The flatpea canopy is dark green in color, there being no flowers crownvetch is blooming profusely.

j. Crownvetch and flatpea near Lovingston

This experiment on a 1:1 cut slope with a roughened surface was established on Route 718 near Lovingston in about 1974. The slope was quickly stabilized with grass and leguminous vegetation, flatpea establishing more readily than crownvetch (Wright et al., 1976). Presently (June 1980) there has been soil slippage due to the shallow rooting of the legumes because of the low soil pH and high aluminum in the subsoil. Crownvetch appears more vigorous and spreads more rapidly at this site than does flatpea; however, both legumes are well adapted.

k. Legumes with companion species

This experiment on U. S. 460 and Route 291 near Lynchburg was established in May 1975. Of the three cool season legumes seeded with various companion species, crownvetch spread profusely and is invading into plots seeded with other legumes. However, the invasion of crownvetch into flatpea is moderate. In the center of plots seeded to flatpea, there is only a sparse population of crownvetch. All plots seeded with perennial sweetpea are primarily crownvetch. Vegetative covers with flatpea and crownvetch are excellent.

l. Flatpea and crownvetch with lime rates near Lynchburg

This experiment is located on Graves Mill Road, Route 126. Flatpea is well adapted; however, the exceedingly vigorous crownvetch continues to spread rapidly and has invaded into other leguminous plots. Flatpea is vigorous, there being relatively little crownvetch invasion into it.

There is excellent crownvetch growth on cut and fill slopes among the interchanges of 460 and 29 near Lynchburg. Crownvetch is invading into mowed areas and is persisting under mowed conditions.

3. Coastal Plain Region

a. Crownvetch on U. S. 460 near Suffolk

Along U. S. 460 just west of I-85 on a cut slope with a cool aspect of about a 15 to 20 foot slope, crownvetch made up about 80% of the cover when seeded with lovegrass and other grasses. The crownvetch, 1.5 to 2 feet high, was blooming, but the foliage color was light green and plants were less vigorous than for the Piedmont. However, the crownvetch is persisting; growth could likely be improved by appropriate fertilization after soil samples and testing.

b. Flatpea near Suffolk

The slopes of this interchange in the Coastal Plain was seeded by personnel of the Suffolk Highway Department in about 1975. It was considered a failure but inspection in 1977 showed good stands of flatpea. During June 1980, the stands of flatpea continued to provide an excellent canopy cover, being better on slopes with cool as compared to warm aspects.

c. Sericea near Suffolk

This cut on Route 604 near U. S. 58 Suffolk bypass was planned to study weeping and Lehmann lovegrasses with and without molybdenum with pelleted and unpelleted sericea seed. The experiment was established during summer 1977. The sericea stand and growth on this cut slope was very satisfactory. There were no differences in sericea growth and cover with grass associates and molybdenum. Almost all of the lovegrass had died. The sericea stands were best on this slope with the least moisture stress. One plot, composed of clay material, had better stands and growth of sericea than for sandy conditions within the slope. However, this is an exhibit of sericea surviving and being vigorous on sandy soil material.

Various species of woody vegetation were encroaching into the sericea. Natural woody vegetation is encroaching more rapidly into sericea as compared with cool season legumes (crownvetch, flatpea and perennial sweetpea) at other locations. The cool season legumes grow during longer seasons and possess denser canopies than sericea, thereby depressing woody plants.

d. Experiments at intersection I-64 and Indian River Road

These experiments were established by Green et al. (1973) and by Wright et al. (1976). They involved seedings with sericea lespedeza, flatpea, perennial sweetpea and crownvetch. One experiment showed very healthy flatpea and crownvetch though the crownvetch was dwarfed on this sandy fill slope. Nevertheless, the crownvetch encroached into the flatpea much more than the flatpea encroached into the crownvetch. The crownvetch, with a 100% vegetative cover and blooming prolifically, showed drought stress, the leaves being small as compared to better moisture environments.

Another experiment included perennial sweetpea, sericea and crownvetch, all seeded alone. The stands of all legumes were relatively good. The best stands of perennial sweetpea were at the basal part of the fill slope. There was severe encroachment of sumac. Perennial sweetpea was surviving under the sumac. Plots seeded to sericea ranged from dense to poor stands.

In another experiment, sericea had disappeared because of competition from other legumes. Flatpea was generally better adapted than crownvetch; e.g., flatpea invaded laterally more than crownvetch.

It may be concluded that sericea and the three cool season legumes are all suitable for sandy soil cut slope environments in the Coastal Plain.

e. Legume adaptation near Williamsburg

Experiments were established about ten years ago on warm and cool slope aspects on each side of east bound I-64 near Williamsburg (Toano).

On the warm slope aspect, crownvetch and perennial sweetpea are colorful with beautiful displays of flowers where grown alone and in association where plants invaded into each other. Both legumes are adapted to this warm cut slope site in the Coastal Plain with crownvetch making the best cover and giving a 100% vegetative cover over much of this 4:1 cut slope. Crownvetch appears less vigorous in the Coastal Plain than for the Mountainous region, but it is adequately persistent having dominated over grasses and weeds and stabilized the subsoil material on the cut slopes along I-64.

Adjacent to this experiment, crownvetch was seeded with weeping lovegrass where it now makes up 60 to 70% of the cover. The crownvetch cover is excellent along the slope base where there is 100% cover. In the event of erosion from center and apex portions of the cut slope, crownvetch is sufficiently vigorous to continue growth through eroded materials to inhibit erosion. Also, if necessary, the vigor of crownvetch could be augmented by adding lime and/or phosphorus.

Across the road on a cool cut slope aspect, there is a beautiful display of a mixture of crownvetch, perennial sweetpea, some flatpea and sericea lespedeza. The sericea is giving a protective cover on about 10% of the slope along the apex. Crownvetch has made the best growth and has been a strongly invading species. There has been little drought stress on this cool slope aspect during the spring season; hence, plants are more vigorous than for the warm slope previously discussed. With flatpea, the plants are vigorous, often producing canopies more than 4 feet high in islands within crownvetch. Perennial sweetpea appears in mixed associations with crownvetch over the entire experimental area. A sericea lespedeza-flatpea sweetpea association appears attractive, the light green distinctive foliage color of sericea, the dark foliage of flatpea and colorful flowers of perennial sweetpea give a pleasing appearance. In conclusion, all three of the cool season legumes are adapted to the cocl season legumes are adapted to the cool, warm and hot aspects. Sericea had the best stands on the cool slope but it is generally best suited to the warm slope.

f. Experiments with crownvetch along U. S. 17

These experiments established on bare cut slopes with various legumes and other variables located on U. S. 17, 3 miles south of Route 3 intersection were established with a previous project (Adams and Blaser, 1979). Various mulch treatments and pelleted and unpelleted crownvetch seed all gave an excellent cover of crownvetch, making up 70-90% of the soil cover on this east slope aspect. There were a few scattered flatpea and perennial sweetpea plants; seed of these two legumes were not included in the mixture. The seeds had apparently remained in the hydroseeder from a previous seeding. Shoulders around the curve in a turn off into a residence were seeded and had excellent canopy covers of crownvetch.

The second experiment had a seeding mixture of three cool season legumes and sericea lespedeza. The objective of this experiment was to study the effect of micronutrients on the vigor of the legumes (Adams and Blaser, 1979). Unfortunately, uncontrolled water from above the cut slope caused differential erosion and variance among the treatments. After examining the three replications several times, more blooming of crownvetch cover could be associated with the high as compared to the low rate of micronutrients. The check treatments and the treatments with molybdenum were similar. A response to micronutrients with the two perennial peas was not apparent. This was a beautiful exhibit of an intermixture of four different legumes. The reddish flower color from perennial sweetpea within the crownvetch and the distinctive green color of sericea lespedeza and flatpea gave a very attractive canopy cover on this cut on a coolish slope.

g. Legume experiment near Saluda, Coastal Plain

This experiment on a cut slope with a western exposure is located 12 miles north of Saluda on U. S. 17 southbound road. Originally, treatments were woodfiber mulch treatments, surface application, incorporation and rates of the fertilizer materials. The experiments were established on June 6, 1974. By June 1980, there was a fantastically good mixture of flatpea and crownvetch over the entire site. On a few plots where the legumes have not invaded, lovegrass is dying because of low nitrogen status of the soil. Differences in growth of legumes with rates of a 10-20-10 ranging from 750 to 1500 lbs/A could not be detected. It is concluded that crownvetch and flatpea make a beautiful association and are well adapted to this environment for cut slope stabilization in the Coastal Plain region of eastern Virginia.

h. Legumes on cut slope apexes near Richmond

The seeding was planned to develop a canopy cover of legumes across the apex of cut slopes to inhibit erosion. A 6 foot apex section of cut slopes along U. S. 150 Richmond bypass was seeded in March 1979 with a slurry of seeds from three legumes, P_2O_5 at 100 lbs and lime at 2000 lb/A. The base of the cuts are Piedmont granitic material with Coastal Plain depositions on top of the cuts. The 1:1.5 cut slopes have easterly slope aspects ranging from 60 to 100 feet. The leguminous vegetation on the slope apexes is remarkably good for these seedlings 15 months old. The leguminous growth is primarily perennial sweetpea with some perennial flatpea but few or no crownvetch plants. Flatpea and the perennial sweetpea plants had stems 18 inches to 4 feet long and sweetpea was blooming. The best sweetpea plants occur over the crest of the slope where soil moisture and fertility conditions are better than for the cut slope aspect. The poor stand of flatpea and absence of crownvetch are likely associated with severe competition from the weeping lovegrass. This dense grass canopy caused strong moisture and light competition. Seedling vigor, poor for crownvetch, intermediate for flatpea and best for perennial sweetpea, may explain why the best stands occurred with sweetpea. However, perennial sweetpea stands were also inhibited because of the lovegrass competition. It would be desirable to apply lime and fertilizer to augment legume encroachment and soil stabilization. It is expected that the legumes will invade downward on slopes by seed and by vegetative mechanisms, especially if lime and mineral nutrients are applied as needed.

The Kentucky 31 tall fescue or weeping lovegrass on the cuts is highly nitrogen deficient and encountering moisture stress. Although there is little rilling at present, it is anticipated that erosion and rilling will become severe requiring reseeding and costly repair work. To avoid this, it is recommended that a perennial legume mixture be seeded across the basal section of the cuts and/or over the entire cut with lime, phosphorus, and appropriate strains of bacteria for nodulation. It is easier to establish legumes at the base of cuts than for any other slope section. Such established legume canopies would encroach upward on cut slopes and arrest eroding and sloughing material.

On the left of the north bound lane, there were good stands of volunteer growths of perennial sweetpea. In shaded areas, perennial sweetpea was up to 8 feet high climbing over honeysuckle and persisting under trees.

F. Managing Extremely Acid Areas

Additional treatments were applied to an experiment initiated in the previous project (Adams and Blaser, 1979) on the effects of lime and crushed limestone on establishing vegetation on an acid sulfate cut slope near Clifton Forge. The experiment was seeded initially in March 1978, then reseeded in March 1980 with 15 lb deertongue grass, 100 lb Abruzzi rye, and 30 lb/A of unhulled sericea; 1000 lb of 15-30-15 and 1500 lb/A Cellin mulch were also applied. In the final report entitled, "Improving Vegetation and Mowing Management in Highway Corridors" (Adams and Blaser, 1979), there is a detailed discussion of this problem area.

Data obtained in spring 1980 (Table 14) show marked improvements in vegetative cover for each increment of limestone, the vegetative cover being 8.5% without 6 tons per acre lime as compared to 20% cover with 6 T/A of finely ground limestone. Applying crushed limestone in trenches improved the vegetative cover when using 3 T/A of ground limestone.

These data reinforce the idea that stairstep grading of acid sulfate material, filling stairsteps with limestone gravel and applying crushed limestone in the steps, will successfully moderate the acidity from oxidizing sulfide-bearing material (Adams and Blaser, 1979). A vegetative cover on such bare cut slopes to control erosion can be established after applying large amounts of crushed limestone.

Table 14. Vegetative cover with lime and limestone treatments on an acid sulfate cut slope along I-64 near Clifton Forge. (Data recorded May 31, 1980, are percent vegetative cover.)

Lime rate	No lime	3 T/A	6 T/A	3 T/A plus crushed limestone in trenches	6 T/A plus crushed limestone in trenches
Rep I	15	25	75	80	75
Rep II	2	15	60	85	60
Average	8.5	20	67.5	82.5	67.5

III. SUMMARY AND RECOMMENDATIONS FOR IMPLEMENTATION

A. Mulches

Four experiments were conducted on cut slopes to compare paperfiber with woodfiber mulches used alone and as binding agents for straw for establishing vegetation and erosion control. Experiments were begun in different seasons to test the mulching materials under both favorable and stress environments. Seed germination, seedling growth, establishing protective vegetative cover and erosion control on bare slope construction sites depend on many interrelated factors such as temperature, evapotranspiration, rainfall characteristics, species and mixture, soil amendments, slope aspect and chemical and physical properties of soil materials. Because of complex interplaying factors in evaluating mulch materials, the environmental variance on slopes and the short duration of the project, the results are inconclusive. However, the data may be interpreted into useful summary statements for implementation: (1) woodfiber mulch materials, especially Conwed woodfiber, generally give better seedling establishment and develop a vegetative cover more quickly than for paperfiber. Under favorable environments, results with wood and paperfiber are similar; however, under stress environments, woodfiber mulch usually provided a better vegetative cover than paperfiber. Tentative recommendations may be stated as follows: woodfiber mulch is preferred but paperfiber materials meeting the present specifications by the Virginia Department of Highways and Transportation are satisfactory, (2) woodfiber may be used at rates up to 2500 lbs/A during stress environmental conditions, however, it is recommended paperfiber should not be approved for stress environments at high rates of applications. High rates of applying paperfiber results in a hard surface and inferior seedling populations and small seedlings as compared to woodfiber.

(3) all wood and paperfiber materials may be recommended as binding agents for straw, and (4) germination, seedling growth and establishment of a protective vegetative cover were better with straw than paper or woodfiber. Straw was especially superior under stress environments. Straw at 1.5 to 2 T/A tacked with 750 lb/A of paper or woodfiber should be recommended for stress environments where maintaining a protective mulch cover over a prolonged period is necessary.

B. Renovating Grasses in Medians

Vegetation management in medians, especially mowed areas, should embody the development and maintenance of suitable dense canopies to exclude annual weeds and deter most perennial weeds; the latter will require localized and dated application of herbicide for control. Dense grass canopies, good tiller stands and leafy growths obtained with appropriate mowing and fertilization excluded weed seedlings by maintaining light and moisture competition. Adapted grasses degenerate into sparse canopies because of low soil nitrogen, shallow roots due to excessive soil compaction during construction, injury from deicing salts, and adverse physical and chemical properties of soil materials. Thus, several experiments were designed to disclose methods of developing dense canopies of grass without reseeding.

In two experiments, applications of readily available sources of nitrogen gave substantial improvements in canopy cover before and after mowing. Based on soil, it is recommended that a soluble source of nitrogen at 50 lbs N/A or a mixed fertilizer supplying at least 50 lbs N/A be applied on medians with a 50 to 70% grass cover during October or early November. The frequency of applying nitrogen is not known but it is postulated that 50 lb N/A will be needed every two to four years to develop and maintain a dense grass canopy.

Medians with grass tiller populations having less than a 50 to 60% ground cover should be reseeded with grasses to develop dense competitive canopies that exclude weeds. Specific recommendations cannot be made because of inadequate research in medians. It is suggested that seedings be made during the January-February season in eastern and Piedmont Virginia and during February in the Mountainous region of Virginia. The best germination, seedling growth and vegetative cover may be expected with seedbed preparation leaving a roughened and loose soil surface to obtain seed coverage to improve moisture status over a prolonged period. If grasses are seeded on the surface, the best chances of obtaining germination may be expected with January - February seedings when soils are saturated with moisture. Seedings during the autumn season without soil preparation have high probabilities of failure because moisture competition caused by established plants and very poor germination and seedling survival on hard and unusually dry soil surfaces during autumn. Grasses require favorable moisture for a longer period for germination than legumes.

It is recommended that the species in mixtures be similar to specifications for initial seedings of bare slopes; the rates of seeding given in specifications may be reduced by 25%.

It is recommended that the soils along medians with sparse canopies be sampled for analyses at the Soil Testing Laboratory of the Agronomy Department at Virginia Polytechnic Institute and State University to ascertain whether lime and fertilizer nutrients and other nitrogen are needed.

C. Legumes in Medians

Grassy vegetation in medians usually degenerates because of low soil nitrogen and other factors. It is recommended that persistent perennial legumes, crownvetch and flatpea, be used with Kentucky 31 tall fescue in medians in all physiographic regions of Virginia. It is recommended that herbicides should not be used for medians seeded to legumes and that medians with grass-legume mixtures be mowed once yearly to leave a 6-inch stubble. The date of mowing cannot be specifically given for legume species but mowing during May at a date when mowers cut below the buds in flowering stems of grasses is recommended. It is strongly recommended that wide medians should not be mowed. It is recommended that perennial sweetpea along or in a mixture with flatpea or crownvetch be used in medians that are left unmowed.

Observations of many experiments and chance or "escape" seedings show excellent adaptation of crownvetch, flatpea and perennial sweetpea in medians in all physiographic regions of Virginia.

The following recommendations should be followed for establishing perennial persistent legumes crownvetch, flatpea and perennial sweetpea in medians with sparse or degenerating grasses: (a) test soil materials for pH, calcium, magnesium, phosphorus and potassium to ascertain soil amendments before seeding the legume; (b) competition from the grass sod may be nullified in two ways; (1) destroy most of the sod by mechanical methods to leave a rough loose surface so that large seeded perennial legumes become covered naturally or (2) employ a sod-seeding method where legume seeds are placed in rows into the soil; herbicides (paraquat or Round-up) sprayed over the rows in narrow bands (6 to 10 inches) to kill vegetation invariably improving seedling survival and growth.

(c) seedings should be made during the January-February season in the Southern Piedmont and Eastern Virginia and during the February-March season in Mountainous and in northern Virginia for best results, (d) nitrogen alone or in mixed fertilizers should not be used because stimulated competition from grasses deters legume seedlings, (e) the legumes should be inoculated with the appropriate strain of bacteria - crownvetch, flatpea and sweetpea each requiring a specific strain of Rhizobia, (f) the seeding rates given in specifications by The Virginia Department of Highways and Transportation should be employed.

Because legumes recommended herein spread by seed and/or proliferating roots, 3 to 4 foot rows on strip seedings will spread to give a legume canopy cover.

D. Mowing Management

Reasonably dense grass or grass-legume canopies should be developed and maintained through cultural techniques (appropriate varieties, mixtures, grading and soil preparation, seeding procedures and soil amendments). Mowing should be restricted to vegetation that obstructs views for the safety of travelers as along certain medians, shoulders and interchanges. Cut and fill slopes should not be mowed.

1. Mowing cut and fill slopes

Yearly mowing along the base of cut slopes depresses sericea, crownvetch and Kentucky 31 tall fescue, often causing bare soil and erosion. It is recommended that basal sections of cut slopes should not be mowed or that mowing be restricted to one swath at a 6-inch height across the base of a cut slope every two or three years. This is recommended to stop the invasion of woody vegetation. Mowing should be restricted to shoulders adjacent to highways on cut and fill slopes. For areas adjacent to guard rails the vegetation may be economically controlled with herbicides or combinations of herbicides and mowing. Mowing of cut slopes in rural areas is still practiced in some residences and should be prohibited.

2. Mowing management of grasses in medians

Cool season or temperate grasses, as Kentucky 31 tall fescue, the primary grass used in highway medians in Virginia and other cool season or temperate grasses, produce seedheads only once yearly because two sets of environmental conditions are needed: (a) during the fall-winter period, the long night-low temperature combination initiates minute buds in many tillers that are capable of developing seedheads under a second set of environmental conditions, (b) short nights-cool temperatures as during the spring season, causes seedheads to die when mowing below the buds in the tillers; hence, regrowth after mowing below flower or buds or seedheads comes from tillers that form leaves giving a leafy, green and attractive "groomed" appearance.

In the absence of weeds and annual grasses that produce seedheads, one yearly mowing is adequate. Delaying mowing until seedheads of tall fescue turn brownish or seeds mature often causes poor regrowth after late mowing. Low light intensity near the soil level due to tall accumulating grass growth reduces the number of tillers per unit area and their vigor. Also, with such late mowing, large amounts of mowed herbage resting on the stubble deters regrowth of vegetative tillers. Finally, when making the first mowing in June, high temperatures per se augment water loss (high evapotranspiration) and depress regrowth as compared with mowing earlier in spring when temperature and moisture environments are usually favorable for regrowth of vegetative tillers. Thus, an excessive accumulation of mowed material as with late mowing should be avoided. Mowing before seedheads are fully developed reduces the accumulation of mowed grass and enhances the probability of obtaining rapid regrowth due to better moisture and temperature conditions. The high protein content in early as compared to late cut grass decomposes and recycles the nitrogen quickly. Thus, mowing recommendations should approximate the following pattern: (a) wide medians should not be mowed unless the vegetation obstructs vision of travelers, (b) mowing in spring should be delayed until about 25% of the seedheads emerge and specified to begin when mowers cut below the buds in tillers that form seedheads, (c) stubble residues after mowing should average about 5 inches high, (d) the period of starting mowing in spring should not be specified on a date bases because the earliness of spring growth and seedhead development ranges from early to late May in Virginia depending on elevation, latitude and slope aspect; also, there is considerable year variance in seedhead development, (e) the first mowing should be finished in about mid May and late May in Eastern and Mountainous Virginia, respectively, (f) the second mowing in regions with predominately tall fescue may be delayed to the August early September period to mow off seedheads of annual grasses and weeds, (g) by maintaining dense canopies of temperate grasses in medians, only one spring mowing is needed, (h) medians in Southeastern Virginia will usually require a minimum of one spring, summer and early autumn mowing. Because of climatic conditions and relatively sparse canopies of temperate grasses, annual and perennial summer weeds make it necessary to mow more frequently in Southeastern than in Mountainous Virginia.

3. Mowing legumes in medians

The best mowing management of legumes in medians has not been ascertained. However, in medians where crownvetch and/or flatpea have been seeded or volunteered, it is recommended that: (a) mowing be restricted to one annual mowing during spring at a 5 to 6-inch height. Mowing should occur when the mower cuts below about 90% of the buds in grass tillers that develop seedheads, (b) wide medians should not be mowed.

E. Legumes in Cuts and Fills

Crownvetch, flatpea, perennial sweetpea and sericea lespedeza are recommended for cut and fill slopes in all physiographic regions of Virginia. It is stressed that these legumes require two to three years to form dense canopies that persist and eliminate weeds and other undesirable vegetation if mowing is prohibited. These legumes have persisted and maintained a dense monoculture for as many as 24 years without applying additional lime or fertilizer when left unmowed. These persistent perennial legumes also deter the invasion of woody species; however, woody species will eventually invade and dominate over the legumes, tall growths shading the lower growing legume canopies depressing them due to light competition.

Many cut and fill slopes seeded with grasses before legumes were recommended are in a state of grass degeneration and invasion of weeds. Slopes with degenerating non-leguminous vegetation should be seeded to one or a mixture of perennial legumes. To reduce the costs for establishing legumes, it is recommended that strip seedings be made across the apex and/or basal parts of slopes to capitalize on downward and upward invasion by seed and proliferating roots. It is strongly recommended that alternating cut clopes be seeded with different legumes to obtain variations in vegetative cover and color; all blend with the natural vegetation in Virginia Because of a seed shortage of perennial sweetpea, it is recommended that this legume be "spot seeded" across the apex of cut slopes. This perennial legume spreads primarily by dehiscing seed pods; hence, strip or spotted planting for perennial sweetpea across slope apexes is a practical way of covering entire slopes with a small amount of seed.

F. Managing Extremely Acid Areas

Cut slopes with extremely acid sulfur oxidizing minerals should be stair-step graded with steps filled with crushed limestone as grading proceeds. This will neutralize waters flowing off such slopes to avoid harmful polluting effects. Also, neutralizing the soil materials makes it possible to establish a vegetative cover that will persist. On such highly acid bare slope areas, vegetation may be established by making trenches and filling them with crushed limestone.

When grading such highly acid cut slopes, the materials with oxidizing sulfur minerals should be carefully placed in fill areas in a manner to cover the sulfuric acid-bearing materials with 4 feet of good soil and subsoil materials to avoid pollution problems from bare slopes and/or water contaminated with sulfuric acid.

G. Grading Methods

Many good practices that have reached the specification status are not used by highway personnel. For example, stair-step grading and/or leaving loose and roughened surfaces to augment water infiltration, reduce erosion, and to establish vegetative covers quickly, are not usually employed. Instead, objectionable practices of hard glazed slope surfaces and tracking are still used by highway and construction personnel. Some cut slopes are even tracked across slopes where compaction and tracks paralleling the slope make it almost impossible to establish vegetation. Also, steep cuts and fills are left unseeded for prolonged periods after grading causing severe rilling and making it difficult to establish vegetation and causing siltation and pollution.

Other cases where specifications are ignored could be mentioned. There is a critical need for developing educational programs for highway personnel to understand and to use the practices that have been specified.

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