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CONTENTS

FOREWORD

Scientists and engineers in increasing numbers have turned their efforts toward determining the effects of salt on roadside vegetation and learning ways of minimizing detrimental effects from the use of salt for snow and ice control on the nation's streets and highways, and there is reason to hope that detrimental effects can be overcome. One way to offset damage, to some extent at least, is to select salt-resistant grass species. Butler, in his paper in this RECORD, has performed a useful service by listing potentially useful salt-resistant grasses for roadside plantings. He suggests continuing research along such lines.

However, other alternatives should also be investigated. John Stevens in the May 25, 1972, issue of New Scientist reports that good crops can be grown by using saline water if the salt does not remain in contact with the roots for too long. In fact at Eilat, Israel, Hugo and Elizabeth Boyko have successfully grown 180 species out of 200 tested by taking advantage of a sandy or gravelly soil, a minimum amount of sodium-absorbing clay, water with the proper sodium-potassium balance, and a deep water table. Even when they used water with 10,000 parts per million of salt, the mulberry grew well. (Because these results have been questioned by other researchers, further testing of this procedure is recommended.) Some highway roadside areas may provide similar optimum conditions.

The Stevens article also suggests other interesting lines for highway engineers to consider in controlling salt damage along highways. Some plants accumulate salt in above-ground growth, and harvesting removes salt from the soil; thus biological desalination could contribute to reducing the amount of salt present in the soil.

Still other possibilities exist: It was demonstrated in some western states years ago that gypsum treatments are effective in improving salt-laden soil; recently, Hutchinson, in Maine, has shown that similar treatments are beneficial to soils that have been adversely affected by salts used for highway de-icing purposes.

In the second paper in this RECORD, Woodruff, Green, and Blaser report on the successful use of weeping lovegrass for control of erosion on highway slopes in Virginia and West Virginia. Previous work has demonstrated that the grass was effective in certain southern states; the authors' contribution was to demonstrate its use in states in humid regions with fairly cold winters. Roadside specialists in such regions, if faced with the problem of controlling erosion on areas having steep slopes and acidic, infertile soils with poor physical properties, may also want to investigate the use of weeping lovegrass.

A widespread belief seems to exist that highway engineers are "paving the country" and that the acquisition of a right-of-way for highway facilities eliminates the usefulness (other than for use as a transportation guideway) of the entire acquired area. Persons with this belief could not be more mistaken. Rights-of-way have many uses: for buildings, parking, open space in congested urban areas, utility corridors, and nesting areas for birds. All of these activities share the right-of-way with automobiles—and with minimum conflict. But these areas may also have potential for use in other, not yet widely recognized fashions.

The state of North Dakota has sold the rights to produce hay on the highway right-of-way in certain areas for many years, and a number of other state highway departments have permitted similar use by adjacent landowners under special agreements. Professor Young proposes that brush and small trees growing on a right-of-way through forested areas be used as a source for paper and paperboard products and that commercial use of forest products on rights-of-way be encouraged by augmenting woody growth by use of fertilizers and genetically superior species. He suggests that this growth can be harvested commercially on a 10- to 15-year cycle and that this would supply a portion of the projected growth in demand for forest products and might even more than offset expenditures for roadside maintenance.

In their encouraging paper, authors Zak, Troll, and Hyde report that a satisfactory percentage of large seeds of woody species emerge through a 2-in. layer of wood chips despite previously expressed fears by other investigators that rodents, protected by the wood-chip cover, would attack the plants or that the seedlings would not emerge through the mulch. This report should be of keen interest to highway authorities and utility companies, because opening slopes to erosion is discouraged and open burning is now restricted. It seems likely that wood chips from clearing operations can be used successfully as an erosion preventive and woody plant mulch.

The papers in this RECORD should interest a wide variety of persons: designers, maintenance engineers, landscape architects, agriculturists, contractors, engineers for utility companies, city officials, and the public at large.

SALT-TOLERANT GRASSES FOR ROADSIDES

J. D. Butler, Colorado State University

An accelerated use of sodium chloride and other salts for de-icing highways has caused widespread destruction of roadside vegetation. Satisfactory alternatives to salting have not yet been devised; thus the need for plants that are tolerant of a drastically changed environment must be considered. This discussion is limited to several grasses found in the United States, which have demonstrated good salt tolerance. Specific growth characteristics and habitats of the grasses pertinent to roadside use are discussed. Research with specific grasses is cited, and the need for further in-depth research and development with salt-tolerant grasses is noted.

•THE establishment and maintenance of roadside vegetation for aesthetic and utilitarian reasons date back many centuries. Better and more serviceable roads have become a prime factor in our current mode of living. Man's current ability to alter his environment—both physically and chemically—in the construction and maintenance of highways has brought about many serious plant problems. Among those to be considered in plant production are poor soil conditions with high- and low-moisture regimes and temperature extremes.

Salt damage to roadside plantings has become a critical problem in recent years. Large increases in the use of salt (primarily sodium chloride) for de-icing are continuously being reported. In Illinois, for example, the amount of salt used on all state-maintained highways during the winter of 1957-58 was 39,234 tons. This increased to 309,900 tons during the winter of 1969-70, which is an eightfold increase in 12 years. Dickinson (4) has reported comparable trends for the entire United States. Because there seems to be no immediate alternative to salt for de-icing, the difficulty of growing plants along salt-treated roads seems almost insurmountable. As reported by Hutchinson (11), the number of sodium and chloride ions is normally the highest near the roadway, decreasing with distance from the highway. Also, their number increases with the length of time that salting has been practiced. In Illinois the salt levels are often high in channels and depressions where runoff water stands.

Near the paved surface, where grasses are needed most for erosion control and stabilization (medians being especially vulnerable), the salt hazard is the greatest. It is in this critical area, where the vegetation disappears first, that the problem is most severe. Without vegetative cover, soil in the runoff water clogs sewers, causing back-up water to be a problem. With the demise of the vegetation, the exposed soil may be covered with concrete, asphalt, or gravel at great expense. This solution, besides being expensive and unattractive, may increase runoff so much that the drainage systems will be inadequate. Also, without soil to store the salt, at least temporarily, the entire application may rapidly find its way into the runoff water and thereby increase stream pollution.

The need for grasses known to have a high tolerance for salt should be considered for use where salt is (or potentially is) a problem. The use of salt grasses on saline areas should be considered a stopgap measure because salt levels would be expected to rise greatly with continued salting. Some highway areas are already too salty for the most salt-tolerant grasses.

Sponsored by Committee on Roadside Development.

SALT-TOLERANT GRASSES

Literature Review

Although only limited research has been done in this area, there is general agreement about a relatively few grasses that seem to have good salt tolerance. It should be noted that the relative salt tolerance of the various grasses cited in the following paragraph was arrived at by using diverse techniques and methods of evaluation. It is not at all unusual to find a grass listed as having good, fair, or poor salt tolerance, depending of course on growing conditions, comparative grasses, and so forth.

Bernstein (1) listed the following grasses as having good salt tolerance: alkali sacaton (Sporobolus airoides), salt grass (Distichlis stricta), Nuttall alkali grass (Puccinellia nuttalliana), Bermuda grass (Cynodon dactylon), tall wheatgrass (Agropyron elongatum), Rhodes grass (Chloris gayana), rescue grass (Bromus catharticus), Canada wild rye (Elymus canadensis), western wheatgrass (Agropyron smithii), tall fescue (Festuca arundinacea), and barley (Hordeum vulgare).

Another source (15) substantiates Bernstein's list, except for tall fescue. Tall wheatgrass was not ranked. Branson (2) considered tall alta fescue to have only medium salt tolerance. Experience along Illinois roadsides that are salty has not shown tall fescue to have suitable salt tolerance. Forsberg (8) found tall wheatgrass to be a highly salt-resistant grass. Based on work by Lunt et al. (12) and Sanks (13), it is appropriate to add weeping alkali grass or spreading meadow grass (Puccinellia distans) to the list.

Grasses Suitable for Roadsides

Duell (7) has noted the need for special grasses for highways; he specifically mentions mowing and appearance. In addition to the potential height of the grass, there are several factors to consider in selecting and breeding roadside grasses. Longevity, method and speed of initial establishment, density of the sward (for erosion and weed control), type of seasonal grass, potential destruction by the grass to the road surface, potential as a weed, and climatic range are some of the more important considerations.

An examination of the grasses listed previously, for use along roadways where salt is or is expected to be a problem, points to the relatively few choices that are available.

Barley is a tall-growing annual that might be of some use as a "nurse" crop for establishing other salt-tolerant grasses. Thus, barley is limited for use along saline roadsides.

Rescue grass is a tall annual or biennial plant that grows primarily in warm regions. It is apparently of little use where roads are salted.

Rhodes grass is a tall perennial grass found in warm regions. It cannot be used in regions where highways would be salted.

Bermuda grass is a low-growing, rapid-spreading, warm-season grass that becomes dormant in cool weather during autumn and often does not "green up" until middle or late spring. The strong rhizomic habit of common Bermuda can cause pavement problems. Although the climatic range may extend well into the North, this grass does best in more southerly locations where de-icing is not too common.

Alkali sacaton (bunchgrass) is found throughout the West and normally is considered a bunchgrass. However, Griffiths et al. (9) reported two distinct types of growth: (a) a continuous uniform growth that approaches a turf and (b) a bunchgrass. As an open bunchgrass of moderate height, alkali sacaton would seem to be poorly adapted to roadside use, but as a "turf" it would have definite possibilities. More work and a better understanding of this grass are definitely needed.

Canada wild rye is a tall, upright, cool-season perennial bunchgrass. Hanson (10) reported that this grass is short-lived. The ability of this grass to persist along roadsides, where mowing is usually frequent and close, is questionable. However, its use in low, unmowed areas might be considered.

Tall wheatgrass is a tall, coarse, late-maturing bunchgrass that can be grown successfully on wet soils. Again, the ability to provide needed cover with frequent mowing along roadsides would be questionable, but its use in low, unmowed areas might be considered.

Western wheatgrass (Colorado bluestem) is a relatively low-growing, cool-season grass that should tolerate highway mowing practices. Underground stems should give some protection from brine splash. Although this grass does best on low areas in arid regions, it will persist with very low rainfall and could possibly be useful, especially in mixtures, along roadsides.

Inland salt grass is a strongly rhizomatous, warm-season perennial found throughout the West, eastward to Iowa and Missouri. Although it is a low-growing grass, has exhibited excellent salt tolerance, provides a dense cover, and is found under quite droughty situations, it does have some distinct disadvantages. Because this salt grass is a warm-season grass, it becomes dormant during cold weather and could become a fire and weed problem. However, because it becomes dormant in the fall, inland salt grass may have a strong resistance to brine splash injury. Another disadvantage is that the strong rhizomes of this grass are frequently seen growing through paved surfaces. Also, this dioecious grass is a poor seed producer, and vegetative propagation is practiced. Extensive studies of salt grass have been made in Nebraska by Dudeck (5, 6). This grass has possibilities for roadside use, especially in areas where it is known to be growing wild.

Nuttall alkali grass (Puccinellia airoides) is a cool-season perennial that grows to a moderate height. It is found growing in the western states and in the northern part of the northeastern states. Griffiths et al. (9) reported that, when it is found, it is usually growing to the exclusion of everything else. They also reported that not only is it able to withstand large amounts of soluble salts in the soil, but also it will grow in situations where large amounts of soluble salts in solution stand on the ground for a month or more at a time. This is important because of the standing water in channels and on frozen soil along highways and because of brine splash. The seed head characteristics of Nuttall alkali grass and of weeping grass are generally similar to some common bluegrasses and are easily confused with them. In some of the early writings, alkali grasses were considered bluegrasses. Both alkali grasses are bunchgrasses. Both tiller vigorously and have unusual seedling vigor and provide quick cover. Both are dark green in color and seem quite promising for use on salty roadsides.

Spreading meadow grass (or weeping alkali grass) is a fine-textured, low-growing perennial grass. It is lower growing than is Nuttall alkali grass. It is a cool-season grass that is quite similar to Kentucky bluegrass (Poa pratensis) except that it is not rhizomatous. It has a rapid rate of tiller production, and under extremely poor soil conditions it has been found to have a good root system. This grass is found in many parts of Canada and the United States. Undoubtedly it now grows in many areas where it did not appear a decade ago, perhaps because of man's influence on the environment. This grass is found on golf course fairways in Colorado, forming dense turf at mowing heights of 1.5 in. or less. It seems promising for roadside use where the soil has a high content of salt.

There are several other alkali grasses that offer possibilities for use on roadsides in the north-central and northeastern United States.

OBSERVATIONS AND RESEARCH

An annotated bibliography on highway turf by Smithberg and White (14) points to the paucity of information on salt and alkali problems, especially when they are concerned with intricacies of roadside conditions. The following observations and research results seem pertinent to those faced with highway salt problems.

Observations in Illinois

For several years, salt has been causing noticeable vegetative damage along the highways in Illinois. In the spring of 1969, a group of Illinois highway maintenance supervisors and plant scientists from the University of Illinois held an advisory committee meeting and a tour of the Chicago Interstate System to assess the major vegetative problems. It was quite apparent that salt damage to the vegetation was a major problem. It was common, often for miles, to find the grass (standard highway mixtures) dead and the soil barren, especially in the median and 10 to 15 ft on either side of the road. However, at the intersection of US-45 and I-55, bunches of alkali grass (later identified as Puccinellia distans) were found growing near the pavement and in a drainage ditch. It seems most likely that the alkali grass was introduced at this site as a contaminant in the specification seeding; however, there are several other possibilities.

In 1969 and 1970 a search for alkali grass seed was undertaken. Small quantities of Nuttall and lemmon alkali grasses (Puccinellia lemmoni) were obtained for experimental purposes. At that time after extensive search, neither Nuttall alkali grass nor weeping alkali grass, the two grasses that seemed to offer the most promise for Illinois roadsides, was available in quantity.

By the spring of 1970, the weeping alkali grass at US-45 and I-55 had become established by reseeding itself to such an extent that sufficient seed could be harvested for experimental work. This alkali grass was most noticeable where the brine concentrated and flowed directly from the pavement onto the soil. The grass that had been originally planted had died, and most of the soil was exposed. During 1970, weeping alkali grass began to appear at a few locations along the Chicago Interstate System. By 1971, this alkali grass could be found to a limited extent along roadways outside Cook County in central and northern Illinois. A concentrated seed harvest effort in 1971 provided the needed seed to establish additional nursery plots for seed production. In 1972 sufficient seed for more extensive roadside testing and experimental work should be available.

It is of interest here to note a change in the roadside ecosystem in the Chicago area, which appears to be primarily a salt effect. The transition seems to be from Kentucky bluegrass and tall fescue to quack grass (Agropyron repens)—perhaps under some conditions quack grass sod should be used for stress areas—then to quack grass-alkali grass, and finally to alkali grass with some Mexican fireweed (Kochia scoparia) and orache (Atriplex patula). The latter two are annual broadleaf weeds that do not offer the erosion control or aesthetic qualities of alkali grass but are salt-tolerant.

Seed and Seedling Characteristics of Weeping Alkali Grass

Weeping alkali grass is a prolific seed producer, normally seeding at about the same height as Kentucky bluegrass. Seed size is similar to Kentucky bluegrass, and there are at least 2 million seeds per pound. In seed harvesting, timing is critical because there is a very short period between seed ripening and shattering. In the fall, the seed that has shattered and fallen to the ground germinates and forms a dense stand of young seedlings between normally isolated bunches. Also, the spread of the grass can sometimes be directly correlated with direction of water flow and mowing.

Research in Illinois

Because of the urgency of the roadside salt problem in Illinois, a crash program has been carried out. Much of the work that has been done needs to be repeated in more detail and on a larger scale.

It is not uncommon for grasses to show a positive growth response to low levels of sodium chloride in the soil. In greenhouse studies, the growth of alkali grass at 1 percent salt (by weight) in the soil was not noticeably affected. Even at 2 percent salt levels, growth was 80 percent normal, as compared with less than 60 percent for perennial ryegrass (Lolium perenne), Kentucky bluegrass, western wheatgrass, and crested wheatgrass (Agropyron cristatum) (3).

Weeping alkali grass seed that was collected in Illinois produced greenhouse-grown plants that were slightly more salt tolerant than Nuttall alkali grass and lemmon alkali grass from the West (3).

Because of the scarcity of weeping alkali grass seed and because of the adaptability of sod (established sod would be expected to have more salt tolerance than seedlings), a study was conducted by Sanks (13) to determine the mixture ratio of weeping alkali grass and Kentucky bluegrass in order to produce a liftable sod. In less than a year, a mixture of weeping alkali grass and Kentucky bluegrass at a seeding ratio of 9 to 1 (by weight) had produced a strong, liftable sod. Even though the Kentucky bluegrass would tend to go out at high salt levels, it served to bind the sod and increased distribution of the limited quantities of alkali grass seed.

Early in the spring of 1971, weeping alkali grass-Kentucky bluegrass sod was lifted and moved to an area along the roadside at the intersection of US-45 and I-55 and along the sidewalks at the Illinois Highway Office Building where salt has been a problem. Along the roadside, the Kentucky bluegrass soon died out, but the alkali grass remained.

Direct foliar application of salt as spray from the highway has been of concern to those seeking salt-tolerant grasses. (Normally, soil or vegetative growth levels are used as the criteria for determining salt tolerance in plants.) Sanks (13) compared the damage caused by brine applications to two alkali grasses and two wheatgrasses. He made eight winter applications of a strong brine solution to well-established plants. The rate of salt application was equal to 42 tons of sodium chloride per lane-mile. Nuttall alkali grass and weeping alkali grass showed the least damage from the sodium chloride solution. Western and crested wheatgrasses were killed or seriously injured at this salt level.

Research in Colorado

At Colorado State University, J. L. Fults has made morphological comparisons of both Nuttall alkali grass and weeping alkali grass. One of the collections of weeping alkali grass (Accession-666) from the Boulder, Colorado, Country Club shows excellent turf characteristics and deserves further testing and study.

Another collection made by Fults exhibits a stoloniferous growth habit. If this feature is reproducible, and not a pseudo-characteristic, then progeny from this plant could provide more rapid establishment and cover than the bunch type alkali grasses now being considered for use.

RESEARCH AND EXPERIENCE NEEDS

The need for research and experience with plant problems associated with high levels of roadside salt is great. The information available on salt grasses has been gathered from diverse and often artificial situations. The complexity of situations along roadsides in urban areas makes it impossible to consider all of the variables, let alone devise a workable model. Consequently, the experience and technical knowledge of the plantsman will be quite beneficial whether tolerant species (either herbaceous or woody) should be considered. Some highways have been constructed such that initial establishment of grass in the median or near the pavement is sheer waste because the cover has declined and disappeared even without the presence of salt and with ideal care.

A few of the immediate needs that deserve attention are as follows:

1. Selection of individuals within the various species that have the highest salt tolerance; Dudeck (6) has noted that unclipped clones of salt grass differed significantly in their response to sodium chloride;
2. Development of better seeding and vegetative methods of establishing grasses in high salt areas; and
3. Study of seeding habits and commercial production of the seed of salt-tolerant grasses.

SUMMARY

The continued use of salt for de-icing has increased the need for salt-tolerant grasses that can be used on roadsides. Although there are several grasses that have shown good tolerance, only a few of these can be used for highway purposes. Because of the seriousness of vegetative destruction by salt and the resulting problems, continued research and development are needed.

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WEEPING LOVEGRASS FOR HIGHWAY SLOPES IN THE VIRGINIAS

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Research investigations were conducted in several geographical sections of Virginia and West Virginia to determine the general adaptability of weeping lovegrass to the various soils and climates along roadsides in these two states. Weeping lovegrass gave quick-establishing cover and slope protection during the hot summer periods in both states. In contrast, cool-season species such as Kentucky 31 fescue generally established much slower and were not as effective for obtaining quick erosion control during the summer period. Liming appeared to be necessary only on certain acid soil formations in the mountainous regions and on the very acid pyrite soil materials in the coastal plain region of Virginia. The use of a 10-20-10 fertilizer at 750 lb/acre was generally satisfactory for obtaining quick-establishing stands of weeping lovegrass and for allowing gradual botanical shifts to sericea lespedeza, crown vetch, or woody vegetation. Increasing this fertilizer rate to 1,500 lb/acre greatly increased the density and persistence of lovegrass on the vary steep slopes. Applying lateral furrows to the slope face prior to seeding greatly improved the rapidity of obtaining lovegrass stands, especially with the low fertilizer rates on loose, friable, and steep slopes. The best and fastest establishing lovegrass stands were obtained with seedings made during the late spring and early summer periods. Seeding in early spring often gave good lovegrass stands, but these grew very slowly during the cool spring and were subjected to frost kill at higher elevations. Seeding before late summer was necessary to allow lovegrass to complete seedling development prior to the end of the growing season to ensure winter survival.

•ESTABLISHING good persistent sods rapidly is a major problem along highways, especially in areas with steep slopes where soil materials are acid, infertile, and poor in physical properties. It is necessary to grow good sods soon after grading to aid in controlling erosion and siltation and to avoid polluting water courses. Ideally, slopes should not be made steeper than 2½:1, and 3:1 grades are preferable for ease of establishing and maintaining suitable soil vegetative cover. However, because of steep terrain, difficulty of obtaining sufficient right-of-way, and costs, many roadside slopes in the Virginias have 1:1 or steeper grades. In gently rolling terrain, such steep slopes are common along secondary roads that have been widened where additional right-of-way for flatter slope construction was not obtained.

It is expedient to first establish vigorous-growing grass sods to provide quick soil stabilization and water control. Where the soil fertility level and plant population density are carefully manipulated, such sods provide suitable environments for the establishment of perennial legumes and woody vegetation. Kentucky (Ky.) 31 tall fescue has produced good sods on steep slopes where slow-release (urea-formaldehyde) nitrogen or periodic applications of maintenance fertilizers were used (2). However, it is

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difficult to establish Ky. 31 fescue or other cool-season perennials during late spring and summer because of adverse high temperatures and drought.

Weeping lovegrass [Eragrostis curvula (Schrad) Nees.] develops quickly during the late spring and summer on steep and infertile roadside slopes in some southern states (1, 3). There is little information that shows methods of establishing and maintaining lovegrass stands for quick erosion control and for establishing perennial legumes in humid-region states having fairly cold winters.

This paper summarizes many experiments giving information on the adaptability of weeping lovegrass to Virginia and West Virginia soils and climates along roadways. Data and practical results from experiments with variable fertility, mulches, seeding dates and rates, companion grasses, and sloping cuts and fills with diverse environmental conditions are included so that lovegrass culture can be implemented in highway turf programs.

EXPERIMENTAL PROCEDURES

Experiments were established along highways on cool and warm cuts and fills in the different geographical regions of Virginia and West Virginia to investigate (a) general adaptability of weeping lovegrass to different soils, slopes, and climates and (b) responses to lime, fertilizer, companion grasses, and seasons of seeding. Mulching for a given experiment was not varied; either small-grain straw at 3,000 to 4,000 lb/acre, tacked with asphalt, was used or wood cellulose mulch at 1,250 to 1,500 lb/acre. Experimental treatments were generally applied to cut and fill slopes on plots 10 to 20 ft wide that extended vertically from the top to the bottom of the slope. Slopes along newly constructed highways or bare eroding slopes were used. The slopes were generally graded and scarified before applying experimental variables. Most of the experiments were established on sites along highways where cool-season grasses had failed because of adverse slope or soil conditions.

Parameters for evaluating the treatments were as follows: population of lovegrass and companion species, botanical compositions, seedling development of weeping lovegrass measured by heights and weights of seedlings, percentage of soil cover, and winter survival.

Because there were many different experiments, this summary report excludes details. Experiments were replicated 2 to 4 times by using randomized or split-plot design. All data were subjected to analysis of variance to ascertain significant differences among treatments.

RESULTS AND DISCUSSION

Lime and Fertility Responses

Growth responses of lovegrass to surface applications of hydrated and finely ground limestone on acid soils materials were variable. Both sources of lime improved lovegrass growth and persistence on acid soil in the Appalachian region, but growth and stands from liming on most acid soils in the Piedmont and coastal plains regions of Virginia were small or nil (Table 1). In mountainous regions, lovegrass plants on limed areas produced more top and root growth and were stronger during winter than those without lime.

On highly oxidized and extremely acid pyrite soil materials (pH of 2.5 to 3.0) in the coastal plains region, the use of 8 to 16 tons of dolomitic lime/acre in the top 4 in. of soil was essential for establishing lovegrass. Even then, roots of lovegrass grew only in the limed soil layer. Consequently, after heavy rains there was slippage of plants with surface soil on some plots. Because of shallow rooting, the soil cover of lovegrass degenerated from 80 to 100 percent at 60 days after establishment to less than a 50 percent cover 2 years later. Although it was not persistent on such extremely acid soils, the lovegrass did reduce erosion and encourage the encroachment of broom sedge and certain woody plants.

Growth and persistence of lovegrass with a 10-20-10 fertilizer were generally good but varied with soil, slope, exposure, and construction of lateral furrows (Table 2).

Table 1. Influence of liming on weeping lovegrass stands.

Region and Location	Slope Grade	Initial pH	Lovegrass Soil Cover (percent)					
			No Lime (year)			2 Tons of Lime[a] (year)		
			1	2	4	1	2	4
Appalachian								
Marion I	1:1	4.8	55	40	12	95	85	76
Marion II	1:1	4.7	30	22	5	70	92	68
Blacksburg I	2:1	5.4	72	53	32	75	50	27
Blacksburg II	2:1	5.0	88	90	79	87	78	70
Piedmont								
Lynchburg I	2:1	5.1	89	82	56	94	86	68
Lynchburg II	1:1	4.9	100	95	72	97	92	59
Danville	1:1	4.5	89	100	66	94	100	81
Altavista	3:1	5.0	—	—	—[b]	97	85	—
Coastal plains								
Dinwiddie	3:1	4.7	100	—	74	100	—	81
Suffolk	1:1	5.2	87	—	73	94	—	82
Fredericksburg[c]	2:1	2.8	16	1	—	87	51	22

[a]8 to 16 tons of finely ground dolomitic lime were applied and incorporated in the top 4 in. of soil in the Fredericksburg experiment. In all other experiments, the lime was applied on the surface.
[b]Data not obtained.
[c]Very acid pyrite soil materials.

Figure 1. Weeping lovegrass stand on steep highway slope with encroaching woody plants.

Table 2. Growth of weeping lovegrass with fertilizer.

Location	Slope Grade	Lovegrass Soil Cover (percent)			
		Fertilizer 750 lb/acre		Fertilizer 1,500 lb/acre	
		Lateral Furrows	No Lateral Furrows	Lateral Furrows	No Lateral Furrows
Marion	1:1	88	64	96	75
Lynchburg I	1:1	92	57	100	86
Lynchburg II	2:1	87	—	100	—
Dinwiddie	3:1	100	94	100	98

Note: Data were collected during the second growing season of each experiment.

Table 3. Growth of weeping lovegrass and sericea lespedeza as influenced by seeding date, nitrogen rate, and companion species.

Seed Mixture	Seeding Rate (lb/acre)	Height of Plants (in.) on 10/12/70								
		Seeded 4/15/70			Seeded 6/15/70			Seeded 8/14/70		
		75 N	150 N	Avg.	75 N	150 N	Avg.	75 N	150 N	Avg.
Lovegrass										
Lovegrass	5	17.1	22.8	20.0	19.1	21.4	20.3	7.2	7.2	7.2
Lovegrass and annual ryegrass	5, 5	17.0	22.0	19.5	21.2	22.6	21.9	7.4	8.3	7.9
Lovegrass and Ky. 31 fescue	5, 40	18.2	24.9	22.1	18.2	22.1	20.0	6.9	7.5	7.2
Average		17.4	23.2	—	19.5	22.0	—	7.2	7.7	—
Sericea Lespedeza										
Lovegrass	5	8.3	6.6	7.5	5.4	6.0	5.7	2.3	4.1	3.2
Lovegrass and annual ryegrass	5, 5	6.4	7.3	6.9	6.3	5.4	5.9	3.1	3.0	3.1
Lovegrass and Ky. 31 fescue	5, 40	7.5	8.0	7.7	6.1	6.8	6.5	4.0	3.6	3.8
Average		7.4	7.3	—	5.9	6.1	—	3.1	3.6	—

Note: Date averages that are different by greater than the following numbers are significantly different at the 5 percent level: for lovegrass, 4.2; for sericea lespedeza, 2.7.

Table 4. Influence of seeding date, nitrogen rate, and companion species on soil cover of various grasses.

Seed Mixture	Seeding Rate (lb/acre)	Soil Cover (percent) on 6/28/71					
		Seeded 4/15/70		Seeded 6/15/70		Seeded 8/15/70	
		75 N	150 N	75 N	150 N	75 N	150 N
Weeping Lovegrass							
Lovegrass	5	71	87	72	93	19	7
Lovegrass and annual ryegrass	5, 5	72	84	80	83	7	4
Lovegrass and Ky. 31 fescue	40	64	78	77	89	10	6
Sericea[a]							
Lovegrass	5	13	3	2	1	22	3
Lovegrass and annual ryegrass	5, 5	12	2	3	2	17	2
Lovegrass and Ky. 31 fescue	40	13	1	5	6	18	14
Companion Species and Weeds							
Lovegrass	5	1	0	0	0	32	61
Lovegrass and annual ryegrass	5, 5	5	3	0	0	41	53
Lovegrass and Ky. 31 fescue	40	3	2	0	0	27	72
Total Soil Cover							
Lovegrass	5	85	90	74	94	73	71
Lovegrass and annual ryegrass	5, 5	89	89	83	85	65	59
Lovegrass and Ky. 31 fescue	40	80	81	82	95	55	92

[a]All mixtures had 45 lb/acre "Interstate sericea lespedeza."

In the mountainous region near Marion, Virginia, sod establishment and soil cover during the first 3 years on sunny slopes were much better using 1,500 as compared to 750 lb/acre of 10-20-10 fertilizer. On cool slopes 1,500 lb/acre of 10-20-10 fertilizer was essential for maintaining lovegrass for more than 2 years. With 750 lb/acre of 10-20-10 fertilizer, sods of weeping lovegrass completely degenerated on cool slopes in this experiment during the first 2 years. In the Piedmont and coastal plains regions, excellent sods of lovegrass persisted for more than 4 years when fertilized with 750 lb/acre of 10-20-10 fertilizer at establishment. In all cases, the higher rates of fertilizer (1,500 lb/acre of 10-20-10) have produced denser and darker green foliage. The reduced growth with 750 lb/acre of 10-20-10 fertilizer appeared to be desirable when using lovegrass as a companion species in establishing sericea or crown vetch.

A sod of lovegrass having a high nitrogen content or receiving periodic maintenance with nitrogen fertilizer becomes dense, but with a low nitrogen content it gradually thins, which makes possible a botanical shift to woody plants, sericea, or crown vetch (Fig. 1).

In a study near Altavista, Virginia, an increase in the nitrogen rate from 75 to 150 lb/acre did not affect the rapidity of lovegrass establishment, but added nitrogen increased the growth (Table 3) and cover (Table 4) and caused the sod to be dark green for April and June seedings.

Delaying seedings until August substantially depressed populations (Table 5) of lovegrass regardless of companion species. However, stand reductions for the August seeding were greatest when annual ryegrass was used to seed, especially where nitrogen rates were increased from 75 to 150 lb/acre. Lovegrass seeded without a cool-season companion grass in August allowed noticeable erosion during the subsequent winter.

Soil Preparation

On steep 1:1 slopes with loose, friable soil, lateral furrows (approximately 3 in. deep and 18 in. apart) parallel to roads were very desirable and often necessary to get rapid satisfactory lovegrass establishment (Table 2). The microclimate was improved by applying lateral furrows. Seedlings emerged and grew rapidly in the furrows to stabilize soils on the steep slopes.

Lovegrass germinated and grew faster in the furrows, but these were only necessary on the steep slopes with loose surface soil materials. Applying fertilizer, especially nitrogen, in a two-step operation (before late summer) generally improved lovegrass growth and appearance. This practice appeared to be especially desirable on slopes where lateral furrows were not constructed.

Dates and Rates of Seeding and Slope Environments

Experiments in different locations with different seeding dates show that the seedling vigor of lovegrass was generally good but variable with location and season of seeding. The best growth and stands of weeping lovegrass were obtained on sunny slopes with late spring to early summer seedings. As compared with May to June seedings, March to April seedings often gave poor stands because of poor germination, frost damage, and slow seedling growth due to cool temperatures. However, in the absence of severe frost damage to seedlings, early spring seedings often gave good lovegrass stands if competition during the spring months from cool-season associates was not excessive.

Observations of seedlings from March seedings near Lynchburg and Wytheville indicated that death occurred because of heavy April frost. At Blacksburg, good lovegrass stands were obtained by using winter and early spring seedings with mulches and without companion species. This occurred because the lovegrass did not germinate and grow until late spring, thereby escaping frost damage. Young lovegrass seedlings do not withstand hard frost, and they grow very slowly until temperatures become moderately warm in spring. With an April seeding along a secondary road in the coastal plains area, it also took about three times as long to get a lovegrass stand suitable for slope protection as for a June seeding (Table 6).

Seedings of weeping lovegrass made at two locations in West Virginia gave excellent stands from April 17, 1970, and May 5, 1971, seedings (Tables 7 and 8). Weeping lovegrass at Lewisburg, West Virginia, was distinctly superior to all other grasses in density and ground cover throughout the summer of 1970 (Table 7). The extremely droughty soil conditions at Lewisburg in the summer of 1970 gave unsatisfactory sods of all grasses except lovegrass, which was on a very dry, warm, stoney, and compacted 5:1 slope (Fig. 2).

Near Beckley, West Virginia (Table 8), May seedings on a hot compacted 2:1 slope (pH of 5.3) showed that weeping lovegrass and orchard grass gave the best stands and soil cover for prevention of erosion.

Spring seeding on warm slopes or summer seeding on all slopes with cool-season grasses along with lovegrass generally gave predominately lovegrass sods. Lovegrass grows much better during the summer months than do the cool-season grasses.

Seeding lovegrass at 5 to 6 lb/acre has given quick stands of dense sods for late spring and early summer seedings (Fig. 3). Seeding lovegrass at high rates (8 to 15 lb/acre) gave dense stands but did not improve the rate of obtaining soil cover over lower rates. Seeding rates should not exceed 2 to 5 lb/acre when using lovegrass to stabilize slopes while establishing crown vetch or sericea. If a very dense sod of lovegrass is produced, it competes aggressively for light, moisture, and nutrients, thereby exterminating slow-growing crown vetch and sericea seedlings.

Excellent slope cover for erosion control with lovegrass has been obtained in all soils and climatic areas of Virginia, but stands on cool shaded slopes at higher altitudes west of the Blue Ridge Mountains have thinned the first 4 years. Stands in mountainous regions on southerly slopes and in all other areas on cool and warm slopes have now persisted for 5 years in Virginia and $1\frac{1}{2}$ years in West Virginia.

Winter Survival of Lovegrass

Some of the late summer seedings (August) in the Piedmont sections have given good lovegrass stands by the second year, but little growth and inadequate soil cover occurred during the first growing season. However, if the seedings are made so late in the summer that lovegrass plants do not complete seedling development before the first killing frost, they generally do not survive the winter.

The percentage of winter survival of first-year lovegrass plants appears to be closely related to the age and size of lovegrass plants at the end of the first growing season (Tables 3 and 5). Near Altavista, the lovegrass populations were substantially reduced when seeding was delayed from June 15 to August 15. Because of dry weather, lovegrass seedlings from the August 15 seeding did not begin to germinate and grow until September and grew little prior to the first killing frost; these were only about one-third as large as plants from April or June seedings (Table 3).

Data obtained at Lewisburg, West Virginia, in June 1971 (Table 7), show that there was about 5 to 10 percent kill of weeping lovegrass, but there was still about an 80 percent soil cover as compared to a very poor soil cover of 30 to 55 percent for the other species.

Establishing Sericea Lespedeza, Crown Vetch, and Native Woody Vegetation

Perennial legumes such as sericea or crown vetch make excellent persistent vegetative cover for steep highway slopes because they do not require nitrogen and consequently little or no fertilizer for maintenance. These legumes have poor seedling vigor and generally require 2 to 3 years to develop a near total vegetative cover for erosion control. By using medium to low rates of nitrogen fertilizer, we can develop a good soil cover of weeping lovegrass, but the growth stays short and the sod becomes thin after a few years. Lovegrass with restricted nitrogen is very desirable for obtaining a sod quickly. At the same time it allows a gradual botanical shift to slow-establishing legumes such as sericea lespedeza, crown vetch, or woody vegetation.

In two experiments near Lynchburg, there were initially more sericea and crown vetch seedlings in a Ky. 31 fescue than in a weeping lovegrass association because of

Table 5. Winter survival rates of weeping lovegrass populations.

Seed Mixture	Seeding Rate (lb/acre)	Plants per Square Foot: Seeded 4/15/70			Seeded 6/15/70			Seeded 8/14/70			Winter Survival (percent): Seeded 4/15/70		Seeded 6/15/70		Seeded 8/14/70	
		75 N	150 N	Avg.	75 N	150 N	Avg.	75 N	150 N	Avg.	75 N	150 N	75 N	150 N	75 N	150 N
Observation, 9/18/70																
Lovegrass	5	52	48	50	81	100	90	17	22	20	—	—	—	—	—	—
Lovegrass and annual ryegrass	5, 5	31	20	26[a]	89	97	93	12	7	9[a]	—	—	—	—	—	—
Lovegrass and Ky. 31 fescue	5, 40	47	43	45	96	103	100	22	19	20	—	—	—	—	—	—
Average		43	37	—	89[a]	100	—	17	16	—	—	—	—	—	—	—
Observation, 6/28/71																
Lovegrass	5	43	45	44	63	72	68	3	8	5	83	94	78	72	18	36
Lovegrass and annual ryegrass	5, 5	27	22	23[a]	66	69	68	1	4	3	87	100	74	71	9	50
Lovegrass and Ky. 31 fescue	5, 40	44	36	40	71	78	75	7	5	6	94	84	74	76	32	26
Average		38	34	—	67	73	—	4	6	—	—	—	—	—	—	—

[a]Significantly different at the 5 percent level.

Table 6. Effect of seeding date of weeping lovegrass on percentage of soil cover established.

Seeding Date	Soil Cover (percent) on Observation Date: 4/19/68	5/16/68	6/21/68	7/15/68	8/20/68
4/1/68	1.5	5.0	35.0	73	89
6/4/68	—	—	7.0	66	88

Table 7. Performance of grasses near Lewisburg, West Virginia: Population and soil cover.

Grass	Seeding Rate (lb/acre)	Population (plants/ft^2) 5/19/70	Soil Cover (percent) 9/28/70	6/14/71
Ky. 31	60	7.8 c	36 bcd	37 bcd
C.R. fescue	50	13.3 bc	54 b	55 b
Ky. blgr.	50	5.1 c	37 bcd	35 bcd
Orchard grass	45	21.4 abc	43 bcd	43 bcd
Redtop	10	7.6 c	40 bcd	35 bcd
P. ryegrass	50	26.4 ab	43 bcd	30 cd
Weeping lovegrass	10	33.1 a	86 a	80 a
Ky. blgr. and C.R. fescue	30	7.8 c	34 cd	36 bcd
Ky. 31 and C.R. fescue	30	20.2 abc	51 bc	51 bc

Notes: The grasses were seeded on 4/17/70 on a hot 5:1 compacted fill slope that was very droughty. Soil pH was 7.2 to 7.6, and all plots were treated with 1,000 lb/acre of 10-20-10 fertilizer. Treatments not followed by the same letter are significantly different at the 5 percent level of probability.

Table 8. Performance of grasses near Beckley, West Virginia: Population and soil cover.

Grass	Seeding Rate (lb/acre)	Population (plant/ft^2)	Soil Cover (percent)
Bromegrass	60	33	40 b
Sand bluestem	64		1 c
Sand lovegrass	10		0 c
Weeping lovegrass	10	98	77 a
Switch grass	50		0 c
Orchard grass	60	142	87 a
Ky. 31 fescue	60	37	47 b

Notes: The grasses were seeded on 5/5/71 on a hot 2:1 compacted fill slope. Soil pH was 5.3 before application of 2 tons of agricultural limestone and 1,000 lb/acre of 10-20-10 fertilizer. Census was made on 9/1/71.
Treatments not followed by the same letter are significantly different at the 5 percent level of probability.

Table 9. Influence of weeping lovegrass and Ky. 31 fescue companion grasses on seedling populations of legumes.

Plant	Population (plant/ft^2) 11/3/70	6/2/71	Total Soil Cover (percent)	Soil Cover by Legumes (percent)
Weeping Lovegrass				
Crown vetch	8.5	8.7	81	57
Sericea	50	143	77	62
Ky. 31 Fescue				
Crown vetch	6.8	6.7	74	39
Sericea	40	63	66	40

Note: This experiment was seeded on 5/21/70 south of Princeton, West Virginia. The slope is a 2:1 cut (cool exposure) where a previous seeding by a contractor had resulted in a complete failure.

Figure 2. Comparison of perennial ryegrass (lower right), broom grass (lower left), tall fescue (upper left), and weeping lovegrass (upper right).

Figure 3. Weeping lovegrass on steep secondary slopes.

less growth and seedling competition. However, after two seasons, crown vetch soil cover was better with weeping lovegrass than with the fescue association.

On a cool cut slope south of Princeton, West Virginia, weeping lovegrass allowed somewhat more crown vetch and sericea seedlings than did Ky. 31 fescue (Table 9). Sod cover by the two grasses was similar (45 to 60 percent) by September 1970, with tall fescue providing slightly more soil cover than did lovegrass; however, by June 1971, the best soil cover occurred in the lovegrass association. This was attributed to better legume cover from sericea lespedeza and crown vetch, which were seeded with weeping lovegrass rather than with Ky. 31 fescue. This indicates that lovegrass was the least competitive toward the legumes. Although there was some winter kill of the lovegrass during the winter of 1970-71, no erosion occurred, and crown vetch and sericea lespedeza had developed a complete cover by August 1971.

Weeping lovegrass and German millet were seeded at a rate of approximately 5 and 15 lb/acre respectively on June 23, 1971, on a sunny bench slope near Charleston, West Virginia. Observations made in August showed good grass stands for the June seeding.

Crown vetch, a cool-season legume, starts growing earlier in the spring than does the warm-season lovegrass. Consequently, crown vetch can grow rapidly during spring—before lovegrass competes for light, nutrients, and moisture. Sparse populations of crown vetch spread rapidly after the first growing season by underground laterally spreading roots that produce many new plants.

A comparison of sericea lespedeza stands in lovegrass with those in the Ky. 31 fescue association near Lynchburg, Virginia, shows that the sericea stands after 2 years were poorer in lovegrass. Lovegrass seedlings established rapidly and produced 90 to 100 percent soil cover 2 months after seedings. This fast growing "shaded out" most of the sericea seedlings during the first year. After the first year, depending on the initial nitrogen rate, the stands of sericea improved.

The vigorous late spring and summer growth of weeping lovegrass with sericea occurs because both species grow during the warm season. Thus, if weeping lovegrass is to be used as a companion grass for establishing sericea, the nitrogen rate should be kept low to reduce lovegrass growth and competition.

SUMMARY AND APPLICATIONS

The work summarizes research on the adaptation and use of weeping lovegrass in the Virginias during the past 5 years. Excellent lovegrass stands were usually obtained with ease on numerous slopes previously considered too difficult for establishing grass vegetation. Lovegrass is widely adaptable and can easily be established on acid infertile soils. Because it is drought-tolerant and makes very efficient growth in the hot summer during periods of ample soil moisture when cool-season species produce little growth, it appears to be especially desirable for use on a wide range of slope environments for obtaining quick and permanent soil cover.

Liming improved lovegrass growth and persistence only on certain acid soils in the mountains and on the extremely acid pyrite soil materials in the coastal plains region of Virginia. Liming was very desirable for establishing crown vetch with the weeping lovegrass association, but it was not necessary for establishing sericea or woody vegetation with the weeping lovegrass association. A 10-20-10 fertilizer spread at 750 lb/acre generally gave quick-establishing lovegrass stands with excellent erosion control and also allowed botanical shifts to slow-establishing legumes or woody vegetation after 1 to 3 years. By increasing the fertilizer rate to 1,500 lb/acre, we obtained much denser and more persistent lovegrass stands. On several steep erosive slopes, applying lateral furrows about 2 to 3 in. deep generally improved lovegrass stands and initial erosion control.

Dates of seeding and companion grasses also influenced the establishment and persistence of lovegrass. Seeding in late spring and midsummer produced rapid-growing sods and quick soil cover; during this period cool-season species usually give poor germination and seedling survival because of high temperature and moisture stresses.

However, early spring seedings generally gave slow establishment and often poor stands of lovegrass because of frost kill and excessive light competition from the cool-season grasses at low spring temperatures, especially on cool slopes in the mountainous sections. Also, with several of the late summer seedings, lovegrass plants did not complete seedling development the first year, and high seedling mortality resulted during the first winter.

Personnel of highway departments often encounter problems and high costs for establishing vegetation on slopes along roads where seedings made by grass contractors fail or give only partial soil cover and erosion control. Partial failures occur under difficult environments such as steep slopes with erosive, infertile, droughty, and/or acid soil conditions; but, with adequate fertilization, lovegrass has persisted well in such difficult environments where cool-season grasses, such as Ky. 31 fescue, fail to give satisfactory sod cover for erosion control.

The highway department in Virginia is now successfully using weeping lovegrass in many areas for vegetating difficult slope environments and for obtaining quick cover for erosion control during the hot summer. They have found the species to be especially useful on steep secondary road slopes. These slopes are too steep for applying topsoil and are considerably more difficult to vegetate than shallower slopes with topsoil. Using weeping lovegrass has been the most expedient way of rapidly stabilizing these areas. Including sericea lespedeza or crown vetch in the seeding mixture and a fairly low rate of nitrogen has subsequently produced good legume stands. In forested areas, simply reducing the nitrogen rate has allowed botanical shifts from lovegrass to woody vegetation. The relative ease of establishing lovegrass under adverse conditions, its persistence with adequate fertility, and its compatibility with leguminous or woody vegetation make this species particularly suitable for use on roadside slopes in most sections of the Virginias and other eastern states.

ACKNOWLEDGMENT

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WOODY FIBER FARMING: AN ECOLOGICALLY SOUND AND PRODUCTIVE USE OF RIGHTS-OF-WAY

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The transportation and transmission systems in the United States are estimated to have more than 22 million acres of rights-of-way of which approximately 6 million acres are forest land. The present annual national maintenance cost for mowing, cutting, burning, and spraying is estimated to be at least $200 million, an amount that increases each year. The serious national concern about air and water pollution has already encouraged some voluntary and some legislative action to eliminate burning and spraying. In the absence of these techniques, maintenance costs are increased by a factor of five, and the future annual maintenance bill may be $1 billion if all burning and chemical spraying are stopped. Biomass, nutrient, and pulping studies led to the Complete Tree Concept in 1964. An evolution of this concept is the production and utilization of the currently noncommercial tree and shrub species, commonly called "puckerbrush," that occur on rights-of-way. These species will produce useful paper and paperboard products in less pulping time than commercial tree species. Because "puckerbrush" is not large, 10 to 30 ft in height, and because there are many stems per acre, special harvesting equipment must be developed. Naturally occurring "puckerbrush" on rights-of-way can be harvested in 10- to 15-year cycles. Growth can be augmented by use of fertilizers and by deliberately developing genetically superior species. Thus, it should be possible to derive from the management of rights-of-way on forested land a net profit that will drastically reduce the overall right-of-way maintenance cost.

•THE land area of the United States including Alaska and Hawaii has been 3,548,974 square miles (16) or 2,271,340,000 acres for at least 400 years. The natural forest area once was approximately half of the total land area, but this has been reduced to 759,000,000 acres, about one-third, because of agriculture, urban development, and transportation and utilities rights-of-way. As the population in our country increases, there will inevitably be fewer forested acres. It is appropriate now for us to consider a basic question: Does man need forests and if so to what extent?

In the photosynthetic process, green plants synthesize carbon dioxide and water into carbohydrates in the presence of light. Oxygen is produced as a by-product that enters the atmosphere. Man requires oxygen to live, and it is extremely doubtful that he could live in the total absence of green plants.

There are three other major uses of the forest by man. One is watershed management for the retention and distribution of water for drinking and other purposes. The second is recreation, which is becoming increasingly important to people who live in cities. The third is as the source of wood for solid products such as lumber and railroad ties and reconstituted products such as paper and paperboard, particle board, and fiber board. No one now knows how much forest land is essential per person to meet the four major human demands on the forest.

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It is possible to forecast future wood requirements. Duerr (2) has depicted these requirements in Figure 1, which shows an overall increase in the use of wood, an increase in the proportional number of reconstituted products, and a decrease in the per capita consumption of wood. Unhappily, we cannot forecast in a quantitative manner the increasing demands for oxygen, water, and recreation in the forests. The demand will be proportional to the increase in population, but the effect on the forest may be much greater. It is safe to state that the four major uses of the forest by man are exerting pressure and that the pressure will continue to increase unless some direct action is taken to reduce it.

The exact acreage of transportation and utilities rights-of-way is not known. Estimates (1) are given in Table 1. The Maine State Highway Commission (3) has estimated that the rights-of-way on rural roads in Maine (exclusive of roadway) take up approximately 95,000 acres on 21,340 miles of road. By extrapolating this limited information to the U.S. rural road network and by incorporating the national proportion of forested lands, the Commission made estimates of the rights-of-way acreage extending through forested land. These rights-of-way are currently maintained by planting and mowing grass, by cutting and burning woody vegetation, or by periodically spraying chemicals to destroy the wood vegetation.

The Maine State Highway Commission has voluntarily banned brush burning, and the legislature of Vermont has made illegal the chemical spraying of brush. It is entirely possible that legislative action in other states will follow along similar lines. Maintenance costs appear to increase by a factor of five when burning and spraying are prohibited. If the nation continues to exert pressure on all forms of pollution, the annual right-of-way maintenance cost could reach the $1 billion level within a decade.

This paper will present a method whereby the cost of right-of-way maintenance can be drastically reduced without polluting the environment. Simultaneous pressure on the forests will be reduced by providing an alternative source of raw material for reconstituted woody fiber products.

DEVELOPMENT AND EVOLUTION OF THE COMPLETE TREE CONCEPT

Pulping, biomass, and nutrient studies were initiated in 1959. By 1964 the Complete Tree Concept (9) had crystallized based on the available data. This is a biological concept and consists of technological investigation of the entire tree from the root hairs to the leaf hairs. This is in sharp contrast to the concept of the merchantable bole, which is currently in vogue. A series of papers and bulletins (3, 4, 6, 9-15) show the following:

1. Regardless of size or species, the distribution of wood fiber is approximately as follows: bole (65 percent), unmerchantable top (5 percent), branches (5 percent), stump (15 percent), and roots (10 percent) as shown in Figure 2;
2. Approximately half of the 15 essential elements in a tree are in the merchantable bole with about half in the wood and the remainder in the bark;
3. Pulp made from the wood of the logging residue is similar in yield and physical properties to pulp made from the wood of the merchantable bole except for the branches, which have a lower yield and poorer physical characteristic;
4. Use of all of the logging residue would increase yield from the forest by 50 percent.

The merchantable bole is commonly measured in board feet or cords, two units of cubic measurement. The varied size, shape, and abundance of branches and roots made it impractical to use volume as the measuring unit because of the time and errors in volume determination. It was preferable to use weight in the complete tree studies because of its simplicity, it rapidity, and the limited sources of error. Despite the fact that only mature trees were used in the initial study, all of the tree components were measured in the same unit: weight. With attention focused on the Complete Tree Concept rather than only the merchantable bole, it was possible and reasonable to look at the forest from a much broader perspective. The Complete Tree Concept led to an

Figure 1. Consumption of wood products in the United States, 1900 to 2000: 13-year moving average quantities expressed in terms of roundwood equivalents, including both domestic and imported wood.

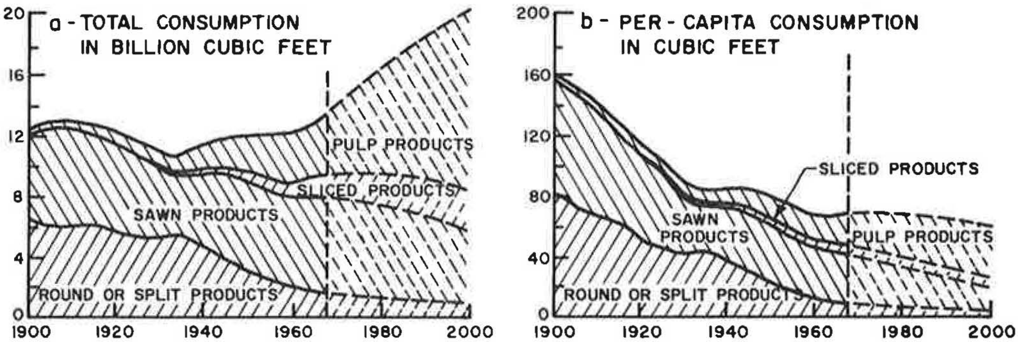
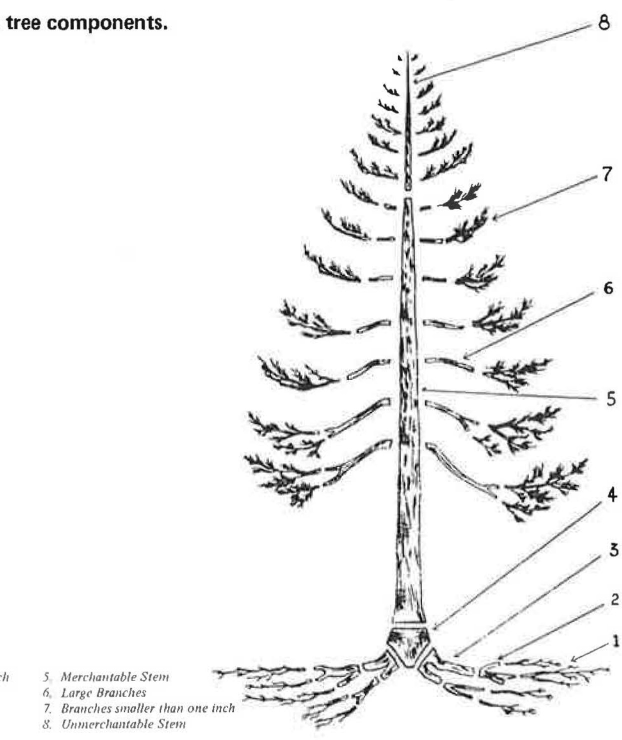


Table 1. Rights-of-way estimates for the United States.

Right-of-Way	Miles	Total Acreage	Forested Acres
Rural roads	3,152,047	15,000,000	3,700,000
Power transmission	300,000	4,000,000	1,300,000
Railroads	208,111	3,300,000	800,000
Total	3,660,158	22,300,000	5,800,000

Figure 2. Eight tree components.



examination of the entire standing crop of trees, which encouraged consideration of dry matter production per acre in much the same manner as agricultural specialists think about wheat, corn, and other crops.

Regeneration for the next crop is obtained in present forest management in one of two ways. One is by deliberately leaving a few or many seed trees and the other by clear cutting and planting. The former is by far the dominant method on a worldwide basis. From the perspective of the Complete Tree Concept, both methods leave much to be desired. In the selective logging method, many small trees are incidentally destroyed; in the clear cutting method, all trees not immediately harvested are deliberately destroyed prior to planting. Studies of the smaller trees and shrubs (15, 16) led to the Complete Forest Concept in 1967. This is a biological concept and includes a technological study of all of the woody shrubs and trees with a view to intensive management of selected areas.

Up to this point, the major thrust of the research has been with seedlings, saplings, and mature specimens of commerical tree species. Only minor effort has been expanded on woody shrubs. In other words, no attention had been placed on noncommercial trees and shrubs. In Maine there are more than 50 species of noncommercial hardwood tree and shrub species. These commonly grow in dense stands with literally thousands of stems per acre and are commonly called "puckerbrush." Inasmuch as "the bush" is a common term for commercial forests in several countries, the term puckerbrush can be applied equally as well to currently noncommercial tree and shrub species, which occur as successional species on every continent.

WOODY FIBER PRODUCTION AND UTILIZATION CONCEPT

The Complete Tree Concept was based primarily on studies of mature specimens of climax forest species. Because forest management and forest industries are based on the Merchantable Bole Concept, a considerable amount of knowledge has accumulated of such species. The Woody Fiber Production and Utilization Concept is simply the notion of utilizing all woody shrub and tree species regardless of size. This includes all of the currently noncommercial trees and shrubs in the successional stages as well as those currently recognized as being of commercial importance. Because of the current and past indifference to the potential usefulness of "puckerbrush," our knowledge of this species is extremely limited.

The serious study of "puckerbrush" within the Woody Fiber Production and Utilization Concept raises many questions. How rapidly does each species grow, and how does the overall growth compare with commercial species? What is the inventory of such species? What products can be made from such species? How can such species be harvested, and would the harvest cost be economically acceptable? How will "puckerbrush" fit into our economy, and what impact will its use have on our natural resources?

The Complete Tree Concept was publicly unveiled in 1964. Serious response took place in Canada (1967), the United States (1968), and Finland (1969) in major forest products laboratories. It now appears that the cooperative effort of the Finnish Forest Research Institute and a number of Finnish pulp and paper companies will be the first to bring this concept into reality by 1973. The Woody Fiber Production and Utilization Concept was publicly announced in 1970.

WOODY FIBER FARMING

Woody fiber farming, the practical application of the Woody Fiber Production and Utilization Concept, can be accomplished by two different approaches. One, the method of opportunity, is to harvest "puckerbrush" stands that have grown in naturally on abandoned fields, burned-over areas, or cutover areas with the intent of harvesting every 10 to 15 years. The other, the plantation or seeding method, is based on distributing genetically superior seed or planting genetically superior stock on rights-of-way. The intent here would be to harvest the succeeding coppice stands on a 10- to 15-year cycle. The first method requires no investment in the crop and consequently should not have as high a yield. The second method requires an investment initially in research followed by the cost of seed orchards or nurseries; however, in return it should provide higher yields that more than cover the added cost. The discussion that follows is directed at the plantation and seeding method.

Current right-of-way maintenance methods in forested areas eliminate woody vegetation by cutting and burning brush or by spraying chemicals. Both methods work, but they are costly and will continue to increase in cost as wages increase. If neither of these expensive methods was used, natural vegetation would grow and would pass through the successional stages until the climax forest was achieved, which would be undesirable to the right-of-way owner. By using 10- to 15-year periodic harvests, we could maintain the woody vegetation in a successional stage. The natural-occurring woody vegetation might not be fully stocked, might not be the most desirable species, and might not grow rapidly, but fertilization would increase annual dry matter production. Seeding with genetically superior seed or planting with genetically superior stock appears to be the best way to ensure fully stocked stands that will produce the maximum fiber per acre per year. The seeded or planted stock would regenerate and, after several cycles, would have to be supplemented by additional planting or seeding.

In Maine, "puckerbrush" (17) is producing about 1.2 tons of dry matter on the above-ground portion per acre per year exclusive of the leaves. By using fertilization and plant improvement practices, we might develop fully stocked stands that would produce 5.0 tons of dry matter on the above-ground portion (exclusive of the leaves). Research will determine the maximum and economic optimum amount that can be grown.

Appropriate questions at this point are as follows: What will it cost to harvest "puckerbrush"? What will transportation costs be? What are the expected prices for "puckerbrush" delivered to the mill? Will pulp mills use such material? There are no established anwers available. Morbark Industries has recently made several tests (25,000 tons of chipped material per test). They estimate that the cost of green chips delivered a distance of 50 miles would be $4.87 per ton including stumpage of $0.50 per ton and all depreciation, maintenance, and labor costs. It will take at least two green tons of chips to be the equivalent of a cord, which would be competitive with hardwood cordwood delivered to the mill.

A considerable amount of work is under way to determine the quality of products that can be produced from "puckerbrush." Professor Chase has demonstrated in the laboratory that usable paper products can be made from "puckerbrush." At least one paper company (5) is making similar tests on a pilot plant scale using wood and bark from both small and large hardwood trees. Several other companies have indicated that they have been conducting laboratory studies. It appears that the problem is centered on the cooking conditions and amounts of chemicals to be used rather than the need to use new equipment.

Successful woody fiber farming of rights-of-way should markedly change maintenance costs. Woody fiber farming should result in a small net profit per acre in place of the $100 to $200 per acre costs for cutting and burning or spraying. Some areas will be unsuitable for woody fiber farming, and methods now in use will be continued as a direct cost. The net effect of woody fiber farming of rights-of-way should be a drastic reduction in overall maintenance costs, a considerable reduction in pollution, and the establishment of an additional source of raw material to meet the rapidly rising demand for wood products. Another potential advantage of fiber farming is in the area of safety. When an automobile leaves the highway at a high speed, the trees and shrubs should have a braking effect in contrast to the skidding action on grass.

There are two distinct types of research personnel working separately on complete tree utilization and biomass of complete trees and shrubs for ecological purposes. It appears that there are five major aspects of woody fiber farming that should be investigated by both types of researchers:

1. Utilization studies: for all reconstituted products that are currently on the market plus novel possibilities such as insulation material;
2. Biomass studies: there are many species, and very little work has been done to date;

3. Plantation and species improvement studies: these will require more time than the other aspects but will determine the maximum potential about species for which little is currently known;
4. Economic studies: sufficient biological and technological information is available for objective economic evaluation; and
5. Engineering studies: feasibility studies should be made followed by the development of prototype "puckerbrush" harvesters and complete tree harvesters.

With sufficient funds, staff, and equipment, all but the plantation and species improvement studies could be completed within a 5-year period for an extensive region. The plantation and tree improvement studies would take at least 15 years and possibly longer because woody vegetation does not produce during the first season.

For those who think only in terms of eliminating vegetation on rights-of-way, woody fiber farming must seem like an impossible dream. There are no biological or technological barriers, and, if the sociological barrier could be overcome quickly, woody fiber farming could become a reality by 1977 or earlier.

SUMMARY AND CONCLUSIONS

Biomass, nutrient, and pulping studies performed over a 12-year period led to the Complete Tree Concept, which evolved into the Complete Forest Concept and more recently the Woody Fiber Production and Utilization Concept. The latter is based on the use of successional species of trees and shrubs called "puckerbrush" in Maine which are not of commerical value today.

Woody fiber farming of rights-of-way is a practical application of the Woody Fiber Production and Utilization Concept. It will eliminate brush cutting and burning and brush spraying, two sources of pollution, and simultaneously provide an alternative source of raw material for mills making reconstituted products from wood. This should yield a small net profit for rights-of-way (specifically in fiber farming) and thereby dramatically reduce the overall maintenance costs, which will include a high percentage of rights-of-way that cannot be fiber farmed.

Woody fiber farming is only an idea in 1972, but it is based on considerable research. It can become reality by 1977 if sufficient funds are made available to do the necessary work in the engineering, economic, utilization, biomass, and tree improvements phases of the overall research.

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DISCUSSION

Alfred C. Scheer, Montana State University

Harold Young's paper deserves consideration as a serious proposal for the multiple use of transportation rights-of-way. One of the more sensible trends in recent years has been the acceptance of the fact that there is merit in utilizing transportation rights-of-way for various other constructive purposes that are compatible with the primary transportation function.

Apart from economic considerations, which could be of considerable importance in some instances, one could classify a proposed multiple usage as excellent, from a transportation functional perspective, if its net effect is to enhance or improve the transportation function; as acceptable if it neither enhances nor degrades the transportation function; and as undesirable if it has a distracting or degrading effect on the transportation function. Unfortunately, this classification cannot be made on a sweeping general basis but must be made on a finely subdivided station-to-station basis because a single proposed multiple usage might well be excellent at one station but highly undesirable at another.

I see Young's woody fiber farming usage as one that definitely falls into the latter category: excellent in some places, probably acceptable in many places, and highly undesirable in some other places.

Although at some time in the future it may become economically feasible to nurture and harvest small-stem brush for its woody fiber in certain adaptable highway right-of-way plots, there is nevertheless a greater immediate need for finding or developing the best species and then using them advantageously to enhance the transportation function as a permanent part of the right-of-way environment. A few of the more advantageous locations for permanent stands of relatively small-stem brush are as follows:

1. In the median strips of divided highways to screen headlight glare and to serve as a resilient median barrier to prevent cross-median accidents and to safely decelerate vehicles that wander into the median strip.

2. Beyond the roadway at the starting point of a horizontal curve. Even a relatively unalert driver who sees a thicket of brush straight ahead is likely to deduce that he will need to make a turn soon to avoid ending up in the brush thicket. If the driver does miss the turn and runs off the road, he still has a pretty good chance of surviving as he plows through several yards of nonrigid brush before coming to a relatively gentle stop.

3. As a crash cushion planted in front of rigid objects or other collision hazards located off the side of the road in places where there is room to plant enough brush for an effective crash cushion without creating other hazards. One could argue for a small-

stem brush crash cushion in almost any location where a driver might accidently run off the road.

4. As a screen planting for beautification purposes to hide junkyards and other roadside eyesores or to enhance an already pleasant view; also as a screen planting to screen the highway and its associated noise and glare from abutting or nearby property and to create a park-like environment to enhance the value of abutting property.

5. As a natural snow fence to force snow to drift into off-the-road areas instead of forming drifts on the roadway.

6. At incipient gully locations to inhibit gully scour that smaller vegetation might not be able to control and to prevent surface erosion on potentially unstable slopes.

7. As windbreaks in specific locations where sudden crosswinds catch drivers by surprise and cause accidents or serious driving tensions.

8. In wide rights-of-way, as wildlife habitat for numerous species of birds and small animals. Recent North Dakota studies have shown that managing rights-of-way as small game habitats does not create a significant accident problem.

9. Dense thorny brush thickets along right-of-way lines could eliminate the need for right-of-way fences in some locations.

This list is far from complete, and I may have overlooked some of the best reasons for desiring permanent stands of brush on highway rights-of-way, but it should at least serve to point out that small-stem brush does have a valid permanent role in comprehensive roadside management.

Unfortunately, stands of roadside brush may also have some very undesirable effects that are sometimes entirely incompatible with the primary transportation functions. Some of the more obvious negative factors are as follows:

1. Brush too close to the roadway will inevitably create some very dangerous sight-distance problems. Naturally occurring trees and shrubs on the convex side of horizontal curves must be removed or trimmed frequently to prevent the loss of safe sight distance. In my opinion, few maintenance organizations do an entirely satisfactory job of coping with this problem at the present time. Woody fiber farming simply could not be tolerated at any site where it might cause a loss of safe-passing sight distance or safe-stopping sight distance. Even on tangent sections of highway, it would be necessary to specify a rather generous minimum clearance distance between the shoulder and the "puckerbrush jungle" in order to give drivers a chance to avoid hitting any animal or person that suddenly emerges from the brush thicket and to prevent windstorms from blowing significant quantities of limbs or branches onto the roadway.

2. Brush should not be grown in locations where it would cause snow-removal problems or where it would form a natural snow fence that would cause snowdrifts to form on the highway or at locations where it would shade the highway and cause unexpected icy spots on the road. Autumn leaf fall could also create accident hazards at some sites.

3. It is virtually impossible to effectively remove the typical accumulation of roadside litter from a dense thicket of roadside brush. On the other hand, the brush would do a rather effective job of hiding some types of litter that could be "harvested" immediately after the harvesting of the brush for its woody fiber. Also, it is conceivable that public attitudes will change sufficiently to markedly reduce the amount of litter dumped on the roadside.

4. I worry that the "puckerbrush" stubble, following the wood fiber harvest, might well constitute an offensive eyesore that would be difficult to justify on the basis of a small woody fiber profit.

In view of the necessity to maintain a sizable brush-free strip on each side of the road for sight-distance safety reasons and because there will still be a need to pick up roadside litter, it is highly unlikely that woody fiber farming would reduce roadside maintenance costs by the amount that Young suggests.

To summarize my feelings on the matter, I see a lot of merit in growing small-stem brush species on transportation rights-of-way in places where this will improve the transportation function or enhance the value of the abutting property. In these cases, however, the brush should be maintained indefinitely instead of being periodically harvested. If we include areas on which a stand of brush would be incompatible with the transportation function, there still remain large portions of rights-of-way on which brush thickets could probably be grown and periodically harvested for their woody fiber without creating significant transportation or environmental problems.

I am not opposed to the proposal to grow small-stem brush on rights-of-way except in the incompatible locations mentioned earlier. I would be happy to see thickets of small-stem brush grown and maintained on transportation rights-of-way. If it ever becomes economically feasible to harvest these thickets, we can then worry about which thickets, if any, should be harvested and which ones should be permanently maintained.

AUTHOR'S CLOSURE

It was my pleasure a few years ago to visit the national monument near Kitty Hawk, North Carolina, where the Wright brothers achieved the first successful airplane flight. As I walked along the tiny track appropriately marked to show the distances of the first flights, I thought about their imagination, daring, and inventiveness as well as the myriad developments in the airplane since December 17, 1903. The Wright brothers did not believe that it would be possible to fly at night, and they did not foresee the impact of the airplane on civilization.

For woody fiber farming it is now, figuratively speaking, not 1903 but 1913. Insufficient research funds is the only factor that is preventing the full development of woody fiber farming.

Professor Scheer has admirably listed a number of likely advantages and disadvantages of woody fiber farming. Within a few years, I expect a few state highway commissions and electric transmission companies to try woody fiber farming on a small scale. As operational techniques are developed, confidence will be established and practical limits will come into focus. Then and only then will we really know the true relation between the sum total of the advantages and the sum total of the disadvantages.

DIRECT SEEDING ALONG HIGHWAYS OF WOODY PLANT SPECIES UNDER A WOOD-CHIP MULCH

John M. Zak, Joseph Troll, and Leslie C. Hyde, University of Massachusetts

•DURING highway construction, natural communities of plants are completely destroyed; the bare road banks are subjected to full exposure to the sun, fluctuations in temperature, changes in moisture conditions, and erosion. Such adverse conditions make it difficult for most plants to become established, and it may take years, if left alone, before the bank becomes stabilized with vegetation. However, with the use of wood-chip mulches and the seeding of selective woody plant species, vegetation would quickly heal the scars of construction.

At the present time, shrubs and trees are planted along slopes in Massachusetts mainly to restore a natural balance in the roadside design (2). The cost of plant materials and planting is very expensive. Direct seeding would reduce this cost, speed-up vegetation on areas where it is hard to plant grass, and would allow diversity in the species that could be planted. Very little work has been done on the direct seeding on roadside slopes of woody plant species under a wood-chip mulch. Direct seeding of native shrubs along highway slopes was first suggested by William C. Greene in 1957 (3). Because the burning of trees, brush, and trash is banned in Massachusetts, wood chips become a valuable by-product that can be used as a mulch on new seedings and for erosion control on slopes. The Massachusetts land area is composed of approximately 60 percent forest; therefore, a good supply of wood chips should be available for use during road construction. Mulching (1) has become an integral part of seeding operations for erosion control and better seed germination, and various mulches are used according to their cost and availability.

In November 1964 (4), seeds of various woody plant species were seeded on a roadside slope using different kinds of mulches. Seed germination was best under the wood-chip mulch.

The purpose of this investigation was to determine the possibility of establishing species of woody plants from seed under a wood-chip mulch.

GREENHOUSE EXPERIMENT

Materials and Methods

Wooden flats, 12 by 24 in., were divided in half to make two, 1-sq ft planting areas. These were filled to a depth of 1½ in. with a soil mixture that was composed of two parts loam and one part sand. Fifty viable seeds of four woody species of different seed size were used per plot (Table 1). Seeds were lightly covered with soil. Four different depths of mixed hardwood chips that were previously passed through a 1½-in. mesh screen were used as a mulch. The check plot had no mulch. The plots were replicated three times. The seed treatments before seeding were (a) bristly locust—seeds immersed in hot water (water heated to 212 F) and allowed to soak for 8 min as the water cooled; (b) Tatarian honeysuckle (same as the previous treatment except water was brought to a temperature of 175 F); (c) indigo bush—seeds immersed in sulfuric acid for 10 min; and (d) dyer's greenweed—no treatment.

The check plot with no mulch was watered every day, and the mulched plots were watered 1 to 2 times weekly. Seedling emergence counts were taken during a period of 2 months after seeding.

Sponsored by Committee on Roadside Maintenance.

Table 1. Seed count per pound and seed weight (in milligrams) of various woody plant species. Percentage of seedling emergence under four depths of wood-chip mulch.

Species	Number of Seeds per Pound	Seed Weight (milligrams)	Percentage of Emergence: Check (no mulch)	1 in.	2 in.	3 in.	4 in.
Arnot's bristly locust (Robinia fertilis Arnot)	25,560	18.3	44	60	50	32	6
Indigo bush (Amorpha fruticosa L.)	45,536	6.8	18	24	12	0	0
Dyer's greenweed (Genista tinctoria L.)	118,948	3.7	6	5	2	0	0
Tatarian honeysuckle (Lonicera tatarica L.)	165,256	2.8	50	60	5	0	0

Results

The emergence data (Table 1) show that large seeds were able to emerge through 2 in. or more of wood-chip mulch. Small seeds evidently do not have enough stored energy in the form of carbohydrates to push a sprouting seedling through a thick layer of wood chips. Bristly locust had 60 and 50 percent emergence under the 1- and 2-in. layers of mulch respectively. It appears that use of the 2-in. depth of wood chips on roadside slopes would give satisfactory emergence of the bristly locust and would also control erosion.

Tatarian honeysuckle had 5 percent emergence through a 2-in. layer and 60 percent through a 1-in. layer of mulch. However, a 1-in. layer of wood chips may not be satisfactory for erosion control on a steep slope to be seeded with this plant. Another method of mulching must be found for species whose seedlings do not emerge through the 2-in. depth if they are to be seeded successfully on steep slopes. The value of a mulch is illustrated well by comparing the percentage of emergence of seedlings in the check plot with those under the 1-in. mulch. This is manifested well in the test results of bristly locust, indigo bush, and Tatarian honeysuckle (Table 2).

Table 2. Number of seeds per pound and treatment of seed before seeding. Plant count per square foot (6 replicates) from 10 viable seeds and average height of seedlings in 1970 and 1971.

Species	Number of Seeds per Pound	Seed Treatment Before Planting	8/26/70: Average Number of Seedlings per Square Foot	8/26/70: Average Height (in.)	11/3/71: Average Number of Seedlings per Square Foot	11/3/71: Average Height (in.)
Indigo bush (Amorpha fruticosa L.)	45,536	Scar.[a] (hot water, 5 min)	8	2	7	10
Oriental bittersweet (Celastrus orbiculata Thunb.)	56,024	Strat.[b] (peat moss 112 days cold)	2	1½	1	—
Bayberry (Myrica pennsylvanica Lois)	19,976	Mech. scar. to remove wax; strat. peat moss 118 days cold	6	1½	3	11
Autumn olive (Elaeagnus umbellata Thunb.)	27,694	Strat. (peat moss 118 days cold)	6	2	5	16
Japanese larch (Larix leptolis Sieb. and Zucc.)	95,612	Strat. (peat moss 90 days cold)	0	—	0	—
Spanish broom (Spartium junceum L.)	38,453	None	13	3	0	—
Red cedar (Juniperus virginiana L.)	50,076	None	0	—	5	2
Black locust (Robinia pseudoacacia L.)	24,516	Scar. (hot water, 5 min)	9	4	8	41
Fragrant sumac (Rhus aromatica ait.)	22,382	None	1	—	5	3

[a]Scarification: water brought to boil and seeds immersed as water cooled. [b]Stratification: temperature of 41 F.

The percentage of emergence of dyer's greenweed was low because of seed embryo dormancy. Tests conducted since this experiment show that cold stratification for 90 days at 41 F will overcome this dormancy and increase germination to 72 percent.

ROADSIDE EXPERIMENT

Materials and Methods

A north-facing 2:1 fill slope in Gardner, Massachusetts, consisting mostly of a sandy loam texture, was used in this experiment. Plots 5 by 25 ft, replicated two times, were set out near the top of the slope. Seeds of nine different woody species (Table 2) were broadcast to give 10 viable seeds per square foot of plot on June 16, 1970. Some seeds were given a pretreatment before seeding. Two in. of wood-chip mulch were hand-spread over the area. Data were taken on germination and the height of plants.

Results

Seedling counts (Table 2) of indigo bush, bayberry, autumn olive, and black locust, taken August 26, 1970, showed good density and emergence under the 2-in. depth of wood-chip mulch. Survival was good the first and second years. Because there is no competition from other vegetation, there are more plants than necessary for the area.

Red cedar and fragrant sumac seed did not receive any treatment before seeding and therefore did not germinate until the second year, after a good stand had been established. Seeds of these species will not germinate when seeded in the spring unless they are stratified prior to seeding. Fall and natural seedings remain on the ground through the winter and pass through a period of natural stratification.

Oriental bittersweet and Japanese larch were rated poor in performance. Many of the seeds of the former species were rotten after being stratified, whereas the seeds of Japanese larch evidently were too small (Table 2) for many of the seedlings to emerge through the 2 in. of wood chips.

Spanish broom had a very good percentage of emergency through the wood-chip mulch and good seedling establishment the first year; however, all plants were winter-killed. This species could be used on Cape Cod or in other areas of the country where the winters are less severe than those in Massachusetts.

SUMMARY AND CONCLUSIONS

Very good results were obtained with the direct seeding of indigo bush, bayberry, autumn olive, black locust, red cedar, sumac, and Spanish broom under a 2-in. depth of wood chips. Better results should have been obtained with Oriental bittersweet and Japanese larch. In a trial experiment, Oriental bittersweet performed very well in 1968. Seed dormancy is common in many of the tree and shrub species. Breaking this dormancy requires some kind of scarification and/or stratification before seeding, especially for spring seedings. With many species, seedings made in the fall require no seed treatment. Various trials were run in the laboratory on the species used in these experiments to determine the best preseeding treatment for best germination. As more information is obtained on the treatment of seeds to break their dormancies, the more successful will become the direct seeding of these species under a wood-chip mulch along highways.

Wood chips are an excellent mulch material. They are weed-free, they prevent the soil from drying out, and they aid germination and seedling establishment. There was no soil erosion on the 2-in. mulched plot area during the entire experiment. Instead of waiting some 15 years for natural vegetation to establish itself on slopes that are mulched with wood chips, it seems more logical and practical to seed, before mulching, species of woody plants that are adapted to these areas. Thus, one provides in the roadside pattern a view of the landscape: the highway, the strip of mowed grass and legumes, and the short woody species that blend into the larger trees and forest to form a natural ecotone.

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