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Establishment, Protection, and Reestablishment of Urban Roadside Vegetation Against Salt and Ice

Minnesota Local Road Research Board

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The use of salt as a de-icer is common in Minnesota, because of its low cost and efficiency. But it causes many problems for highway maintenance staff because of its impact on the adjacent vegetation. Salty soils are not conducive to healthy vegetation growth, and the absence of healthy vegetation along the road may lead to weed control problems, increased erosion, and resulting damage to the pavement structure.

The report outlines salt effects on soil, as well as methods to avoid vegetation damage by salt and ice before it occurs and to repair damage. It also contains a list of salt-tolerant grasses and woody plants for use in Minnesota.

Preventive methods include selection of appropriate vegetation for conditions; use of salt-tolerant grasses and sods; use of native grasses and wildflowers; effective turf establishment practices; protection of existing vegetation; optimization of salt use; and use of products that are friendly to vegetation.

Maintenance methods include irrigation to flush salt from soil; soil treatments; vacuuming and sweeping; rejuvenation of damaged areas; and design and construction strategies.

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Establishment, Protection, and Reestablishment of Urban Roadside Vegetation Against Salt and Ice

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EXECUTIVE SUMMARY

The use of salt as a de-icer is common in Minnesota, due to its low cost and effkiency. Its use causes many problems for highway maintenance staff because of its effect on the adjacent vegetation. Salty soils are not conducive to healthy vegetation growth, and the absence of healthy vegetation along the road may lead to weed control problems, increased erosion, and resulting damage to the pavement structure.

Effective roadside vegetation management is important. There are many problems associated with establishing, growing, and maintaining roadside vegetation. This synthesis outlines some recommended practices for alleviating the effects of salt and de-icing operations. Both preventive treatments and maintenance operations are included.

Efforts can be made to avoid vegetation damage by salt and ice before it occurs, or can be made in maintenance activities to repair damage.

Recommended practices for alleviating the effects of salt and de-icing operations are given in the tables below. Both preventive treatments and maintenance operations are included.

Table 1. Preventing salt and compaction damage along roadsides

Method	Description	Treatments	Resources
Selecting the right vegetation for conditions	The wrong selection can lead to more maintenance, or expensive removal and replacement of dead plants.	Minnesota Department of Transportation (Mn/DOT) Office of Environmental Services has developed a CD for roadside plant selection in Minnesota., entitled *Woody & Herbaceous Plants for Minnesota Landscapes & Roadsides*. CD cost is $35.	Mn/DOT Office of Environmental Services Web site at www.dot.state.mn.us/environment, or call Scott Bradley at (651) 284-3758.
Use of salt-tolerant grasses and sods	Mn/DOT has developed a new seed mixture for use in areas with high salt. It is for low maintenance turf, reaching a height of about 12 inches.	Mn/DOT mixture 60A Modified (60B)	*Mn/DOT Standard Specifications for Construction*, available through Mn/DOT Office of Manuals and Sales at (651) 296-2216. Mn/DOT Seeding Manual available at www.dot.state.mn.us/Environment.
Use of native grasses and wildflowers	Some native grasses can be salt tolerant, as well as prevent weed growth and erosion. Native grasses and wildflowers can establish a diverse plant community that is adapted to local conditions.	**Grasses**: Canadian wild rye, Indian grass, little bluestem, blue grama, side oats grama **Wildflowers**: Black-eyed Susan, purple prairie clover, yarrow, bush clover	Best Practices Manual for Roadside Vegetation, Mn/DOT Manual No. 2000-19, available through the Mn/DOT Library or ORSS at (651) 282-2274.
Effective turf establishment practices	Plants will not grow in a poorly prepared soil. Compacted soil contains inadequate air voids, which prevents healthy root establishment.	Successful turf establishment involves four critical steps: 1. Site and soil preparation 2. Seed selection 3. Proper planting 4. Care and maintenance	Mn/DOT Standard Specification 2575 for Turf Establishment, *Mn/DOT Standard Specifications for Construction*, available through Mn/DOT Office of Manuals and Sales at (651) 296-2216.

Table 1. Preventing salt and compaction damage along roadsides (continued)

Method	Description	Treatments	Resources
Protecting existing vegetation	Roadside vegetation can be protected from snowplows and maintenance activities	Strategies include: • Push and store snow in the middle of the road, instead of on the sidewalk or boulevards. • Plant sensitive woody plants as far from the roadway as possible. • Avoid planting sites near heavy runoff areas, such as in low slopes. • Use chemicals that are not damaging to roadside vegetation	
Optimizing salt use	Mn/DOT's Salt Solutions program was designed to reduce the level of salt and sand use. It includes tools that allow operators to make better application rate decisions.	A key component of the Salt Solutions program is the use of truck-mounted infrared pavement temperature sensors. These sensors provide critical information that assist truck operators in selecting salt and sand application rates. The Salt Solutions program also includes operator training, application guideline charts, equipment calibration and repairs. These application rate charts correlate pavement temperature and weather conditions to assist the operator in application rate selection.	Mn/DOT Report No. 1998-20, "Salt Solutions – Statewide Salt and Sand Reduction", available through the Mn/DOT Library or ORSS at (651) 282-2274. Mn/DOT Salt Solutions Coordinator is John Tarnowski at (651) 297-1843.
Use of products that are friendly to vegetation	Several products are available that are not harmful to the soil or vegetation.	Use of the following: • Low salt index fertilizers • Liquid organic compost • Calcium chloride • Magnesium chloride • Calcium magnesium acetate (CMA)	Call Dwayne Stenlund at the Mn/DOT Office of Environmental Services (available at (651) 284-3787) for information.

Table 2. Maintenance activities to repair salt and compaction damage along roadsides

Method	Description	Treatments	Resources
Irrigation to flush salt from soil	Irrigation leaches the accumulated salt down into the soil below the root zone.	The required amount of irrigation depends on how saline the soil is and the depth of soil to be leached. To determine the amount necessary, excavate a shallow basin along the roadside, and fill it with water. Then judge the depth of the water entering the root zone. After the salt in the soil has been reduced, continue to apply extra water periodically when irrigating to prevent a new buildup of salt.	
Soil treatments	Several soil treatments may reduce the salt effects on the soil. They include improving drainage in an area, fertilizing the soil, or adding soil amendments to change the soil's chemical properties.	Treatments include: • Drainage improvements • Fertilizer • Soil amendments: • Potassium chloride • Potash • Gypsum	Stephanie Lynn Neid or Dr. Dave Biesboer at the University of Minnesota Department of Plant Biology at (612) 625-1234.
Vacuuming and sweeping	Vacuuming, raking, or sweeping the roadside each spring will remove much of the salt and sand remaining from winter maintenance operations.	Special equipment is not required. To totally replace soil around vegetation, an air spader is available that will blow all of the soil away from the roots. New, healthier and non-compacted soil may then be placed.	Call Dwayne Stenlund at the Mn/DOT Office of Environmental Services (available at (651) 284-3787) for more information.
Rejuvenation of damaged areas	Areas that have been damaged by salt or ice may be repaired by: • mechanically reseeding using a salt-tolerant seed mixture (mix 60B), or • aeration. Products that incorporate plastic elements designed to resist compaction under loading may also prevent severe soil compaction. Thousands of small pieces of mesh are blended into the soil. When the stabilized rootzone is compressed, the mesh elements flex and spring back, creating and maintaining voids along the length of the mesh pieces.	Mn/DOT has an aeration machine that is available for distribution. Potassium or lime nitrate may be applied in the fall. The treatments act as a root conditioner, hardening them gainst winter damage. An especially heavy-duty aeration machine, the "ERA-vator" from First Products is one of the few available that can effective break through dry, compacted soils that are commonly found along roadsides	Call Dwayne Stenlund at the Mn/DOT Office of Environmental Services (available at (651) 284-3787) for information.
Design and construction strategies	Other practices can be adopted during the design and construction of a roadway to reduce the impacts of salt and deicers.	Crown medians to direct the snow melt to gutters, instead of the soil. Placement of gravel shoulders to provide a buffer zone for adjacent roadside vegetation.	

CHAPTER 1: INTRODUCTION

Because it is inexpensive and effective for de-icing roads, salt is the most widely used de-icing compound. However, its use kills adjacent vegetation, and the absence of healthy vegetation along the road may lead to weed control problems, increased erosion, and resulting damage to the pavement structure. The degree of damage from salt use is related to the amount used, the soil type in an area, the amount of precipitation, and the plant species. The University of Minnesota and the M&DOT Offtce of Environmental Services have researched the effects of salt, sand, and other deicers on various types of roadside vegetation and soils. Results are included in this synthesis, along with recommended practices for use in given areas.

This project was selected because effective roadside vegetation management is an important and time-consuming operation for many local agencies. The problems associated with establishing, growing, and maintaining roadside vegetation are familiar to many maintenance and engineering staff Reduced staffing and funding resources have created the need for better management of roadside maintenance activities. Effective management requires an integrated approach, which considers the needs of local communities and users; a broad knowledge of plant ecology and natural processes; design, construction, and maintenance considerations; government statutes and regulations; and new technology. All of these factors must be considered to develop a plan to economically manage roadsides for safety, environmental health, and visual quality.

Two cost categories are important when assessing the cost-effectiveness of ways to manage the roadside environment:

- soil foundation and turf establishment costs

- maintenance and repair costs

Grading and turf establishment costs are easy to quantify from construction bid schedules. Maintenance costs, which can be much higher than initial establishment costs, are more difficult to quantify. Staff hours, equipment, and supplies are expensive, but selecting appropriate maintenance techniques and products can optimize those costs. Investment in construction of a solid soil foundation and initial turf establishment may significantly reduce maintenance costs for many years.

Note that the *Best Practices Handbook on Roadside Vegetation Management* (Mn/DOT Report No. 2000-19) offers many suggested practices for maintaining roadside vegetation. This report can be obtained from Mn/DOT's Office of Research and Strategic Services or from the Mn/DOT Library at (651) 296-2385.

Problem Statement

The use of salts or de-icers on the pavement is required for safety in Minnesota. However, these products are very damaging to roadside vegetation, especially within the first 50 feet of the pavement. The damaging effects may extend hundreds of feet, depending on traffic, speed and wind direction. Salt kill of sod is an expensive problem in urban areas, but can be equally expensive in rural areas as well. The expense is not only associated with the costs to reestablish the vegetation. Establishing vegetation adjacent to roadways prevents soil erosion by wind and rain, and the soil adjacent to the road provides pavement support. Losing that support can cause

damage to the pavement structure, and the resulting pavement distress can be much more expensive to repair than lost vegetation.

Erosion is the displacement of soil particles by rain, water flow, or wind. Sedimentation is the deposition of the soil particles. Erosion and runoff can be a serious problem along roadsides, both during and after construction. In addition to losing valuable soil resources, erosion results in an unhealthy environment for growing vegetation, pollutes waterways with sediment and other particles, and results in costly maintenance activities to repair damage. Evidence of damage at the site may include rilled and gullied slopes, washed out ditches, damage to pavements and drainage structures, clogged pipes, and flooding. Damage to water bodies occurs when they become filled with polluting sediment, making them susceptible to flooding and stream bank erosion.

The presence of vegetation retards erosion. Studies show that, in a given rainfall episode, bare soil can lose up to 100 pounds of sediment, mulched soil loses up to 20 pounds, and well vegetated soil loses only up to one pound. The presence of well-established vegetation, or even a mulch cover will preserve the soil and reduce the effects of erosion on an area.

Salt Effects on Soil

The health of the roadside soil is an important factor for establishing a healthy roadside environment. Even the most appropriate and useful tools for roadside vegetation management may not work if the soil lacks the nutrients to support the targeted vegetation. If the soil in an

area is unhealthy, a variety of measures, including the use of fertilizer, aeration, or deep scarification to incorporate oxygen can be taken to improve it.

The ideal surface soil is comprised of approximately 5% organic matter, 25% air, 45% mineral material, and 25% water. The organic material provides fertility, water holding capacity and supports microbial life. The oxygen is required for all root growth. Typically along roadsides, the soil is stripped of its nutrients and is compacted such that little air remains in the soil, leaving a very hostile environment for vegetation to flourish. When troubleshooting to determine causes of vegetation problems, assessing the soils in an area may explain excessive weed growth or resistance to chemical control methods. (3)

The accumulation of salt in a soil can also affect its drainage or infiltration capabilities because the soil structure is changed significantly. High sodium levels in the soil reduce its cation exchange capacity, creating a tighter packed soil that results in poor drainage. Also, fewer exchange sites in the soil prevent other nutrients from bonding and make it more difficult for the plant to get nutrients. (3)

The high salt levels also create drought conditions for the plant by increasing the osmotic potential of the soil solution. This means that more water is tightly retained in the soil structure rather than being made available to plants. This drought stress is especially a problem in dry years. Signs of high soil salt levels include:

- irregular vegetation growth, and lack of plant vigor
- white surface-crusting

- broken-ring pattern of salts adjacent to a water body
- white spots and streaks in the soil, even where no surface crusting occurs
- presence of naturally growing, salt-tolerant vegetation

Salinization of the soil and subsequent salinization of the downstream water degrades the quality of shallow groundwater and surface waters such as ponds and ditches. (3)

High sodium levels create a number of problems, but chloride irons actually cause damage to more species of plants than the sodium. Scientists are not sure how the chloride is toxic, but do know that plants with chloride toxicity show burning of leaf tips and margins, bronzing, yellowing, and premature leaf drop. (5)

The amount of salt that a soil retains is also related to its clay content. Specifying or incorporating soils that are granular allows water to drain from the soils, taking salt with it. High clay soils retain water, along with the sodium and chloride ions.

Salt Effects on Vegetation

Damage to plants originates from both salt spray and salt in the soil. Salt spray affects growth, worsens the appearance, and lowers the economic value of trees. It may kill sensitive species like white pine. The most apparent damage is death of buds and twig tips. As the tips of the plants die, the plant responds by growing an excessive number of side branches. When coniferous trees are injured by salt spray, their needles turn yellow or brown in early spring. If salt is excessive in the soil, new needles may also die with the accumulation of chloride ions.

One characteristic of salt injury is that it is often confined to branches facing the road. Trees closer to the road suffer more damage than those farther back. (7)

Generally, trees that are most sensitive to salt are the broad-leafed species, such as linden, black walnut, and sugar and red maples. Research indicates that, in maples planted alongside roads, chloride levels at just 0.5 percent dry weight of plant tissue result in moderate leaf damage, and levels of 1 to 2 percent result in severe leaf burn, defoliation, and even death of the plant. In conifers, chloride concentrations of just one percent in the needles of red and white pine have shown to cause extensive damage. Salt tolerant trees include oak, birch, white ash, and Scotch and jack pine. (8)

Salt effects do not occur until the first winter. Directly after construction, the turf and soil may appear to be healthy. Once the soil is salted during snow and ice control operations, germination is affected, and damage occurs. If the construction has been completed, the Owner agency may not have recourse to repair the damage within the contract. The problem then gets handed over to maintenance staff. (1)

Soil salinity also injures plants indirectly because weaker plants may be more susceptible to frost injury, diseases or insects. In addition to problems caused by salt, sanding operations are hard on roadside environments. The accumulation of sand buries vegetation, making it difficult to flourish and grow in some areas.

Mn/DOT recently completed a study to determine the value of using various types of grasses, including short-stature native grasses, along the edge of heavily traveled highways. It showed that soil salt concentrations as small as 1000 ppm delay germination of native grasses by 10 to 50%. This is significant, since concentrations of 1000 ppm represent only moderately saline soil. Soil salt concentrations along roadways can be much higher. At 5000 ppm, germination is completely inhibited for some grasses. The study found that the impact on the soil was dependent on the lateral distance from the road, and that the majority of the salt in the soil was found within five feet of the roadway edge. Salt effects were especially significant within the first two meters of the road.

Disturbance of the soil and plants, especially by snowplow blades within one meter of the inslope appeared to be the likely cause of the plants dying. However, the potentially high soil salt levels during the winter months when the soil is frozen and the plants are dormant was not been ruled out as a cause for the failure to grow. In their study, Mn/DOT mix 30A modified (30B), which contains native species as well as the non-native alkali grass (*Puccinellia distans*), was most successful at providing vegetative cover along the highway inslopes in this region.

The study also showed that flowers were much more sensitive to salt than the grasses. The relative salt tolerances of the species varied depending on the life stage (germination, seedling, mature). Generally, the native plantings along the shoulders and inslopes were found to be only somewhat successful with only about 10-20% of the desirable native species surviving, and an indication that the native species cover was not increasing over time. This is true for all grass plantings, not just native grass plantings. Although germination and seeding establishment was

initially high, large losses of desirable species occurred within one meter of the pavement edge after the first winter, with the exception of the non-native alkali grass. Kentucky bluegrass, which is often specified along roadsides, was found to be very susceptible to salt damage, and should not be used in high salt areas.(3) However, there are varieties available that are more salt tolerant.

CHAPTER 2: SOLUTIONS

In a 1999 study, the Nevada Department of Transportation identified the following factors as having a significant effect on the degree of vegetation damage:

- Temperature: higher temperatures compound the effects of salt.
- Light: exposure to direct light increases the rate of dehydration caused by salt exposure.
- Humidity: high humidity lowers the rate of dehydration, and alleviates water stress.
- Wind: exposure to wind increases the rate of dehydration.
- Soil water: as salt content increase, the soil water available to plants decreases. High concentrations of soil salt can cause more injury when soil water is limited from low precipitation.
- Soil texture and drainage: the ability of soil to retain salt is somewhat determined by soil texture and drainage characteristics.
- Precipitation: rain and other precipitation can transport salt away from the plant. Rainfall can flush deposits from leaves and dilute salt solutions in water. (8)

The type and condition of the roadside vegetation also affects the degree of damage. Different species have varying tolerances for salt, and within species, plant maturity and size affect salt tolerance. Considering these factors can assist in developing strategies for reducing salt damage.

Preventive treatments

Efforts can be made to avoid vegetation damage by salt and ice before it occurs, or can be in maintenance activities to repair damage. The following preventive treatments are offered in this synthesis:

- Selection of appropriate vegetation for conditions
- Use of salt-tolerant grasses and sods
- Use of native grasses and wildflowers
- Effective turf establishment practices
- Protecting existing vegetation
- Optimizing salt use
- Use of products that are friendly to vegetation

Selection of appropriate vegetation for conditions

A challenging element of roadway design and maintenance is selecting the appropriate vegetation to plant in the project right-of-way. The wrong selection can lead to more maintenance, or expensive removal and replacement of dead plants. To assist designers and maintenance staff with this task, the Mn/DOT Office of Environmental Services developed an interactive, easy-to-use, multimedia system for roadside plant selection in Minnesota. The system is available on CD-ROM for use with personal computers, and is titled *Woody & Herbaceous Plants for Minnesota Landscapes & Roadsides*. Its purpose is to improve the quality of roadside plant selection and management in Minnesota by offering expert assistance in selection, and by increasing the likelihood that plants will be placed in locations and under conditions in which they are likely to survive, if not flourish.

The program can be used by district maintenance staff, external agency staff, consultants, and community landscaping professionals to select appropriate trees, shrubs, groundcovers, grasses, sedges, ferns, perennial flowers and vines for any combinations of desired characteristics and

existing site conditions. Site conditions are typically characterized by soil sampling and testing. It allows the user to quickly and accurately determine the most appropriate plant(s), based on the location, site conditions, and expected functions for landscape design, restoration and management. It is available through the Mn/DOT Web site, or by contacting Scott Bradley, in the Mn/DOT Office of Environmental Services, at (651) 284-3758. The cost of the CD is $35.

Figure 1. *Woody & Herbaceous Plants for Minnesota Landscapes & Roadsides* is a helpful tool for selecting the correct vegetation in a given area.

For a given area, the user is provided a list of site conditions. Two variables relating to salt use on roadways are included:

- Soil salt content - low, medium, high
- Salt spray - based on Average Daily Traffic and distance from roadway

The expected salt spray quantity is determined by an area's distance from the road and the average daily traffic (ADT) volume. Increased traffic results in more salt spray. Some plants

tolerate salt spray better than others. Relative plant tolerances that are given in Table 3 are defined as follows:

Sensitive Deciduous woody plants exhibit bud kill and twig dieback that makes the plants unsightly, reduces growth and may eventually cause plant death. Evergreen trees exhibit needle browning, reduced growth, and may eventually die. Plants rarely flower, e.g. eastern white pine, American linden. Herbaceous plant damage is less conspicuous and may result in death of mature plants and high seedling mortality.

Moderate Plants exhibit lesser degrees of dieback, disfigurement, and growth reduction. During most years the aesthetic impact is visible but acceptable, e.g. Amur maple, green ash.

Tolerant Plants show little evidence of dieback and disfigurement except at high ADT and close proximity to the road, e.g. honeylocust, Siberian peashrub.

Table 3 shows the plant effects based on ADT and distance from the roadway.

Table 3. Plant effect as a function of ADT and distance from roadway

ADT (000's)	Distance From Roadway (feet)						
	0-7	8-29	30-44	45-64	65-84	85-149	>149
0-9	No Plants	Moderate	Moderate	Sensitive	Sensitive	Sensitive	Sensitive
10-19	No Plants	Tolerant	Tolerant	Moderate	Moderate	Sensitive	Sensitive
20-39	No Plants	No Plants	Tolerant	Moderate	Moderate	Moderate	Sensitive
40-59	No Plants	No Plants	Tolerant	Tolerant	Tolerant	Moderate	Moderate
60-79	No Plants	No Plants	Tolerant	Tolerant	Tolerant	Moderate	Moderate
>79	No Plants	No Plants	No Plants	Tolerant	Tolerant	Moderate	Moderate

After identifying soil salt content and salt spray exposure for a specific site, the program quickly and accurately provides a list of appropriate plant(s), based on the location, site conditions, and expected functions for landscape design, restoration and management.

Use of salt tolerant grasses and sods

The use of salt tolerant vegetation along the roadways is an important tool for sustaining vegetation along the road. Mn/DOT has developed a new seed mixture 60A Modified (60B) for use in areas with high salt. It is a low maintenance turf mix, which reaches a height of about 12 inches. The application rate is 100 pounds per acre, and the composition is shown in Table 4.

Note that not all roadside soils in one area will be equally salty. The 60A Modified seed mixture is a combination of non-salty and salty seed species. Bluegrass is included for those areas that are not affected by the salt. The mix is intended to bridge areas that are and are not salty.

Two salt tolerant sods used in Minnesota contain alkalai grasses named "salty" and "fults", and both are available from several Minnesota suppliers, including Glenn Rehbein and Central Landscaping. The sod is yellow green, contains the same species as the 40A mix, and costs approximately 30-40% more per square yard than sod that is not salt tolerant. A recommended practice is to sod all newly constructed areas, then seed with a 60A mix to fill in areas that did not survive the first winter.

Table 4. Mn/DOT Seed Mixture 60A Modified (60B)

Common Name	Botanical Name	Percent of Mix
Fescue, creeping-red "Cindy"	*Festuca rubra*	10.0
Rye-grass, perennial "Elf"	*Lolium perene*	14.0
Bluegrass, Canada "Reubens"	*Poa compressa*	12.0
Bluegrass, fowl	*Poa palustris*	10.0
Bluegrass, common "98/85"	*Poa pratensis*	12.0
Bluegrass, Kentucky "Park"	*Poa pratensis*	12.0
Bluegrass, Kentucky "Caliber"	*Poa pratensis*	10.0
Alkali grass, "Salty"	*Puccinella distans*	19.0
White clover	*Trifolium repens*	1.0
	Total	100.0

Source: *Standard Specifications for Construction*, Minnesota Department of Transportation.

Use of native grasses and wildflowers

Some types of native grasses may be more naturally salt adapted than others. For instance, blue grama that is grown in Kittson County appears to be more tolerant of salty conditions than that from Isanti County. This may be due to the higher pH soils and high calcium and magnesium salts that are present in Kittson County soils. The Isanti County grasses are adapted to slightly acid soils. This may be a factor when selecting native grasses grown in one county or another. For information about seed suppliers and their products, contact Mn/DOT Office of Environmental Services at (651) 284-3750. Both Dwayne Stenlund and Bob Jacobsen can offer assistance in this area.

Native grasses and wildflowers can also prevent weed growth and erosion control. Native grasses and wildflowers are used to establish a diverse plant community that is adapted to local conditions. Other benefits of planting them include:

1. Spending less money on herbicides, fertilizers, and maintenance because native plants are self-sustaining and require less maintenance. Their dense roots also force out competing plants, requiring less herbicide use.
2. Holding the soil through the use of native prairie grasses. The dense and deep root systems (typically 6-8 feet, and as deep as 12-14 feet) for these grasses not only force out competing weeds, but also prevent erosion and slope failure.
3. Beautifying the roadsides and enhancing wildlife habitat by restoring a piece of Minnesota's natural heritage through the use of prairie grasses and wildflowers.
4. Ecological benefits from more diverse, self-sustaining planting without chemicals or mowing, and reduced environmental impacts from maintenance operations.
5. Increased water and air quality.

These objectives are accomplished by integrating several management techniques into a system that encourages desirable vegetation and prevents undesirable vegetation from establishing.

The following natives or wildflowers may be used with success in areas where salt is an issue:

Native grasses: Canadian wild rye, Indian grass, little bluestem, blue grama, side oats grama

Wildflowers: Black-eyed Susan, purple prairie clover, yarrow, bush clover

Effective turf establishment practices

Vegetation will not flourish in a poorly prepared soil. Soil that has been compacted during construction contains inadequate air voids, and prevents healthy root establishment. Mn/DOT's

Turf Establishment Specification 2575 requires that the soil be adequately prepared. This involves loosening the soil, and leaving lumps and tillage ridges to provide resistance to erosion. To keep the seed on the soil surface, this specification must be enforced.

Specification 2575.3B Soil Preparation reads as follows:

> Immediately prior to sowing the seed or placing sod, the Contractor shall loosen the soil to a minimum depth of 80 mm on all areas except slopes steeper than 1 vertical to 2 horizontal, using disks, harrows, field diggers, or other suitable cultivating equipments. In compacted areas, the Engineer may require ripping, additional equipment, or other necessary measures to ensure proper soil loosening. On slopes the cultivating equipment shall be operated in a general direction at right angles to the direction of surface drainage wherever practical. The soil surface shall be left in a roughened condition with clods, lumps, and tillage ridges approximately 80 mm high left in place for maximum resistance to erosion. No additional loosening of the soil will be required on slopes steeper than 1 vertical to 2 horizontal, other than that obtained with the equipment used in removing vegetation or performing the finishing operations. Vegetation other than undesirable weeds shall be disked into the soil, cleared, or chopped up with a rotary or flail mower, as the Engineer approves.
>
> On all areas to be sodded, the Contractor shall prepare the soil as necessary to provide a reasonably smooth, moist, and evenly textured foundation. All washouts on the areas to be seeded or sodded shall be filled prior to the soil loosening operations. The fill material shall be compacted sufficiently to provide reasonably uniform density in the upper soil layer as the Engineer considers necessary to resist erosion.(9)

Other information is available regarding soil preparation. Richard Duble, Turfgrass Specialist with the Texas Agriculture Extension Service recommends the following:

Successful turf establishment involves four critical steps:

1. Site and soil preparation
2. Seed selection
3. Proper planting
4. Care and maintenance

Site and soil preparation - The first element, proper site and soil preparation, is the most important element in turf establishment. The seedbed refers to the top several inches of tilled soil, and poor conditions in this area result in long-term maintenance and growing problems. Critical elements in proper site and soil preparation are outlined below:

- Topsoil must be placed on subsoil that is loose, scarified, or bulldozer-tracked perpendicular to slope contours so that a bond occurs, to prevent slippage.
- After placement of the topsoil, remove all construction debris, such as concrete residue, rocks, tree stumps, and weeds. Remove all rocks and gravel from the top two inches of soil, as well as organic debris and tree stumps.
- Pull or spray weeds with herbicide before planting new vegetation. Disking or rototilling the site immediately before planting can remove many annual weeds. This also breaks up the soil, making it easier for new roots to establish and grow.
- Cultivate the soil to alleviate compaction from construction activities. This also creates more uniform and favorable soil conditions. Large tractor-drawn equipment can be used on large sites. A plowed soil can be further broken up with a disk and harrow. Disking in several directions will loosen the upper four inches and eliminate most of the vegetation. Disking during the summer is the most effective treatment for removing weeds. Harrowing or dragging a chain or heavy mat will further pulverize and smooth the soil surface after disking. All of the cultivation operations should be done with the soil moist, but not wet. Cultivating wet soil destroys its structure and produces large clods.
- In some cases, the soil may need modifications, such as fertilizers or the addition of gypsum. Individual soil tests should be conducted to determine the soil

composition, and needed alterations. These tests are available from the University of Minnesota Extension Service.

- Because drainage is very important in the establishment and maintenance of roadside vegetation, some additional grading may be required. Usually, fine grading of slopes is not desirable. Moderately rough surfaces provide an opportunity for trapping seed and moisture, and will result in more successful vegetation establishment.

Seed selection – Information is given in Tables 3 and A-1 about selection of appropriate seed for a given area. To accelerate seed growth, a fast-growing seed species may be selected and mixed in with one that is salt tolerant. The Mn/DOT Seeding Manual is also available on the Mn/DOT Office of Environmental Services web site at www.dot.state.mn.us/environment.

Proper planting – Mn/DOT standard specifications may be used as a guide for planting techniques and dates. Planting techniques are outlined below.

- Immediately after seeding, within 14 days, cover the area with mulch. Mulching protects the soil and seed, holds the seed in place, helps to reduce severe changes in temperature, reduces the flow velocity of rain and runoff, and retains moisture. Mulches used in sensitive areas should be certified as being free of weeds. Note that hay mulch generally contains more weeds than straw. Currently, there are five vendors who are certified by the Minnesota Crop Improvement Association for weed-free production. Their names can be obtained at the Mn/DOT Office of Environmental Services web site, a www.dot.state.mn.us/environment.

- After mulch is applied, drive over the area with a disc to anchor the mulch to the ground. Cover areas directly adjacent to the roadway with liquid tack. Wood chips may be used as a mulch around trees.
- Use a germination blanket to assist with turf establishment. Blankets and soil stabilizers protect the soil until the vegetation is established, and are used in areas with high slopes and heavy runoff velocities, and that need permanent protection.

  Note that blanket is not needed with mulch, and should be used on steeper slopes and in channels.

Care and maintenance – To encourage the newly planted seeds to grow, the following care and maintenance activities are recommended.

- Water newly planted areas lightly and frequently to prevent the surface from drying out.
- As the grass begins to grow, or sod takes root, reduce the frequency of watering and increase the amount of water applied per watering. This encourages the development of a deep root system, which will reduce the amount of water needed for the life of the plant.

Protecting existing vegetation

Roadside vegetation can be protected from snowplows and maintenance activities. Several suggestions are listed below:

1. Protect trees and woody vegetation by erecting screens of fencing or burlap to ward off salt spray from the roads.
2. Do not pile salt and snow around plants or in areas where the resulting runoff will drain into the plants. The areas around the roots that are exposed to salt should be flushed with fresh water as soon as the show melts.
3. Push and store snow in the middle of the road, instead of on the sidewalk or boulevards.
4. Plant sensitive woody plants as far from the roadway as possible.
5. Avoid planting sites near heavy runoff areas, such as in low slopes.
6. Use coatings or alternative deicing agents that are not damaging to vegetation. (See following section.)

Optimizing salt use

To balance winter mobility and safety needs with environmental concerns, the most promising approach is to avoid the excessive use of salt altogether. Mn/DOT's Salt Solutions program was designed to reduce the level of salt and sand use. It includes tools that allow operators to make better application rate decisions. While the initiative for the program was to save costs on sand and salt, its effect was to reduce salt damage to vegetation along roadways, as well as to the roadway infrastructure.

A key component of the Salt Solutions program is the use of truck-mounted infrared pavement temperature sensors. These sensors provide critical information that assist truck operators in selecting salt and sand application rates. The Salt Solutions program also includes operator training, application guideline charts, equipment calibration and repairs. These application rate

charts correlate pavement temperature and weather conditions to assist the operator in application rate selection.

The process of quantifying the salt and sand use at each maintenance shop is cumbersome. Poor record keeping and the need to find a consistent and relatively accurate method for measuring salt and sand use accounts for many problems. To correctly measure salt and sand use, maintenance trucks must be fitted with a device that accurately regulates the material dropped. Augers that control the amount of sand and salt deposited on the roadway must be fitted and adjusted for the actual mix of sand and salt being used.

During the program development, some supervisors thought they could save money by using more sand and less salt for ice control. Total sand costs actually include much more than just material costs. The combined materials, clean up, hauling, and screening costs result in a high cost for sand applied to the roads. Environmental effects must be considered as well. In general, the program found that using more sand to save salt was not a successful answer.

Criteria developed for the Salt Solutions program is given in Table 5. Infrared sensors were used to determine pavement temperature.

Table 5. Salt/Sand Application Criteria

Pavement Temperature (°F)	Weather Conditions	Pounds per 2-lane Mile	Operation
30° +	Snow	200-400	As needed
	Freezing Rain	200	Re-apply as necessary
25° – 30°	Wet Snow	400-500	Re-apply as necessary
	Freezing Rain	300 200	Re-apply as necessary
20° - 25°	Wet Snow Sleet	1200 Sand/Salt	Repeat as necessary
	Freezing Rain	1200 Sand/Salt	Repeat as necessary
15° – 20°	Dry Snow	1200 Sand/Salt	Sand hazardous areas 20:1 Sand/Salt Mixture (Stockpile)
	Wet Snow Sleet	1200 Sand	Repeat as necessary
Below 15°	Dry Snow	1200-1500	Sand hazardous areas 20:1 Sand/Salt Mixture (Stockpile)

Results of the program are available in Mn/DOT Report No. 1998-20, entitled "Salt Solutions – Statewide Salt and Sand Reduction." This report can be obtained from Mn/DOT's Office of Research and Strategic Services or from the Mn/DOT Library at (651) 296-2385.

Use of products that are friendly to vegetation

Several products are available that are not harmful to the soil or vegetation. They include:

- Low salt index fertilizers
- Liquid organic compost
- Calcium chloride
- Magnesium chloride
- Calcium magnesium acetate (CMA)

Using low salt fertilizers or liquid organic compost to fertilize roadside vegetation reduces the overall salt load that the soil must accommodate. Use of these products reduce the amount of salt deposited into the soil, and eliminate many of the problems caused by soil salinity.

CMA is an effective de-icer that will also reduce the salt load on a soil. Research indicates that the use of CMA has little negative effect on the environment. CMA concentrations used to de-ice roads have a minimal toxic effect on grass, trees, roadside vegetation, or aquatic life. It is non-corrosive, biodegradable and can effectively prevent the formation of ice-surface bonds when applied before the snow or rain hits. The major barrier to using CMA is the cost. At approximately $675/ton, the cost of CMA is 20 - 30 times the cost of road salt (at about $30/ton.) CMA has been shown to minimize scaling and corrosion on bridges, which is another benefit of its use. Decisions to use the material should not be made solely on the cost. If damage to the roadside environment can be eliminated with the use of CMA, its cost (both tangible and intangible) may be justified. (10)

Maintenance Practices

Many times, ice and salt damage cannot be prevented. Effective maintenance practices for reducing or repairing ice and salt damage that are offered in this synthesis are listed below:

- Irrigation to flush salt from soil
- Soil treatments
- Vacuuming and sweeping
- Rejuvenation of damaged areas

- Design and construction strategies

Irrigation to flush salt from soil

Irrigation leaches the accumulated salt down into the soil below the root zone. The required amount of irrigation depends on how saline the soil is and the depth of soil to be leached. To determine the amount necessary, excavate a shallow basin along the roadside, and fill it with water. Then judge the depth of the water entering the root zone. Table 6 shows an approximate amount of water required to leach the salt for each foot of soil to be leached.

Table 6. Irrigation required for each foot of soil to be leached.

Percent of salt leached	Irrigation depth required (inches)
50%	6
80%	12
90%	24

After the salt in the soil has been reduced, continue to apply extra water periodically when irrigating to prevent a new buildup of salt. (8)

Soil treatments

Several soil treatments may reduce the salt effects on the soil. They include improving drainage in an area, fertilizing the soil, or adding soil amendments to change the soil's chemical properties.

Drainage improvements - If drainage is poor, and excess sodium is not the cause, installation of underdrain tile may be necessary to remove the salt water from beneath the root zone. (8)

Fertilizer - To determine the correct fertilizer formula, test soils annually. Soil testing will identify the soil composition, and outline the appropriate application amount as well. As noted earlier, use low-salt fertilizer to avoid additional salt problems.

Use of soil amendments - Heavy irrigation may not be possible, and may cause problems in areas with poorly drained soils. Poor drainage may be caused by the excess sodium, which may be removed by adding gypsum to the soil. Gypsum is one of the most common soil amendments to reduce the effects of salt. The additional calcium ions replace sodium ions on cation exchange sites on soil particles and reduce or eliminate the loss of aluminum and iron, which increases soil particle aggregation and maintains soil structure.

Potash is also commonly used for soils that have low potassium contents, and as a chloride salt, is an alternative chemical de-icer. Potassium nitrate is a common fertilizer that adds potassium

to neutralize the excess sodium, and provides a source of nitrogen for emerging plants. Treatment or pre-treatment with potassium nitrate has also been shown to increase seed germination in many plant species. (11)

Gypsum is not effective on sandy soils. It may, however, work well in certain circumstances. To predict the applicability, small test plots can be developed. Variables include water table, soil type, and climate or precipitation. Do not apply gypsum or other amendments unless a soil test shows a definite need, and then only apply the amount recommended on the soil test. Soil tests are the only way to determine excess salt quantities.

A recent University of Minnesota study (Neid) evaluated ways to alleviate salt effects on seed germination by restoring the ionic balance to a saline soil. Three soil amendments were selected: gypsum, potash, and potassium nitrate. They were chosen for their chemical properties and low costs. Three grass species were selected, each with a varying degree of salt tolerance. They included Kentucky bluegrass, blue grama, and alkali grass. Kentucky bluegrass is a component of most non-native seed mixtures that are widely used along roadsides in urban areas. It is salt-sensitive relative to many other species. Blue grama is a native species of the short-grass prairie, is drought tolerant, and considered to be moderately salt tolerant. Alkali grass is non-native, and has been shown to be very salt tolerant.

Without any soil amendments, the presence of salt in the soil significantly decreased the overall germination of the Kentucky bluegrass and blue grama. The alkali grass was less affected. The

amendment compounds had differing effects on each of the grass species, and seed germination for each of the grasses was greater with gypsum in the soil. (6)

However, the study found that gypsum alone did not affect germination at any treatment level for the Kentucky bluegrass. Addition of potassium alone to the soil actually decreased the seed germination of Kentucky bluegrass. The germination of alkali grass was affected by the interaction between gypsum and the soil salt. Gypsum interfered with germination rates and with percent germination. However, the interference only occurred at high concentrations.

Conclusions of the study are outlined below:

- A single application of amendment compound (e.g. simultaneously with seed planting) is insufficient to alleviate salt-induced stress. Multiple applications may offset the salt effects, but this would decrease the cost benefit.
- Some soils require reclamation before successful plant establishment can occur. This could include treatment with calcium amendment compounds, and or flushing the soil with freshwater. Total soil replacement may be the only option.
- Although potassium chloride is not necessarily successful when used as a soil amendment, it is a chemical deicing compound. Adding KCl to the salt-sand mixtures may enhance plant establishment at a relatively low cost without jeopardizing safety of travel.
- Irrigating spring plantings would likely increase seed germination and plant establishment in roadside soils.(6)

Vacuuming and sweeping

Vacuuming, raking, or sweeping the roadside each spring will remove much of the salt and sand remaining from winter maintenance operations. Special equipment is not required. To totally replace soil around vegetation, an air spader is available that will blow all of the soil away from the roots. New, healthier and non-compacted soil may then be placed. Dwayne Stenlund, in the Mn/DOT Office of Environmental Services, at (651) 284-3787 can provide more information about this machine.

Rejuvenation of damaged areas

Areas that have been damaged by salt or ice may be repaired. The area may be mechanically reseeded using a salt-tolerant seed mixture (mix 60B), or it may be aerated. Mn/DOT has an aeration machine that is available for distribution.

Potassium or lime nitrate may be applied in the fall. The treatments act as a root conditioner, hardening them against winter damage.

Along roadsides, compaction can be especially severe, and periodic aeration is required to keep the turf healthy. Extensive loosening of the soil in the root zone significantly improves infiltration of air, nutrients, and water. It also minimizes runoff during rain or irrigation. An especially heavy-duty aeration machine, the "ERA-vator" from First Products, Inc. is shown in Figures 2 and 3.

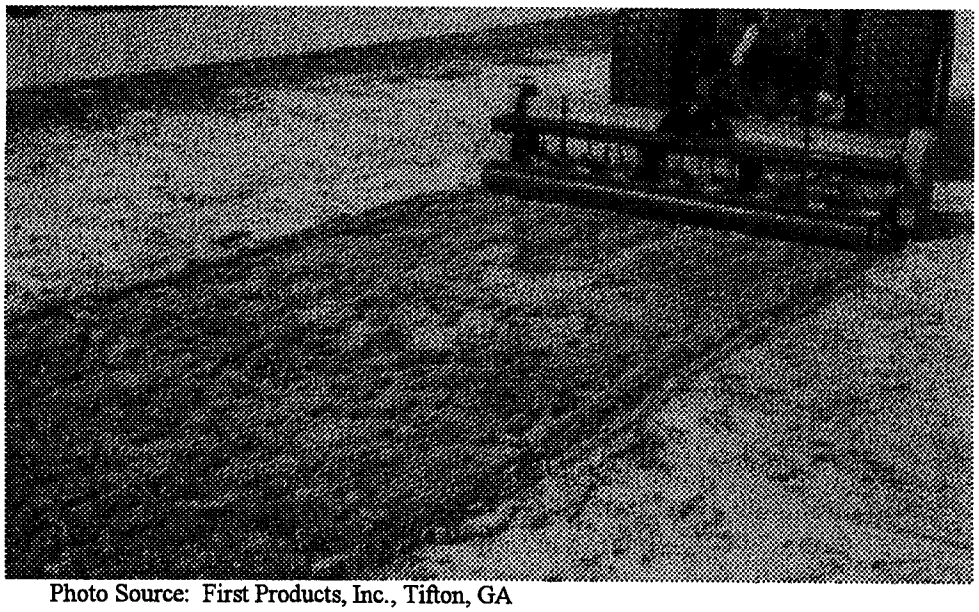

Photo Source: First Products, Inc., Tifton, GA

Figure 2. An aeration machine may be used to loosen compacted soil in preparation for seeding and sodding.

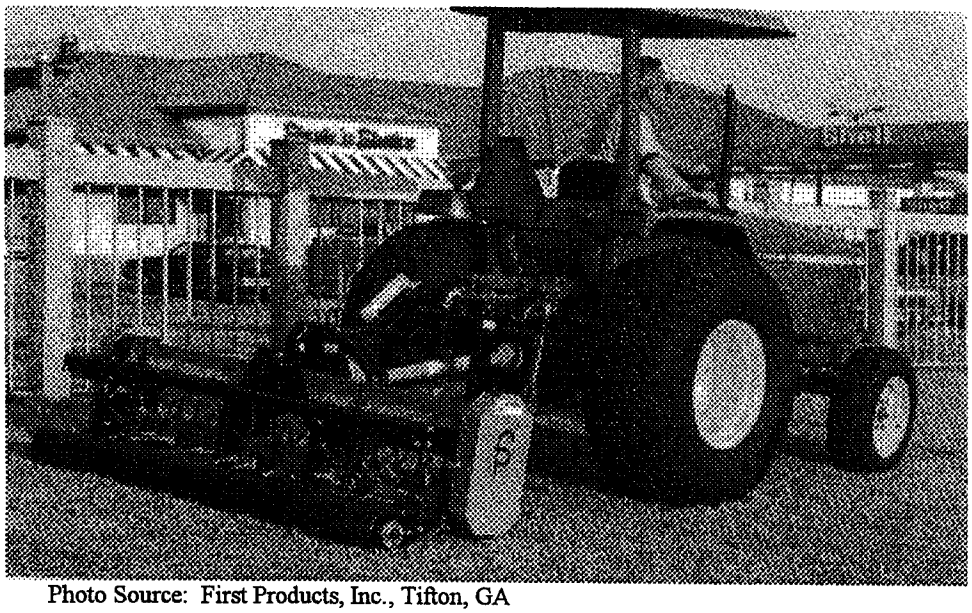

Photo Source: First Products, Inc., Tifton, GA

Figure 3. This aeration machine has a high-speed rotor shaft that vibrates the tines at high frequency. This allows loosening of even the most densely compacted soil.

This machine is one of the few available that can effective break through dry, compacted soils that are commonly found along roadsides. Dwayne Stenlund at Mn/DOT Office of

Environmental Services at (651) 284-3787 can also provide more information about this equipment.

Another option for preventing compacted soil is to use one of the new products that incorporate plastic elements designed to resist compaction under loading. With these products, thousands of small pieces of mesh, each about the size of a playing card, are blended into the soil. The mesh pieces interlock with each other and the rootzone particles to create a stable, three-dimensional structure. As turf roots develop, they grow through the mesh to provide a deep, anchored root system. When this stabilized rootzone is compressed, through snow or wheel loading, the mesh elements flex and spring back, creating and maintaining voids along the length of the mesh pieces. The presence of these voids maintains aeration and good drainage properties in the soil. Surfaces containing this mesh are stable, but not hard, and the mesh elements are not hazardous to wildlife.

Infiltration rates in sandy soils with mesh added are almost twice as much as in those soils without mesh. When added to sandy clay loam and sandy loam, the mesh improves infiltration rates by a factor greater than ten times.

Design and construction strategies

Other practices can be adopted during the design and construction of a roadway to reduce the impacts of salt and deicers. They include crowning the medians to direct the melting snow to gutters, instead of the soil, and placement of gravel shoulders to provide a buffer zone for adjacent roadside vegetation.

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Table A-1. Plants Suitable for Use in Salty Soil Conditions

Grasses and Sedges	Trees and Shrubs	Flowers
Slender Wheatgrass	Norway Maple	Yarrow
Redtop	Cleveland Norway Maple	Black-eyed Susan
Seaside Bentgrass	Columnar Norway Maple	Purple prairie clover
Sheep or Blue Fescue	Crimson King Norway Maple	Yarrow
Common Reed	Emerald Queen Norway Maple	Bush clover
Alkali Grass	Emerald Lustre Maple	Giant Hyssop
Canadian wild rye	Schwedler Maple	Prairie Onion
Indian grass	Superform Maple	Swamp Milkweed
Little bluestem	False Indigo	Common Milkweed
Blue grama	Siberian Peashrub	Butterfly Milkweed
Side oats grama	American Bittersweet	Whorled Milkweed
	Russian Olive	Heath Aster
	Silverberry	Smooth Blue Aster
	Ginkgo	New England Aster
	Princeton Sentry Ginkgo	Sky-Blue Aster
	Common Honeylocust	Silky Aster
	Thornless Common Honeylocust	Canada Milk Vetch
	Imperial Honeylocust	Partridge Pea
	Shademaster Honeylocust	Stiff Tickseed
	Skyline Honeylocust	Crown Vetch
	Sunburst Honeylocust	White Prairie Clover
	Kentucky Coffeetree	Purple Prairie Clover
	Andorra Compact Juniper	Showy Tick Trefoil
	Red Mulberry	Pale Purple Coneflower
	Black Hills Spruce	Flowering Spurge
	Jack Pine	Prairie Smoke
	Mugho Pine	Stiff Sunflower
	Dwarf Mugho Pine	Ox-Eye
	White Poplar	Hyperion (Yellow) Daylily
	Bolleana Poplar	Stella d Oro Daylily
	Eastern Cottonwood	Tawny Daylily
	Siouxland Poplar	Daylily (Midsize)
	Quaking Aspen	Daylily (Short)
	Tower Poplar	Daylily (Tall)
	Bush Cinquefoil	Round-Headed Bush Clover
	Abbotswood Potentilla	Rough Blazingstar
	Jackmann Potentilla	Dotted Blazingstar
	Black Cherry	Prairie Blazingstar
	White Oak	Great Blue Lobelia
	Bur Oak	Birdsfoot Trefoil
	Chinkapin Oak	Wild Lupine
	Black Oak	Wild Bergamot
	Fragrant Sumac	Slender Penstemon
	Gro-Low Fragrant Sumac	Showy Penstemon
	Black Locust	Woodland Phlox
	Belle Poitevine Rose	Japanese Fleeceflower
	Grootendorst Red Rose	Columnar Coneflower
	Hansa Rose	Gray-Headed Coneflower
	Jens Munk Rose	Black Eyed Susan
	Sir Thomas Lipton Rose	Missouri Goldenrod
	Theresa Bugnet Rose	Gray Goldenrod
	Magnifica Rose	Upland White Aster
	Peach Leaf Willow	Stiff Goldenrod
	Bebb Willow	Showy Goldenrod
	Northern White Cedar	Ohio Spiderwort
	Pyramidal Arborvitae	Red Clover (Including cultivars)
	Siberian Elm	White Clover
		Blue Vervain
		Hoary Vervain
		Hairy Vetch