Initiating Seed Production for Effective Establishment of Native Plants on Roadsides in New England

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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Preface

Roadsides are environmentally significant areas because of their vast scale and connectivity in the New England landscape. When covered with native vegetation, they contribute to biodiversity in this region. Roadsides have the potential to provide corridors for species distribution while supporting a diversity of wildlife, including threatened pollinator species (Hopwood et al. 2016).

Native species build a foundation for the ecological health of a region, and their use is currently a high-profile global priority, as epitomized by the launch of the United Nations Decade on Ecosystem Restoration (https://www.decadeonrestoration.org/). Recent policy in the U.S. gives preference to the use of native plants as the first choice in roadside revegetation efforts. Native plant species, which have evolved with local climates and soil conditions, generally require less maintenance after establishment, provide erosion control, help to catch snow in wintertime, and, most critically, they persist longer than introduced species. Native plants provide long-term defense against invasive and noxious weeds while reducing the maintenance costs associated with management of weedy vegetation and wildlife habitats. Thus, the shift toward native species along the roadsides manifests proactive environmental stewardship and provisions for healthy ecosystems.

The previous project NETC 09-2 developed a Manual “Effective Establishment of Native Grasses on Roadsides in New England” (later called NETC 09-2 Manual), which outlined the methods for the establishment of native communities. It recommended locally sourced, geographically

appropriate plant material to ensure sound conservation practices and to protect the genetics of local plant populations.

The current project NETC 21-3 “Initiating Seed Production for Effective Establishment of Native Plants on Roadsides in New England” continues to develop guidelines on the establishment of native plantings in New England and makes the previous recommendations more practicable.

Chapter 1: Seed Mixes for Roadsides

This chapter outlines species selection criteria for plants to be used along roadsides. Four herbaceous seed mixes are described and proposed for roadside conditions in New England – mesic, dry, wet, and coastal. In addition, two lists of native woody plants are recommended – one for use along most roadsides, the other for coastal regions where plants are subjected to greater salt exposure.

Each seed mix includes native grasses and grass-like plants (graminoids) and wildflowers (forbs) that together build well-structured plant communities that provide important ecosystem services. In addition to native species, seed mixes include non-native annual cover crops, which supply essential benefits for successful establishment of biodiverse native plant communities, reduce erosion, and block weeds during the establishment period.

These mixes are appropriate for use both on bare soil following new construction or when converting existing vegetation to native plantings.

1.1 Plant Species Selection Criteria for Use Along Roadsides

The following criteria were used to select plant species suitable for each seed mix (the detailed explanations of these criteria are presented in Appendix 1).

Criterion 1. Use Only Native Species. The Federal Highway Administration recommends the ecoregion approach for species selection (FHWA, 2019). Ecoregions are areas where ecosystems are generally similar. This approach means to use species native to an ecoregion where the project site is located (see section 4.3 on p. 56) The "Go Botany" website (https://gobotany.nativeplanttrust.org/) hosted by the Native Plant Trust can be used to define the species status for ecoregions in the six New England states.

Criterion 2. Avoid Using Species of Conservation Concern. The species of conservation concern include rare, threatened, endangered, and uncommon plants and are excluded to avoid conservation issues. The conservation status of each species can be verified at the "Go Botany" website and state official rare and endangered plants lists.

Criterion 3. Choose the Right Plant Type for Roadside Conditions. For safety concerns, plants should be short or moderate in height for visibility and provide ecosystem services including erosion control, flood protection, snow drift minimization, air and water purification, carbon sequestration, and noxious weed control, and should be prioritized when selecting plants for roadside conditions.

Criterion 4. Prioritize “Workhorse Species”. Native plants that provide reliable performance, establish quickly with minimal water and fertilizer, thrive in various

climates, and soil conditions should be selected. These plants should be adaptable, disease-resistant, long-lived, and stable, without being aggressive.

Criterion 5. Focus on Species with High Wildlife Value. Native plants that support wildlife, including pollinators, by providing nesting sites, larval host plants, flower at different times for continuous resources of nectar and pollen, should be prioritized.

Criterion 6. Include Aesthetically Pleasing Species. To increase driver awareness, decrease fatigue, plants with showy flowers, attractive foliage, bright fall colors, or winter silhouettes should be included to enhance the visual appeal of roadsides.

Criterion 7. Ensure Availability and Economic Feasibility. Plant selection should focus on native species that are easy and cost-effective to produce, that can be stored, have straightforward planting and harvesting techniques, and are within budget constraints for roadside revegetation projects.

In summary, a native plant ideotype for roadside plantings should be a perennial herbaceous plant of short or moderate height (up to 24") for safety, easy to establish, suitable for various conditions, long-lived, and attractive. It should have deep roots for erosion control, a strong vertical habit for mowing, high value for pollinators with low browse value for animals and be inexpensive and easy to propagate and establish.

Ecologically Appropriate Plant Combinations in Seed Mixes

The compositions of mixes are based on knowledge of ecological plant associations from reference sites. Plant communities along disturbed sites, such as old road cuts and fills, are most useful references since they reflect a similar recovery path. These sites demonstrate various vegetative outcomes, such as successful restoration with native species or a problematic recovery with potential issues like soil erosion or weed infestation. Understanding these outcomes guides the choice of plant species for seed mixes.

Native graminoids and forbs play several crucial ecological roles in roadside revegetation and native plant communities including:

1. **Soil Stabilization**: Their extensive root systems stabilize soil, reducing erosion and preventing soil loss, especially on slopes and disturbed areas along roadsides.
2. **Habitat Creation**: These plants provide essential habitat offering food, shelter, and breeding grounds for various wildlife, including insects, birds, and small mammals, thus supporting local biodiversity.
3. **Pollinator Support**: Many native forbs support pollinators like bees, butterflies, and other insects. This helps maintain pollinator populations, which are crucial for the reproduction of many plants.

4. **Nutrient Cycling**: Native plants contribute to nutrient cycling by returning organic matter to the soil through leaf litter and root decay. This process enriches the soil and supports the growth of other plants.
5. **Water Infiltration and Retention**: The root systems of native plants improve soil structure, enhancing water infiltration and retention. This reduces runoff and helps maintain the local water cycles.
6. **Bulwarks against Invasive Species**: Established native grasses and forbs can act as bulwarks against invasive species by utilizing resources more effectively and forming dense plant communities that help prevent the spread of invasive plants.
7. **Aesthetic and Cultural Value**: Native plants have cultural significance and contribute to the natural beauty of an area. They enhance the visual appeal of roadsides and promote a sense of place.

Proposed seed mixes use a *shotgun approach* to disperse seed over a target area, which may include environmental variations. Each mix includes small amounts of numerous "pellets" or "buckshot" in the form of 30-40 plant species seed, broadcast over a planting site. It is possible that all species may not proliferate at each site, and the final communities will reflect the specific topographic and microclimatic conditions of each habitat. However, it is expected that a diverse and resilient plant community will be established at every site. This approach considers site variations while eliminating the decision-making process by the DOT managers to adjust the seed mix to each site based on the local condition.

Creating Effective Pollinator Habitats

The establishment of effective pollinator habitats along roadsides is of imminent importance. When composing each seed mix, include a suite of native grasses and forbs with special attention to species that support pollinators to create a well-structured native plant community, following these recommendations:

- Prioritized nectar-producing and pollen-rich plants.
- Include larval host plants for specific pollinators, such as milkweed for Monarch butterflies.
- When possible, add species important for specialists and at-risk pollinators.
- Include native bunch grasses, such as big bluestem (*Andropogon gerardi*) and purple lovegrass (*Eragrostis spectabilis*), to provide places for pollinators to nest and lay eggs.

Importance of Sequential Flowering

Pollinator habitats should have a diversity of plants that flower at different times throughout the season, and plants with overlapping bloom times to provide continuous floral resources. By carefully selecting native plant species with a range of bloom periods, vegetated roadsides provide multiple ecosystem services, and create biodiverse, sustainable, and resilient

environments. For each mix, sequential flowering charts for spring, early and late summer, and fall to ensure uninterrupted nectar and pollen sources were created. It is possible that not all species in the recommended seed mixes are available from producers. Some flexibility in the selection of herbaceous plants used to make up the seed mix has been considered. The goal is to include at least five species blooming simultaneously during each period, with a variety of flower colors and shapes.

Offering a variety of native plant species for each bloom period, is important for several reasons:

1. **Extended Foraging Period for Pollinators**: Different native species bloom at various times throughout the growing season. Selecting species with staggered bloom periods provides continuous supplies of nectar and pollen for bees, butterflies, and other insects. This helps support pollinator populations by ensuring they have food sources available over a longer period.
2. **Increased Biodiversity**: Including a variety of plant species with different bloom periods maximizes overall biodiversity and supports a wider variety of wildlife by providing habitat and food sources throughout the growing season. This includes not only pollinators but also other insects, birds, and small mammals that rely on diverse plant communities. This diversity creates a resilient ecosystem that can withstand environmental stresses, such as pests, diseases, and climate fluctuations.
3. **Visual Appeal**: A well-developed mix of species that provide sequential flowering creates a more visually appealing landscape throughout the year. This can enhance the aesthetic value of roadsides, making them more attractive to travelers and contributing to community pride and local identity.
4. **Nutrient Cycling, Soil Health and Erosion Control**: Different plants contribute to nutrient cycling in unique ways. Inclusion of species with different bloom periods ensures a balanced and efficient nutrient cycling process, which benefits overall soil fertility and plant health. Varying root structures and growth habits of plant species with different flowering times improve soil health and stability. A diverse seed mix ensures the soil is protected year-round, reducing erosion and promoting healthy soil structure.
5. **Adaptation to Environmental Variability**: Offering a variety of species with different bloom periods ensures that some plants will thrive regardless of specific environmental conditions each year. This reduces the risk of total revegetation failure due to unusual weather patterns or other environmental changes.
6. **Reduced Competition and Enhanced Growth**: Plants that bloom at different times are less likely to compete directly for the same resources at the same time. This reduces competition and allows each species to grow more effectively, leading to a healthier and more robust plant community.

Why Pure Live Seed (PLS) is Used to Measure Native Seeds

Pure Live Seed (PLS) is a measure used to determine the quality and viability of a seed lot. It represents the percentage of seeds in a sample that are both pure and capable of germinating. PLS is a critical concept in ecological restoration because it helps ensure that planting efforts are effective and efficient.

Components of Pure Live Seed

PLS measures the **purity** and **germination rate** for a lot of seed. Native seed companies determine the PLS for a harvest of seed by sending samples of a lot to either government or private testing organizations.

Purity: When native seed is harvested, the resulting harvest is composed of pure seed, inert matter, and other seed. Pure seed refers to the seed of the desired native species, free from contaminants. Inert matter consists non-seed material, such as soil, plant debris, or stones. Other seed comes from other plant species, including weeds or other stray native species that may grow in a specific species' crop field.

Germination Rate: Harvested native seeds consist of viable and non-viable seeds. Viable seeds are capable of germinating and developing into healthy plants. Non-viable seeds are those that are damaged, immature, or otherwise incapable of germination.

Calculation of PLS: PLS is calculated by multiplying the purity percentage by the germination percentage of a seed lot. The formula is:

$$\text{PLS (\%)} = [\text{Purity (\%)}/100] \times [\text{Germination rate (\%)}] \times 100$$

For example, if a seed lot has a purity of 90% and a germination rate of 80%, PLS would be:

$$\text{PLS} = [90/100] \times [80/100] \times 100 = 72\%$$

This means that 72% of the seed lot consists of seeds that are both pure and capable of germinating.

Importance of PLS

- By knowing the PLS, project managers can accurately determine how much seed to plant to achieve the desired plant density and coverage.
- Purchasing seeds based on PLS ensures that buyers get value for their money, as they are paying for viable seeds that will germinate and not for inert matter or non-viable seeds.
- In restoration projects, using seeds with high PLS ensures that native plants establish successfully, which is crucial for restoring ecosystems and promoting biodiversity.

The Benefits of Cover Crops for Native Plant Community Establishment

Non-native cover crops are included in native seed mixes because they improve soil health and help suppress weeds.

Cover crops improve soil health in several ways. They provide erosion control by acting as physical barriers, shielding the soil from the impact of rain and wind (Tambo & Mockshell, 2018; Daryanto et al., 2018). Since the cover crops are annuals, their roots help to hold the soil in place while the perennial native seed establish. When cover crops decompose, they add organic matter to the soil, improving soil structure, water retention, and microbial activity. By improving soil moisture retention, cover crops lower the soil temperature and creating a more favorable environment for the establishment and growth of native plants (Fageria et al., 2005). They capture nutrients that might otherwise be lost and recycle them back into the soil, enhancing soil fertility. Furthermore, the root systems of cover crops can help to improve soil structure, increase water infiltration, and reduce compaction, all of which can create a more favorable environment for the establishment and long-term success of native plants (Lu et al., 2000).

Cover crops help suppress weed growth. By competing with weeds for light, water, and nutrients, cover crops effectively limit weeds' ability to outcompete the desired native species (Adetunji et al., 2020). This can be especially important in the early stages of establishment, when native plants are more vulnerable to competition from invasive or aggressive weeds.

For well-drained soils, it is recommended to use the short-lived oats (*Avena sativa*) from January 1 to July 31 or cereal rye (*Secale cereale*) from August 1 to December 31. For wetter sites and coastal seedings, it is recommended to use cereal rye from September 1 to April 30 or Japanese millet (*Echinochloa esculenta*) from May 1 to July 31.

Seeding Rates

Cover crops

Mesic and dry sites:

Oats (*Avena sativa*) used from January 1 to July 31: **30 lbs/acre**
Grain Rye (*Secale cereale*) used from August 1 to December 31: **30 lbs/acre**

Wet and coastal sites:

Grain Rye (*Secale cereale*) used from September 1 to April 30:: **30 lbs/acre**
Japanese millet (*Echinochloa esculenta*) used from May 1 to July 31

Seed mixes

Note: *A range is given for the amounts of seed that can be used for a site. If a site tends to be drier or has a history of drought conditions, native seed rates toward the higher end should be used. In addition, if a site is sloped less than 3:1 and subject to wetter conditions, which may wash the seed downslope, again use native seed rates toward the higher end of the range. For slopes greater than 1:3, the recommended native seed rates do not have to be adjusted since the suggested rates are already adjusted. As noted in the text box below, "The Impact of Seeding Timing on Establishment", if a construction project ends during the heat of the summer and needs to be seeded to prevent erosion, increase the native seed rate should be increased by 50% in case the summer heat results in drought conditions.*

While native seed rates increase under certain circumstances, the cover crop rates do not change.

Mesic and dry sites:

Less than 3:1 Slope: **10 to 15 lbs PLS/acre.**
Slopes of 3:1 or steeper: **35 to 40 lbs PLS/acre**

Wet and coastal sites: **15 lbs PLS/acre**

The Impact of Seeding Timing on Establishment

The time of year when seeding takes place impacts the germination of the seed. Since DOT construction projects require that seeding take place soon after project completion, it is important to understand species establishment dynamics. In addition, the seeding rate will change if the project completes during July and August.

If seed takes place anytime from spring to early fall, seeds will germinate seedlings for that season. As examples of this dynamic, the grass seeds for the CT demonstration site occurred in early June 2023, providing enough time for the grasses to establish seedlings. As a result, by spring 2024, the cool-season species Virginia wild rye (*Elymus virginicus*) had had enough time for its seedlings to establish extensively enough the previous season, thus resulting in mature stands that dominated the site, as the picture above illustrates.

The Vermont site was seeded in late August 2023, giving the seeds enough time to germinate seedlings. As a result, black-eyed Susan (*Rudbeckia hirta*), a biennial, had the first season of its two-year growth cycle in fall 2023. In spring 2024, black-eyed Susan put on a showy display, as the picture on the left illustrates. This contrasts with the CT and MA sites, which were seeded in mid-October 2023 just as the weather cooled enough to prevent germination that year. As a result, only the rosettes of the first year of their growth cycles were present at these sites.

If a project ends during the summer, it is important that the seeding rate be increased to take into consideration that the summer heat may result in drought conditions. Therefore, the 10-15 lbs/acre recommended rates need to be increased by 50% to 15-22 lbs/acre.

Seed Mix Table Key and Accessing Seed Mix Sortable Tables

The tables included in this report are examples of mixes that could be used for each roadside condition. However, when composing mixes, use the Excel files for each roadside condition. Species are grouped by bloom periods from which 3 to 5 species can be selected. When composing seed mixes, it is recommended that landscape designers consult with a seed company botanist or horticulturalist to determine the proportion of each species to include in a mix.

The seed mix tables included in this report include the botanical and common names for each species and proportions of each species as recommended by the head botanist from Ernst Conservation Seed. It also indicates which species should not be included in the mixes for those states for which the species is of conservation concern. Finally, the colored bands indicate the months when species are in bloom and the band colors designate the color of the flowers

Species with names in blue provide resources for specialist and endangered species of pollinators but are not necessarily workhorse species. Specialist pollinators have evolved a specific relationship with a few or even just one plant species. Including native forbs that cater to specialist pollinators helps combat the degradation of these pollinator populations

Each seed mix table has two methods for accessing sortable Excel files for composing seed mixes for each roadside condition:

- A hyperlink for when this manual is used online
- A QR code for when this manual is in hardcopy form

1.2 Native Seed Mix for Mesic Sites

A significant portion of New England roadsides tends to have mesic soils. Mesic sites usually contain sandy loam, loamy sand, or sand soils that drain well or moderately well. Water is usually available throughout most of the growing season. However, plants may suffer under drought conditions. Therefore, the mesic site mix contains species adapted to a broad range of moisture classes but are dominated by upland species.

The following seed mix was used for demonstration sites. The mix is composed of approximately 40.7% grass-like species and 59.3% forbs by seed count.

Access the sortable table here Native Mesic Mix.pdf or scan this QR code:

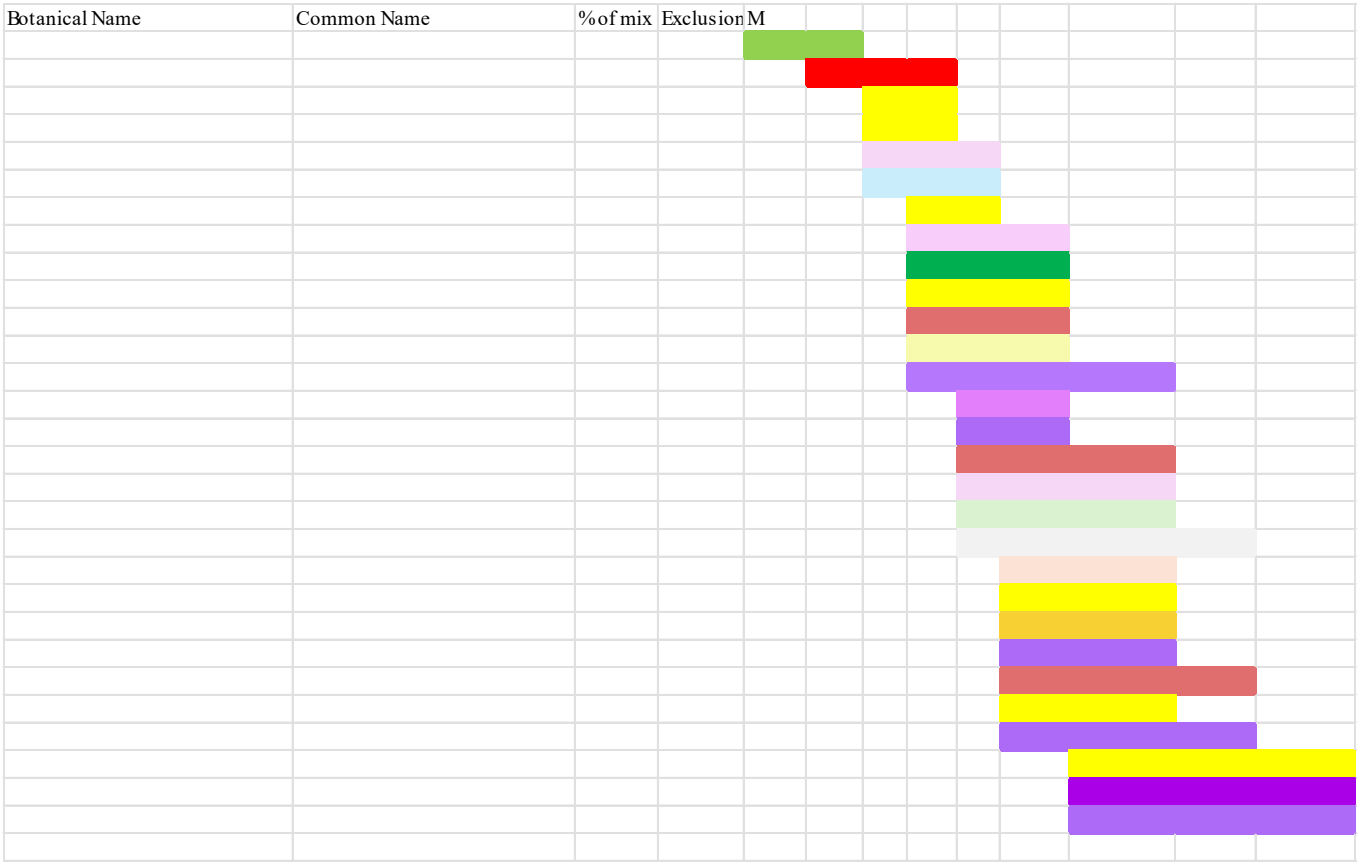
Botanical Name	Common Name	% of mix	Exclusions	March	April	May	June	July	August	September	October
Elymus virginicus	Virginia wildrye	30.8									
Anemone virginiana	tall windflower	0.7									
Viola sororia	**woolly blue violet**	**0.4**									
Fragaria virginiana	wild strawberry	0.4									
Zizia aurea	Golden Alexanders	2.3									
Penstemon digitalis	Foxglove beardtongue	1.5	RI								
Asclepias exaltata	poke milkweed	0.4	RI, VT								
Eupatorium perfoliatum	boneset thoroughwort	0.8									
Rudbeckia hirta	Black-eye Susan	4.6									
Asclepias tuberosa	butterfly milkweed	0.9	ME, NH, RI, VT								
Eutrochium dubium	coastal plain Joe-Pye wee	0.8	ME								
Schizachyrium scoparium	Little bluestem	28.7									
Solidago juncea	**early goldenrod**	**0.4**									
Asclepias incarnata	Swamp milkweed	1.1									
Asclepias syriaca	Common milkweed	0.5									
Solidago flexicaulis	zig-zag goldenrod	0.4	RI								
Achillea millefolium	Common yarrow	0.2									
Chamerion angustifolium	fireweed	0.6									
Cirsium discolor	field thistle	0.4	VT								
Cirsium pumilum	field thistle	0.4									
Monarda fistulosa	Wild bergamot	0.5									
Vernonia noveboracensis	New York Ironweed	0.8									
Desmodium canadense	showy tick-trefoil	0.8									
Symphyotrichum novae-angliae	New England Aster	0.8									
Eutrochium purpureum	purple Joe-Pye weed	0.8	ME								
Panicum virgatum	switch panicgrass	4.6	VT								
Pycnanthemum muticum	Broad-leaved mountain m	0.2	ME, VT								
Pycnanthemum tenuifolium	Narrowleaf mountain min	0.5									
Lespedeza capitata	round-headed bush-clov	1.5	VT								
Solidago nemoralis	Gray goldenrod	0.5									
Symphyotrichum cordifolium	heart-leaved American-as	0.6									
Eragrostis spectabilis	purple lovegrass	1.5									
Solidago puberula	downy goldenrod	0.2									
Tridens flavus	purple top	8.8									
Symphyotrichum lateriflorum	calico American-aster	0.8									
Symphyotrichum novi-belgii	New York American-aster	0.6									
Solidago caesia	Blue-stem goldenrod	0.2									

1.3 Native Seed Mix for Dry Sites

Dry plant communities occur on sand or loamy sands, which are excessively to somewhat excessively well-drained. They are often found on sandy glacial outwash dominated by shallow soils composed of medium to coarse sands and gravel. Existing native plant communities in these areas are usually dominated by warm-season grasses with deep roots that can access water. Dry roadside native plant communities are typically patchy and shorter compared to those at mesic sites.

The following example of a mix for a dry site is composed of approximately 45% grass-like species and 55% forbs by seed count.

Botanical Name	Common Name	% of mix	Exclusion M



Access sortable table here [Native Dry Mix.pdf](#) or scan this QR code:

1.4 Native Seed Mix for Wet Sites

Wet soils have poor drainage and can be temporarily wet. The plants selected for wet soils are typically classified as *facultative* plants, which can thrive in both wetlands and non-wetlands, tolerating a wide range of soil moisture conditions. These plants often occur in hydric soils, in areas where water saturates the soil or floods the surface at least seasonally. Their presence in different habitats is influenced by various environmental factors besides hydrology, such as soil pH, elevation, and light.

The following example of a mix for a wet site is composed of approximately 75% grass-like species and 25% forbs by seed count.

Access sortable table here [Native Wet Mix.pdf](#) or scan this QR code:

Botanical Name	Common Name	% of mix	Exclusion	March	April	May	June	July	August	Septembe	October	Novembe
Elymus virginicus	Virginia wildrye	24.7										
Packera aurea	**golden groundsel**	0.4										
Apocynum cannabinum	**hemp dogbane**	0.2										
Iris versicolor	Blue Flag Iris	0.8										
Juncus tenuis	path rush	0.7										
Zizia aurea	Golden Alexanders	1.3										
Geranium maculatum	**spotted crane's-bill**	0.5										
Carex lurida	sallow sedge	6.8										
Solidago juncea	early goldenrod	0.1										
Asclepias incarnata	swamp milkweed	2.7										
Carex vulpinoidea	common fox sedge	19.1										
Lilium canadense	Canada lily	0.6	RI									
Oenothera biennis	common evening-primrose	0.2										
Mimulus ringens	Monkeyflower	0.2										
Lysimachia terrestris	swamp yellow-loosestrife	0.4										
Verbena hastata	blue vervain	4										
Vernonia noveboracensis	New York Ironweed	1.3										
Carex scoparia	pointed broom sedge	6.8										
Scripus hattorianus	Northern bulrush	0.4										
Desmodium canadense	showy tick-trefoil	0.7										
Chelone glabra	Pink turtlehead	1										
Juncus effusus	common soft rush	2										
Panicum virgatum	switch panicgrass	17.2	VT									
Hypericum majus	greater Canada St. John's-v	0.6										
Scutellaria galericulata	hooded skullcap	0.4										
Eupatorium perfoliatum	boneset thoroughwort	1.3										
Cirsium muticum	swamp thistle	0.2										
Impatiens capensis	jewelweed	0.4										
Lobelia cardinalis	cardinal-flower	0.2										
Symphyotrichum novae-ang	New England Aster	1.7										
Solidago rugosa	wrinkle-leaved goldenrod	0.5										
Solidago sempervirens	seaside goldenrod	0.5										
Gentiana clausa	meadow bottle gentian	1										
Solidago patula	rough-leaved goldenrod	0.3	ME, RI, VT									
Symphyotrichum laterifloru	calico American-aster	0.8										
		100										

1.5 Native Seed Mix for Coastal Sites

New England coastal regions have a wide range of habitats and growing conditions, including tidal marshes and coastal forests. The soils vary from fine silts to sandy or rocky soils, with moisture conditions ranging from wet to moist to very dry. Species selection for roadsides in coastal regions requires plants that can tolerate both dry periods and occasional flooding. Most importantly, these plants should have high salt tolerance and be able to thrive in sunny conditions.

The following example of a mix for coastal sites is composed of approximately 90% grass-like species and 10% forbs by seed count.

Botanical Name	Common Name	% of mix	Exclusion M
	common wrinkle-leaved golden	0.8	
Solidago sempervirens	seaside goldenrod	0.8	

Access sortable table here [Native Coastal Mix.pdf] or scan this QR code:

1.6 Lists of Native Shrubs

Native shrubs are recommended for planting in areas away from roads, typically along woodland edges and back slopes, to provide additional floral resources, which are particularly important in spring and early summer, and to encourage wood tunnel nesting bee populations. A separate group of native woody plants for coastal regions lists species that grow well in the

soils, habitats, and growing conditions of coastal roadsides, where plants are subjected to greater salt exposure in the form of salt spray or accumulation in soils.

Woody plants for use on all roadside conditions other than coastal regions

Botanical Name	Common Name	Excl.	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Juniperus communis	common juniper													
Salix bebbiana	long-beaked willow													
Salix lucida	shining willow													
Salix humilis	prairie willow													
Alnus incana	speckled alder													
Amelanchier canadensis	eastern shadbush	VT												
Arctostaphylos uva-ursi	red bearberry													
Aronia melanocarpa	black chokeberry													
Chamaepericlymenum canadense	bunchberry	RI												
Corylus cornuta	beaked hazelnut	VT												
Gaylussacia baccata	black huckleberry													
Ilex verticillata	common winterberry													
Lindera benzoin	northern spicebush	ME												
Morella caroliniensis	small bayberry													
Myrica gale	sweetgale													
Rubus allegheniensis	common blackberry													
Salix discolor	pussy willow													
Swida amomum	silky dogwood													
Swida sericea	red-osier dogwood													
Vaccinium angustifolium	common lowbush blueberry													
Viburnum dentatum	smooth arrowwood													
Amelanchier laevis	smooth shadbush													
Comptonia peregrina	sweet-fern													
Rosa palustris	swamp rose													
Sambucus nigra	black elderberry													
Clethra alnifolia	coastal sweet-pepperbush	ME												
Diervilla lonicera	bush-honeysuckle													
Kalmia angustifolia	sheep American-laurel													
Rhus hirta	staghorn sumac													
Rosa carolina	Carolina rose													
Rosa virginiana	Virginia rose													
Rubus odoratus	flowering raspberry													
Cephalanthus occidentalis	common buttonbush													
Rosa blanda	smooth rose													
Spiraea alba	white meadowsweet													
Spiraea tomentosa	rosy meadowsweet													
Corylus americana	American hazelnut													
Salix petiolaris	meadow willow		N/A											

Woody Plants for Coastal Regions

Botanical Name	Common Name	Exclusions	January	Feburary	March	April	May	June	July	August	September	October	November	December
Salix bebbiana	long-beaked willow													
Salix discolor	pussy willow													
Rosa palustris	swamp rose													
Lyonia ligustrina	maleberry	VT												
Prunus maritima	beach plum	ME												
Cephalanthus occidentalis	common buttonbush													
Iva frutescens	maritime marsh-elder	ME, NH												
Gaylussacia bigeloviana	dwarf huckleberry	ME, RI												
Spiraea alba	white meadowsweet													
Spiraea tomentosa	steeplebush													
Chamaecyparis thyoides	Atlantic white cedar	ME, NH												
Salix petiolaris	meadow willow		N/A											

The Benefits of Using Native Shrubs in Roadside Ecotones

Ecotones, the transitional zones between different ecosystems, can play a crucial role in maintaining the delicate balance of natural habitats. Using native shrubs in roadside ecotones offers several environmental, ecological, and economic benefits to both humans and wildlife.

Solitary tunnel-nesting bees shelter in the pith or hollow stems of some native shrubs, such as black elderberry, staghorn sumac, speckled alder, raspberry, and blackberry. In addition, native shrubs provide floral resources for pollinators, especially in spring and early summer. For example, ground-nesting pollinators, such as bumblebees, depend upon the pollen and nectar from willows – one of few early spring flowering species – to nourish their colony of eggs. Berry producing shrubs, such as shadbush, winterberry, and chokeberry, supply birds with nutritional resources, especially during winter months. By providing habitat and food sources for local wildlife, ecotones constructed of native shrubs enhance local biodiversity

Native shrubs have root systems well-adapted to local soils, making them effective at stabilizing the soil and reducing erosion. Their extensive root systems also promote water infiltration into the soil, reducing runoff and the risk of flooding. Since native shrubs are well-adapted to local climates and soil types, they are more resilient to pests, diseases, and extreme weather conditions. Once established, native shrubs require less frequent maintenance compared to non-native species, reducing the long-term costs for roadside management.

Native shrubs can help preserve the natural character and aesthetic of our region, enhancing the visual appeal of roadside landscapes.: Many native plants have cultural or historical significance to local communities, contributing to a sense of place and heritage.

New England Departments of Transportation often face the challenge of preventing encroaching woodlands from impacting road infrastructure. To address this issue, native shrubs can act as a physical barrier that slows or prevents the spread of trees and woodland species toward road pavement, thus providing a sustainable and cost-effective solution to infrastructure maintenance.

Chapter 2: Establishment of Demonstration Sites

The objective of establishing the demonstration sites was to familiarize New England DOTs with protocols for native plant establishment and identify potential impediments they might encounter when establishing such habitats. This chapter outlines the process behind the selection of demonstration sites and the strategy of differentiating each site to maximize the data collected. This chapter also covers steps that were taken before planting that should also be conducted when DOTs plan native seedings, including site selection, assessment, and preparations, seed mix parameters, seeding methods, and post-establishment monitoring.

2.1. Site Selections

To stay within budgetary constraints, it was determined that three sites in three different states would be established. By selecting sites interconnected by one roadway, the work on the demonstration sites provided examples of how DOTs could focus on corridor development and conceptualize and relate future projects beyond the implementation phase of this grant.

Therefore, to increase the impact of these projects, the sites were strategically incorporated into a larger concept or holistic plan that the DOTs can use in the long-term. The location of the site in each state would allow the comparison of how establishment efforts fare under different state regulatory regimes and environmental conditions. In addition, different establishment techniques for each site were proposed, which would involve diverse experiences occurring during different times of the year and would allow testing of the impact that current roadside maintenance schedules may have on establishment protocols.

Figure 2-1. Location of demonstration sites along Rte. 91.

The two-way migratory routes that monarchs navigate when they migrate from Mexico to Canada and back to Mexico indicate that the north-south orientation of US Interstate Highway 91 (I-91) provides an effective corridor for monarch butterfly migration. The fact that I-91 spans from the CT coast to the Canadian border allowed for the choice of sites at different latitudes from 41° 23' to 44° 56' within three states – CT, MA, and VT.

Criteria For Site Selection

Once the determination was made that the three demonstration sites would be located along I-91 in CT, MA, and VT, DOT managers from each state were asked to select potential locations for the sites following these criteria:

- Roadside plots that could accommodate plantings of between 0.5 to 1.5 acres of native plant communities beyond the 15' clear zone, which required mowing to allow vehicles to safely pull off onto the side of roads.
- Plots that require new plantings following new construction or roadsides with existing vegetation that could be transitioned to native plant communities.
- Sites that would allow safe and easy access during the establishment process for landscape personnel and researchers.
- Sites that are visible for highway drivers to increase awareness of the change to new roadside revegetation protocols to promote support for the transition.
- Avoid sites infested with invasive plant species, especially those hard to eradicate, like mugwort (*Artemisia vulgaris*), Japanese knotweed (*Reynoutria japonica*), and common reed (*Phragmites australis*).
- Avoid sites situated too close to sensitive areas, such as wetlands or avian migratory waystations, which create regulatory challenges.

2.2. Site Assessments and Seed Mixes

The following site assessment tools and parameters for seed mixes were used for the demonstration plots and should be used when surveying sites for seeding.

Soil Tests

It is highly recommended that State Cooperative Extension Soil Tests and Percolation Tests be conducted before seeding. Together, these tests should provide sufficient data when selecting seed mixes. For example, if percolation test results indicate that a site has poorly draining soil, the seed mix for wet sites should be used since the included species can withstand extended periods of moisture. In addition, soil test results pointing to a mesic soil regime implies potentially greater weed pressure after seeding than would occur at a drier site. Furthermore, soil tests conducted by the extension service may show extremely low levels of nutrients. In such cases, it is important to include plant species that can tolerate nutrient poor soils. Perhaps, only warm-season grasses and a few forbs would establish on such a site.

Physical Surveys. The following parameters were recorded to confirm site suitability for plantings:

- Climate and microclimate
- Topography
- Sunlight and exposure
- Hydrology
- Soil pH and other characteristics. Mesic soils, which are most prevalent along roadsides in New England, were selected for all three sites (Appendix 2).

The process of surveying each site's physical parameters was guided by NETC 09-2 Manual.

Biotic Surveys. A detailed biotic survey was conducted for each site before any work commenced and included:

- indicator species that provide information on the ecological conditions of the site as this information assists in selection of an appropriate seed mix for the site (for example, presence of sedges would indicate wet/moist soils).
- existing ecological communities for preservation, restoration, or enhancements.
- presence of undesirable vegetation and invasive species encroachment, to guide management control including herbicide application.

Parameters For Seed Mix

Based on the criteria for seed mixes outlined in Chapter 1, the research team selected appropriate seed mixes for each site. For the three demonstration sites, soil analyses determined that each site had mesic soil, containing a mixture of sandy loam, loamy sand, and sand that drains well or moderately well. The soil remains moist throughout most of the growing season, though some areas at MA site were excessively moist during periods of rain. Therefore, the native plant communities should contain species adapted to a broad range of moisture conditions but are dominated by species of upland affinity (Appendix 3). To promote monarch butterfly habitats, an increased amount of *Asclepias* species – swamp milkweed (*Asclepias incarnata*) and butterfly milkweed (*Asclepias tuberosa*) – were included in a mix compared to the standard native plant mixes. Common milkweed (*Asclepias syriaca*) already frequently exists along roadsides in New England.

2.3. Site Preparation

Two methods exist for site preparation when transitioning from existing vegetation to native plant communities:

Herbicide Application. The application of herbicides to eliminate existing vegetation is best suited when using the no-till seed drill technique for seeding native species. The drill can

penetrate dead vegetation and roots to keep the soil intact, preventing soil erosion. A broad spectrum, non-selective systemic herbicide is customarily used to kill existing vegetation prior to seeding.

The type of herbicide is selected based on the information obtained during plant inventory. For example, glyphosate-based herbicides (commercial names Roundup, Rodeo, and AquaNeat) are frequently used because glyphosate is one of the least toxic broad-spectrum herbicides available. However, glyphosate is less effective in killing some broadleaf invasive species, like mugwort (*Artemisia vulgaris*). Therefore, some sites may require an application of both glyphosate and triclopyr (commercial names Garlon or Pathfinder). Triclopyr is a selective herbicide that kills broadleaf plants but not grasses. Triclopyr is especially effective in killing woody invasive plants, such as autumn olive (*Elaeagnus umbellata*), Asian bittersweet (*Celastrus orbiculatus*), and tree-of-heaven (*Ailanthus altissima*).

Note: *Herbicides should only be applied by personnel with the appropriate licenses.*

Excavation of vegetation and the top three inches of soil. However, since this method requires the excavated soil to be placed elsewhere, this method is only recommended if the soil can be moved to a neighboring area.

2.4. Seeding Methods

No-till seed drilling. No-till seed drills are specifically designed for ground that has not been tilled and is covered with dead vegetation after herbicide application. However, some practitioners have had success drilling seed into existing vegetation. While some no-till seed drills can be operated on slightly sloped terrain, most are best used on flat areas. These drills have heavy openers that cut through terrain and sod to make a furrow for seed placement and discs that aid in loosening the soil. They are usually equipped with closing or packing wheels that follow seed placement. No-till seed drills are designed to achieve uniform seed distribution over the site with good seed-to-soil contact and seed placement set to an effective depth (1/4”-1/2”). No-till seed drills need to be calibrated before each job to accommodate the seed bulk density and required application rates of a seed mix.

No-till seed drills are designed to work with a range of native seed structures. Unlike traditional seed drills that are designed to handle only seeds with high bulk density, such as oats and wheat, no-till seed drills, such as Truax, have specialized seed boxes that are effective for planting fluffy seed, such as little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), and Indiangrass (*Sorghastrum nutans*), that will not readily flow through a traditional seed drill. Bulking agents, such as cat litter, dry sawdust, vermiculate, or rice hulls may be used to improve fluffy seed flow.

Sourcing no-till seed drills in New England. At the time of publication, Connecticut was the only New England state that owns no-till seed drills. The CT DOT acquired two no-till drills in 2024 – one by Land Pride and another by Brillion. Previously, the state Department of Energy &

Environmental Protection (DEEP) administered a Truax no-till drill for conservation work, and prioritized their own projects before they would accommodate those of other agencies and entities. Also, DEEP managers will not use the Truax drill before June 1 because they claim Connecticut soil is too moist for the drill to work properly. This schedule became problematic for those who work with native seeds because experience has shown that native grasses tend to establish better from mid-May to mid-June, when soil is warm and moist. Therefore, considering the DEEP drill schedule and our desire to conduct a split-season seeding that involves seeding grasses in the spring and forbs in the fall, the research team explored the possibility of contracting private companies to conduct seeding before settling on Matt's Landscaping from Fall's River, CT**.**

Broadcast Seeding. Broadcast seeding is reserved for prepared sites with no previous vegetation, such land recovery following roadway construction. It is important to ensure sufficient soil depth for root growth (generally 4 inches), by either conducting revegetation following construction or after the removal of vegetation and the top three inches of soil for sites with pre-existing vegetation. Seed can also be sown either manually or by broadcast spreader equipment.

Manual. Hand seeding involves casting seed onto bare soil. Hand seeding is most appropriate on smaller plots or difficult terrain, such those that are steeply sloped, where seeding with machinery is not an option. (Hydroseeding is also applicable in such situations. See description below concerning hydroseeding using native seed, which differs from hydroseeding turfgrass.) The goal is to achieve an even distribution of seed over the entire site, which can be accomplished by spreading half of the seed in one pass and the balance in a perpendicular pass. To ensure uniform seed application, conduct a test run over a small area using the appropriate amount of seed for that area. When the volume of seed to be applied is small (less than 50 lb. per acre), a bulking agent helps to provide the volume necessary to achieve uniform application. Such bulking agents include cat litter, dry sawdust, vermiculite, or rice hulls.

Broadcast seed equipment. A broadcast spreader consists of a hopper with an adjustable opening that regulates seed flow onto a spinner. Some broadcast spreaders use an agitator to assist with seed flow within the hopper. Broadcast spreaders are commonly used to spread seed, fertilizer, lime, and other granular products. The width of seed distribution from the spreader determines the width of each pass. Optimal distribution can be achieved by spreading half of the seed in one pass and the balance in a perpendicular pass. It is recommended to refill the hopper when it is 1/3 full rather than letting it run out.

Fluffy native seeds will not uniformly flow through a broadcast spreader. Mixing the seed with a bulking agent of similar density will enhance the flow. Dry sawdust, vermiculite, or rice hulls are some options. Using a hopper with an agitator may be required in these circumstances. It is recommended to use a minimum rate of 50 lb. per acre of seed and bulking agent. For fine seeds, cat litter is the appropriate bulking agent.
After broadcasting seed, lightly rake the seed to a depth of 1/4" and/or firming with a lawn or Brillion-type roller to achieve good seed-to-soil contact. Do not roll or track the seed if the soil

is wet. Cover with straw matting or straw mulch at 70 lbs. per 1,000 sq ft, or hydromulch at 34 lbs. per 1,000 sq ft.

Hydroseeding. A hydroseeder combines water, seed, fertilizer, and hydromulch, and then pumps this slurry from a turret or hose through a nozzle onto the ground to uniformly cover the area with seed. With a reach of 150' or more, hydroseeders allow seeding of terrain not easily or safely accessible with other seeding methods, such as steep slopes, roadside cuts, or sites that are too wet. However, since native seed requires good seed-to-soil contact, hydroseeding native seed is best conducted by first either spreading the seed upon bare soil using broadcast methods or spraying them with the hydroseeder without the hydromulch. Cover the seed with hydromulch, which contains a tackifier that helps the hydromulch and seed to maintain contact with the soil. It is recommended that 34 lbs. per 1,000 sq ft of hydromulch.

2.5. Site Establishment

Below is a summary of the characteristics and seeding methods of the three demonstration sites installed in 2023 (see Appendix 4 for more details).

Table 2-1. Site characteristics and seeding methods.

State	Site Location	Soil pH	Seeding Method/ Planting time	Seed Mix
CT	Windsor	6.8	• Conversion of existing turf • Split-season seeding using Truax drill on June 2 and October 16	• Mesic mix • Grass and oat cover crop seeded early June • Forbs seed seeded in mid-October
MA	Holyoke	6.8	• Conversion of existing turf • Fall seeding using Truax drill on October 16	• Mesic mix • Both grasses and forbs seeded with a cover crop of cereal rye
VT	Lyndon	7.7	• Following new construction • Broadcast seeding covered with straw matting to provide erosion control on August 22	• Mesic mix • Due to high pH, used 1.5 seeding rate, as per Ernst Conservation Seed's recommendation • Both grasses and forbs seeded with a cover crop of cereal rye

Table 2-2. The most significant challenges encountered at each demonstration site.

State	Challenges	Details
CT	Weed infestation	• About 25% of the site was populated in mid-July by yellow foxtail (*Setaria glauca*), and to a lesser extent nutsedge (*Cyperus esculentus*). • The patches of yellow foxtail and nutsedge were mowed on August 11 and September 8.
MA	Herbicide regulations	• MA regulations governing the application of pesticides in rights of way proved to be complex and cumbersome. • Site had to be moved from Northampton to Holyoke when the local government predicted that approval for herbicide application would require a town hall meeting in Northampton. • Herbicide application in Holyoke required a multi-step approval process. • Herbicide applicators are required to have specific certifications.
VT	High soil pH	• Soil pH was not optimal for establishment of native species and seeding rates needed to be increased. • Imposed timetable following new construction required planting date sooner than optimal.

2.6. Post-establishment Monitoring

Monitoring during the first year

One of the greatest challenges encountered during the transition to native roadside vegetation involves changing the expectations of what constitutes a successful establishment. The way biodiverse native plant communities are established differs greatly from the way cool season turfgrasses establish.

Cool season sod-forming grasses germinate and grow relatively fast. Small green seedlings quickly sprout all over the field and grow to relatively uniform heights, resulting in a field with an even, clean appearance. Within several weeks, if successfully established, the ground has the appearance of a green carpet. By the end of the first growing season, turf has developed. On the other hand, native plant communities consisting of warm-season grasses and perennial forbs usually take 3–5 years to fully establish.

Tips For Monitoring and Evaluating New Plantings

- Inspect the planted site at least three weeks following the seeding.
- Evaluate weed pressure. If heavy – at least 25% coverage – plan and implement weed control measures. The degree and rate of success of any seeding project will depend on weed control during the establishment period.

- Where erosion is evident, repair areas by reseeding and mulching.
- If erosion control matting exhibits significant movement, reinstall and staple as needed.
- If the site was drill-seeded, examine the rows and look for patterns of similar seedlings. This helps develop an eye for distinguishing between desirable and undesirable seedlings.
- If uncertain about the success of a planting, consult a botanist for help identifying seedlings.

Unless heavy rains wash away most seed, allow two full growing seasons to determine whether seeding was successful or not.

First-year native seedlings are small and grow more sparsely and much less uniformly than turf grass seedlings. As a result, during early evaluation, people often worry or assume their plantings have failed. While the aboveground growth of newly planted, warm-season grasses may appear subpar, in fact native warm-season grasses during their first year put most of their energy into developing extensive root systems. Leaf and stem growth rarely reach more than one foot tall by the end of the first growing season. In many cases, relatively little flowering occurs the first year. Not until the second or third growing season does considerable aboveground biomass develop, finally resulting in grasses flowering and producing seed. If seedling density appears sparse, there is no need to panic. An adequate, mature stand of native warm-season grass might have as few as one plant per square foot. Individual plants grow quite large and may fill in poor stands by self-seeding or spreading vegetatively. A mature little bluestem clump eventually can measure one foot in diameter.

During the first year, the field will appear entirely green, similar to turfgrass establishment, though taller. There are some weeds growing among fields of desirable native seedlings. Because native seedlings frequently grow among weed seedlings, it is important to develop the ability to distinguish weed seedlings from desirable native seedlings. People unfamiliar with native warm-season grass seedlings often conclude a planting has failed because they have not yet developed the ability to properly identify and distinguish between the various species within a planting. This is especially true when seeds are broadcast rather than planted with a no-till drill, which creates rows of plants that help guide the eye to where the new seedlings will appear. One approach helpful in identifying native seedlings involves digging up a few new seedlings and looking at the attached seed. This requires creating a chart of the seeds that were included in the original mix. Most native warm-season grass seedlings appear fountain-like and, on average, do not grow closely together. Frequently during the first growing season dicot seedlings are mistakenly identified as weeds when they are in fact desirable with perennial forbs that only grow rosettes their first year. Many perennial plants may take two or three years before they flower. However, some seedlings in fact may be undesirable and need to be removed before they flower and add to the field's seedbank.

Figures 2-2. Inspecting seed germination: if using a no-till drill, look for new seedlings by following the furrows created by coulter blades.

Evaluate stands when seedlings are approximately 6”-12” in height. For slopes of 5:1 or greater, a seedling density of 8–100 seedlings per square foot is desirable. For conservation seedings where erosion control is a concern, a seedling density of 40–50 seedlings per square foot is desirable. For conservation plantings when erosion control is not the primary objective, 20–25 plants per square foot will satisfy most needs. Warm-season grasses tolerate less density, although early density is important to compete with weeds. It is normal for stands to thin out during the establishment period and stands of 50% of the above densities are acceptable in the spring following seeding. Warm-season grasses can obtain canopy cover after several years with as few as two seedlings per square foot if weeds are controlled. A less-dense stand will lend itself to more species diversity, which is desirable for some conservation objectives. Although some of these species could be considered weeds with the potential to spread to other fields, it is important to carefully evaluate native seedings so that effective management decisions can be made. For warm-season grasses on soils with areas prone to frost heaving, evaluate again the following spring.

Expectations For Native Species Emergence

Warm season grasses. Germination of warm season grasses occurs in the spring when moisture conditions are appropriate, and soil temperature exceeds 55°F (12°C) at 3” depth. Best germination occurs when soil temperatures are much higher. Most species do not require cold, wet stratification, or exposure to cold, damp conditions over the winter which signals to the seed that it is time to germinate when the soil warms up in spring. However, 20%-50% of the seed may remain dormant, emerging by the end of the second full growing season. Greatest growth of warm season grasses occurs when air temperatures are 75°F-95°F (24°C-35°C). Very few (<5%) plants will flower and set seed in the first growing season. The plants will mature after two years.

Cool season grasses. Some cool season grass species will germinate when temperatures are a little higher than 40°F (4°C) while others will require warmer temperatures. They may

germinate in the spring or fall. Adequate stands of most species do not require stratification. However, 50% of the seed may remain dormant without stratification. Most seedlings to emerge will grow by the end of the second full growing season. Greatest growth occurs when temperatures are 65°F-85°F (18°C-29°C). With adequate moisture and nutrients, some flowering and seed set may occur in the first growing season.

Forbs. Some broadleaf forb germination will occur in the first year without stratification. However, a high percentage of species are likely to germinate following the first winter after seeding, and most will have germinated by the end of the growing season following stratification.

The flowering of some species may occur as following:

Second growing season: black eyed Susan (*Rudbeckia hirta*), *Aster*/*Symphyotrichum* spp., *Monarda* spp., *Penstemon* spp., Solidago spp.
Three to five growing seasons: *Liatris* spp.
Not until the seventh growing season: yellow false indigo (*Baptisia tinctoria*)

Experience has shown that some species may emerge earlier or later, depending upon a site's microclimate parameters.

The Seedling Gallery helps identify successful germination of some species during the first year. The Gallery can be accessed using the following link if this manual is being used online. Seedling Gallery Guide.docx

If the manual is being used as a hard copy, access the Gallery by using the QR code below.

Post-Establishment Weed Control

Because native warm-season grass seedlings initially grow slowly, competition from cool-season grass and broad-leaf weeds can be detrimental to native seedling establishment. Some weed control is recommended at new establishments during the first three years. Also spot treatment using selective herbicides will help to prevent tree and shrub encroachment

Flail mowing. Native plant stands, which should be mowed once a year or every other year, will require DOTs to switch from using conventional mowers for maintaining roadsides to using flail mowers. DOTs have usually used flail mowers mounted on extendable arms to mow

downslopes, where woody plants tend to take root since downslopes are mowed relatively infrequently. Flail mowers have a horizontal drum with sharp knives or blades attached in staggered rows that spin around a shaft as it moves parallel to the ground. These multiple blades moving vertically make flail mowers able to pulverize woody stems with diameters as wide as 4", unlike conventional mowers, which have one blade that rotates horizontally. Flail mowers are better equipped to cut through the additional biomass of native plant stands.

When choosing flail mowing equipment, consider both the terrain on which the planting occurred and the height of the mowing. Mowing for weed control is conducted at heights greater than those used for turf mowing. Generally, turfgrass is mowed at heights ranging from 1" to 4" depending on application. Native plant stands on the other hand, require mowing heights ranging from 6" to 12" during the first two years of establishment. Therefore, while heavy-duty riding lawnmowers, wheeled brush mowers, string trimmers, and tractor-mounted mowers can all be used for weed control mowing, the equipment must be adjusted to the proper height. String trimmers work best for spot mowing, and where other equipment cannot be used, such as steep slopes and low wet areas. In addition, they can cut at any height, and, unlike many mowers, can lay down the cut material gently without clumping, which can suffocate seedlings.

First year. Mow weeds to a height of 6" early in the first year and to 12" later in the year if the native grasses grow higher than six inches tall. Mow just above the tops of the native grasses. This prevents weeds from shading the shorter grass seedlings and setting seed, thus reducing weed pressure in following years. Expect to mow two to three times in the first year. Do not allow the weeds to grow over 12" tall before mowing. Otherwise, the mowed material can smother the small seedlings.

Second year. Mow annual and biennial weeds in mid- to late June at a height of 12" to prevent annual and biennial weeds from forming seeds. Many native grasses begin growing vigorously during the second season. If weeds continue to cause a problem later in the second year, mow again just above the tops of the warm-season grasses. Since many warm-season grasses start to flower and set seed during the second year, it is important not to mow off their flowers before their seeds have ripened. Flail-type mowers work best in these situations because they chop the material, allowing it to dry rapidly without smothering the smaller grass seedlings below. Rotary mowers usually leave the cuttings in piles, creating a thick mat of clippings that can smother the young native plants.

Third year and beyond. Mow in the spring and rake off the cut material will help expose the soil to sunlight, thus accelerating soil warming, which favors warm-season grasses and forbs over cool-season turfgrass. Mow close to the soil surface – 1"- 2" if possible. This achieves an effect similar to prescribed burning – which is not safe to conduct along roads – by giving warm-season native plants an advantage over cool-season weeds and grasses.

Considerations for future replacement of mowing equipment. Flail mowing equipment owned by New England DOTs either may not adjust to recommended heights or may do so with much

difficulty. Nevertheless, with the regions' DOTs transitioning to revegetating roadsides using native plants, DOTs maintenance departments need to be aware that, when they inevitably replace equipment, that they need to select equipment that can be easily adjusted to recommended heights. The highest setting most mowers mow is between 4" and 5". For heights greater than 5", it is recommended to use bush hogs for larger fields and trimmers or brush cutters for smaller areas.

Chapter 3: Conservation Mowing

This chapter outlines the mowing regimens that benefit pollinator health. It includes the benefits of conservation mowing, how to start a conservation mowing program, and approaches for inventorying roadside vegetation.

3.1. Benefits Of Conservation Mowing

Mowing helps to maintain roadside vegetation, reduce the spread of invasive species and woody plants, improve driver sight lines, and provide areas for vehicles to safely pull off. Vegetation in recovery areas – also referred to as clear zones – is mowed regularly to keep it short for drivers who need to regain control of their vehicles. Conservation mowing involves reduced mowing regimens outside clear zones with the goal of cultivating pollinator-friendly habitats. In addition to the benefit to pollinators, conservation mowing reduces expenses and provides other environmental benefits, such as greater erosion control and reduced runoff pollution.

Figure 3-1. The appearance of milkweed on the roadside because of reduced mowing mid-summer creates important habitats for monarch butterflies.

Adverse Ecological Effects of Regular Mowing for Native Plant Communities

- Weakens and suppresses stands of native species present at a site. Low mowing heights expose bare soil and damage the crowns of native grasses. Regular mowing removes tall reproductive structures, such as flowering stems, resulting in no seed formation or dispersal of native plants.
- Promotes cool season turfgrasses rather than native plant communities because biologically turfgrass is adapted to low mowing regimens with high regrowth ability. It also stimulates low-

growing annual or biennial species, resulting in a reduction of structural complexity, floral diversity, biomass litter dynamics, and soil enrichment.

- Decreases plant diversity, resulting in fewer resources for wildlife, especially invertebrate communities, detrimentally impacting their abundance and richness.
- Increases the likelihood of pest and weed invasions because of disturbance. Regular mowing increases the occurrence of invasive species and allergenic plants by the distribution of their propagules, especially during the seed dispersal phase. Intense mowing also causes common ragweed—one of the most allergenic plant species found in North America and Europe—to colonize disturbances. Thus, it increases pollen load in the air, the severity of hay fever symptoms, the number of people affected, and medical costs.
- Incurs considerable economic costs. Even small reductions in mowing result in cost savings.
- Contributes to excess greenhouse gas emissions.

Benefits of Reduced Mowing

- Reduction in mowing is a simple and effective way to improve habitats and enhance overall environmental stewardship, resulting in an increased diversity of plants, invertebrates, and soil microbes, as well as significant cost savings.
- Helps the proliferation of mowing-intolerant native species and leads to nutrient-rich flowering, which provides pollen and nectar for pollinators and facilitates the dispersal of mature seeds of native species.
- Longer stems create sheltered microclimates promoting beetles and other small insects. Sparrows, goldfinches, and other migrating birds feed upon the seeds.
- Altering the timing of vegetation management practices contributes significantly to monarch butterfly preservation – one of the conservation actions promoted under the Candidate Conservation Agreement with Assurances (CCAA).
- Reduced disturbance leads to less invasive species spread. More vibrant plant communities create appealing roadsides, while stimulating the senses and decreasing driver fatigue.
- Helps improve water quality because taller vegetation can capture and contain more stormwater runoff.
- Unmowed roadsides contribute to reduced snow drifting in winter. Lower labor and fuel costs.
- Reduced greenhouse gas emissions – a strong motivator for reducing the intensity of roadside management.
- Contrary to popular opinion, conservation mowing does not equate to increased animal collisions (NASEM, 2023). Conversely, white-tailed deer and moose prefer to forage on fresh plant growth. Therefore, mowing outside the clear zone could result in animal foraging in those areas and in turn result in more opportunities for vehicle-animal collisions.

3.2. Starting a Conservation Mowing Program

As noted in "Pollinator Habitat Conservation Along Roadways, Volume 11: Northeast" (Hopwood et al., 2023), conservation mowing requires roadside maintenance crews to understand the life cycles of pollinators to aid in the timing, frequency, and height of mowing.

Detailed guidelines regarding mowing schedules and strategies should be developed by each state DOT, and many factors should be considered to achieve the best habitats. The following guidelines can be used as reference to help New England DOTs create a three-year conservation mowing plan. The transition can be gradual, with new areas added over the subsequent three years.

Who makes mowing decisions?

Each state structures their roadside maintenance departments differently. In some cases, individual maintenance districts are responsible for determining with their own mowing programs. In others, mowing schedules are done centrally. Either way, whomever determines the mowing schedule of a particular state should communicate to those performing mowing regimens that the implementation of conservation mowing will require observation of existing plant communities to prioritize when and how to mow particular sections of roadside.

Federal Highway Administration (FHWA) Recommendations for Conducting Inventories of Roadside Vegetation

The FHWA online publication "Roadside Best Management Practices that Benefit Pollinators: Handbook for Supporting Pollinators through Roadside Maintenance and Landscape Design" (Hopwood et al., 2016), recommends DOTs to conduct roadside inventories to manage their roadside green assets. A roadside vegetation inventory involves the mapping of the composition and condition of the current roadside vegetation, including native plants, turfgrass, invasive, and noxious weeds. Roadside vegetation inventories inform management plans that can benefit pollinators in several ways. Identification of vegetation plant communities assist roadside managers to make informed decisions about how to manage such areas to promote native seed banks to emerge and existing native plant communities to flourish. Roadside inventories can also be used to map out existing weed and invasive populations and identify emerging weed problems. Inventory data can then be used to help target management operations that reduce costs and to evaluate the effectiveness of native plant community and weed management techniques. Finally, inventories can help inform and direct future plantings when used to identify rights-of-way that might be candidates for revegetation efforts.

However, New England DOT roadside maintenance managers may find the FHWA recommendations too intricate and cumbersome to implement. Therefore, the following more simplified approach has a more realistic chance of being implemented.

3.3. Roadside Vegetation Inventory

Use the first year of a three-year mowing plan to scout for three easy to identify plant communities of invasive, native and introduced species.
Invasive plants. Mowing of invasive species can lead to the spread of invasive species via residual seeds, roots, and plant parts on mowing blades. Therefore, reduced mowing approaches should not be applied to extensive invasive species infestations. Each DOT should follow their own invasive species removal protocols.

Many areas supporting native species are mostly self-sustaining and can be maintained as established habitats by only occasional herbicide spot-spraying of invasives. This would eliminate the need for annual mowing.

Figure 3-2. Autumn olive (*Elaeagnus umbellata*) along Rt. 6 near Willimantic, CT.

Conservation areas along Rt. 6 in Connecticut have already established plant communities with rich assortments of native species. However, there are some invasive species in many areas that would likely proliferate if the sites were not mowed frequently. Therefore, to promote stable native habitats that can exist for some years without much input, patches of these invasive species should be eliminated by spot treatment with herbicides.

Native plant communities. Native plant communities are usually composed predominantly of warm-season bunch grasses and flowering forbs. These communities arise as a result of the germination of seed in seed banks and the dispersal of seed from the surrounding areas. Many native species are already present but are suppressed by mowing before they can set seed. The New England roadsides already contain seed banks for native plant species and many sites have good regeneration potential. When the native seed bank is already present, it is appropriate to promote its natural regeneration.



Figure 3-3. Native forb populations to identify in **early to mid-summer:** yellow wild indigo (*Baptisia tinctoria*), common milkweed (*Ascepias syriaca*), Foxglove beardtongue (*Penstemon digitalis*).

Figure 3-4. Grasslands with native warm-season grasses are easy to detect during the **late summer-fall period** when their inflorescences are showy if the sites are not mowed.

Figure 3-5. Native forbs to identify in the **fall**: many asters (*Symphyotrichum* spp.*)* and goldenrods (*Solidago* spp.) are indicators of native communities that can be detected in the fall.

Issues to Consider When Conducting Roadside Inventories

- Prioritize roadsides along the migratory route of the Monarch butterfly.
- Milkweed patches can be easily detected during flowering in June and July if the roadside has not been mowed. These areas should be prioritized for reduced mowing.
- When defining road segments, prioritize roadsides with adjacent farms—for example, cranberry bogs in Massachusetts and blueberry farms in Maine—that may benefit from increased feeding and nesting opportunities provided by the roadside pollinator habitats.

Introduced Plant Communities. Introduced plant species are non-native plants that become established and spread beyond the place of introduction and considered naturalized but do not spread invasively. Introduced plant communities can occur either interspersed among native grasses and forbs or among turfgrass communities. While native plants are often the most environmentally appropriate – adapted to the prevailing soil and climate – roadsides support many introduced species, which also create abundant floral resources and should be viewed as important forage for pollinators and other insects.

Figure 3-6. Pollinator habitats can be enhanced by the presence of non-native or introduced species, such as white clover (*Trifolium repens*), and yellow bedstraw (*Gallium verum*), which offer abundant pollen and nectar for pollinating insects.

Figure 3-7. Turfgrass can be identified by the presence of inflorescences (such as the fescue inflorescences above) that typically arise after several weeks of non-mowing. In many turfgrass communities, there are introduced forbs that provide pollinator resources.

3.4. Fact Sheets

Fact sheets quickly and efficiently distribute information, data, and research to particular audiences. In this case, fact sheets were created to communicate information related to the transition to new roadside revegetation practices to two audiences – DOT personnel and the public.

Recommendations for Conservation Mowing summarizes the reduced-mowing practices for the DOT personnel.

To access printable versions of this fact sheet when using this manual online, use the following link: Conservation Mowing.pdf

If using a hard copy of this manual, access the fact sheet using the QR code below.

New England Roadsides Can Support Pollinators.

The proliferation of native and introduced forbs and grasses is observed because of conservation mowing. These plantings look different from the mowed swaths of turfgrass, which drivers and passengers are used to seeing along roadsides. The Fact Sheet discusses seasonal changes of the roadsides as a result of conservation mowing to educate the public about the new looks of the roadsides.

To access printable versions of this fact sheet when using this manual online, use the following link: New England Roadsides Can Support Pollinators.pdf

If using a hard copy of this manual, access the fact sheet using the QR code below.

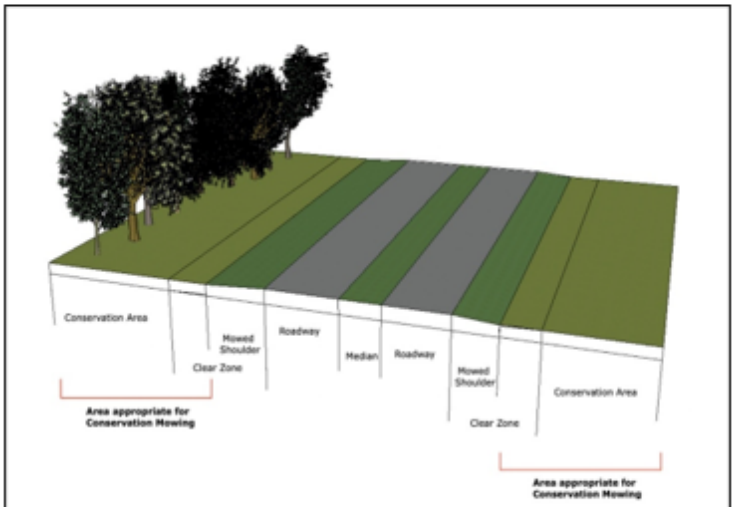
How Roadsides Can Support the Eastern Monarch Butterfly discusses the lifecycle of this iconic species, its unique relationship with milkweed and the importance of including milkweed in roadside habitats.

To access printable versions of this fact sheet when using this manual online, use the following link: How Roadsides Can Support the Eastern Monarch Buterfly.pdf

If using a hard copy of this manual, access the fact sheet using the QR code above.

Recommendations for Conservation Mowing

Conservation Mowing involves reduction of mowing frequency and alteration of mowing schedules to encourage the growth and establishment of native plants and their seed banks currently existing along roadsides. Native plants provide pollinators and other beneficial insects habitats rich with pollen, nectar, and shelter and nesting opportunities. Compared to turfgrass, native grasses and wildflowers have deeper roots, which improve soil structure and provide greater erosion control. In addition, reduced mowing results in decreased equipment emissions and likely lower labor and operational costs.



ROADWAY CROSS-SECTION – light green areas are appropriate for conservation mowing; dark green zones receive repeat mowing

Conservation Mowing Calendar for New England

	March	April	May	June	July	August	Sept	Oct	Nov
Windows for Annual Mowing	Yes	Yes	Until May 15	June 1-20 Mow only milkweed	No	No	No	After Oct 15	Yes

Conservation Mowing Best Practices

The goal of Conservation Mowing is to ensure that roadside maintenance does not restrict driver safety or interfere with native plant growth and flowering periods. The window for Conservation Mowing in New England is **late fall after October 15th and early spring before May 15th**. Spring mowing is the optimal time to allow seeds to ripen and disperse in the fall and to provide wildlife sheltering opportunities in the dormant vegetation during winter months. For this fact sheet, the section of roadside beyond the 30 foot of the Clear Zone will be referred to as the **Conservation Area**. The **Area appropriate for Conservation Mowing** encompasses the Conservation Area and the portion of the Clear Zone beyond the Mowed Shoulder, which will receive repeated mowing to prevent potential hazards for errant drivers. Medians and ramp sections wider than 60 feet would also be areas appropriate for Conservation Mowing.

The **Conservation Mowing height** should vary depending upon the season. Clippings from fall mowing will disperse and decompose over the course of the winter, so **fall mowing should be at minimum 4 inches.** With spring mowing, however, clippings could smother spring emerging plants. Therefore, it is advised that **spring mowing heights should be higher, between 6-8 inches**.

Reduced mowing may also help to limit the proliferation of invasive species by decreasing the potential for mowing equipment to spread invasive plant stems and seeds and by fostering more widespread and better-established native plant communities with deeper, more extensive root systems. Therefore, **Conservation Areas should be mowed no more than once a year or once every other year.** For zones populated with woody saplings, it is recommended to mow once a year to prevent woody plants from establishing.

Mowing the Shoulder

Roadways require a 30-foot **Clear Zone** for vehicle recovery. Within the Clear Zone, the **Mowed Shoulder** next to the roadway pavement is mowed frequently to prevent possible vegetation fire hazards from errant drivers leaving the road and to prevent obstruction of signs and object markers. The width of the Mowed Shoulder is determined by each DOT and is often dictated by the width of the flail mowers used. Since spring and summer are the growth periods for most plants, mowing of the Shoulders is recommended during these seasons.

While functional, Mowed Shoulders also create the impression of intentional, active management. In addition, the mowed edges minimize vehicle-insect conflict because insects will tend to remain within the habitats of taller, unmowed vegetation.

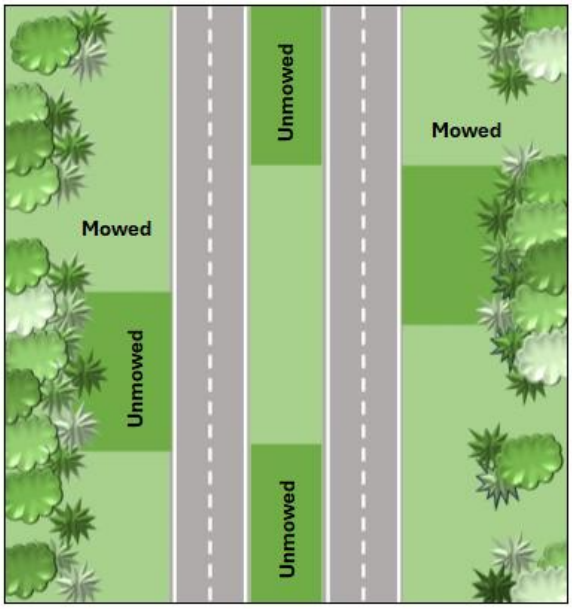
Maintaining Sight Lines

To maintain clear sight lines, vegetation should be routinely mowed at intersections, around signage, and on medians and ramp sections less than 60 feet wide.

Staggered or Mosaic Mowing

Staggered Mowing helps preserve corridors of habitat often eliminated when long stretches of roadsides are mowed, requiring pollinators to expend precious energy reserves searching for resources, which research shows threatens their lives and has contributed to declines in their populations. Staggered mowing involves mowing roadsides into segments near one another on alternate sides of roadways, leaving continuous, easily accessible patches of nutrient rich refuge areas for insect migration. **It is recommended to leave about 30% of an area uncut during annual cycles of staggered mowing.**

Rotating sides: Long portions of roadsides on alternate sides of roadways may be mowed at different times of the year to ensure that habitat always exists for pollinator to forage, shelter, and nest. Each side can be mowed entirely every 2 or 3 years.



Mowing to Benefit Monarch Butterflies

Milkweed (*Asclepias* spp.) is a critical resource for monarch butterflies, which lay their eggs exclusively on its leaves to allow their caterpillars to feed upon its leaves and ingest the plant's milky sap, making them toxic for ingestion by birds. The milkweed leaves need to be fresh to produce sap. **By mowing milkweed at a height of 6 - 8" between June 1-20**, milkweed delays flowering, puts out new growth, and produces fresh sap, which benefits monarch butterflies migrating back to Mexico in the fall. However, best practices recommend leaving a third of a site's population unmowed during this June window to allow butterflies to lay eggs while the mowed milkweed regenerates. **For further information about monarchs, see fact sheet *"How Roadsides Can Support the Eastern Monarch Butterfly".***

Campanelli, J., Urban, L., and Kuzovkina, Y.A. (2024). New England Transportation Consortium. University of Connecticut. Department of Plant Science and Landscape Architecture.

New England Roadsides Can Support Pollinators

Pollinator Decline

Pollinators, including bees, butterflies, moths, flies, and beetles, play a vital role in the health of our ecosystems. They are required for the reproduction of over 75% of the world's plants and nearly 35% of global agricultural plants. Pollinators support the global agriculture industry by aiding in the production of fruits, vegetables, and nuts, thus contributing significantly to the world's food supply.

Pollinator populations are declining due to habitat loss, excessive pesticide use, climate change, and the spread of invasive species.

Eastern tailed-blue butterfly (*Cupido comyntas*)

Great spangled fritillary (*Argynnis cybele*)

Roadsides as Corridors

Roadsides, when properly managed, can serve as corridors for pollinators. These linear spaces along highways and secondary roads offer refuge and foraging habitats and connect fragmented landscapes. The vegetation provides important resources for pollinators, such as food, shelter, and breeding

Snowberry clearwing (*Hemaris diffinis*) with bee balm

Roadside native plant community

Converting Turfgrass to Native Vegetation

Traditionally, roadsides have been planted with non-native cool season turfgrass because it provides quick establishment and more immediate erosion control while tolerating repetitive mowing.

State Departments of Transportation (DOTs) are adopting measures, such as reduced mowing, which allows for the growth of wildflowers and grasses. Often, roadsides already harbor a bank of dormant and suppressed native seeds and plant material that can generate growth. With the implementation of reduced mowing, roadsides can transition into beneficial habitats for pollinators. In addition, reduced mowing practices result in decreased emissions and savings for DOTs.

Planting native wildflowers and grasses amplifies benefits of roadside meadows, such as stormwater runoff filtration and carbon capture capabilities. Compared to turfgrass, native plants have deeper, more extensive root systems, allowing water percolation into the soil, which filters out runoff pollutants. Native plants take in carbon dioxide (CO_2) for photosynthesis through their leaves, converting the carbon into energy and storing it in plant parts.

Urban, L., Campanelli, J., and Kuzovkina, Y.A. (2024). New England Transportation Consortium. University of Connecticut. Department of Plant Science and Landscape Architecture.

Seasonal Changes of Roadside Vegetation in New England

As DOTs implement new roadside management practices, the appearance of the landscape will change. Roadsides will transition from traditionally short, mowed turfgrass to taller, less manicured landscapes featuring native grasses and wildflowers. This shift will be clearly visible along roadsides. Additionally, the increased height of the vegetation will highlight seasonal changes more prominently.

Spring

Roadside meadows come out of dormancy. Grasses begin to grow taller, and early native wildflowers are beginning to bloom. As the temperatures warm and pollinators become more active, these plants play a crucial role in providing nectar and pollen. In addition to wildflowers, trees and shrubs start to bloom as well.

Spring Blooming Native Wildflowers: lupine, iris, geranium, and beardtongue

Trees & Shrubs: dogwoods, willows, rhododendrons, and northern spicebush

Foxglove beardtongue (*Penstemon digitalis*)

Summer

Roadside meadows reach their peak flowering period with some species continuing to bloom through September.

Summer Blooming Native Wildflower: blue vervain, rudbeckia, evening primrose, bee balm, aster, Joe-Pye weed, ironweed, milkweed, and boneset.

Shrubs: viburnum, mountain laurel, meadowsweet, sweet pepperbush, buttonbush, and sumac

Joe-Pye weed *(Eutrochium maculatum)*

Autumn

As the growing season nears its end, plants divert their energy to seed production. The landscape changes from vibrant greens to muted neutrals, creating a backdrop of bare stems with seeds and dried grasses.

Pollinator activity starts to decrease, and many insects seek overwintering shelter. When roadsides are not mowed in the fall, the vegetation will provide shelter for overwintering insects and small animals.

Autumn Blooming Native Wildflowers: American witch hazel and various species of goldenrods and asters

Little bluestem (*Schizachyrium scoparium*)

Winter

During the winter season, the roadside meadow enters a phase of dormancy. Despite the outer appearance of brown and seemly dead vegetation, some stems can be filled with life waiting for the arrival of spring. Numerous insects and other organisms rely on the dried stems and plant debris for shelter and protection from the cold.

Unmowed roadsides provide refuge for many wildlife species, aiding their survival.

Various dried grasses and wildflower stems

How Roadsides Can Support the Eastern Monarch Butterfly

Monarch Butterfly

The monarch (*Danaus plexippus*) is a milkweed butterfly with orange, black marking on its wings and is native to North, Central and South America.

The **Eastern monarch butterfly** population contains individuals whose breeding grounds are east of the Rocky Mountains, including regions in New England. Eastern monarchs undertake an impressive multigenerational migratory journey, traveling approximately 3,000 miles from central Mexico to Southern Canada through the Eastern United States during the summer, and then return to Mexico for the winter.

Monarchs can be anticipated in New England from June to September, with their peak presence occurring in August.

Monarch butterflies live for approximately 3-5 weeks during their migratory journey north, with multiple generations being born each summer. The final generation, born in late summer or early fall, extends its lifespan by ceasing to reproduce and channeling its energy to fly south to their overwintering grounds in central Mexico. There, they spend the winter clustered together with others in large colonies known as a "flutters."

Monarchs and Milkweed

Monarchs have a unique relationship with plants in the genus *Asclepias* commonly known as milkweed. Seventy-three species of milkweed grow native in the U.S, but only 7 are native to the Northeast. Monarch butterflies lay their eggs exclusively on milkweed because the caterpillar can only eat its leaves.

Milkweed latex contains specialized chemicals called cardiac glycosides, which are absorbed by the caterpillars as they consume the leaves. This latex makes them unpalatable and toxic to many predators, such as birds, safeguarding them during their vulnerable growth stages. This natural defense mechanism is a component in the monarch's survival.

Unfortunately, factors like suburban sprawl and current agriculture practices result in losses of habitats containing wild milkweed in the landscape, which significantly threaten monarch butterfly reproduction. Preserving milkweed habitats, while also providing diverse nectar-rich flowering plants, can assist in the survival of monarchs and their successful migration.

Roadside Vegetation

As monarch butterflies migrate, they rely on wildflowers to restore their energy reserves. Highway roadsides can serve as corridors for monarch migration, providing long, linear expanses of habitat, feeding sources, and breeding grounds. These resources are abundant when roadsides are revegetated using native plants and managed as conservation zones through reduced mowing.

Monarch's Importance

Monarchs play important roles in ecosystems. First, they are valuable pollinators, aiding in the reproduction of many plant species. Second, while the milky sap in milkweed stems and leaves make monarch caterpillars and butterflies toxic to some, for others, they serve as a food source. Finally, they provide an important service, as they are ecological indicators. The health and migratory patterns of populations can reflect broader environmental changes including the impacts of climate change, pollution, and habitat destruction while providing insights into the health of our ecosystems.

Roadsides populated with milkweed are important habitats for monarchs.

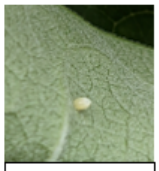
Urban, L., Campanelli, J., and Kuzovkina, Y.A. (2024). New England Transportation Consortium. University of Connecticut, Department of Plant Science and Landscape Architecture.

Monarch Life Cycle

The monarch butterfly undergoes four stages in its life cycle: egg, larva (caterpillar), pupa (chrysalis), and adult (butterfly).

Adult female monarchs lay eggs on milkweed leaves and secrete a small amount of glue to attach the eggs directly to the plant.

The eggs, about the size of a pinhead and cream-colored in the beginning, turn black on top about 4 days before the caterpillar emerges.



Monarch egg on milkweed leaf

Over the next 2 weeks, the caterpillar goes through 5 life stages called instars, shedding its skin to accommodate growth. During the final instar, the caterpillar encloses itself within a chrysalis.

Monarch chrysalis

After approximately 9 days, the adult monarch butterfly becomes visible through the chrysalis which signals it is about to emerge.

Upon emergence, the monarch's wings are wrinkled and wet, so they flap them to pump in fluids and dry them in the sun. As an adult butterfly, the monarch engages in multiple mating sessions during its lifespan. A female can lay between 300-500 eggs in her lifetime.

Monarch caterpillar on milkweed seedpod

Rt. 6 roadside meadow in Mansfield, CT

Threats to Monarchs

Several factors contribute to the drastic decline of monarch populations, but changes in land use is of primary concern. This includes logging and deforestation in Mexico that impact areas which are vital for their winter survival, as well as transformation of most breeding grounds into farmland, where herbicides are used to eradicate the monarch's host plant.

Furthermore, climate change is a key driver in monarch population decline, causing droughts, wildfires, and temperature fluctuations, which affect the monarch migration due to a lack of resources including nectar-rich plants like milkweed to lay eggs upon.

Female monarch butterfly depositing eggs on common milkweed

Monarchs: Endangered Status

The monarch butterfly, renowned for its unique migration habits and attractive orange and black markings recently has faced significant challenges. The Eastern monarch butterfly population decreased by 85% from 2019 to 2024 (MonarchJointVenure.org, 2023).

How the general public can support monarch health.

Plant native milkweed species in home gardens. Small patches can be used as stepping-stone habitats where monarchs feed, grow, reproduce, and then travel further.

Be sure to choose milkweed species carefully as some can spread aggressively, such as common milkweed (*Asclepias syriaca*).

Create habitats rich in nectar-producing flowers, which offer food resources for adult monarchs and other pollinators.

Minimize the use of pesticides to help protect monarchs and their habitats.

Participate in citizen science programs, such as monitoring monarch populations and migration patterns, to advance our understanding of these iconic insects and to assist conservation efforts.

Raise awareness and become actively involved in New England conservation initiatives tailored to the monarch butterfly's unique migration cycle.

For more information on monarch butterflies, visit:
https://xerces.org/monarchs
https://monarchwatch.org/
https://journeynorth.org/

Chapter 4: Ecotypic Seed Production in the Northeast region

Ecotypic plants are native plant species that have adapted to the climatic conditions of a region and share the genetic markers of local plant species. Research has shown the importance of prioritizing the use of local ecotypes over non-local ones for restoration purposes. First, local ecotypes have adapted to regional environmental conditions. Therefore, they are likely to establish and persist more successfully. For example, a red maple that has evolved in the deep South, where winters are milder and summers are more humid, would not fare as well in northern regions, where winters are harsher, and soil may have lower pH. Second, ecotypes co-evolve with local pollinators and wildlife populations, which depend upon native plant communities for food, nesting, and shelter. Research has shown that local and non-local ecotypes frequently have different biological cycles, such as bloom time. These differences in biological cycles may result in the misalignment of the floral resources with the emergence of native pollinator populations. Third, local ecotypes likely have greater resistance to disease and local herbivores. Finally, non-local genotypes could be established to such an extent that they become problematic. The interaction between introduced plants from remote regions and local native populations could result in species interbreeding, which may compromise the ability of native plant communities to remain adapted to a region's climatic conditions.

In January 2023, the National Academies of Sciences, Engineering, and Medicine released a 228-page report," An Assessment of Native Seed Needs and the Capacity for Their Supply," (NAS, 2023) that found the current supply of U.S. native seeds is insufficient to meet near future restoration needs. A 2018 survey of 760 respondents across Eastern U.S. states undertaken by the Mid-Atlantic Regional Seed Bank and the University of Maryland indicated that seed buyers sourced seeds from vendors located an average of 418 miles away from their restoration sites – typically from vendors in the Upper Midwest (Tangren, et al., 2022). The Transportation Research Board's Standing Technical Committees on Roadside Maintenance Operations and Landscape and Environmental Design released a webinar in 2024, "Native Seeds – Research, Development, Demand, and Application," that emphasized the importance of DOTs using locally adapted native seeds and the need for regions to increase native seed and plant research and production.

However, the lack of ecotypic native seed supplies for the New England region was the major concern raised in the NETC 09-2 Manual. While several growers have offered some ecotypic plants for several years, as of Summer 2024, production of ecotypic seed in New England is limited. To improve the supply chain of ecotypic plants, the Northeast Seed Network (NSN) was established to better coordinate efforts among regional stakeholders involved in native seed production.

While it is recommended that the New England Department of Transportation eventually use ecotypic plant material for roadside restoration, waiting for sufficient quantities of seeds to be produced at a reasonable price will take years. At the same time, non-ecotypic plant materials

can also be used: large seed producers, such as Ernst Conservation Seed in Pennsylvania and Prairie Moon Nursery in Minnesota, offer many of the seed varieties recommended in this manual. As mentioned above, Ernst Conservation Seed produces several ecotypic seeds from New England, upstate New York, and New Jersey that can be used for planting in the Northeast.

4.1. Establishment of Northeast Seed Network: Developing Capacity of Local Seed Production

Most native plant seed production occurs in regions outside of the Northeast supplying ecotypes originating from other regions. Although the production of Northeast ecotypic seeds lags behind other regions, efforts have recently been initiated in the region to accelerate and increase the production of Northeast ecotypic plant materials by encouraging collaboration among stakeholders working with native plants. The timeline of this development is outlined below.

Table 4.1. Northeast Seed Network major milestones.

Month/Year	Milestone
March 2022	Virtual roundtables with opinion leaders and stakeholders provided useful feedback
October 2022	A follow-up in-person meeting at Highstead Arboretum in West Reading, CT
November 2022	Need for Seed Symposium organized by Native Plant Trust
March 2023	The formation of the NSN was announced at The Native Seed Conference. The website was launched.
2023-2024	NSN developed a five-year vision of values, priorities, and goals, and formed committees.
Spring 2024	NSN Map was launched.

Roundtables with stakeholders. Two virtual roundtables, which took place in March 2022, were organized by Eve Allen, an MIT graduate student, who studied ecotypic seed production for the Northeast using information from supply chain management and social network analysis (Allen, 2022), with the assistance of John Campanelli. Stakeholders, including seed and plant producers, conservationists, landscape architects, academics, and end-users, were invited to express their views on the importance of an ecotypic plant material supply chain in the region.

Future actions suggested strengthening collaboration among stakeholders, increasing the availability of native plants, and supporting restoration efforts across the Northeast. They included the assemblage of the Target Species Lists for production, creation of an online Regional Needs Directory to record demand for native plant materials, and the development of a comprehensive Regional Strategy Plan to strengthen the native plant supply chain.

Initial meeting to discuss the production of ecotypic seed for the Northeast. An in-person meeting was held October 3, 2022 at Highstead Arboretum in West Reading, CT. The purpose was to bring together stakeholders from various sectors discussing strategic planning for strengthening native plant material supply chains in the Northeast, to address gaps and barriers in the supply chain in the short-term (6-12 months) and mid-term (12-36 months), and to define the structure of the network.

A virtual symposium "Need for Seed: A Strategy for the Northeast". Native Plant Trust brought stakeholders together to catalyze a regionwide initiative. This can be view online: (https://www.youtube.com/playlist?list=PLAEgMlkLFzuErcZCFbvuI3ow-kIGP-hQJ). The Northeast Seed Network was formed, and its vision was outlined as: "Building a network of trusted partnerships across all the key seed and plant material supply chain steps to increase the accessibility of genetically diverse, source-identified wild seed and plants for the ecoregions of the northeastern US".

Formation of the NSN. During a symposium titled **"Emerging efforts in the US Northeast to address native seed and plant material needs"** conducted at the Native Seed Conference in Alexandria, VA, March 26-30, 2023, **the NSN was introduced to national and international stakeholders.** The unique land ownership patterns and demand needs of the Northeast, which require distinctive strategies to strengthen supply chains as well as the NSN alignment with the national seed strategy, were discussed, along with other topics.
More detailed descriptions of the NSN milestones can be accessed using the following hyperlink if using this manual online: Ecotypic Seed Production in the Northeast region.docx
If using a hard copy of this manual, access the detailed descriptions using the QR code below.

Website. Following the symposium at the Native Seed Conference, the website of the NSN was launched, and hosted by the Native Plant Trust (https://www.nativeplanttrust.org/northeast-seed-network/).

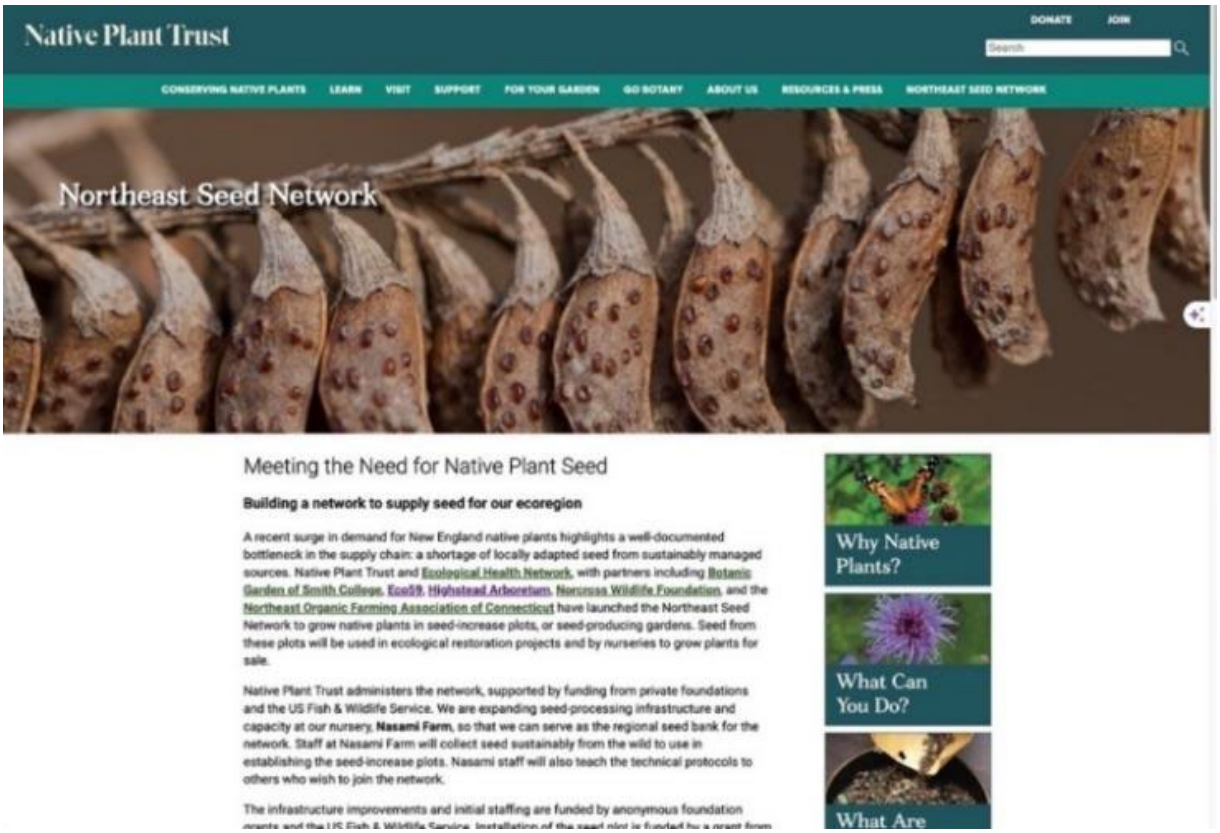


Figure 4.1. NSN main webpage

In subsequent meetings, NSN developed a five-year vision of values, priorities, and goals, and formed committees to promote various aspects of its work and develop supply chain-related policies and actions.

Current NSN committees:

Steering Committee provides network governance and defines the mission, vision, and strategic plan for the NSN.

Species Selection Committee develops a list of priority species suitable for production of in the region, including an initial list of target taxa.

The Market Research Committee surveys native material buyers to determine market demand. *End-User or Market Research Committee* analyzes market demand and supports the development of outreach and educational programs.

Scientific Research Committee promotes and facilitates scientific research with a focus on seed sourcing, climate change, species diversity, and production techniques.

Standards, Protocols, and Definitions Committee develops standards for seed collecting, germination tests, and seed labeling.

Committees in Development (as of June 2024)

Data & Documentation Committee develops systems for collecting, storing, and sharing data.

Education & Training Committee provides education and training on seed collecting, cleaning, storage, and production.

Marketing & Branding Committee develops strategies for marketing and advertising network products and functions.

The NSN conducts comprehensive outreach to expand the network, foster collaboration, and support various restoration projects.

4.2. NSN Map: Locating Ecotypic Plant Material and NSN Participants

The recently developed NSN Interactive Map allows users to search categories for information related to ecotypic seed production and stakeholders who use native plants. It also presents the spatial distribution of subregional efforts.

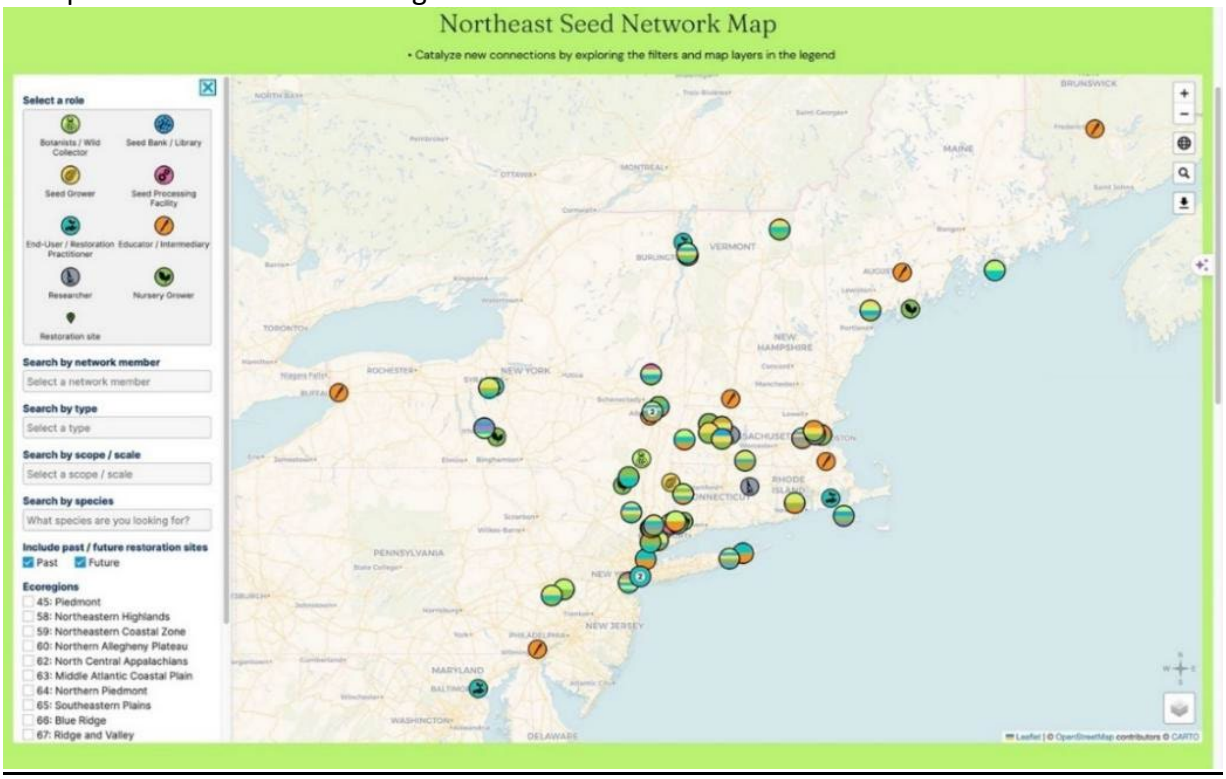


Figure 4.2. The Northeast Seed Network Map is hosted at the CT Northeast Organic Seed Network Ecotype Project website (https://www.ecotypeproject.org/networkmap; accessed June 22, 2024).

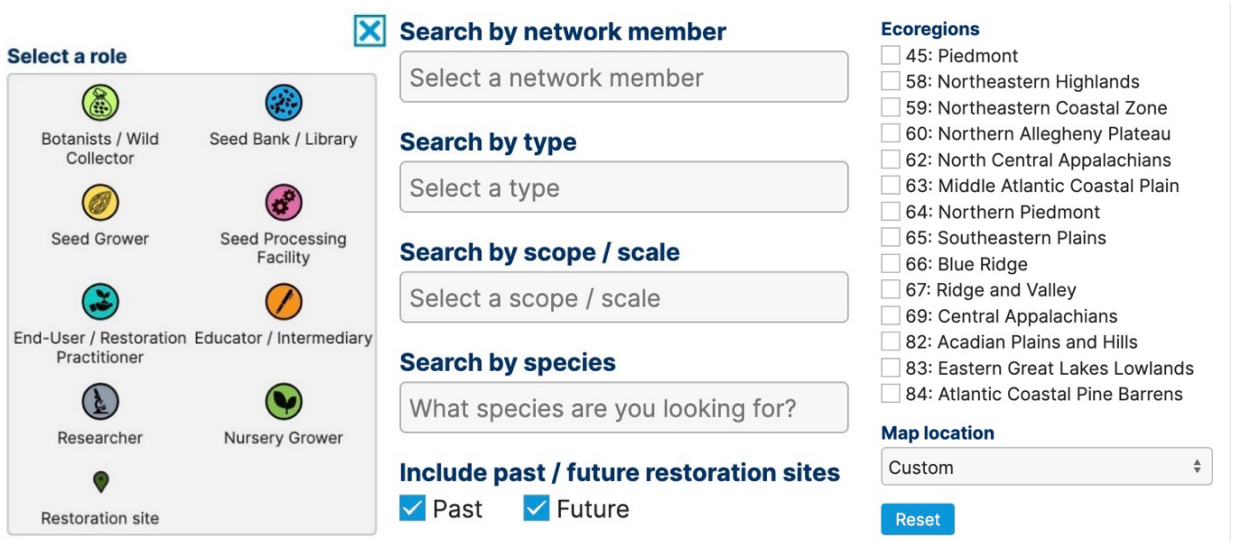


Figure 4.3. Close-up of various categories and layers in the map.

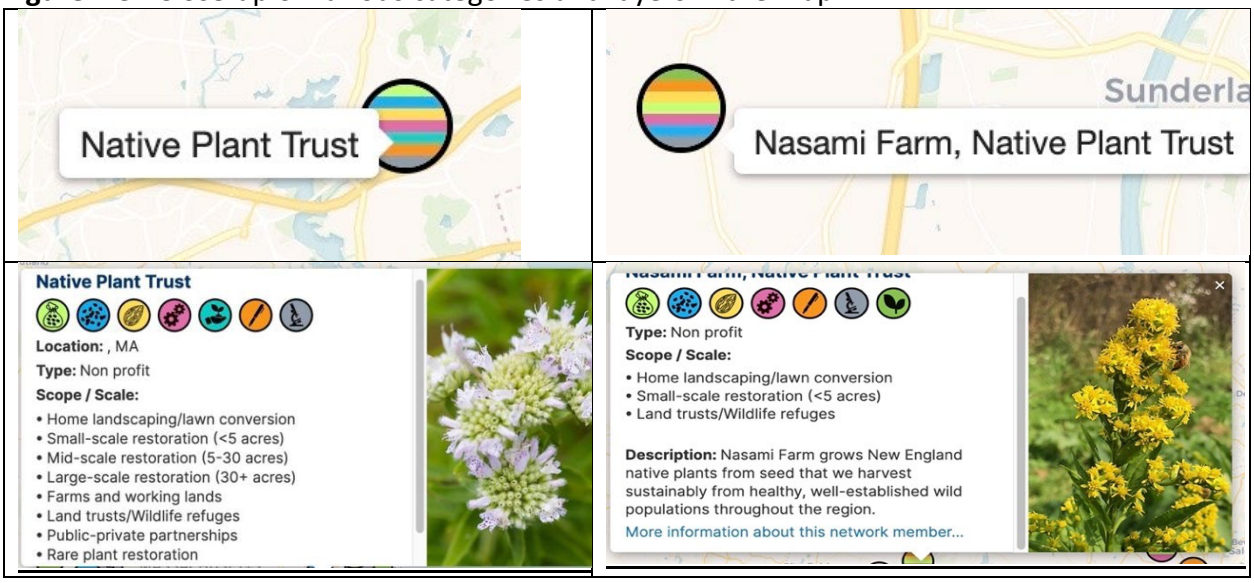


Figure 4.4. Some NSN participants belong to several categories and each category is represented by a different color stripe. For example, the Native Plant Trust and its affiliated nursery, Nasami Farm, belong to various categories.

Figure 4.5. Examples of drop-down menus for various searches.

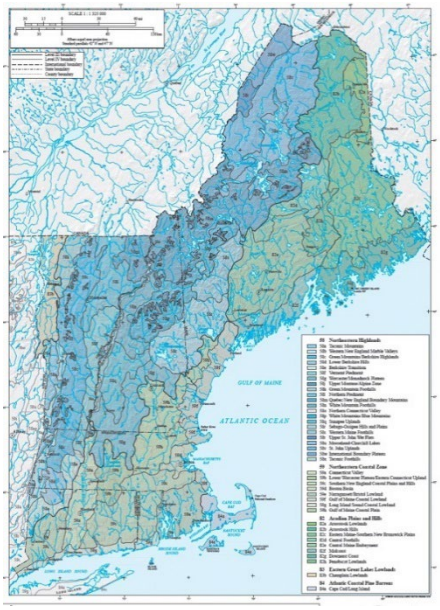
4.3. Seed Zones in the Northeast

A **seed zone** is defined as an area where plant materials can be transferred with little risk of being poorly adapted to their new location. Seed transfer guidelines define where seed from a particular location should be planted (Pike et al. 2020).

Using locally adapted, genetically appropriate seed is an important consideration when planning any restoration project. Nonlocal plant material may decrease the success of restoration efforts if the material is maladapted, potentially negatively impacting adjacent native populations adapted to local climatic conditions through gene flow.

Ideally, **empirical seed zones** should be developed for each species. Empirical seed zones take into consideration species traits such as morphology, phenology, and reproduction combined with climatic variables. Determining these species-specific empirical seed zones usually requires the planting of common garden experiments in several distant locales to determine the ability of that specific species to adapt to the common garden's local climatic conditions. Such mapping of empirical seed zones has mostly happened for species important to the western United States because of extensive support from the Bureau of Land Management. It is unrealistic to establish empirical seed zones for native species in New England. Instead, the more practical approach involves the creation of **provisional seed zones**, which take into consideration two climatic factors: minimum winter temperatures and aridity. Provisional seed are taken into consideration the ecoregions designated by the Environmental Protection Agency.

Figure 4.6. Level III and IV E.P.A. Ecoregions of New England



One of the important tasks of the NSN is to define the Northeast Seed Zones, i.e. how the seed should be transferred within the region. the NSN has initiated regional discussions achieve consensus regarding the seed transfer. Currently, NSN members are collaborating with the University of Massachusetts Spatial Ecology Lab to determine seed transfer zones for the Northeast region (this project is funded by the U.S. Geological Survey Climate Adaptation Science Center). The seed zones being developed by the NSN will be provisionally structured. NSN members expect to initially determine seed zones within 2-3 years. Any guidelines for the empirical seed transfer zone are projected to begin development in 3-5 years if funding can be secured.

4.4. Ecotypic Plant Producers in The Northeast Region

The following profiles of organizations that sell ecotypic plants in the region are presented below. The plant materials are produced as the following:

Herbaceous seed
Herbaceous plugs and containers
Woody plants/containers

It should be noted that the NSN recommends to use protocols provided by the Seeds of Success (SOS) developed for the Bureau of Land Management (https://www.fs.usda.gov/research/treesearch/59993). However, until these protocols are standardized, many of the organizations selling ecotypic material do not provide documentation of their provenance. Some organizations are reluctant to share provenance for fear of other growers returning to and improperly collecting seed from the original site in the wild.

Earth Tones Native Plants
212 Grassy Hill Road, Woodbury, CT 06798 - https://www.earthtonesnatives.com/
Woody plants/containers, Herbaceous plugs and containers
Founded in 2005, Earth Tones Native Plants sources ecotypic plants from the wild within 90 miles of their nursery.

Ernst Conservation Seed
8884 Mercer Pike Meadville, PA 16335 - https://www.ernstseed.com/
Herbaceous seed
Founded in 1964, Ernst Conservation Seed sells mostly ecotypic seed for regions far from New England. However, there are some seeds ecotypic to New England. The following are two lists of species ecotypes that should be prioritized for use in seed mixes in the region.

New England Ecotypes:

- roundhead lespedeza (*Lespedeza capitata*), RI Ecotype
- purple lovegrass (*Eragrostis spectabilis*), RI Ecotype
- little bluestem (*Schizachyrium scoparium*), CT Ecotype
- black-eyed Susan (*Rudbeckia hirta*), VT Ecotype

- Indiangrass (*Sorghastrum nutans*), New England 2 Ecotype

New York and New Jersey Ecotypes

- New York aster (*Symphyotrichum novi-belgii*), Albany Pine Bush-NY Ecotype
- little bluestem **(***Schizachyrium scoparium*), Albany Pine Bush-NY Ecotype
- Virginia wildrye (*Elymus virginicus*), Madison-NY Ecotype
- Indiangrass (*Sorghastrum nutans*), NY4 Ecotype, Long Island-NY Ecotype
- big bluestem (*Andropogon gerardii*), Long Island-NY Ecotype
- switchgrass (*Panicum virgatum*), Long Island-NY Ecotype
- smooth blue aster (*Symphyotrichum laeve*), NY Ecotype
- swamp milkweed (*Asclepias incarnata*), NJ Ecotype
- common sneezeweed (*Helenium autumnale*), NJ Ecotype

Hilltop Hanover
1271 Hanover Street, Yorktown Heights, NY 10598 - https://hilltophanoverfarm.org/programs/native-plants/
Herbaceous plugs and containers
Hilltop Hanover sell plugs of forbs and grasses from seeds mostly sourced from the Northeast Seed Collective.

Long Island Native Plant Initiative
St Joseph's Convent, 1725 Brentwood Rd, Brentwood, NY 11717 - https://www.linpi.org/
Woody plants/containers, Herbaceous plugs and containers
Established in 2011, the Long Island Native Plant Initiative produces ecotypic plant material from Long Island, NY. This material is suitable for planting in the southern coastline of New England and Cape Cod.

Nasami Farm (affiliated with the Native Plant Trust)
128 North St, Whately, MA 01093 https://www.nativeplanttrust.org/for-your-garden/nasami-farm/
Herbaceous seed, Herbaceous plugs and containers, Woody plants/containers,
Nasami Farm has grown plant material from ecotypic seeds for years and currently is increasing its production. Nasami Farm is expanding seed-processing infrastructure and capacity.

New England Wetland Plants
14 Pearl Lane, South Hadley, MA 01075 - https://newp.com/
Woody plants/containers, Herbaceous plugs and containers
Opened 1997, New England Wetland Plants produces some ecotypic plant material collected in the wild from New England states.

Pinelands Nursery
323 Island Rd, Columbus, NJ 08022 - https://www.pinelandsnursery.com/
Herbaceous seed, Herbaceous plugs and containers, Woody plants/containers

Pinelands Nursery has grown native plant material since 1983. Located in Columbus, NJ, Pinelands Nursery ecotypic seed is sourced predominantly from the most southern portion of the Ecoregion 84.

Planters' Choice Nursery
140 Huntingtown Rd, Newtown, CT 06470 and 1201 Bunker Hill Rd, Watertown, CT 06795 - https://planterschoice.com/
Herbaceous plugs and containers
Planters' Choice Nursery sells plugs of forbs and grasses from seeds mostly sourced from the Northeast Seed Collective.

The Northeast Seed Collective
36 Lounsbury Rd, Ridgefield, CT 06877 - https://www.northeastseedcollective.com/
Herbaceous seed, Herbaceous plants
The Northeast Seed Collective (formerly Eco59/Eco84) was founded in 2019 and operates at The Hickories, an organic farm in Ridgefield, CT. The Northeast Seed Collective is a farmer collective devoted to growing ecotypic seed collected from U.S. EPA Northeast Ecoregions 59 and 84. The Northeast Seed Collective has the largest amount of ecotypic seed collected and grown in the New England region.

Vermont Wetland Plant Supply
29 Old Foundry Rd, Orwell, VT 05760 https://www.vermontwetlandplants.com/
Woody plants/containers, Herbaceous plugs and containers
Vermont Wetland Plant Supply sells herbaceous and woody plants sourced from wild populations within VT. The seed is not sourced from VT.

Wild Seed Project
21 Memorial Highway, Suite A, North Yarmouth, Maine 04097 - https://wildseedproject.net/
Herbaceous seed
While the Wild Seed Project has grown ecotypic seeds since 2014, its seeds are hand-cleaned by volunteers using seed sieves. The seed is sold in small packets for residential use.

4.5. Lists of Plant Material Currently Available in the Northeast region

Table 4-1. The current availability of Northeast ecotypic plant material was summarized in May 2024. The Ernst ecotypes with **bold** fonts indicate that these ecotypes are either from New England states or share ecoregions with New England. Species in pale salmon-shaded cells benefit specialist pollinators.

Botanical Name	Common Name	NSC Ecoregions	NSC Amount available (oz) 5/24	Pinelands Nursery ecotype	Pinelands Nursery (price/lb) 4/24	Ernst Seed ecotypes	Ernst Seed (price/lb) 4/24	Prairie Moon (price/lb) 6/24
Achillea millefolium	common yarrow	59	16	unknown	$101	unknown	$48	-
Andropogon gerardii	big bluestem	59	0	NY	$16	**NYA/NYLI**	$14.40	$15
Anemone virginiana	tall windflower	-	-	-	-	PA	$ 235.20	$640
Apocynum cannabinum	hemp dogbane	-	-	-	-	PA	$192	$1280
Aquilegia canadensis	columbine	59	16	NJ	$457	unknown	$384	$375
Asclepias exaltata	poke milkweed	-	-	-	-	-	-	-
Asclepias incarnata	swamp milkweed	59/84	6(32)	NJ	$118	**NJ** / PA	$177.60	$120
Asclepias syriaca	common milkweed	59	0	NJ	$160	PA	$96	$90
Asclepias tuberosa	butterfly milkweed	59	26	unknown	$289	PA	$312	$300
Avena sativa	oats, cover crop	-	-	-	-	-	$0.49	$4
Baptisia tinctoria	yellow wild indigo	84	16	NJ	$417	PA	$720	$450
Carex lurida	sallow sedge	-	-	NJ	$99	PA	$67.20	$240
Carex scoparia	pointed broom sedge	-	-	-	-	PA	$81.60	$320
Carex vulpinoidea	common fox sedge	-	-	NJ	$66	PA	$28.80	$120
Chamaecrista fasciculata	partridge pea	-	-	PA	$10	PA	$12	-
Chamerion angustifolium	narrow-leaved fireweed	-	-	-	-	-	-	-
Chelone glabra	pink turtlehead	-	-	-	-	-	-	$1120
Cirsium discolor	field thistle	-	-	-	-	-	-	$600
Cirsium muticum	swamp thistle	-	-	-	-	-	-	$640
Danthonia spicata	poverty oatgrass	-	-	-	-	-	-	-
Desmodium canadense	showy tick-trefoil	-	-	PA	$48	PA	$48	$120
Desmodium paniculatum	panicled tick-trefoil	-	-	-	-	PA	$48	-
Dichanthelium clandestinum	deer-tongue rosette-panicgrass	-	-	unknown	$29	unknown	$24	-
Elymus virginicus	Virginia wildrye	-	-	PA	$10	**NY** / PA	$10.80	$12
Eragrostis spectabilis	purple lovegrass	RI/59 /84	0(32)	NJ	$447	**RI** / PA	$192	$450

Botanical Name	Common Name	NSC Ecoregions	NSC Amount available (oz) 5/24	Pinelands Nursery ecotype	Pinelands Nursery (price/lb) 4/24	Ernst Seed ecotypes	Ernst Seed (price/lb) 4/24	Prairie Moon (price/lb) 6/24
Eupatorium perfoliatum	boneset thoroughwort	-	-	PA	$350	PA	$192	$525
Eurybia divaricata	white wood-aster	59	16	unknown	$329	PA	$432	-
Euthamia graminifolia	flat-top goldentop	84	32	-	-	PA	$504	$1135
Eutrochium dubium	coastal plain Joe-Pye weed	59	36	NJ	$282	-	-	-
Eutrochium fistulosum	hollow Joe-Pye weed	-	-	unknown	$332	PA	$273.60	$400
Eutrochium maculatum	spotted Joe-Pye weed	-	-	-	-	unknown	$288	$400
Eutrochium purpureum	purple Joe-Pye weed	-	-	NJ	$319	-	-	$640
Fragaria virginiana	common strawberry	-	-	-	-	-	-	-
Gentiana clausa	meadow bottle gentian	-	-	-	-	-	-	-
Geranium maculatum	spotted crane's-bill	59	0	-	-	-	-	-
Helenium autumnale	fall sneezeweed	59	0	NJ	$194	NJ / PA	$216	$90
Hypericum majus	Greater Canada St. John's-wort	-	-	-	-	-	-	-
Hypericum punctatum	spotted St. John's-wort	-	-	-	-	PA	$252	-
Impatiens capensis	jewelweed	-	-	-	-	-	-	-
Iris versicolor	slue flag Iris	59	32	-	-	unknown	$240	$416
Juncus effusus	common soft rush	-	-	NJ	$50	unknown	$48	$450
Juncus tenuis	path rush	-	-	-	-	PA	$48	$1280
Lespedeza capitata	round-headed bush-clover	RI	RI	-	-	RI	$115.20	$150
Lilium canadense	Canada lily	-	-	-	-	-	-	-
Lobelia cardinalis	cardinal-flower	59	8	-	-	-	-	$750
*Lobelia siphilitica**	blue lobelia*	59	16	NJ	$322	PA	$384	$450
Lysimachia terrestris	swamp yellow loosestrife	-	-	-	-	-	-	-
Mimulus ringens	monkeyflower	59	8	NJ	$322	PA	$216	$225
Monarda fistulosa	wild bergamot	59	16	NJ	$105	PA	$96	$150

Botanical Name	Common Name	NSC Ecoregions	NSC Amount available (oz) 5/24	Pinelands Nursery ecotype	Pinelands Nursery (price/lb) 4/24	Ernst Seed ecotypes	Ernst Seed (price/lb) 4/24	Prairie Moon (price/lb) 6/24
Oenothera biennis	common evening-primrose	-	-	-	-	unknown	$57.60	$90
Packera aurea	golden groundsel	-	-	-	-	-	-	-
Panicum virgatum	switch panicgrass	59/84	0(16)	unknown	$19	**NYLI / NJ**	$14.40	-
Penstemon digitalis	foxglove beardtongue	59	32	NJ	$154	PA	$168	$90
Penstemon hirsutus	Northeastern beardtongue			NJ	$364	unknown	$480	$400
Pycnanthemum muticum	broad-leaved mountain mint	59	16	-	-	-	-	$1440
Pycnanthemum tenuifolium	narrowleaf mountain mint	59	16	NJ	$187	unknown	$240	$560
Pycnanthemum virginianum	Virginia mountain-mint	59	16	-	-	unknown	$432	$300
Rudbeckia hirta	black-eye Susan	59	16	PA	$290	**VT** /PA	$31.20	$25
Schizachyrium scoparium	little bluestem	59	32	PA	$16	**CT / NY /** PA	$21.60 CT($16.80)	$16
Scirpus cyperinus	common woolsedge, woolgrass	-	-	NJ	$150	PA	$115.20	$125
Scutellaria galericulata	hooded skullcap	-	-	-	-	-	-	-
Scutellaria lateriflora	mad dog skullcap	-	-	-	-	-	-	$480
Secale cereale	cereal rye, cover crop	-	-	-	-	unknown	$0.51	-
Sisyrinchium angustifolium	narrow-leaved blue-eyed-grass	-	-	PA	$173	unknown	$192	-
Solidago bicolor	white goldenrod	59	16	-	-	PA	$240	-
Solidago caesia	blue-stem goldenrod	59	6	-	-	PA	$540	-
Solidago flexicaulis	zig-zag goldenrod	-	-	-	-	-	-	-
Solidago juncea	early goldenrod	**-**	**-**	**PA**	**$606**	**PA**	**$336**	**$149**
Solidago nemoralis	gray goldenrod	**-**	**-**	**NJ**	**$529**	**PA**	**$264**	**-**
Solidago patula	rough-leaved goldenrod	**59**	**16**	**-**	**-**	**PA**	**$432**	**-**
Solidago puberula	downy goldenrod	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Botanical Name	**Common Name**	**NSC Ecoregions**	**NSC Amount available (oz) 5/24**	**Pinelands Nursery ecotype**	**Pinelands Nursery (price/lb) 4/24**	**Ernst Seed ecotypes**	**Ernst Seed (price/lb) 4/24**	**Prairie Moon (price/lb) 6/24**
Solidago rugosa	common wrinkle-leaved goldenrod	-	-	-	-	**PA**	**$264**	-
Solidago sempervirens	seaside goldenrod	59/84	16(32)	-	-	-	-	--
Solidago speciosa	showy goldenrod	59/84	16(32)	-	-	unknown	$264	$375
Sorghastrum nutans	Indian grass	59/84	32(32)	NJ	$31	**NE/NYLI**	$16.80	$16
Symphyotrichum cordifolium	heart-leaved American-aster	59	16	-	-	-	-	-
Symphyotrichum lateriflorum	calico American-aster	59	0	-	-	unknown	$336	$600
Symphyotrichm laeve	smooth blue aster	59	16	PA	$307	**NY**	$336	$180
Symphyotrichum novae-angliae	New England Aster	59	16	PA	$304	PA	$360	$375
Symphyotrichum novi-belgii	New York American-aster	-	-	NJ	$312	**NYA/NYLI**	$432	$800
Thalictrum pubescens	tall meadow-rue	59	16	-	-	-	-	-
Tridens flavus	purpletop tridens	-	-	unknown	$37	PA	$43.20	$45
Verbena hastata	blue vervain	59/84	16(32)	NJ	$86	PA	$38.40	$90
Vernonia noveboracensis	New York Ironweed	59	32	NJ	$242	PA	$264	$320
Viola sororia	woolly blue violet	-	-	-	-	-	-	-
Zizia aurea	golden Alexanders	59	16	PA	$104	PA	$72	$90

Chapter 5: Conclusions and Next Steps

Recommendation 1. Approach Plantings and Conservation Mowing in a Systematic Way

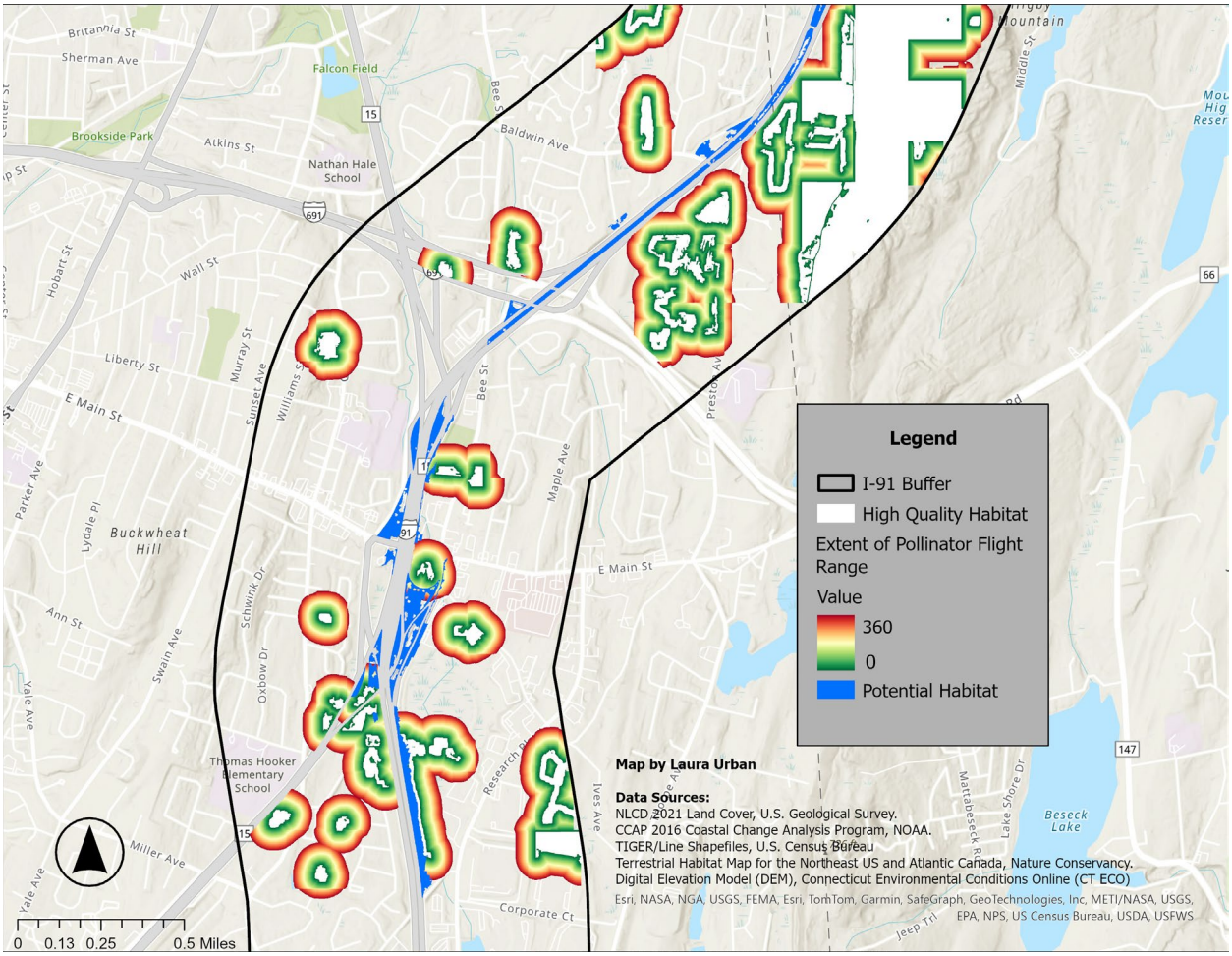
To maximize the impact of native plant communities, plantings should be done in a systematic way that incorporates and coordinates with conservation mowing zones to provide pollinators continuous stretches of habitat and foraging opportunities.

Roadsides provide foraging habitats, breeding, and nesting sites, and function as corridors connecting fragmented habitats This connectivity benefits migratory wildlife like monarchs and various bird species, promoting gene flow and enhancing resilience against challenges such as climate change. Enhancement of pollinator habitats along roadsides can be developed through adopting reduced mowing practices. Review of 44 DOT state mowing manuals demonstrated the effectiveness of these methods. When mowing is limited, particularly during peak flowering seasons, a marked increase in flower production and pollinator densities occur. Beyond attracting pollinators, limited mowing also results in reduced pollinator mortality rates. When roadsides are less frequently disturbed, habitats remain stable, allowing pollinators to thrive.

Coordinating reduced mowing strategies with seeding of native plants along roadsides magnifies the impact of the new plantings. While roadsides already provide substantial habitats for pollinators, native plants can amplify their efficacy, hosting 35% more bee species compared to other habitats (Hopwood et al., 2023). Since reduced mowing also saves money, it is an affordable method to benefit roadside ecosystems along which DOTs will start establishing native plant communities. The creation of ecological corridors, when patches of planted habitat are connected by native plant communities that arise from seed banks unleashed by conservation mowing, promotes the preservation of essential native plant species.

Even before DOTs seed and establish native plant communities, DOTs can create corridors of continuous habitats by using GIS maps created by Laura Urban, a Plant Science Master's student whose research project involves expanding the benefits of habitats along roadsides. Maps for the New England region are still being developed. However, once Laura has completed mapping, she can share them with each state DOT, and they can target their Conservation mowing regimes.

The following is an example of a GIS map created by Laura:



The model identifies areas ideal for reduced mowing or native revegetation, focusing on their proximity to existing high-quality pollinator habitats. This map shows the model applied to a section of Interstate 91 in Middlefield, CT.

The bold black line represents a half-mile buffer from the highway, defining the analysis area. The white areas within the buffer highlight existing High-Quality Pollinator Habitats that provide both forage and nesting opportunities for pollinators and are more than half an acre in size.

Next, the green to red color gradient represents the flight range of target pollinators, in this case native solitary bees with a short 360 foot range. The red areas indicate the maximum

extent of their flight range from nesting sites. These gaps pinpoint where habitat connectivity could be improved.

Lastly, the model identifies roadsides suitable for reduced mowing or revegetation, shown in blue, based on their existing vegetation type and ensuring they are over 60 feet wide, as required by the DOT. By integrating state parcel ownership data, the model ensures that these recommendations are actionable, focusing only on roadsides managed by state or local agencies.

The final goal is to provide roadside management agencies with a GIS tool they can use to input any target road from any Northeastern state and the buffer radius, along with the pollinator flight range, to identify key areas for habitat enhancement. This way, efforts in roadside management can be both efficient and ecologically meaningful.

Recommendation 2: Take small, realistic steps to use available ecotypic seed and plant material.

In accordance with Public Act 16-17, *An Act Concerning Pollinator Health***,** the CT DOT implemented a Pollinator Program in 2017 to establish pollinator corridors in selected locations within the highway system. The CT DOT's model to meet the needs of pollinators can be used by other DOTs to transition to roadside revegetation using native plants.

One of the ways CT DOT met the goals of Public Act 16-17 was to plant Pollinator Areas at rest stops:

Figure 5.1. Cultivated replacement plot, Danbury, CT Rest Area (right), Pollinator Area signage (left) (photo: CT DOT)

Nurseries that grow ecotypic potted plants can be found using the Northeast Seed Network that can be found in section 4.2 of this document. Such Pollinator Areas can also be established using ecotypic seed available, as shown in section 4.5.

Recommendation 3: Establish Communication between DOTs and Ecotypic Seed Producers

During the 2022 roundtables with stakeholders who produce or work with native plants and seeds, the producers shared they have not expanded their production to levels required by the size of DOT projects because they do not know which species will be needed. Therefore, they are unwilling to invest the money to increase the amount of ecotypic seed that the market will demand to produce enough native for DOT projects.

With the development of the Northeast Seed Network, the DOT has a channel for collaborating with producers of ecotypic seed. It will be important for DOTs to realistically estimate the timetable by which their agencies will grow the number and sizes of projects in which they will revegetate roadsides using native seed mixes. Since the NSN Steering Committee has been focusing on developing better relationships with state government agencies that use native seed, including DOTs, DEEPs, and Fish & Wildlife Services, any overtures to open lines of communication will be welcomed.

Recommendation 4: Establish more effective communication between DOT departments, especially with the Maintenance Dept.

Technical Committee meetings for the grant that funded this research illustrated that departments within DOTs do not communicate well with each other regarding effective implementation of protocols for increasing roadside native plant communities. One of the most cost effective ways to increase such communities is for Maintenance programs to increase their use of Conservation Mowing. However, Landscape Designers, who seem to value the importance of changing to such practices, express frustration that Maintenance Departments are not implementing such practices. The only way for such efforts to be coordinated and implements is for better lines of communication to be established among departments. Establishment of such lines of communication can only happen through internal efforts.

Recommendation 5: Designate a Native Plant Specialist to Oversee the Implementation of New Practices

The Iowa DOT was a pioneer in revegetating roadsides using native plants. Each county in Iowa has a native plant specialist who oversees roadside native plant revegetation efforts. Considering the budgetary constraints most DOTs face, it is unrealistic to expect that New England DOTs would hire such specialists at a similar scale. However, designating a person who works on roadside revegetation efforts to oversee projects that involve native plants would be helpful to ensure any money and effort expended is done so effectively.

Revegetating roadsides with native plants is more complicated and more expensive initially than it is with turfgrass. Revegetation efforts that fail or fall short not only cost DOTs ever-shrinking funding but also set back efforts to revegetate roadsides using native plants. Such specialists can oversee design work, subcontractor seeding efforts, and maintenance conservation mowing efforts.

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Appendix 1

Criteria for species selection

Below are the detailed explanations of the criteria that clarify **what makes a plant an appropriate choice for the roadside.**

Criterion 1. ***Include only species native to the region and exclude the introduction of plant species from outside their known historical ranges.***

How to determine the nativity of plant species within the New England ecoregions? Defining what makes a plant species native to a specific region is the vital first step toward species selection. While in-depth discussions about what makes a species native to a region go back a long way, the most common definition of a native species describes it as a plant that was present before European settlement occurred (Richardson & Jaffe 2018), or prior to significant human impacts.

The definition of a "region" is changing as the concept of nativity is evolving from a very broad approach (such as native to a continent) to a very specific approach (such as native to a particular state or county). Historically, the Native Plant Trust focused on plants native to North America, then on plants native to New England, with the latest recommendations to use the ecoregion approach as many ranges of plants match the ecoregion's boundaries (Richardson & Jaffe 2018).

The ecoregions represent areas with similar ecosystems. The ecoregion approach for species selection was recommended by the Federal Highway Administration (FHWA 2023). Finding reliable references to identify regionally appropriate native species is another important step toward native species selection. There is some disagreement among nation-wide databases, such as the Native Plants of North America (Lady Bird Johnson Wild Flower Center), the Biota of North America Program (BONAP), USDA Plant Database or Federal Highway Administration (FHWA 2019), and various regional sources. The issue then becomes: if someone wants to use the national references as a starting point for finding native species in an ecoregion, the accuracy of the listings should be cross-referenced using regional botanical sources. Regional botanical organizations have done extensive research to understand which plants are native to particular areas within regions, and the regional databases and local floras contain the most current sources of information as they are based on accurate botanical records of species presence. The best resource for the six New England states includes the "Go Botany" website maintained by the Native Plant Trust. In addition to "Go Botany," other New England regional and state-wide treatments (Cullina et al. 2011; Haines 2011, Angelo & Boufford 2014; Dreyer et al. 2014; Gilman 2015) provide accurate information about a species' presence in each state of the region.

It is better not to rely on existing recommendations of native plants for the region as it is always better to develop lists based on the above-mentioned dependable sources. Inaccurate

information regarding a species' natural distribution often stems from an incorrect generalization that a species is native to a large region and even to the entire continent. Some lists of recommended species for New England contain North American native species, which are not native to New England, although they may be naturalized, which means spreading non-invasively in the wild after being introduced from elsewhere. For example, *Baptisia australis* (blue wild indigo), *Echinacea purpurea* (Eastern purple coneflower) and *Liatris spicata* (sessile-headed blazing star) which are often marketed as generically native (meaning they are American natives). They are included in some planting guides for New England but are not considered native to this region based on the data used by *Go Botany*. These species are mistakenly indicated as native for parts of New England by the *USDA PLANTS Database* (USDA 2023).

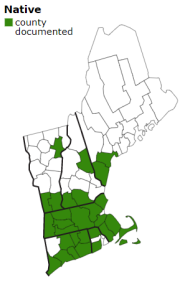
Criterion 2. ***Exclude species of conservation concern ("rare," "threatened," and "endangered" designations) for large scale plantings.***

Following the recommendations of botanists from the Native Plant Trust, we have excluded species of conservation concern, including "rare," "threatened," "endangered," "uncommon," and "special concern" designations, from the seed planting mixes because of potential problems for native plant conservation. It is best to leave rare species alone in their known wild populations to prevent any confusion with the conservation status and origin of the plants. *Go Botany* uses the following categories levels to identify the for state-level conservation status:
H (not seen for several years)
E (endangered)
T (threatened)
S1 (extremely rare)
S2 (rare)
S3 (uncommon)
S4 (fairly spread)
S5 (widespread)

Only species with the conservation status S4 (fairly spread) and S5 (widespread) according to *Go Botany* were included into the mixes.

The conservation status of each species to be included into the roadside planting should be verified by consulting botanists, the "Go Botany" website, and the most recent state conservation lists generated by the Natural Heritage programs or its equivalents. They include the NatureServe Explorer site (https://explorer.natureserve.org/Search), Connecticut Endangered, Threatened and Special Concern Species List (2015), Maine Natural Areas Program Rare, Threatened, and Endangered Plant Taxa (2015), List of Endangered, Threatened, and Special Concern Plant Species in Massachusetts (2019), Rare Plant List for New Hampshire (2018), Rhode Island Rare Plants (2016), and Endangered and Threatened Plants of Vermont (2015).

For example, *Asclepias tuberosa* (butterfly milkweed), an important species for Monarch butterfly conservation, is limited in mixes from all but Connecticut, Massachusetts, and New Hampshire because it appears to be in decline in half of New England states, according to *Go Botany* and *Nature Serve Explorer* (Figure 5 and 6).



Conservation status

Exact status definitions can vary from state to state. For details, please check with your state.

Maine	extirpated (S-rank: SX), potentially extirpated (code: PE)
Rhode Island	rare (S-rank: S2), concern (code: C)
Vermont	historical (S-rank: SH), threatened (code: T)
ssp. tuberosa	
Massachusetts	fairly widespread (S-rank: S4)
New Hampshire	extremely rare (S-rank: S1), endangered (code: E)

Figure 1. The New England distributions map and the conservation status of *Asclepias tuberosa* (butterfly milkweed) according to *Go Botany*.

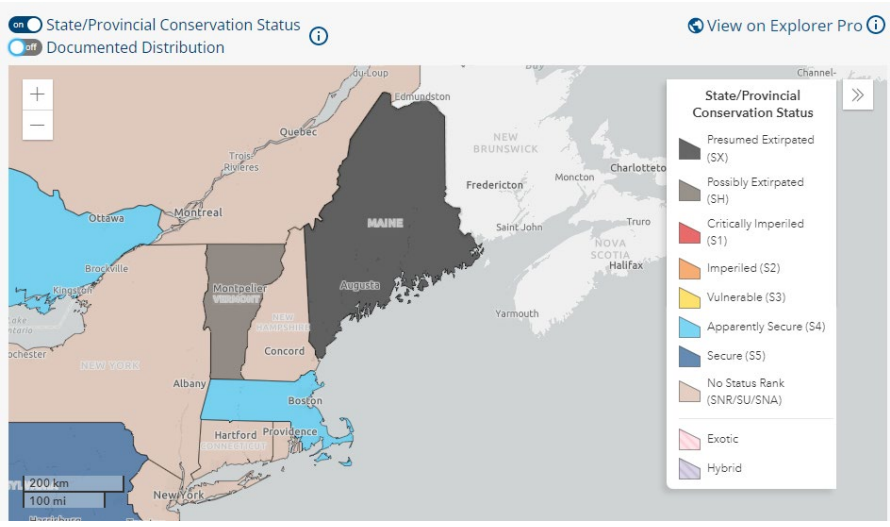


Figure 2. The conservation status of *Asclepias tuberosa* (butterfly milkweed) according to *Nature Serve Explorer*. This species is considered to be "presumably extirpated in Maine,

"possibly extirpated" in Vermont, "no status rank" in New Hampshire and Connecticut, and only "apparently secure" in Massachusetts.

Criterion 3. ***Select an appropriate ideotype for roadside plantings.***

The characterization of the required ideotype, or idealized plant, with a clear set of essential attributes and characteristics relevant to roadside plantings is the first step in plant selection. The following conditions should be met as important considerations for roadside plantings when selecting plant species.

a. Satisfy the DOT requirements of driver, vehicle, and pedestrian safety.

Selected plants should satisfy the main safety-related goals of roadside vegetation (Eck & McGee 2008): maintaining visibility of signs and road users – vehicles, bicycles, pedestrians; improved visibility of wildlife and livestock near roads; eliminating trees growing close to roadways to prevent severe crashes when vehicles need to leave the paved portion of roads; minimizing wildlife related accidents by excluding plant species commonly browsed by wildlife; and improving winter maintenance involving snow drift and ice formation. For maintaining visibility, only plants of short or moderate stature were selected to allow for sight lines and suitable for full sun or partial shade. Grasses should be included to provide stable cover for reducing erosion, minimizing weeds, and promoting successful forb establishment. Cover crops will be included to provide immediate resources for pollinators, decrease erosion, and block weeds during the establishment period for the longer-lived perennials.

b. Provide ecosystem services.

Roadside rights-of-way provide regulating and cultural ecosystem services, which include establishment of vegetation cover for erosion control, flood protection, minimization of snow drift, air and water purification, carbon sequestration, and control of noxious weeds. Native grasses have deep, fibrous root systems, which provide effective long-term erosion control and soil stabilization. Their root systems extend deep into the soil, enabling them to obtain access to essential soil moisture and tolerate drought. Native grasses also address the threat of climate change as they require less frequent mowing, resulting in reduced tractor emissions. Also, labor released from mowing can be directed toward invasive species control.

Criterion 4. ***Prioritize "workhorse species" with the most potential for success in roadside plantings.***

Plant species included in the recommended mixes provide reliable performance defined as "workhorse species" by the Federal Highway Administration (FHWA 2023). The "workhorse species" should be able to establish quickly using minimal agricultural inputs of water and fertilizer in order to stabilize soil in a timely manner and prevent erosion. Plant species suitability for growth along the roadsides with different climatic conditions, various sun exposures, and soil conditions (drainage and nutrients) were also considered. Other important factors include adaptability to low fertility soils, resistance to insect damage and disease, the

ability to sustain themselves without intensive human intervention, long lifespan, and the ability to achieve long term stability and persistence without being aggressive.

Criterion 5. ***Focus on species with high wildlife value.***

The following factors will be considered when selecting species and preparing seed mixes that support various wildlife species including pollinators:

- Sunny bare patches of soil around the base of bunch grasses, such as little bluestem (*Schizachyrium scoparium*) and purple lovegrass (*Eragrostis spectabilis*), provide places for some bumblebee species and other pollinators and insects to nest and lay eggs. Also, some grasses and sedges are larval host plants for butterflies.
- Larval host plants for specific pollinators, such as milkweed for Monarch and other endangered butterflies, should be included.
- Nectar-producing and pollen-rich plants should be prioritized. Pollinator habitats should have a diversity of plants that flower at different times throughout the season, and plants with overlapping bloom times to provide continuous floral resources. For each mix, sequential flowering charts were created for early and late spring, early and late summer, and early and late fall to ensure uninterrupted nectar and pollen sources. The goal is to include at least three species blooming simultaneously during each season, with a variety of flower colors and shapes.
- Cover crops will be included to provide immediate resources for pollinators during the establishment period for the longer-lived perennials.
- In addition, native shrubs may be recommended for areas distant from the road and along woodland edges and back slopes, to encourage populations of wood tunnel–nesting bees and provide additional floral resources especially important in early spring.

Varieties of pollinators include bees, butterflies, moths, birds, beetles, and flies. Most recommended seed mixes include limited number of plant species that would provide resources for a wide range of common species, which are mostly generalist, meaning they have broad diets consuming pollen and nectar from a wider range of flowers and visiting many unrelated plant taxa. However, the populations of many generalist species are stable, and it is important to attract and sustain many threatened pollinator species which may have specialized needs. In fact, recent studies of the northeastern United States bee community found a disproportionate loss of specialist bee species. Thus, it is important to not only provide resources for generalists but also to include plants important for the survival of **specialists and endangered pollinator species**. Specialist species have individualized needs for survival. They include various wild bees, including bumble bees, as well as Monarch and other butterflies.

Criterion 6. ***Include some aesthetically pleasing species.***

Important cultural services of native plant communities include aesthetic appeal that add to the sense of ecoregional identity of roadsides and visual enhancement of transportation corridors. Roadside native plantings should appear pleasing with diverse colors and textures that not only decrease incidents of road rage but also increase driver awareness and reduce driver fatigue

(Fitzpatrick et al. 2014). Desirable traits include multiple seasonal interest, showy flowers, attractive foliage, bright fall coloration, winter silhouettes, and reliable performance throughout the growing season. Every mix will include aesthetically pleasing plants to improve public perception of the plantings, which will look different from the mowed swaths of turfgrass drivers and passengers are used to seeing along roadsides.

Criterion 7. ***Ensure economic feasibility to produce.***

Production of native species is not achieved equally. Some biological characteristics of plants make their production difficult. For example, the Northeast Seed Network decided to exclude recalcitrant species and focus only on species of seed that can be stored. In addition, each species has unique qualities that impacts the cost of their production, including different stratification regimens as well as different planting, harvesting, and cleaning techniques. As a result, the prices of species vary widely. Because roadside revegetation projects are government funded, projects have limited resources. Therefore, it is imperative to select species that are economically feasible within budget constraints.

In summary, to meet these seven criteria, a native plant ideotype should include multiple traits and characteristics, defined as being optimal for roadside plantings. Traits include being a perennial herbaceous plant of short or moderate stature that conforms to the specific size of up to 24" to meet DOT safety concerns; easy to establish under various roadside conditions; suitable for full sun or partial shade; able to survive and grow on highly unfavorable substrates, including dry soils; and has a long-life span and attractive appearance. A plant should have a deep and extensive root system for erosion control and rapid recovery after frequent disturbances if vehicles pull off onto the side of the road. It should have a strong vertical habit, which is important for mowing once a year or even once every other year with persistent aboveground structures in wintertime to minimize snowdrift. An appropriate plant should have low value for animal browse, but high wildlife value for arthropods while providing superior nutrition, breeding and shelter habitats for various pollinators. The general criteria also include being inexpensive and easy to propagate and establish in the field.

Appendix 2

Soil characteristics at the demonstration sites

Soil Test Summaries

Site	pH	Ca lbs/acre	Mg lbs/acre	P lbs/acre	K lbs/acre	Texture	Sand %	Silt %	Clay %	Organic matter %
CT Windsor	6.8	2607	233	6	106	Sandy loam	61	34.6 .	4.4	3.3
MA Holyoke	6.8	2983	413	11	112	Loam	49.2	39.8	11.0	5.1
VT Wheelock /actual construction site	7.7	> 4000	245	3	37	Sandy loam	72.0	25.2	2.	1.6
VT Wheelock /adjacent site	6.6	3254	75	1	108	Sandy loam	63.6	32.6	3.8	4.0
VT Wheelock / Lyndon generate material	7.4	2430	53	1.2	30					2.1

Appendix 3

Seed mixes used at the demonstration sites

CT Spring Grass Seeds

Ernst Conservation Seeds Inc
8884 Mercer Pike
Meadville, PA 16335-9275
Phone (814) 336-2404; (800) 873-3321; Fax (814) 336-5191
www.ernstseed.com; sales@ernstseed.com

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Quote Date 5/26/2023
Page Number 1 of 1

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3 Discovery Dr Unit 608
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Fax 860-486-5803
Email

SHIP TO:

University of Connecticut - Attn. John Campanelli
1376 Storrs Rd Unit 4067
Storrs, CT 06269-4067
UNITED STATES
Phone: 203-596-8004

Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
PH 052623 LS 2	CONN009	UPS GROUND		Credit Card	

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
1.000		EACH	DRY MESIC MX W/OATS		$0.00000	$0.00
0.109	0.105	LB PLS	ELYVIR07	Virginia Wildrye, Madison-NY Ecotype	$9.00000	$0.95
0.001	0.001	LB PLS	ERASPE05	Purple Lovegrass, Fort Indiantown Gap-PA Ecotype	$222.40000	$0.22
0.010	0.009	LB PLS	PANVIR32	Switchgrass, NJ Ecotype	$14.00000	$0.13
0.097	0.082	LB PLS	SCHSCO08	Little Bluestem, Fort Indiantown Gap-PA Ecotype	$14.00000	$1.15
0.014	0.013	LB PLS	TRIFLA01	Purpletop	$36.00000	$0.47
0.938	0.789	LB PLS	AVESAT01	Oats, Variety Not Stated	$0.48276	$0.38
0.000		EA	TOTAL	MIX NOTES	$0.00000	$0.00

$3.47/lb PLS includes 5% Custom Mix Charge
Total = 100%
Seed at 29lbs PLS/ac

Prices quoted are firm for 30 days.

Checks received may be converted to a one-time electronic funds transfer. Funds may be withdrawn from your account on the date payment is made.
Prices are F.O.B. Meadville. Items are subject to availability at time of delivery.
DISCLAIMER: Seeds are labeled as required by State and Federal laws.
RETURNS: Individual items and Ernst Mixes are subject to 10% restocking fee and must be made within 30 days of invoice date. No returns on custom mixes. There is a 25% restocking fee on cancelled or returned bioengineering orders.

Subtotal	$3.30
Trade Discount	$0.00
Shipping/Handling	$0.00
Miscellaneous	$0.17
Tax	$0.00
Total US$	$3.47

CT Fall Forbs Mix

Ernst Conservation Seeds Inc
8884 Mercer Pike
Meadville, PA 16335-9275
Phone (814) 336-2404; (800) 873-3321; Fax (814) 336-5191
www.ernstseed.com; sales@ernstseed.com

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Quote Date	9/27/2023
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ATTN: John M. Campanelli
UNITED STATES
Phone: 203-586-8004

Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
EM 092623 GS1	CONN009	UPS GROUND		Credit Card	

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
0.000		EACH	NORTHEAST UPLAND MES	Northeast Upland Mesic Wildflower Mix	$0.00000	$0.00
0.010	0.009	LB PLS	ACHMIL01	Common Yarrow	$42.31111	$0.38
0.058	0.051	LB PLS	ASCINC01	Swamp Milkweed, PA Ecotype	$169.70667	$8.66
0.026	0.023	LB PLS	ASCSYR02	Common Milkweed	$88.93913	$2.05
0.060	0.037	LB PLS	ASTLAT01	Calico Aster	$450.49730	$16.67
0.051	0.037	LB PLS	ASTNOV01	New England Aster, PA Ecotype	$383.90270	$14.20
0.060	0.037	LB PLS	ASTPIL01	Heath Aster, PA Ecotype	$355.50811	$13.15
0.041	0.037	LB PLS	DESCAN01	Showy Ticktrefoil, PA Ecotype	$43.92432	$1.63
0.043	0.037	LB PLS	DESPAN04	Panicledleaf Ticktrefoil, PA Ecotype	$46.33514	$1.71
0.069	0.037	LB PLS	EUPPER01	Boneset, PA Ecotype	$298.24865	$11.04
0.075	0.070	LB PLS	LESCAP03	Roundhead Lespedeza, RI Ecotype	$102.37714	$7.17
0.029	0.023	LB PLS	MONFIS03	Wild Bergamot, Fort Indiantown Gap-PA Ecotype	$101.80870	$2.34
0.146	0.140	LB PLS	PENDIG01	Tall White Beardtongue, PA Ecotype	$145.51000	$20.37
0.010	0.009	LB PLS	PYCMUT01	Bigleaf Mountainmint, PA Ecotype	$222.66667	$2.00
0.025	0.023	LB PLS	PYCTEN01	Narrowleaf Mountainmint	$151.01739	$3.47
0.010	0.009	LB PLS	PYCVIR01	Virginia Mountainmint, PA Ecotype	$508.80000	$4.58
0.227	0.215	LB PLS	RUDHIR05	Blackeyed Susan, VT Ecotype	$27.43665	$5.90
0.028	0.023	LB PLS	SOLBIC01	White Goldenrod, PA Ecotype	$242.95652	$5.59
0.017	0.009	LB PLS	SOLCAE01	Blue Stem Goldenrod, PA Ecotype	$846.50000	$7.62
0.027	0.023	LB PLS	SOLNEM01	Gray Goldenrod, PA Ecotype	$259.88696	$5.98
0.058	0.037	LB PLS	VERNOV01	New York Ironweed, PA Ecotype	$343.85405	$12.72
0.113	0.107	LB PLS	ZIZAUR01	Golden Alexanders, PA Ecotype	$63.18505	$6.76
0.000		EA	TOTAL	MIX NOTES	$0.00000	$0.00

$161.69 PER PLS LB INCLUDING 5% MIX FEE
TOTAL 100%
SEED AT 2.98 PLS LBS/ACRE

CONTINUED ON NEXT PAGE

CT Fall Forbs Mix

Ernst Conservation Seeds Inc

8884 Mercer Pike
Meadville, PA 16335-9275
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Page Number	2 of 2

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UNITED STATES
Phone: 203-586-8004

Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
EM 092623 GS1	CONN009	UPS GROUND		Credit Card	

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
0.000		EACH	NOTES	**IF SEEDING AN EXISTING GRASS MEADOW, NO COVER CROP IS NEEDED IF NOT, USE ONE OF THE FOLLOWING COVER CROPS AT 30 LBS/ACRE:**	$0.00000	$0.00
0.000		EACH	NOTES	**OATS (1 JAN TO 31 JULY) GRAIN RYE (1 AUG TO 31 DEC)**	$0.00000	$0.00

Prices quoted are firm for 30 days.

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DISCLAIMER: Seeds are labeled as required by State and Federal laws.
RETURNS: Individual items and Ernst Mixes are subject to 10% restocking fee and must be made within 30 days of invoice date. No returns on custom mixes. There is a 25% restocking fee on cancelled or returned bioengineering orders.

Subtotal	$153.99
Trade Discount	$0.00
Shipping/Handling	$0.00
Miscellaneous	$7.70
Tax	$0.00
Total US$	$161.69

MA Fall Seed Mix

Ernst Conservation Seeds Inc
8884 Mercer Pike
Meadville, PA 16335-9275
Phone (814) 336-2404; (800) 873-3321; Fax (814) 336-5191
www.ernstseed.com; sales@ernstseed.com

QUOTE

Quote Number Q282581
Quote Date 9/27/2023
Page Number 1 of 2

BILL TO:

University of Connecticut
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Storrs, CT 06269-6080

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1376 Storrs Rd Unit 4067
Storrs, CT 06269-4067
ATTN: John M. Campanelli
UNITED STATES
Phone: 203-586-8004

Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
EM 092623 GS2	CONN009	UPS GROUND		Credit Card	

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
0.000		EACH	NORTHEAST UPLAND MES	Northeast Upland Mesic Meadow Mix	$0.00000	$0.00
0.002	0.002	LB PLS	ACHMIL01	Common Yarrow	$42.40000	$0.08
0.049	0.046	LB PLS	ANDGER01	Big Bluestem, 'Niagara'	$12.00000	$0.55
0.013	0.011	LB PLS	ASCINC01	Swamp Milkweed, PA Ecotype	$169.66182	$1.87
0.006	0.005	LB PLS	ASCSYR02	Common Milkweed	$88.96000	$0.44
0.013	0.008	LB PLS	ASTLAT01	Calico Aster	$450.45000	$3.60
0.011	0.008	LB PLS	ASTNOV01	New England Aster, PA Ecotype	$383.95000	$3.07
0.013	0.008	LB PLS	ASTPIL01	Heath Aster, PA Ecotype	$355.57500	$2.84
0.009	0.008	LB PLS	DESCAN01	Showy Ticktrefoil, PA Ecotype	$43.95000	$0.35
0.009	0.008	LB PLS	DESPAN04	Panicledleaf Ticktrefoil, PA Ecotype	$46.35000	$0.37
0.322	0.308	LB PLS	ELYVIR07	Virginia Wildrye, Madison-NY Ecotype	$9.00000	$2.77
0.016	0.015	LB PLS	ERASPE06	Purple Lovegrass, RI Ecotype	$174.29333	$2.61
0.015	0.008	LB PLS	EUPPER01	Boneset, PA Ecotype	$298.20000	$2.39
0.016	0.015	LB PLS	LESCAP03	Roundhead Lespedeza, RI Ecotype	$102.40000	$1.54
0.006	0.005	LB PLS	MONFIS03	Wild Bergamot, Fort Indiantown Gap-PA Ecotype	$101.76000	$0.51
0.041	0.038	LB PLS	PANCLA01	Deertongue, Tioga	$20.00000	$0.76
0.053	0.046	LB PLS	PANVIR32	Switchgrass, NJ Ecotype	$14.00000	$0.64
0.031	0.030	LB PLS	PENDIG01	Tall White Beardtongue, PA Ecotype	$145.50667	$4.37
0.002	0.002	LB PLS	PYCMUT01	Bigleaf Mountainmint, PA Ecotype	$223.00000	$0.45
0.005	0.005	LB PLS	PYCTEN01	Narrowleaf Mountainmint	$150.92000	$0.75
0.002	0.002	LB PLS	PYCVIR01	Virginia Mountainmint, PA Ecotype	$508.80000	$1.02
0.049	0.046	LB PLS	RUDHIR05	Blackeyed Susan, VT Ecotype	$27.43565	$1.26
0.335	0.287	LB PLS	SCHSCO08	Little Bluestem, Fort Indiantown Gap-PA Ecotype	$14.00000	$4.02
0.006	0.005	LB PLS	SOLBIC01	White Goldenrod, PA Ecotype	$242.80000	$1.21
0.004	0.002	LB PLS	SOLCAE01	Blue Stem Goldenrod, PA Ecotype	$846.00000	$1.69
0.006	0.005	LB PLS	SOLNEM01	Gray Goldenrod, PA Ecotype	$260.04000	$1.30
0.053	0.046	LB PLS	SORNUT08	Indiangrass, PA Ecotype	$14.00000	$0.64
0.013	0.008	LB PLS	VERNOV01	New York Ironweed, PA Ecotype	$343.75000	$2.75
0.024	0.023	LB PLS	ZIZAUR01	Golden Alexanders, PA Ecotype	$63.18261	$1.45

CONTINUED ON NEXT PAGE

MA Fall Seed Mix

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QUOTE

Quote Number	Q282581
Quote Date	9/27/2023
Page Number	2 of 2

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ATTN: John M. Campanelli
UNITED STATES
Phone: 203-586-8004

Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
EM 092623 GS2	CONN009	UPS GROUND		Credit Card	

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
0.000		EA	TOTAL	MIX NOTES	$0.00000	$0.00
				$47.57 PER PLS LB INCLUDING 5% MIX FEE **TOTAL 100%** **SEED AT 13 PLS LBS/ACRE WITH 30 LBS/ACRE OF A COVER CROP**		
0.000		EACH	NOTES		$0.00000	$0.00
				USE ONE OF THE FOLLOWING COVER CROPS: **GRAIN RYE (1 AUG TO 31 DEC)** **OATS (1 JAN TO 31 JULY)**		

Prices quoted are firm for 30 days.

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DISCLAIMER: Seeds are labeled as required by State and Federal laws.
RETURNS: Individual items and Ernst Mixes are subject to 10% restocking fee and must be made within 30 days of invoice date. No returns on custom mixes. There is a 25% restocking fee on cancelled or returned bioengineering orders.

Subtotal	$45.30
Trade Discount	$0.00
Shipping/Handling	$0.00
Miscellaneous	$2.27
Tax	$0.00
Total US$	$47.57

MA Fall Seed Mix

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ORDER

Order Number	718631
Order Date	9/27/2023
Page Number	1 of 1

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UNITED STATES
Phone: 203-586-8004

Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
CAMPANELLI	CONN009	UPS GROUND		Credit Card	GABBY

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
3.563	3.000	LB PLS	CONN00903	Northeast Upland Mesic Wildflower	$161.69000	$485.07
11.229	10.000	LB PLS	CONN00904	Northeast Upland Mesic Meadow Mix	$47.57000	$475.70
22.500		LB BLK	SECCER01	Rye, Variety Not Stated	$0.43000	$9.68
		Bag: 56.00	Lot: 1368CO385R23	22.500 LB BLK		

Subtotal	$970.45
Trade Discount	$0.00
Shipping/Handling	$26.00
Miscellaneous	$0.00
Tax	$0.00
Total US$	$996.45

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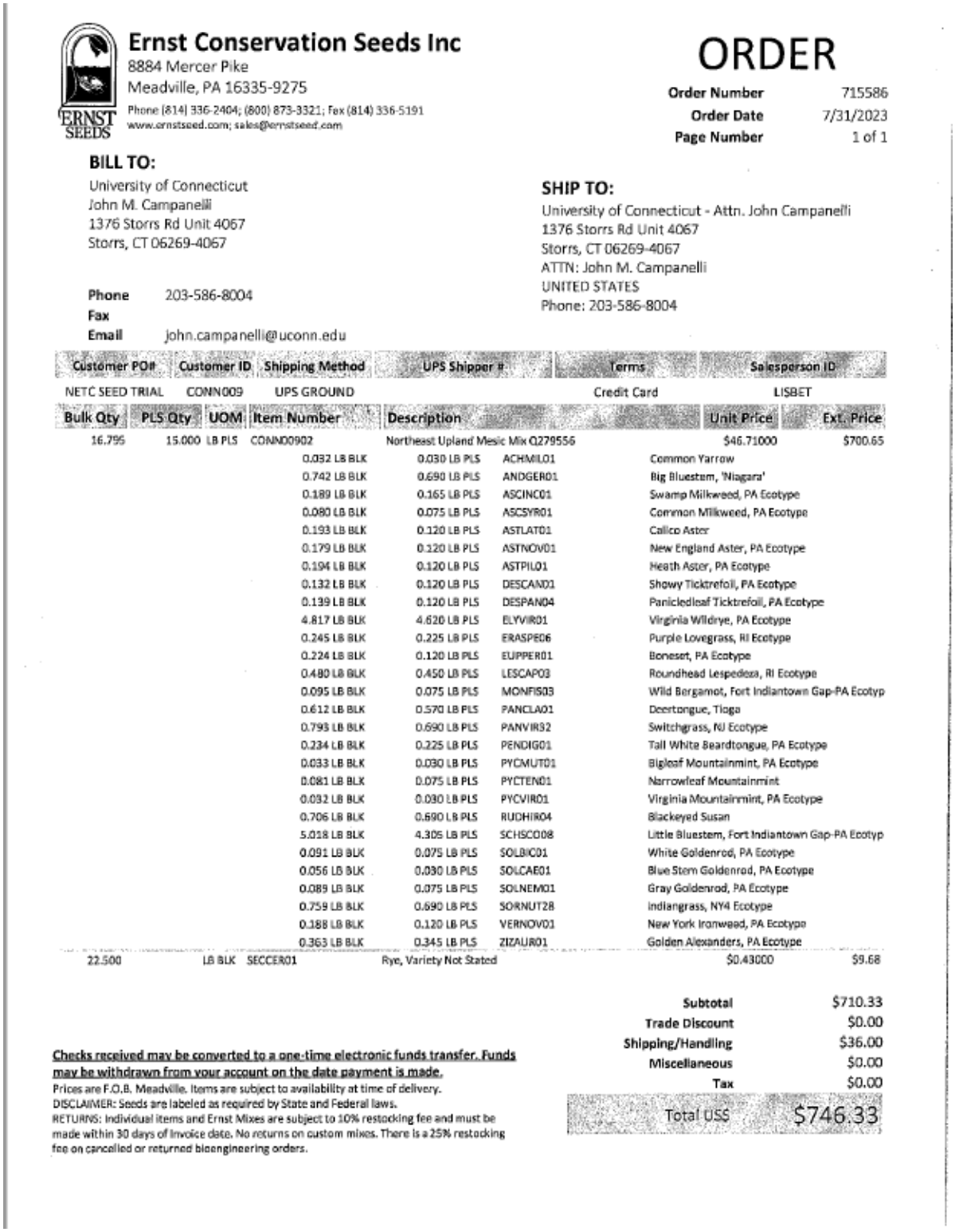
VT Seed Mix



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ORDER

Order Number 715586
Order Date 7/31/2023
Page Number 1 of 1

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Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
NETC SEED TRIAL	CONN009	UPS GROUND		Credit Card	LISBET

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
16.795	15.000	LB PLS	CONN00902	Northeast Upland Mesic Mix Q279556	$46.71000	$700.65
	0.032 LB BLK		0.030 LB PLS	ACHMIL01	Common Yarrow	
	0.742 LB BLK		0.690 LB PLS	ANDGER01	Big Bluestem, 'Niagara'	
	0.189 LB BLK		0.165 LB PLS	ASCINC01	Swamp Milkweed, PA Ecotype	
	0.080 LB BLK		0.075 LB PLS	ASCSYR01	Common Milkweed, PA Ecotype	
	0.193 LB BLK		0.120 LB PLS	ASTLAT01	Calico Aster	
	0.179 LB BLK		0.120 LB PLS	ASTNOV01	New England Aster, PA Ecotype	
	0.194 LB BLK		0.120 LB PLS	ASTPIL01	Heath Aster, PA Ecotype	
	0.132 LB BLK		0.120 LB PLS	DESCAN01	Showy Ticktrefoil, PA Ecotype	
	0.139 LB BLK		0.120 LB PLS	DESPAN04	Panicledleaf Ticktrefoil, PA Ecotype	
	4.817 LB BLK		4.620 LB PLS	ELYVIR01	Virginia Wildrye, PA Ecotype	
	0.245 LB BLK		0.225 LB PLS	ERASPE06	Purple Lovegrass, RI Ecotype	
	0.224 LB BLK		0.120 LB PLS	EUPPER01	Boneset, PA Ecotype	
	0.480 LB BLK		0.450 LB PLS	LESCAP03	Roundhead Lespedeza, RI Ecotype	
	0.095 LB BLK		0.075 LB PLS	MONFIS03	Wild Bergamot, Fort Indiantown Gap-PA Ecotyp	
	0.612 LB BLK		0.570 LB PLS	PANCLA01	Deertongue, Tioga	
	0.793 LB BLK		0.690 LB PLS	PANVIR32	Switchgrass, NJ Ecotype	
	0.234 LB BLK		0.225 LB PLS	PENDIG01	Tall White Beardtongue, PA Ecotype	
	0.033 LB BLK		0.030 LB PLS	PYCMUT01	Bigleaf Mountainmint, PA Ecotype	
	0.081 LB BLK		0.075 LB PLS	PYCTEN01	Narrowleaf Mountainmint	
	0.032 LB BLK		0.030 LB PLS	PYCVIR01	Virginia Mountainmint, PA Ecotype	
	0.706 LB BLK		0.690 LB PLS	RUDHIR04	Blackeyed Susan	
	5.018 LB BLK		4.305 LB PLS	SCHSCO08	Little Bluestem, Fort Indiantown Gap-PA Ecotyp	
	0.091 LB BLK		0.075 LB PLS	SOLBIC01	White Goldenrod, PA Ecotype	
	0.056 LB BLK		0.030 LB PLS	SOLCAE01	Blue Stem Goldenrod, PA Ecotype	
	0.089 LB BLK		0.075 LB PLS	SOLNEM01	Gray Goldenrod, PA Ecotype	
	0.759 LB BLK		0.690 LB PLS	SORNUT28	Indiangrass, NY4 Ecotype	
	0.188 LB BLK		0.120 LB PLS	VERNOV01	New York Ironweed, PA Ecotype	
	0.363 LB BLK		0.345 LB PLS	ZIZAUR01	Golden Alexanders, PA Ecotype	
22.500		LB BLK	SECCER01	Rye, Variety Not Stated	$0.43000	$9.68

Subtotal	$710.33
Trade Discount	$0.00
Shipping/Handling	$36.00
Miscellaneous	$0.00
Tax	$0.00
Total US$	$746.33

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ORDER

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Page Number	1 of 1

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Customer PO#	Customer ID	Shipping Method	UPS Shipper #	Terms	Salesperson ID
NETC SEED TRIAL	CONN009	UPS GROUND		Credit Card	LISBET

Bulk Qty	PLS Qty	UOM	Item Number	Description	Unit Price	Ext. Price
16.795	15.000	LB PLS	CONN00902	Northeast Upland Mesic Mix Q279556	$46.71000	$700.65
22.500		LB BLK	SECCER01	Rye, Variety Not Stated	$0.43000	$9.68

Subtotal	$710.33
Trade Discount	$0.00
Shipping/Handling	$36.00
Miscellaneous	$0.00
Tax	$0.00
Total US$	$746.33

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Appendix 4

Establishment of the Demonstration Sites

Site location

A CT DOT Bureau of Highway Operations manager selected the potential site for the CT demonstration plot in January 2023. The site was first surveyed in winter of 2023 to verify that it met selection criteria.

Figure 1. Aerial map of the CT site outlined in red.

Site description

An approximately 1-acre triangular portion of a vegetated roadside in Windsor, CT, sits adjacent to the southbound portion of I-91 on its eastern side, framed on its western edge by the exit ramp of Exit 38 and on its southern side by a commuter parking lot. While portions of the site next to the parking lot had invasive species colonies including mugwort (*Artemisia vulgaris*), spotted knapweed (*Centaurea stoebe*), and black locust (*Robinia pseudoacacia*), the remaining portion that is visible to highway drivers and those using the exit ramp was mostly populated with tall fescue (*Festuca arundinacea)*. Proximity to a commuter parking lot enabled safe access to the site by non-DOT personnel working on the project.

Site assessment

A site assessment was conducted of soil characteristics and an inventory of the existing plant species to confirm the suitability of the selected seed mix to the site.

Seeding method: split-season no-till drilling

The split-season seeding method, which involves seeding the grasses in spring and the forbs in fall, was proposed for this site. The potential benefit from this approach involves the differences in the ways grasses and forbs establish. Grasses usually do not need cold stratification before germinating, while forbs usually need at least one cold season of stratification, if not more, before germinating. Sowing grass seed in spring allows grasses to germinate and establish during the summer, providing erosion control and a cover crop for the native plant community. Seeding the forbs in the fall allows for winter cold seed stratification and ground heaving, which draws the forbs seed deeper into the ground, thus providing better soil to seed contact while increasing their rates of germination. Fall seeding also minimizes forb seed predation since the ungerminated seed does not lie on the ground during the summer months.

Site preparation and seeding

CT DOT mowed the site during the first week of May 2023 in preparation for the herbicide application. On May 14, the area that needed to be sprayed was demarcated to ensure that a 15 foot clear zone mowed shoulder was not part of the site (this zone gets mowed multiple times per year and does not need to be seeded). After mowing there were considerable amounts of tall fescue detritus, which was removed by hand using rakes prior to the application of herbicide.

The employees from the UConn Research Farm with commercial supervisory and operational certifications to engage in use of pesticides conducted the glyphosate application on May 16, at least two weeks prior to seeding. Roundup Pro was applied at a rate of 75 ml/gal. using backpack sprayers and 1-meter-wide wands. A green dye, Foursome, was added to the herbicide to mark areas where the herbicide was applied. Four man-hours were required to manually apply the herbicide to a three-quarters acre site.

On June 2, two employees from Matt's Landscaping used a Flex II Truax no-till seed drill to seed the site. The drill was set at 40-50 lbs. of seed per acre, the seed mix was combined with clay cat litter as a carrier, seeded at a rate of 100%. Two hours were required to drill one pass of the grass seed mix.

Site monitoring following spring seeding

Germination of the little bluestem was recorded 4-6 weeks after the seeding. On August 2nd, about 25% of the site was populated predominantly by yellow foxtail (*Setaria glauca*), and to a lesser extent nutsedge (*Cyperus esculentus*). There were fewer native grass seedlings emerging among the foxtail and nutsedge compared to those areas where the oat cover crop had established. Since foxtail is an annual, the head botanist from Ernst Conservation Seeds recommended mowing before the foxtail put out seeds. For the nutsedge, it was suggested to use a selective herbicide S-metolachlor; however, S-metolachlor could inhibit the germination of the native grasses during the first year of seeding. Since the nutsedge infestation was relatively minor, mowing was conducted to prevent these species from interfering with the

native plant establishment. The employees from the UConn Research Farm mowed the colonies of foxtail and nutsedge on August 11 using a Harvester model 722 sickle bar mower by BCS. A line trimmer was also used for those stray patches within the areas with oats. On August 31, the foxtail had regrown and was on the verge of going to seed. On September 8, the site was mowed once again.

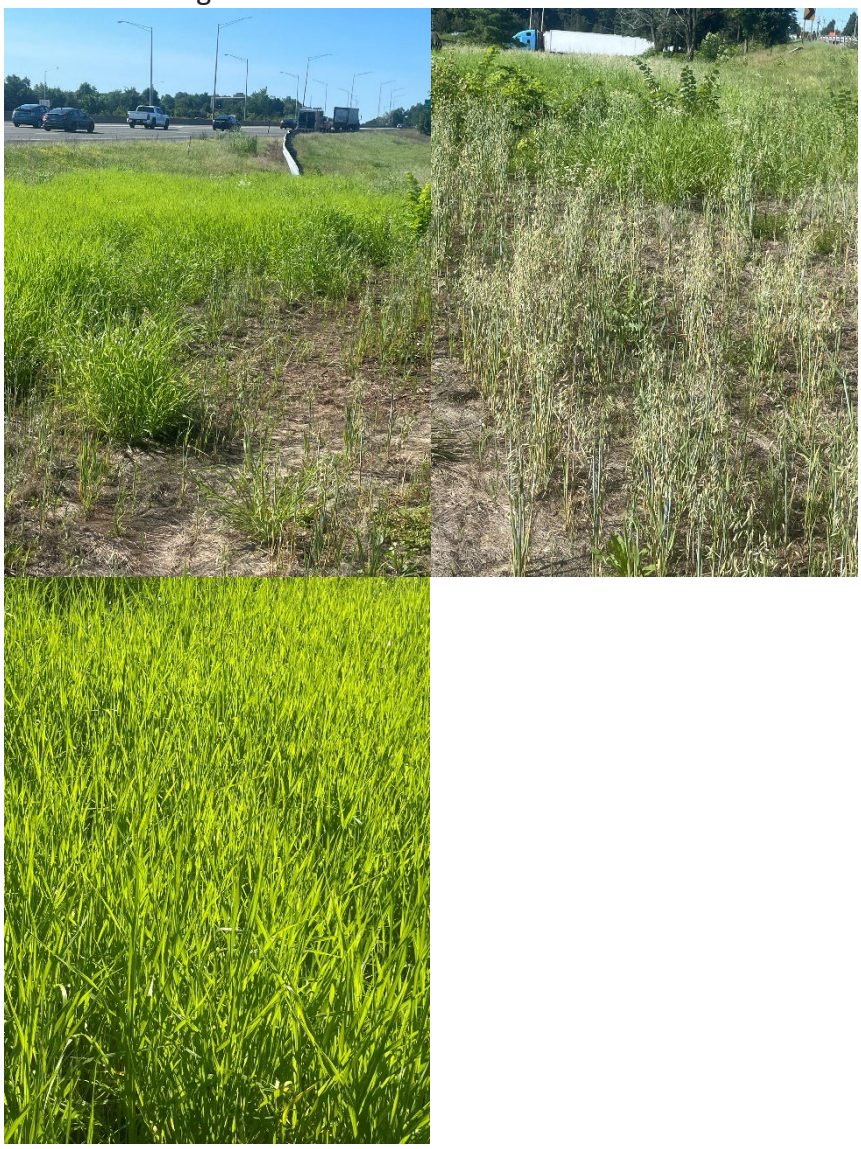

Figure 2. August 2, 2023. CT site following spring seeding: oat cover crops (left); foxtail patches (center); close up of foxtail foliage (bottom).

During summer 2023, several patches of native species established from existing seed banks, including blue vervain (*Verbena hastata*), black-eyed Susan (*Rudbeckia hirta)*, common evening-primrose *(Oenothera biennis*), common milkweed (*Asclepias syriaca*), steeplebush (*Spirea tomentosa*), and switchgrass (*Panicum virgatum*).

Figure 3. August 2, 2023. Native plants emerged from seed banks at CT site following a season without mowing: common evening primrose (left), black-eyed Susan (center); blue vervain (right);.

Figures 4. August 11, 2023. UConn Research Farm employees mow foxtail (left); little bluestem seedling (right).

Fall seeding of the site

CT DOT mowed the CT site on October 12, 2023, and forbs seeding was conducted on October 16. Two employees from Matt's Landscaping seeded the forbs mixed with clay cat litter as the carrier in two passes of the Truax seed drill set at 50% to obtain an even distribution of the seed.

Note: The split-season seeding approach at the CT site resulted in slightly higher prices compared to the seeding of grasses and forbs all-at-once at the MA site. This is justified by the fact that Ernst Conservation Seeds only sells seed at full pound increments. Therefore, Ernst Conservation Seeds sent 3 lbs. of forbs seed, which is greater than the approximately 2.25 lbs. of forb seeds included in the grass and forbs seed mix which would be used for 3/4 of an acre.

Since the forbs seed cost is $161.69/lb., which is much higher than $47.57/lb. for the combined grass and forb mix, the 3 lbs. of forb seeds for ¾ of an acre equaled $485.07, while the grass and forb for ¾ of an acre equaled $475.38.

Figure 5. October 16, 2023. Fall seeding of CT site: Truax drill (left); mixing seed with clay cat litter carrier (left).

Figure 6. October 16, 2023. Fall seeding of CT site (left and right).

Fall site monitoring

The site was inspected on November 20, 2023. No new growth was detected. Grooves from the Truax seed drill were still visible.

Figure 7. Site appearance on November 20, following Close up of the grooves left by Truax seed drill (left). fall seeding (right).

Spring 2024

In Spring 2024, the Connecticut site was dominated by Virginia wildrye (*Elymus virginicus*), a cool season grass that was part of the spring seed mix planted in June 2023. It had a season for seedlings to germinate. By 2024, it had mature plants, a contrast to warm-season grasses, which take several seasons to reach maturity. Pre-existing common milkweed (*Asclepias syriaca*) stands increased their presence as a result of reduced mowing.

Figure 8. May 16, 2024. The edge of the seeding with the pre-existing vegetation in the foreground (left). Virginia wild rye mingled among common milkweed (center). Virginia wild rye with its characteristic purple at the bottom of its blades (right).

Later in the season, daisy fleabane (*Erigeron annuus*), a native species that germinated from a pre-existing seed bank, dominated the planting along with Virginia wild rye. Rosettes of black - eyed Susan (*Rudbeckia hirta*) were present under the canopy of taller plants, whose height nursed these maturing seedlings.

Figure 9. August 11, 2024. Daisy fleabane stands (left). Black-eyed Susan rosettes (right).

Massachusetts

Site selection

MassDOT District 2 suggested three sites from which to choose the demonstration sites. The sites were in West Hatfield, Northampton, and Holyoke. Each site had existing vegetation that needed to be removed prior to the planting of native species. The first site assessment, which was accompanied by a District 2 representative, took place on February 24, 2023, when the sites were covered with snow.

The following are descriptions of each site:

Holyoke: This site is situated off exit 14 of I-91 and is framed by southbound I-91 on its east side, Cherry St on its south side, and the on-ramp to southbound I-91 on its west and north sides. While it has relatively open access, it was initially advised that vehicles parked outside the gate of a neighboring park. Later visits made apparent that vehicles could be parked on the outer edge alongside the on-ramp. Although the site was covered in snow, it was apparent that the edges of the site were populated by invasive species mugwort.

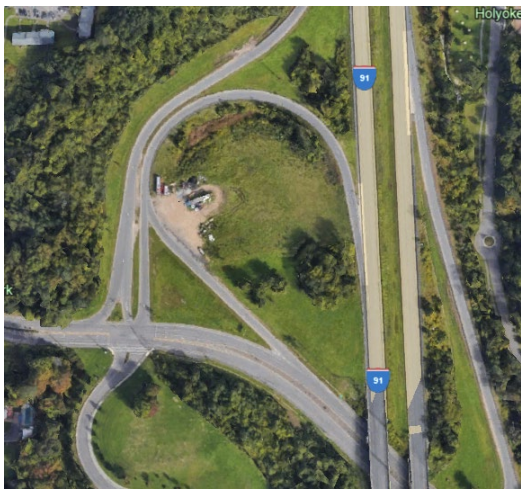

Figure 9. Aerial view of Holyoke site

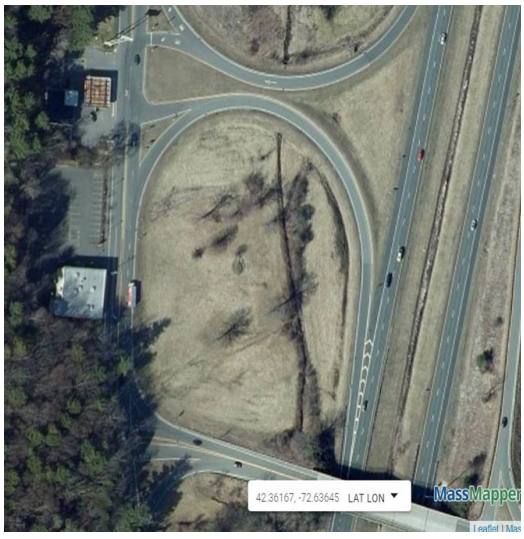

Figure 10. Aerial view of Northampton

Northampton: This site is situated off exit 27 of I-91 north and framed by Allen Rd. on the south, North King St (US Route 5) on the west, and the on-ramp to southbound I-91 on its north and east sides. This site had the benefits of being situated nearby the MassDOT District 2 facility to its north and visible to drivers on Elm St, N King St, and the on-ramp to I-91 south. It was apparent that vehicles needed to be parked across the street at a Sunoco gas station.

West Hatfield: This site is framed by West St. (US Route 5) on its west and north sides, southbound I-91 on its west side, and the on-ramp to southbound I-91 on its southside. The west, south, and east sides were surrounded by guardrails, which required vehicles be parked along West St., a very busy road, making access problematic. The site lacked much visibility for drivers, except those driving on the on-ramp to I-91 south.

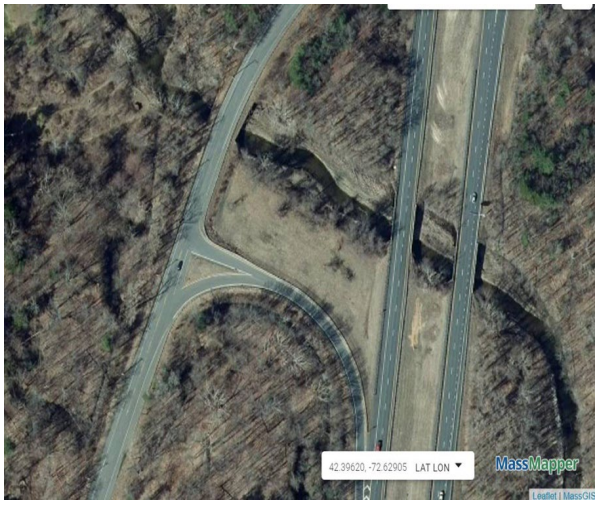

Figure 11. Aerial view of West Hatfield site.

The Northampton site was chosen because it had relatively easy access, good visibility for drivers to see the native planting, and proximity to the MassDOT District 2 facility, which provided the additional possibility that MassDOT employees would see the benefits of transitioning roadside vegetation to native plant communities.

However, we encountered the following two challenges:

1. MA Regulations for pesticide usage in the right of way (ROW) require notifying public officials as part of the permit process.
2. When notified, Northampton Mayor's Office expressed concern and could not give concurrence because Northampton has a pesticide bylaw: 13491 (northamptonma.gov).

Therefore, the Mayor's Office, while in favor of the project, did not feel comfortable complying with the use of herbicide. (see *Seeking Approval for Planting in Northampton* on page 16 within *Regulatory requirements for herbicide application in Massachusetts* text box).

After reviewing the other two sites, the Holyoke site was ultimately chosen for the establishment of the demonstration site.

Seeding method: fall no-till drilling

The conventional no-till approach in which the forbs, grass, and cover crop seeds were seeded concurrently, was implemented at the site. In this case, the seeding was conducted in fall since several months were required to fulfill the MA regulatory requirements for herbicide application.

Regulatory requirements for herbicide application in Massachusetts

Application of herbicide for this project required obtaining a Limited Application Waiver from the Massachusetts Department of Agricultural Resources (MDAR) to meet the requirements of 333 CMR 11.03(14) Rights of Way Management regulations

The following documents are to be uploaded to the State Highway Access Permits System website:

a) An aerial photo with demarcation of the area for future planting that will receive herbicide.
b) A description of the activity that will take place in the demarcated area, including the purpose of applying for the permit.
c) The proposed herbicide name and rate (Note: the applicant can only choose an herbicide from the "Herbicides Recommended for Use in Sensitive Areas List" approved by the Pesticide Division of the MDAR. The herbicide must have the EPA Registration Number exactly as listed).
d) The Material Safety Data Sheet for the herbicide.
e) It needs to be determined if a wetland is near the site and, if so, it needs to be demonstrated that the area to be sprayed is at least 10 ft. away from the wetlands.
f) Only one application of herbicide will occur within a five-year period unless another application is shown to benefit the health or safety of the public.
g) A letter of concurrence from the chief elected official – either the mayor or the board of selectmen of the municipality where the application is to be made.
h) Approval from the municipality's Conservation Commission.
i) An herbicide applicator certified by the state of MA to apply herbicide.
j) A person with a Category 40 license be present at the site to oversee proper application of herbicide.
k) Certified letters that show receipt of said letters that inform the town's mayor, Conservation Commission, Water Department, and Department of Health of a span of time during which the herbicide will be applied either 10 days preceding a particular date or 10 days following that date, the specific herbicide that will be used, and the name and contact information of the applicator.
l) At least 48 hours prior to application, an advertisement at least four by five inches in size must be placed in a local newspaper that indicates the specific herbicide that will be used, a span of time during which the herbicide will be applied either 10 days preceding a particular date or 10 days following that date, and the name and contact information of the applicator, thus allowing citizens to contact the applicator with any concerns.

Seeking approval for planting in Northampton

The first step taken was data entry into the SHAPS system, followed by contact from the Northampton Conservation Commission. The representative of the Commission reviewed the site selected, determined that the site contained wetlands, and that any herbicide application needed to be at least 10 ft. away from the wetlands. The office of mayor was contacted concerning the existence of wetlands at the site. The mayor's office made clear that, because Northampton has a particularly active citizenry concerning environmental issues, the proposed application of herbicide would require a public hearing, which not only would consume precious time needed to set the date for application but probably would result in opposition to the herbicide application. Therefore, it was suggested another location be selected.

Seeking approval for planting in Holyoke

On June 12, the research team revisited the West Hatfield and Holyoke sites. This time, without snow cover, extensive populations of poison ivy were apparent at the site; also, the guardrails posed an access problem. The Holyoke site had better access and visibility to the public than the West Hatfield site. It was determined that the Holyoke site was the better choice of the two sites.

The head of Holyoke Conservation Commission examined a map of the site and determined a wetland existed at the site. On July 24 the research team met with Conservation Commission members to determine and mark with PVC stakes an area that was at least 100 ft. from the site's wetlands. A ¾ acre portion of the site was demarcated. This was followed by a request for a member of the research team to attend the monthly Conservation Commission meeting on July 27 to provide information concerning the project to receive Commission approval. Following the presentation, Commission members unanimously approved the project, and a Wetland Protection Act (WPA) form of approval was provided on July 28.

A request for approval from the Mayor of Holyoke to apply herbicide was granted in a letter dated August 2, 2023.

On August 8, a District 2 Engineer for MassDOT informed the research team that a construction company had requested to use a portion of the Holyoke site as a staging area during renovations being conducted on the Veteran's Home across the street. He requested and arranged a meeting on August 9 at the site with members from the research team to determine if the demarcated portion needed to be moved. After the meeting, it was determined that the staging area could be located elsewhere at the site and the original demarcations could remain. During this visit, a soil sample was collected, and a plant inventory was performed.

Arranging herbicide application

In March 2023, MassDOT District 2 provided a list of approved Invasive Plant Management Contractors. The research team selected a MA certified herbicide applicator and contracted for his services on August 11 that set his rate at $125/hour.

Upon reviewing the list of herbicides approved by the MDAR, the applicator suggested using AquaNeat, an herbicide that contains glyphosate.

Since the applicator did not have a Category 40 License required by law for application of the herbicide, a person holding a Category 40 License was contacted. A window of September 2-22 for the application of herbicide was determined and certified notices of application were sent to the Holyoke mayor, Water Department, and the Health Department. However, since three people would have to be present during the application – the herbicide applicator, the holder of the Category 40 License, and the representative from the MDAR – finding a date when all three were available within the window became difficult. When it was determined that the herbicide applicator would not be available until the end of September, it was decided that a new applicator needed to be contracted. Nevertheless, the original herbicide applicator charged $750 for five hours of work consisting of phone calls, emails, and research concerning herbicides.

On September 7, MassDOT District 2 provided the name of an employee of vegetation management company who not only was state certified to apply herbicide but also holds a Category 40 License. With just two people – the herbicide applicator and the representative from the MDAR – whose times needed to be coordinated, the date of September 15 was arranged for herbicide application. New letters were sent to the appropriate parties and an advertisement was placed in the Springfield Republican newspaper with the appropriate information. The vegetation management company applied the herbicide AquaNeat in one hour at a rate of 0.1875 gallons diluted in 20 gallons of water using an All-Terrain Vehicle with a boom attachment. The company charged $200 for the application.

Seeding the site

The seeding was conducted on October 16 by Matt's Landscaping. The seed was mixed with clay cat litter as a carrier at a rate of 100%. One and a half hours were required for the seeding to be performed in one pass. The same species composition as at the CT site, which was seeded using the split-season approach, was used with all species seeded at once.

Figures 10. October 16, 2023. Fall seeding of MA site (left and right).

Fall site monitoring

On November 20, 2023, the site was inspected. Cereal rye cover crop had already been established, and its seedlings should persist over the winter months.

Figures 11: November 20, 2023. At MA site, Truax seed drill left grooves from packing wheels following rain (left); emergence of cereal rye seedlings (right)

Spring 2024

The seed mix cover crop, cereal rye (*Secale cereale*) created a dense stand in the drier portion of the site. In the portion of the site with poor drainage, cereal rye did not germinate. However, later in the season, it was evident that the elimination pf Kentucky bluegrass (*Poa pratensis*) presence, which allowed existing stands of carex, juncus, and dropseed to spread more extensively in the wetter portion of the site. In addition, other pre-existing native plants were

able to increase their presence, including swamp milkweed (*Asclepias incarnata*), boneset (*Eupatorium perfoliatum*), blue vervain (*Verbena hastata*), and various goldenrods. Throughout both the dry and wet portions, black-eyed Susans (*Rudbeckia hirta*) rosettes germinated from the seed mix.

Figure 12. May 16, 2024. Cover crop of cereal rye growing in the drier portion of MA demonstration site (left). Lack of cereal rye in the wetter portion of the site (right).

Figure 13. August 11, 2024. Pre-existing sedges (left) and rushes (center) spread in the wetter portion of the MA site with the elimination of Kentucky bluegrass with the application of

herbicide in fall 2023. Rosettes of black-eyed Susan (right) from the seed mix established throughout the site.

Vermont

Site selection

VTrans selected a median on I-91 of approximately 0.7 acre (28,600 sq. ft) in Lyndon, VT, located near the Canadian border. The median, which had been used as a staging area during road work, would be available for native planting in the beginning of August 2023 following removal of asphalt millings. Seeding would need to occur within two weeks of construction completion to prevent soil erosion.

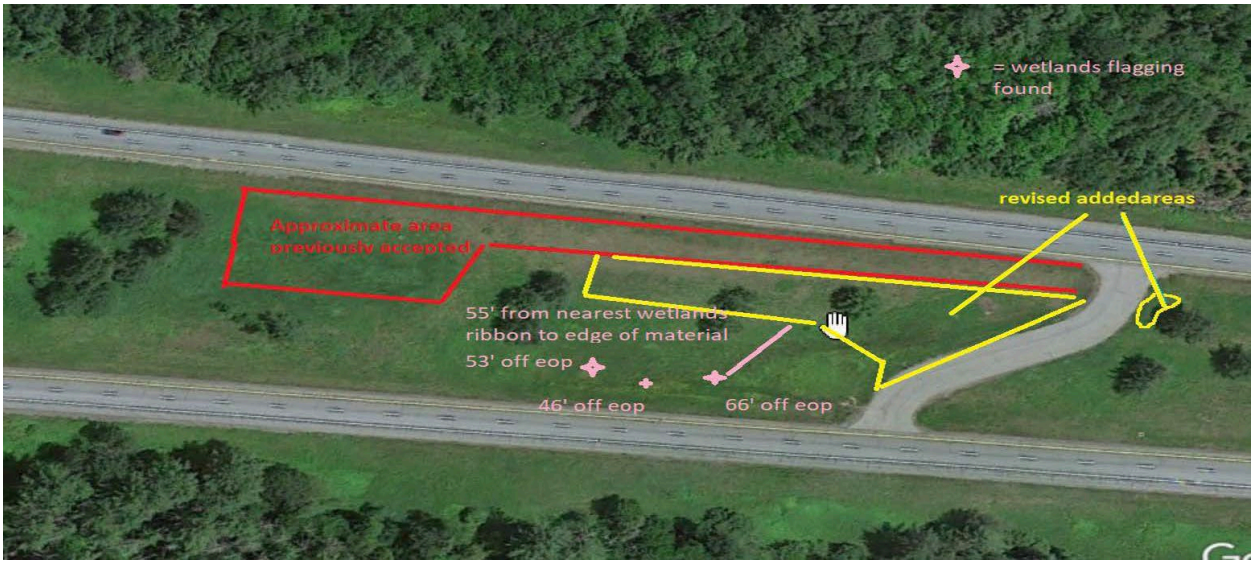

Figure 14: The YELLOW area is the approximate site for seeding.

Figure 15: Asphalt millings covering site.

Figure 16: The location of the proposed demonstration site.

Seeding method

Since this is the only demonstration site to be established on previously unvegetated area following road renovation, the original proposal suggested hydroseeding. Half of the site would receive standard native seed hydroseeding, which involves broadcasting the seed mix and covering the seed with typical hydroseeding mulch. The other half of the site would receive hydraulically applied biotic soil medium, engineered mulch, and seed (All Habitat approach. A tackifier included in the mulch would help prevent erosion on slight slopes. However, following a Technical Committee (TC) meeting, TC members expressed doubt that DOTs would adopt this approach because of its high cost and difficulty finding hydroseeding contractors with knowledge of this approach.

Next, it was proposed that half the site would use broadcast seeding and straw matting, and the other half would be hydroseeded using the standard approach used for native seed. VTrans officials requested an estimate from the contractor to calculate an estimate for hydroseeding the native seed, too. Due to contract complications, and the fact that the native seed component was added to the project during construction, hydroseeding was ultimately not possible on this project. Hydroseeding can be incorporated on future projects if it is included in the contract plans. Additionally, allowing outside contractors onto the interstate to work on an active construction site would create uncertainties and safety issues that VTrans was unable to resolve.

Therefore, the final proposal involved broadcast seeding the whole site and covering it with straw matting.

Resolving the high soil pH level of the Vermont site

Soil testing

VTrans collected a soil sample from the site at 6" deep by clearing a portion of the asphalt millings. The test revealed a pH of 7.7, which is higher than the pH range recommended for most native plants. The pH of the surrounding soil was 6.6, which is within the range recommended for native plants. It was hypothesized that the asphalt had raised the pH in underlying soil. The soil removed and set aside during construction also had a high pH of 7.4. As a result, it was determined that a method had to be developed to deal with the high soil pH to make it suitable for native planting once the asphalt millings were removed.

Resolving the issue of elevated soil pH

A common practice for lowering soil pH is amending the soil with several applications of sulfur over the course of a year, which was not practical for roadside planting. Aluminum sulfate works faster in fewer applications than sulfur, however, the amount of aluminum sulfate required is much greater and the price is considerably higher compared to using sulfur. It was estimated that the Vermont site would need nearly two tons of aluminum sulfate, and its total cost would significantly exceed the price of the seed. Also, DOT managers indicated that they rarely add amendments other than lime making the soil acidification process impractical. Working under the principles of adaptive management, the research team tried to develop recommendations that would likely be replicable within the current practices of the DOTs. If DOTs rarely applied soil amendments, it shouldn't be expected they would do so in the future. It was determined that an alternative had to be found to adding soil acidifiers.

Operating under inflexible time constraints, the roadsides had to be revegetated soon after hardscape construction was completed to prevent erosion, and a solution needed to be found that would work within the deadline and budget parameters. The recommendation from Ernst Conservation Seeds was to increase the amount of seed by 50% to improve chances of some species establishment and compensate for possible fluctuations of the pH levels. While this decision substantially increased the cost of the seed, the increase was less than would have been spent on either aluminum sulfate or sulfur and labor costs to apply those amendments.

Therefore, as is obvious from this example, it is important to conduct soil analysis as early as possible in the planning of construction and revegetation projects. This will give those implementing the plans more time to prioritize resources to address issues like soil pH levels and their impact on native plant community establishment.

Determination of the seeding date

This demonstration site had to be seeded soon after the removal of asphalt millings. The window for doing so was from mid-August to the first week of September. This is not the best time for seeding since it could lead to early germination and the killing of native plant seedlings

by frost. However, if the seeding takes place within a month of the site's first frost date, early germination shouldn't occur. The Farmer's Almanac forecasted the first frost date for Lyndon to be September 27, 2023. VTrans conducted seeding as close to the deadline and when it was practical for the agency, which was on August 22.

Ordering straw mat materials

The straw mat was selected and ordered from the VTrans Approved Product List. A purchase was placed with Everett J Prescott Inc. in Barre, VT.

VTrans seeding of the demonstration site

The following descriptions of VTrans activities during the day of seeding came from a report compiled by VTrans:

- The project contractor prepared the site by removing the asphalt millings and spreading 4" of soil collected from the roadside borrow pit across planting area.
- The native seed mix and cover crop were mixed and hand-broadcast over the site.
- Following seeding, half the site was hand-raked, while the other half was left unraked to gauge the impact of raking on seed establishment.
- Using shovels, a trench was dug at the top of the slope to key-in the erosion control matting. The erosion control mats were lined up along the top of the slope, keyed-in with soil, and rolled out one-by-one down the slope. Edges of the matting were overlapped.
- To secure the matting to the ground, landscape staples were installed along the top and bottom edges, staggered on the overlap (seam), and in-between seams. Excess erosion control matting material was cut at the bottom of slope.

Figure 17: August 22, 2023, VT site ready to be seeded and matted.

Figure 18: August 22, 2023, Mixing the seed mix and cover crop for broadcasting by hand (left); gently raking seed after broadcasting (right).

Figures 19: August 22, 2023, Digging a trench to key-in erosion control matting (left); preparing to set erosion control matting (right).

Figure 20: August 22, 2023, Installing landscape staples in matting (left); completed installation (right).

Fall site monitoring

On November 13, 2023, VTrans employees visited and photographed the VT site and questioned why the turfgrass appeared lusher than the area planted with native seed and cover crops. Three main factors contributed to the turfgrass appearing denser than the cereal rye cover crop:

1. The turfgrass mix consisted of 75% by weight of creeping red fescue and tall fescue, which are used for erosion control because they are known for establishing faster than most other grass species.
2. Cereal rye has a slower germination rate than turfgrass species, especially in colder weather, and may not have yet germinated fully.
3. The straw matting, which provided additional erosion control required for sloped sites, could have inhibited the emergence of the cereal rye. The matting ensures that the native seed maintains contact with the soil and stays in place rather than move down the gradient because of rain, wind, and gravity.
4. The contractor had hydroseeded all the turfgrass for the project except for this staging area, which was broadcast seeded and topped with loose straw for mulch. Research has found that loose straw allows for greater vegetation emergence compared to straw matting. While the netting of straw matting is made of photodegradable polypropylene, its presence while the seeds are germinating can inhibit seedlings, especially such large ones as cereal rye.

Figure 21. November 13, 2023. On left hand side, the native seed planting with straw mat. On the right hand side, the turfgrass with loose straw.

Figures 22. November 13, 2023. Cereal rye seedling (left); cereal rye emerging through straw matting (right).

Spring 2024

Because the Vermont site was seeded at the end of August 2023, the seed mix had enough time to germinate and establish seedlings in fall 2023. As a result, by spring 2024, the black-eyed Susan (*Rudbeckia hirta*), a biennial, was able to establish its first year of rosettes in fall 2023 and flower by summer 2024. This contrasted with the CT and MA sites, which were seeded in mid-October 2023, which was too late in season to allow seeds to germinate before temperatures dropped as winter approached.

Figure 23. Since the VT seeding happened in August 2023, black-eyed Susan, a biennial, was able to germinate and put out rosettes in fall 2023 and flower in spring 2024.

Figure 24. The righthand portion dominated by black-eyed Susan shows the dividing line between where the VT site was seeded with native seed and where it was seeded with a standard turfgrass mix.