Roadside Wildflower Meadows: Summary of Benefits and Guidelines to Successful Establishment and Management

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For the past 4 years, research has been conducted to refine the state of knowledge about the establishment and management of herbaceous meadows for highway landscapes in Massachusetts. As alternatives to turfgrass, meadows can provide three principal types of benefits: (a) ecological benefits derived from a more diverse self-sustaining planting without a reliance on agrichemicals and mowing, (b) economic benefits through dramatic reductions in mowing, and (c) aesthetic improvements resulting from a diverse planting of indigenous flowers and grasses. A split-block replicate experimental planting was installed in 1989 to test the effects of three tillage treatments, three fertilizer treatments, and two postemergent herbicide treatments. Two years of field observations on species diversity and plant density found that tilling permitted better establishment of wildflowers than not tilling; preemergent treatments showed a significant decrease in invasive grasses and an increase in wildflowers; fertilization did not improve the growth of wildflowers, grasses, or broadleaved weeds; and the monocot-specific herbicide was effective in controlling invasive grasses. The research documented that the primary obstacle to successful wildflower establishment is the spread of opportunistic turf-forming grasses and broadleaved weeds. This experiment has led to revised site preparation and establishment specifications to help maintain successful, self-sustaining meadows for highway landscapes.

Wildflower meadows enhance the aesthetic and ecological value of the landscape and reduce the time, money, and resources spent on conventionally mowed turfgrass areas (*1*). Highway meadows provide seasonal color changes along roadsides and expose surrounding vistas. Meadows of native vegetation also provide habitat and food for wildlife. Once the wildflower meadow becomes a well-established plant community, it is less susceptible to weed invasions and less in need of maintenance (*2,3*). However, proper site-preparation and management techniques are essential to establishing a stable plant community and aesthetic wildflower meadow planting. Proper site preparation will permit the establishment of wildflowers while reducing undesirable opportunistic grasses and weeds. Opportunistic grasses are defined as turf-forming species (fescues, bluegrasses, perennial ryes) that successfully invade and displace desirable wildflowers and clump-forming grasses (bluestem, side-oats grama, Indian grass, switch grass). Weeds are defined as annual or perennial forbs that exhibit undesirable invasive behavior (spotted knapweed, some goldenrods), that are noxious or allergenic (ragweed, nettle), or that are visually unacceptable (burdock, dock). Proper management can sustain a desirable species mix and an attractive appearance.

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BENEFITS OF WILDFLOWER MEADOWS

The principal advantages of wildflower meadows are ecological, economic, and aesthetic. The extent to which these benefits are achieved depends on many factors, including species selection, planting site location, establishment cost and success, and management. The following sections will elaborate on these potential benefits.

Ecological Benefits

The value of maintaining a diversity of habitat types has long been recognized as being important to environmental health and quality. The plant community is substantially more diverse when highway rights-of-way are managed as meadows than they are when managed as turfgrass landscapes. In addition, highway meadows may provide habitat for wildlife and insects. These meadows may provide a vegetational buffer between the highway and the adjacent forest—a common landscape context for highways in New England. If implemented on a large scale, highway meadows can provide a network of linked corridors that supports a diversity of plant and animal life.

Another form of ecological benefit is the reduced environmental effects of maintaining highway meadows when compared with maintaining turfgrasses. The management of turfed highway rights-of-way affects water quality because pesticides, oil, gasoline, lead, and sediments are contributed to the runoff (*4*). Wildflower meadow maintenance does not entail using pesticides, so this form of pollution can be reduced or eliminated. Other pollutants can be reduced by the wildflowers themselves, which trap and filter airborne pollutants on their leaves and stems. The efficiency of this pollutant trapping increases directly in proportion to a plant's total surface area (*5*). Thus, a growth of wildflowers 2 to 3 ft high will be more efficient at trapping pollutants than a growth of turfgrasses 6 in. high. Furthermore, once these pollutants are trapped by the vegetation, they are more likely to leach into the soil than to run off into surface waters. This is because there is less runoff with wildflower vegetation than with turf

(*6*). Because soil is an effective sink for these pollutants, water quality can be improved substantially.

Economic Benefits

The primary and most obvious economic benefit of managing a highway with meadows is the reduction in mowing requirements. Turfgrasses require 6 to 20 mowings a year (depending on the weather and desired appearance), but typical roadside meadows need only one mowing a year. In Massachusetts the Department of Public Works manages roughly 3,300 acres of roadside turf at a 1987 cost of approximately $1.1 million, or $337/acre, for six mowings (Evans, unpublished data, 1987). It can then be assumed that for every acre managed as wildflowers, a cost savings of 83 percent, or $280/acre/year, can be realized. The actual figure may vary considerably when wildflowers are planted in small areas where the time and effort to mow around them eliminates any cost savings; this is an important consideration in planning and designing highway wildflower meadows.

Aesthetic Benefits

Wildflowers are often praised for their aesthetic benefits, which include increased color, more interesting textures, and greater awareness of seasonal change. Research on environmental preference has found that although nature is often considered synonymous with the open landscape (such as a highway right-of-way), these wide, open spaces are not universally preferred (*7*). In fact, scenes that lack particular characteristics of spatial definition tend to be disliked. Only when these areas include elements that help to differentiate the openness, such as groupings of trees and shrubs, are they preferred. These landscapes, often described as being like parks or savannah, have invoked high preference in a number of studies. This suggests that to make highway landscapes more aesthetically appealing, elements that articulate and differentiate the highway's visual space should be incorporated. Wildflowers and masses of native woody plants are a means of achieving this vegetative diversity while attaining the ecological and economic benefits discussed earlier. Wildflower meadows are increasingly used as transitions between formally maintained landscapes and relatively unmanaged areas, even in urban contexts (*8*).

WILDFLOWER ESTABLISHMENT

There are many opinions about what constitutes appropriate site-preparation and management techniques and about which of these techniques are the most cost-effective (*1–3,9–12*). Interested in developing locally relevant procedures, the Massachusetts Department of Public Works commissioned a study to determine the effects of tillage, fertilizer, and herbicide preparation techniques on the growth and establishment of a wildflower meadow planting. This study has given the department suggestions for cost-effective and successful preparation techniques for roadside wildflower meadows. Following is a discussion of the results from the second season of the wildflower meadow establishment in this experiment. The results from the first year were reported by Barker and Ahern (unpublished data).

Research Procedure

Site Description

The site selected for this study was a parcel of land in the right-of-way of State Route 116 at the intersection of Sunderland Road in Amherst, Massachusetts. Within this site a study area 45 × 300 ft was staked out (Figure 1). The study area was approximately 100 ft from Route 116 and 50 ft from the tree line on the south end of the site. The study area was divided into four blocks, each 45 × 75 ft, to allow for replication of treatments. Each block was further divided into nine plots, which received a different preparation treatment. The nine preparation treatments consisted of three tillage treatments combined with three fertilizer treatments. Each of these preparation treatments occurred once in a random position in each of the four blocks, yielding four replicates of each of nine preparation techniques. Randomizing the treatment position ensured that location in the study area did not influence growth and establishment trends. Each plot was further divided into two equal subplots and received one of two postemergent herbicide treatments. Plant density data was collected in 1-m^2 quadrants at random locations within each of the subplots.

Wildflower Seed Installation

The seed mix and seed rate used were the standards used by the Massachusetts Department of Public Works for all wildflower plantings done statewide in 1989. Wildflower seeds were installed with a wildflower seed drill capable of high precision in seed dispersal and planting depth. All plots were seeded on June 29, 1989. Species and seed rates are shown in Table 1.

Fertilizer Treatments

Fertilizers are commonly recommended in the establishment of lawns and tree and shrub plantings. Wildflower planting guidebooks either are silent on the topic or recommend against it (*1–3,9,10*). These recommendations are rarely referenced to empirical studies. In the interest of challenging these recommendations, this study included three fertilizer treatments that were broadcast by hand and watered immediately after application.

Unfertilized No fertilizer was applied.

Urea A nitrogen-only fertilizer was applied. The urea was applied at a rate of 1.75 lb/1,000 ft^2 (75 lb/acre) of nitrogen. The urea was applied on June 30, 1989.

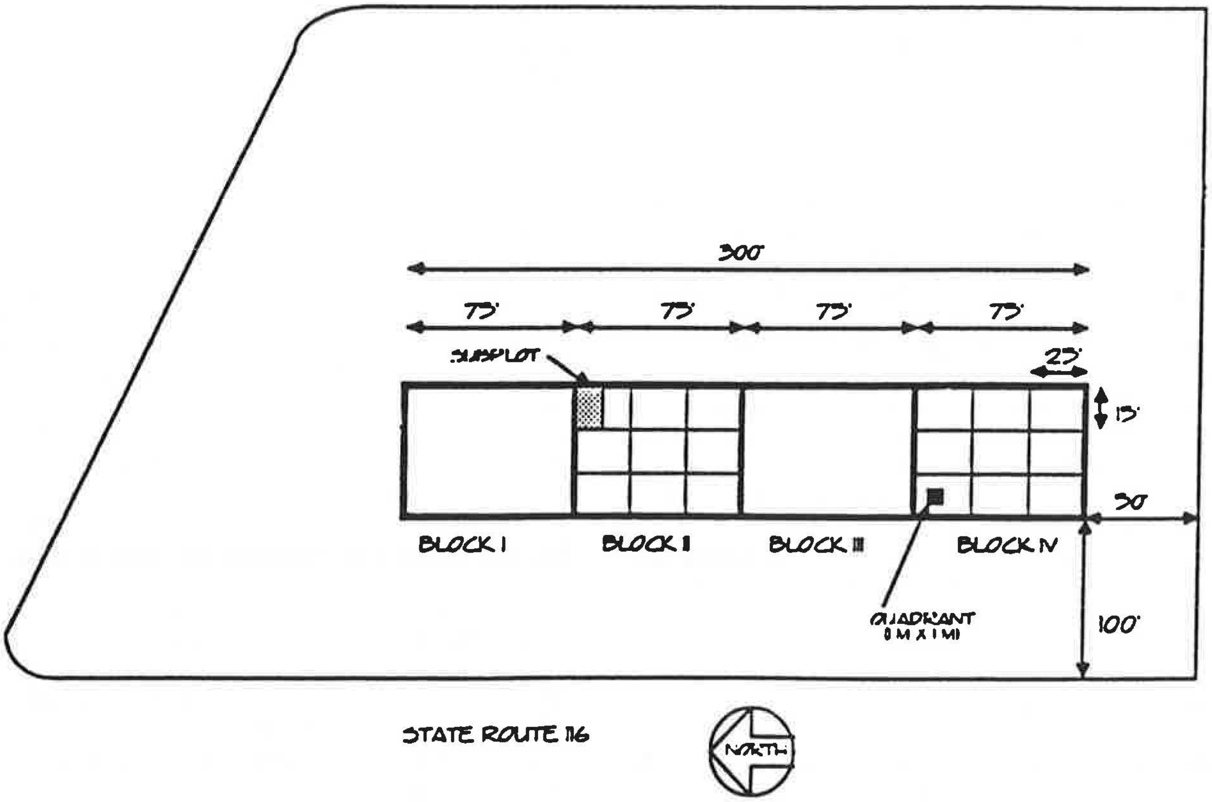


FIGURE 1 Arrangement of site.

TABLE 1 WILDFLOWER SEED MIX AND SEEDING RATES (SEED INSTALLATION: JUNE 29, 1989)

	Rate (lb/acre)
Annuals	
Baby's breath (*Gypsophilia elegans*)	0.56
Chinese houses (*Collinsia heterophylla*)	0.24
Perennials and Biennials	
Yarrow (*Achillea millefolium*)	0.56
New England aster (*Aster novae-angliae*)	0.22
Oxeye daisy (*Chrysanthemum leucanthemum*)	1.48
Coreopsis (*Coreopsis lanceolata*)	1.48
Queen Anne's lace (*Daucus carota*)	0.89
Dame's rocket (*Hesperis matronalis*)	0.92
Chicory (*Cichorium intybus*)	0.93
Black-eyed Susan (*Rudbeckia hirta*)	1.11
Showy goldenrod (*Solidago speciosa*)	0.09
Yellow coneflower (*Ratibida pinnata*)	0.31
Purple coneflower (*Echinacea purpurea*)	0.56
Total seed	9.35

10-10-10 Fertilizer A 10-10-10 fertilizer was applied at a rate of 1.75 lb/1,000 ft^2 (75 lb/acre) of nitrogen, 0.75 lb/1,000 ft^2 (30 lb/acre) of phosphorus, and 1.45 lb/1,000 ft^2 (60 lb/acre) of potassium. The 10-10-10 fertilizer was applied on June 30, 1989.

Tillage Treatments

Three tillage treatments were tested to evaluate a wide range of potential site-preparation techniques. Site preparation is one of the more expensive parts of wildflower establishment, so it has the potential for cost savings if labor can be reduced. In addition, the Massachusetts Department of Public Works was interested in developing planting methods that could be implemented by its staff rather than by outside contractors.

No Till The existing vegetation was killed with glyphosphate (Round-Up) applied at 1 oz active ingredient/100 ft^2 (2.5 lb/acre). After about 2 weeks the treated area was mowed. This treatment involved the least expense in terms of labor, equipment hours, and material cost. The initial treatment occurred on May 26, 1989.

Tilled Only The plots were cultivated with two passes of a tractor-mounted rototiller and then York-raked. Plant debris was raked and removed from the site. The tilling was performed on May 31, 1989.

Tilled Followed with Preemergent Herbicide The plots were cultivated with two passes of a tractor-mounted rototiller and then York-raked. Plant debris was raked and removed from the site. A preemergent herbicide, Diphenamid (Enide 90W), was applied over the germinating seedlings. The herbicide was applied at 2.6 oz active ingredient/1,000 ft^2 (6.6 lb/acre). To prevent any detrimental effect on wildflower establishment, the Diphenamid was applied when the wildflower seedlings had an average of three true leaves. This treatment is the most expensive in terms of labor, equipment hours, and materials. The tilling was performed on May 31, 1989, the seeding was done on June 29, 1989, and the herbicide was applied on July 28, 1989.

Postemergent Herbicide Treatment

Half of each plot (subplot) was treated with the postemergent herbicide Fluazifop-butyl (Fusilade 4E), which is known to be monocot-specific. The other half of each plot was left untreated. This was done to determine the effect of reducing invasive grasses on the establishment of the desired wildflowers. Wildflower meadows often contain grasses, but many times turf-forming species are overly aggressive in the meadow (*13*).

Fluazifop-Butyl (Fusilade 4E) The Fusilade was applied at the rate of .02 oz active ingredient/1,000 ft^2 (0.5 lb/acre). The Fusilade was applied on August 4, 1989.

No Fusilade Herbicide was not applied to the adjacent subplot.

Treatment Position

Each one of 18 combinations of treatments within each block was numbered (Figure 2). These treatments were in a random position in each of the four blocks (Figure 3).

Data Collection

First Year (1989) The chronology of treatment dates was important to the collection of data in the first year, because treatments were performed concurrently with data collection. When the July data were collected, the study site had not been treated with the postemergent herbicide, Fluazifop-butyl (Fusilade), or the preemergent herbicide, Diphenamid (Enide). Quadrants 1 m^2 were sampled on July 11 and 18 and on

1: TILLED & NO FERTILIZER & NO FUSILADE	1A: TILLED & NO FERTILIZER & FUSILADE
2: TILLED & 10-10-10 & NO FUSILADE	2A: TILLED & 10-10-10 & FUSILADE
3: TILLED & UREA & NO FUSILADE	3A: TILLED & UREA & FUSILADE
4: TILLED/HERBICIDE & NO FERTILIZER & NO FUSILADE	4A: TILLED/HERBICIDE & NO FERTILIZER & FUSILADE
5: TILLED/HERBICIDE & 10-10-10 & NO FUSILADE	5A: TILLED/HERBICIDE & 10-10-10 & FUSILADE
6: TILLED/HERBICIDE & UREA & NO FUSILADE	6A: TILLED/HERBICIDE & UREA & FUSILADE
7: NO TILL & NO FERTILIZER & NO FUSILADE	7A: NO TILL & NO FERTILIZER & FUSILADE
8: NO TILL & 10-10-10 & NO FUSILADE	8A: NO TILL & 10-10-10 & FUSILADE
9: NO TILL & UREA & NO FUSILADE	9A: NO TILL & UREA & FUSILADE

FIGURE 2 Numbering of treatment combinations.

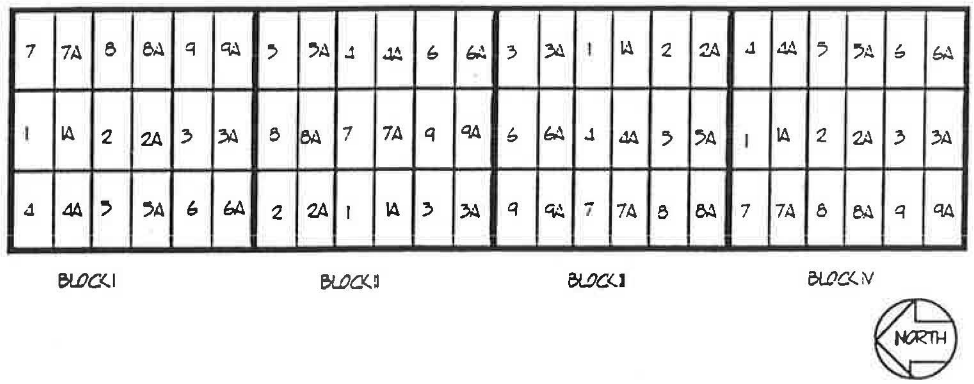


FIGURE 3 Arrangement of treatment subplots in study area.

August 1, 22, 23, and 24. Information about densities and maximum height of wildflower seedlings, broadleaved weeds, and grasses present were recorded. Wildflowers were considered to be those plants that occurred in the seed mix used by the Massachusetts Department of Public Works in 1989 (see Table 1). Grass weeds were considered to be monocots including opportunistic grasses, sedges, and rushes. Broadleaved weeds were considered to be dicot plants that were not part of the wildflower seed mix.

Second Year (1990) Between the first and second years of data collection the site was not mowed. No new treatments to the study area were performed during the second year. Data measurements were recorded the last weeks of June, July, and August. Data from a random sampling of a 1-m^2 quadrant within each subplot were recorded for each month (Figure 4). For each of the species of wildflowers that were seeded, the number present in each quadrant was recorded. The total number of grasses and broadleaved weeds present, the type of broadleaved weeds present, and the maximum height of wildflower plants, broadleaved weeds, and grasses were also recorded.

RESULTS

The results from the first year of data collection have been reported (Barker and Ahern, unpublished data). The data from the second year of collection were averaged across the replicates for each month. The effects of fertilizer, Fusilade, and tillage are summarized.

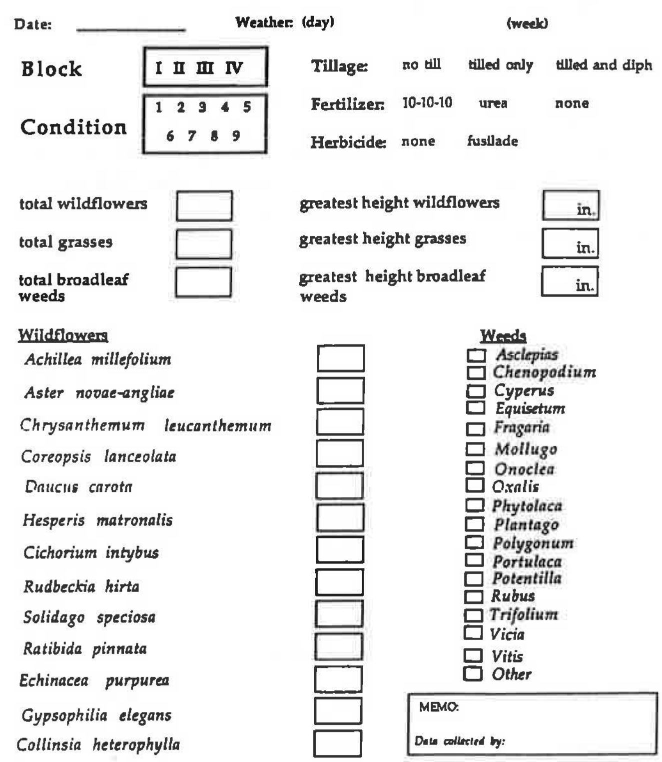
Fertilizer Effects

There was no significant difference between wildflower populations in untreated quadrants and those in quadrants treated with urea or 10-10-10 fertilizer (Table 2). The number of grasses and broadleaved weeds in the quadrants did not demonstrate an increase or decline with respect to fertilizer treatment (Tables 3 and 4). This finding supports the recommendations often made by the wildflower seed industry that fertilizers are not necessary in new wildflower establishment.

Fusilade Effects

There was a significant increase in the wildflower plants in the subplots treated with Fusilade (Table 2). The subplots treated with Fusilade had far fewer grasses (Table 3). This was particularly notable in August, when the number of grasses in the subplots not treated with Fusilade reached the highest densities recorded over this study.

This finding is important because highway wildflower meadows are often planted in a matrix of turfgrasses. These turfgrasses have been observed to be invasive in Massachusetts wildflower meadows, particularly during the establishment period: the first 2 years after planting (Ahern, unpublished data). Fusilade has been shown to control invasive turf-forming


Date: ________ Weather: (day) (week)

Block I II III IV
Condition 1 2 3 4 5 6 7 8 9

Tillage: no till tilled only tilled and diph
Fertilizer: 10-10-10 urea none
Herbicide: none fusilade

total wildflowers
total grasses
total broadleaf weeds

greatest height wildflowers in.
greatest height grasses in.
greatest height broadleaf weeds in.

Wildflowers
Achillea millefolium
Aster novae-angliae
Chrysanthemum leucanthemum
Coreopsis lanceolata
Daucus carota
Hesperis matronalis
Cichorium intybus
Rudbeckia hirta
Solidago speciosa
Ratibida pinnata
Echinacea purpurea
Gypsophilia elegans
Collinsia heterophylla

Weeds
Asclepias
Chenopodium
Cyperus
Equisetum
Fragaria
Mollugo
Onoclea
Oxalis
Phytolaca
Plantago
Polygonum
Portulaca
Potentilla
Rubus
Trifolium
Vicia
Vitis
Other

MEMO:
Data collected by:

FIGURE 4 Data collection format.

TABLE 2 WILDFLOWER POPULATION DENSITIES PER SQUARE METER AVERAGED ACROSS JUNE, JULY, AND AUGUST 1990

NO FUSILADE	NO FERT	10-10-10	UREA	AVERAGE
TILL	90	66	59	72
TILL/HERB	98	111	66	92
NO TILL	56	87	109	84
AVERAGE	81	88	78	82
FUSILADE				
TILL	95	87	80	87
TILL/HERB	99	76	73	83
NO TILL	94	99	147	113
AVERAGE	96	87	100	94

STATISTICS (LSD 0.05)

FUSILADE = 6
FERTILIZERS = NS
TILLAGE = NS
ALL INTERACTIONS = NS

grasses, but it will also reduce the noninvasive grasses that are recommended for wildflower meadows.

Tillage Effects

Wildflower performance was less vigorous in the no-till treatment (Table 2). The tilled-only treatment and the tilled-followed-by-preemergent-herbicide treatment showed similar numbers of wildflowers present. In the no-till treatment there were many more grasses in subplots that were and that were not treated with Fusilade (Table 3). There were fewer grasses in the subplots that were tilled then treated with preemergent herbicide, particularly when it interacted with the postemergent herbicide Fusilade.

TABLE 3 GRASS POPULATION DENSITIES PER SQUARE METER AVERAGED ACROSS JUNE, JULY, AND AUGUST 1990

NO FUSILADE	NO FERT	10-10-10	UREA	AVERAGE
TILL	114	124	115	118
TILL/HERB	65	70	63	65
NO TILL	148	200	92	147
AVERAGE	109	131	90	110
FUSILADE				
TILL	27	23	33	28
TILL/HERB	17	20	21	19
NO TILL	53	26	40	40
AVERAGE	32	23	31	29

STATISTICS (LSD 0.05)

FUSILADE (H) = 32
FERTILIZERS (F) = NS
TILLAGE = (T) = 29

H X F = 26
H X T = 30
F X T = 26
H X F X T = 37

TABLE 4 BROADLEAVED WEED POPULATION DENSITIES PER SQUARE METER AVERAGED ACROSS JUNE, JULY, AND AUGUST 1990

NO FUSILADE	NO FERT	10-10-10	UREA	AVERAGE
TILL	96	87	89	89
TILL/HERB	110	75	83	89
NO TILL	58	27	44	43
AVERAGE	88	63	71	74
FUSILADE				
TILL	121	122	99	114
TILL/HERB	113	108	78	100
NO TILL	93	62	66	74
AVERAGE	109	97	81	96

STATISTICS (LSD 0.05)

FUSILADE ($p \leq 0.10$) = 20
FERTILIZERS = NS
TILLAGE = 15
ALL INTERACTIONS = NS

MANAGEMENT

Once a wildflower meadow has been successfully established, management is relatively straightforward. Most species in the meadows are annuals or perennials with life expectancies of one to several years. They all can reproduce through vegetative growth or seed germination. The meadow can thus be seen as a constantly changing mosaic of herbaceous forbs and grasses. If a highway meadow in New England is not maintained, however, it is likely to succeed to an old field or young forest in 5 to 10 years. To prevent this natural tendency, interventions are needed to stabilize the meadow community and arrest succession. There are three principal ways of achieving this stabilization: mowing, grazing, and burning. Only mowing is considered appropriate in most highway applications, but grazing and burning are worth consideration (*14*).

Mowing selectively favors herbaceous plants over woody species, because woody plants invest more in producing aboveground biomass that is easily removed by mowing. The timing of mowing can be controlled to determine which species will persist in a meadow (*15*). Mowing plants just before the flowers mature will often exhaust their stored energy and prevent them from setting seed. This technique can be used to control invasive species such as Canadian goldenrod (*Solidago canadensis*). The management objective in highway meadow maintenance is usually achieved by an annual mowing. The optimal time to mow is late fall after the seeds have matured; delaying until early spring produces the same control but provides a standing dormant cover for visual interest throughout winter.

Managing the edges of highway meadows presents challenges of a different kind. The matrix of turfgrass that typically surrounds meadows is usually mowed six times a year. Over the course of the growing season, an unnaturally abrupt mowed edge is produced that often dominates the view of the meadow from the highway (Figure 5). In Massachusetts an alternative

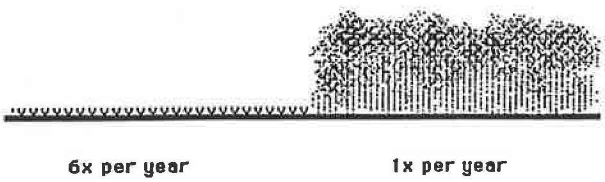


FIGURE 5 Present mowing scheme.

stepped mowing scheme has been designed to resolve this problem. Under this method, each time the turf is cut the mow-line is sequentially moved away from the meadow, producing a stepped or graded edge by the end of the season (Figure 6). This method has been found to be an effective way to allow existing wildflower plantings to increase incrementally in size without any additional cost or effort. It is particularly suited to median applications where wildflower meadows are highly visible from both directions and where mowing is often more dangerous (Figure 7).

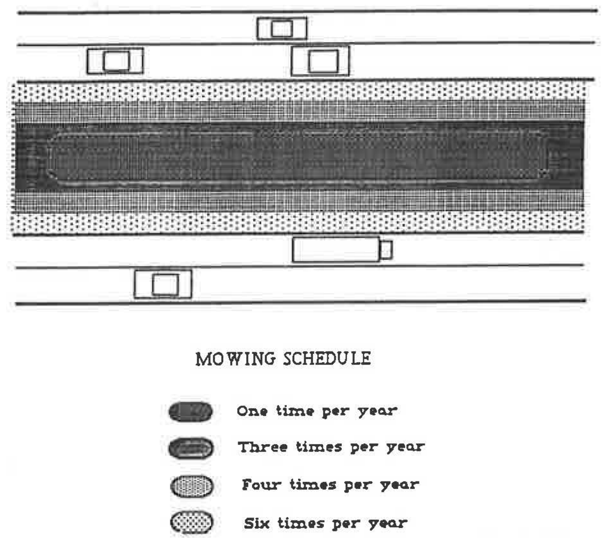


FIGURE 7 Alternative mowing scheme for median wildflower meadow.

CONCLUSIONS

Preparation of the soil by tilling permitted better performance and seedling establishment of wildflower plants than the treatments in which tilling was not used. This enhanced performance of wildflowers in tilled plots was due in part to the reduced number of grasses in these plots. Wildflower growth and establishment was more successful when the competition for light, space, water, and nutrients from invasive grasses was reduced. This competition is further evidenced by the comparison between the subplots that were treated with Fusilade and the subplots that were not. The Fusilade subplots showed a significant decrease in the number of grasses and an increase in the number of wildflowers across all tillage treatments. Wildflower establishment was most successful in the treatments, tilled and Fusilade-treated, in which the numbers of grasses were reduced.

Fertilization did not appear to improve the growth of wildflowers, grasses, or broadleaved weeds. This is not surprising, because the fertilizer treatments had been applied more than a year earlier and their effect had probably diminished. However, it appears that the plots that were not fertilized had more wildflowers. Weeds are opportunistic species that can use sudden influxes of nutrients, water, and light. The application of fertilizer to the meadow during the first year was more effective in aiding the establishment of broadleaved weeds and invasive grasses.

The presence of grasses was an important factor in the attractiveness of the wildflower site. In June, when the oxeye daisies (*Chrysanthemum leucanthemum*) were in full bloom, the grasses were shorter than the wildflowers and did not interfere with their display. By August the grasses had reached 3 to 4 ft, thus obscuring the bloom of the black-eyed Susans (*Rudbeckia hirta*) and the purple coneflowers (*Echinacea purpurea*). It appears that it is necessary to control the growth of opportunistic grasses or to encourage shorter clump-forming native grasses to produce an attractive wildflower site. Using a postemergent herbicide such as Fusilade and preparing the site by tilling are effective means for controlling grasses.

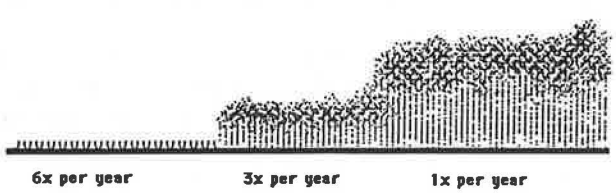


FIGURE 6 Alternative mowing scheme.

These conclusions are useful for modifying future wildflower planting and establishment procedures used by the Massachusetts Department of Public Works. Starting with the plantings done in 1990, the seed mix was expanded to include four species of native grasses in the interest of establishing a more stable herbaceous plant community. As this research has documented, the primary obstacle to successful wildflower establishment is the spread of opportunistic grasses and broadleaved weeds.

The stepped-edge mowing method maintains a more attractive visible edge and can be applied to allow meadows to expand and create a more attractive visible edge. More recent research initiated in 1990 involved establishing no-mow zones to evaluate the potential for native herbaceous vegetation to become reestablished in existing turfed areas without any cultivation or supplemental planting. These natural revegetation areas are located in highly visible locations in public rights-of-way and marked with large signs to provoke public response—which has been overwhelmingly positive. The edges of mowed areas were modified to complement the topography and visual context of the highway. The success of this program is causing fundamental landscape management policies in highway rights-of-way to be reconsidered in hopes of increasing the benefits of wildflower meadows.

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