DEPARTMENT OF TRANSPORTATION

Best Management Practices for Establishment of Salt-Tolerant Grasses on Roadsides

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July 2017

Research Project
Final Report 2017-31

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Roadsides are a unique growing environment for turfgrasses and can be a challenge to establish and maintain. The University of Minnesota turfgrass research program has been investigating low-input turfgrasses that are better adapted for roadsides and our previous research project identified a new mixture for use on Minnesota roadsides that was able to perform adequately under pressure form road salt (MNST-12). As this new mixture was used, it became apparent that more research was needed to better understand how to improve establishment and performance by adjusting typical roadside maintenance practices. In this project, we developed a series of experiments addressing three areas: (1) pre-establishment soil amendments; (2) planting date; and (3) watering during establishment. We found that soil amendments had little effect on roadside turf performance. We found that seeding of low-input roadside mixtures such as MNST-12 should be performed in late summer, while sodding can be done throughout the growing season, assuming that soil moisture is properly maintained. Finally, based on our findings, we recommend that current MnDOT specifications for watering of new roadside turf installations should be changed, especially for mixtures with high proportions of fine fescue.

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BEST MANAGEMENT PRACTICES FOR ESTABLISHMENT OF SALT-TOLERANT GRASSES ON ROADSIDES

FINAL REPORT

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LIST OF ABBREVIATIONS

EC – Electrical Conductivity

ET - Evapotranspiration

DAP – Days after Planting

KBG – Kentucky bluegrass

MnDOT – Minnesota Department of Transportation

MNST-12 – Fine fescue/Kentucky bluegrass mixture seed or sod

TDR – TDR Probe (Soil Moisture Meter)

EXECUTIVE SUMMARY

Turfed roadsides make up a significant portion of the urban and rural landscape. Roadsides are a unique growing environment for turfgrasses and can be a challenge to establish and maintain. The University of Minnesota turfgrass research program has been investigating low-input turfgrasses that are better adapted for roadsides and our previous research project identified a new mixture for use on Minnesota roadsides that was able to perform adequately under pressure from road salt. As this new mixture (MNST-12) was used, it became apparent that more research was needed to better understand how to improve establishment and performance by adjusting typical roadside maintenance practices. Therefore, in this project, we first assessed a number of roadsides to determine why they might be failing. Then, using information gleaned from these observations, we developed a series of experiments addressing three areas: (1) pre-establishment soil amendments; (2) planting date; and (3) watering during establishment.

Surprisingly, soil amendment treatments had little effect on turfgrass quality, regardless of whether the plots were seeded or sodded. Due to this result, and the high cost and logistical complications of amending roadside soils, our recommendation is that soil amendments beyond starter fertilizer are not necessary.

Planting date significantly affected turfgrass quality for both seeded and sodded plots on most rating dates. Sodded plots typically had higher turfgrass quality within each planting date, and were more consistent across planting dates. Based on our results, seeding is the preferred approach to ensure a successful establishment; however, seeding should be limited to August or September and avoided during the heat of the summer. If spring seeding is necessary, a pre-emergent herbicide that is labeled for use on cool-season turfgrasses is recommended. In situations when seeding is not the best option (sloped areas; projects that need to have vegetative cover quickly; etc.), sodding with MNST-12 can be attempted from May to November provided access to irrigation is available.

Watering according to MnDOT specifications resulted in reduced turfgrass coverage of MNST-12 sod compared to Kentucky bluegrass sod 60 days after planting, indicating that current specifications may need to be adjusted based on sod type chosen for installation. Current MnDOT standard specifications for irrigating sod resulted in lower turfgrass coverage and quality compared to those based on replacing 60% or 100% evapotranspiration (ET). Watering to replace 60% ET had similar turf cover and quality to replace 100% ET for both Kentucky bluegrass and MNST-12 sod, suggesting that a change in specifications can improve turf performance and save water. Further research is needed to determine the feasibility of contractors to irrigate sod based on ET rates.

In this report, we provide specific recommendations to hasten establishment and improve management of turfed roadside locations. This research highlights best management practices towards limiting installation failures and reducing maintenance inputs for future installations, providing both an economic and environmental positive impact on the Minnesota green industry.

CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

This report provides an overview of research projects that have been conducted since 2012 addressing the problem of establishing salt-tolerant turfgrass mixtures on Minnesota roadsides. This report establishes the need for this research, describes the methodology and results, discusses the significance of those results, and finally explains the conclusions and implications of this research.

Turfed roadsides are a significant portion of the urban and rural landscapes. In fact, they comprise more than 24,000 acres in Minnesota (*MNDOT Maintenance Manual* 2016). Roadsides present a unique growing environment for turfgrasses because they can have an intersection of numerous stresses such as salt, heat, drought, surface disruption, traffic, diseases, insects, and weeds. Salt used for de-icing roads in winter months is one stress in particular that can limit the adoption of turf in important areas. Historically, Kentucky bluegrass has been the most popular turfgrass to plant as either a sod or seed on roadsides. Unfortunately, its poor salt tolerance has resulted in numerous failed establishments (Figure 1.1). As a result, the University of Minnesota turfgrass research program has been investigating low-input turfgrasses for roadsides that have improved salt tolerance. Recent research has identified improved mixtures such as MNST-12 that contain low-input fine fescues that are well adapted for Minnesota roadsides.

1.2 JUSTIFICATION

We aimed to identify best management practices that can be used during sod and seed establishment of fine fescue on roadsides. We investigated how water should be applied to these new installations (see Chapter 5). We also conducted studies addressing other important factors: (1) the use of soil amendments at establishment, and (2) the effect of the seeding or sodding date. All of these management practices are prescribed (or not prescribed) in the MnDOT specifications; therefore, generating replicated, unbiased data that can inform future MnDOT specifications is a valuable outcome of this work. These best management practices will ultimately result in improved establishment, reduced establishment failures, and lower input requirements to maintain.

Soil amendments have demonstrated effectiveness in enhancing turfgrass establishment from seed or sod (Linde and Hepner, 2005). Roadsides are an environment that might benefit from the use of soil amendments because they are often depleted of important nutrients. More research is needed to determine whether soil amendments could improve the establishment of low-input turfgrasses for roadsides.

One way in particular to ensure a successful seed or sod establishment is planting the turf at the optimum time of year. The time of year can play an extremely important role in the success of an establishment. Natural rainfall, temperature fluctuations, and various pest incidences are all factors that affect turf establishment and are seasonally dependent. Further research is needed to identify optimum planting timings for seed and sod of traditional and newer mixes of turfgrass species and cultivars.

Access to water via either natural rainfall events or supplemental irrigation is probably the most important factor in a successful turf roadside establishment. As a result, irrigation is a significant portion of establishment costs on roadsides, primarily because roadsides have limited access to water, which results in elevated costs for transporting and applying water that is necessary for establishment. Based on of input from contractors, a 2.5-acre roadside in MN costs $20,000 to irrigate to MNDOT recommendations for 30 days (Matt Cavanaugh, personal communication). Consequently, identifying optimum management strategies for low-input turfgrasses on roadsides is essential. Newer improved seed or sod mixes like MNST-12 may have differing requirements for successful establishment compared to other species or cultivars that contractors and other turf professionals are more familiar with. As a result, more research is needed to identify best management practices for successful establishment of low-input roadside turfgrasses.

Specific approaches toward identifying best management practices pursued in this research include the following:

- Determine why installations of MNST-12 sod and seed were failing.
- Identify best management practices for establishing and maintaining low-input turfgrasses for roadsides through three sub objectives:
    - Assess the use of soil amendments for establishment of roadside grasses.
    - Determine the optimum seeding and sodding date that provides the highest amount of winter survival for salt-tolerant turfgrasses along Minnesota roadsides.
    - Determine optimum watering regime for both Kentucky bluegrass and MNST-12 sod.

Figure 1.1. Photo of failed sod establishment of Kentucky bluegrass adjacent to a road entering Minneapolis.

CHAPTER 2: ASSESSMENT OF RECENTLY ESTABLISHED ROADSIDE TURFGRASS AREAS SUBJECTED TO DEICING AGENTS

2.1 INTRODUCTION

Previous research resulted in the use of salt-tolerant sod and seed mixtures on new roadside turf installations in Minnesota; however, several of these sites either failed to establish or performed poorly. In order to determine why these sites failed, and to inform future research, we assessed several roadsides. Site assessments began in July 2013 and continued through 2014. In total, 16 of these sites are included in this report (Table 2.1). Of the sites evaluated, 2 sites were seeded, 13 were sodded, and 1 site had yet to be established. Also, a site in Maple Grove was initially established with seed in June 2013, but due to a severe rain event shortly after seeding and poor germination, had to be entirely redone with sod in September 2013.

2.2 MATERIALS AND METHODS

The goal of the initial phase of this project was to gain information on factors such as soil characteristics, pre/post management effects on plant survivability, and overall plant health at each site. Therefore, the assessment protocol was designed to select measurements and observations that encompassed each of these characteristics. The Minnesota Department of Transportation, local landscape contractors, sod producers, and an online weather site provided background information on each site. Information included:

- Date and time of installation
- Sod or seed used; rate if seeded
- Weather at time of installation and following month (temperature and precipitation being key factors)
- Post-installation irrigation regime
- Post-mowing regime

Measurements at each site were taken at 75 random points within 1000-linear feet. The seventy-five points were then broken down into three subgroups of twenty-five and assigned a number 1-3 representing a zone within the boulevard section (1-edge of curb, 2-middle of boulevard, 3-edge of sidewalk) (Figure 2.1) At each point the following measurements were made:

- Ground cover (percent cover determined by a grid count)
- Soil salinity (EC), temperature and moisture (using Time Domain Reflectometry (TDR))
- Surface hardness (using a CLEGG)
- Depth of sod/soil to top of curb

Ground cover was determined using a 2’ x 2’ grid with 16 quadrants. Within each quadrant, ground cover was assigned a number: 1-Live turf, 2-Dead turf, 3-Weeds, or 4-Bare soil. Soil salinity and soil temperature were measured using a FieldScout Direct EC meter (Spectrum Technologies, Aurora, IL) with three readings taken at each point. Soil moisture was measured using a FieldScout TDR 300 (Spectrum Technologies, Aurora, IL) with three readings taken at each point. Surface hardness was determined using a CLEGG impact soil tester (Lafayette Instruments, Lafayette, IN) with three readings taken at each point reported as a CLEGG impact value (CIV); the higher the number the harder the surface. A total of ten soil samples per site were also taken. One point within each 100-ft section of the entire length was randomly selected and ten individual samples were taken at each point to a depth of five inches with the thatch removed and pooled together for analysis. Soil samples were submitted for routine soil analysis to the Research Analytical Laboratory at the University of Minnesota. Available phosphorus was tested by the Bray method if the pH was below 7.4, but the majority of samples were tested by the Olsen method when pH was above 7.4. Organic matter was determined as a percent of loss of ignition. In addition to the above measurements, photographs and descriptive notes of each site were also taken.

2.3 RESULTS AND DISCUSSION

In general, the established sites exhibited limited consistent pure live turfgrass cover regardless if established with seed or sod (Table 2). Zone two generally had the most live turf cover and zone one had the least. Weeds accounted for a majority of ground cover (Figure 2.2); however, many sites had large areas of bare ground. From communications with homeowners at various locations, a major factor influencing site success may be date of establishment and post-establishment irrigation. For example, at the Bass Lake Road site, the latter 300-ft section had approximately 100% turfgrass cover across all zones. This area was adjacent to a residential housing unit and was receiving supplemental irrigation. Of the soil characteristics, soil moisture was the most variable across all sites (Table 2.3). In addition, variation in soil salinity and surface firmness do not appear to be related to success of the turfgrass at each site. Soil tests indicate that a majority of sites had acceptable levels of phosphorus and potassium and the pH was neutral to slightly alkaline, acceptable for turfgrass growth (Table 2.4). Percent soil organic matter was generally low across all sites.

Based on these assessments and conversations with stakeholders, we decided to proceed with three research studies for the remainder of the project period that address (1) the use of soil amendments during establishments; (2) timing of seed and sod installations; and (3) post-installation watering regimes.

Table 2.1. Site assessment locations.

Location	Seed/Sod	Year Established	Date Assessed
East Lindstrom- CH 8- sodded	Sod	2012	25 July 2013
Richfield- Diagonal Blvd	Sod	2010	29 Aug. 2013
St. Paul- Maryland & SH 35	Sod	2012	6 Sep. 2013
Carver- Levi Griffin Rd	Sod	2012 (redone 2013)	10 Sep. 2013
Coon Rapids- CH 14	Sod	2012	12 Sep. 2013
Maple Grove- 85th Ave N	Sod (after seed failed)	2013	17 Sep. 2014
West Lindstrom- CH 8- seeded	Seed	2013	19 Sep. 2014
St. Paul- English & 36	Pre-sod	2013	24 Sep. 2014
Maple Grove- Bass Lake Road	Sod	2012	26 Sep. 2013
Minnetonka- Gatewood Dr	Sod	2012	10 Oct. 2013
Rogers- TH 101	Sod	2011	17 Oct. 2013
Edina- Washington Ave & 494	Sod	2013	24 Oct. 2014
Edina- Viking Dr & 494	Sod	2012	24 Oct. 2013
Grand Rapids- SH 169	Sod	2010	28 Oct. 2013
Duluth- 26th Ave & London Rd	Sod	2010	28 Oct. 2013
Garrison- Concourse Wayside Pk.[z]	Sod	2013	28 Oct. 2014

[z]No data collected due to frost.

Table 2.2 Percent ground cover for assessed sites.

Zone	Living turf	Dead turf	Weeds	Bare soil
	%	%	%	%
Coon Rapids-CH 14				
1	3.5	6.8	22.5	67.3
2	27.3	48.8	0.8	23.3
3	26.5	73.5	0.0	0.0
Edina-Bass Lake Rd				
1	13.5	2.3	44.0	40.3
2	74.5	4.3	11.5	9.8
3	57.5	6. 0	20.0	16.5
Maple Grove-85th Ave				
1	3.5	0.3	59.0	37.3
2	3.5	0.0	53.8	42.8
3	2.0	0.0	64.5	33.3
St. Paul-Maryland x 35E				
1	33.0	45.3	13.0	8.8
2	41.5	48.5	4.3	5.8
3	50.0	41.5	4.3	4.3
Grand Rapids-SH 169				
1	7.5	1.0	90.3	1.3
2	16.0	3.3	75.0	5.8
3	16.0	6.8	75.0	2.3
Carver- Levi Griffin Rd.				
1	54.3	34.8	9.3	1.8
2	45.8	41.3	9.3	3.8
3	49.0	34.5	13.8	2.8
Minnetonka-Gatewood Dr.				
1	54.5	44.5	0.0	1.0
2	75.5	24.5	0.0	0.0
3	74.3	25.8	0.0	0.0
Lindstrom East- SH 8				
1	22.3	1.3	30.0	46.5
2	35.5	4.3	24.5	35.8
3	38.8	9.0	23.0	29.3
Lindstrom West- SH 8				
1	1.0	0.0	8.3	90.6
2	1.6	0.0	9.4	89.1
3	0.0	0.0	8.8	91.3

Table 2.2 (cont.) Percent ground cover for assessed sites.

Zone	Living turf	Dead turf	Weeds	Bare soil
	%	%	%	%
Richfield- Diagonal Blvd				
1	0.0	0.0	61.3	38.8
2	0.0	0.0	66.9	33.1
3	0.0	0.0	66.7	33.3
Rogers- SH 101				
1	0.0	0.0	93.5	6.5
2	0.0	0.0	99.0	1.0
3	4.8	1.3	92.0	2.0
Edina- Viking Dr.				
1	34.0	54.0	1.5	10.5
2	39.0	43.3	3.5	14.3
3	36.8	56.3	2.3	4.8
Edina- Washington Ave.				
1	53.5	43.3	0.8	2.5
2	55.3	41.8	0.8	2.3
3	41.3	51.0	2.0	5.8
Duluth- London Rd.				
1	36.3	38.0	2.1	3.6
2	49.0	36.2	1.8	13.0
3	45.2	40.5	2.8	11.5

Table 2.3. Soil characteristics.

Zone	Sod depth	Soil Moisture	Soil Salinity	Soil Temperature	Surface Firmness
	in.	VWC	mS/cm	°F	CIV
Coon Rapids-CH 14					
1	0.59	4.0	0.0009	75.9	21.3
2	0.85	4.7	0.0015	76.0	19.4
3	0.84	7.3	0.0344	75.7	20.8
Edina-Bass Lake Rd.					
1	0.38	57.6	1.103	65.8	12.5
2	0.28	60.4	1.198	65.7	11.5
3	0.22	54.4	0.829	66.4	12.4
Maple grove-85th Ave.					
1	0.71	31.2	0.439	60.0	18.9
2	0.76	27.3	0.393	60.6	18.6
3	0.98	30.9	0.498	60.8	19.4
St. Paul-Maryland x 35E					
1	0.42	7.9	0.059	79.5	16.9
2	0.26	8.4	0.089	79.7	16.7
3	0.12	8.9	0.072	79.4	14.9
Grand Rapids- SH 169					
1	0.52	12.0	0.809	47.8	20.9
2	0.34	11.3	0.841	47.5	21.1
3	0.43	12.3	0.821	46.2	21.0
Carver- Levi Griffin Rd.					
1	0.76	19.6	0.392	80.4	20.5
2	0.72	18.6	0.512	79.3	51.6
3	0.84	15.5	0.431	80.2	19.3
Saint Paul- English St.					
1	0.67	16.1	0.312	76.7	19.3
2	0.46	14.7	0.326	75.2	16.7
3	0.45	16.0	0.344	78.0	17.7
Minnetonka- Gatewood Dr.					
1	0.38	14.1	0.854	72.0	10.3
2	0.46	16.0	0.973	72.3	10.2
3	0.29	16.4	0.816	71.9	9.9
Lindstrom East- SH 8					
1	0.36	46.0	0.622	75.2	10.1
2	0.21	41.4	0.672	74.7	9.9
3	0.27	36.6	0.485	76.3	10.6

Table 2.3 (cont.) Soil characteristics

Zone	Sod depth	Soil Moisture	Soil Salinity	Soil Temperature	Surface Firmness
Lindstrom West- SH 8					
1	1.33	40.4	0.497	70.5	20.5
2	1.00	47.6	0.883	70.7	18.6
3	1.00	46.8	0.763	70.8	19.3
Richfield- Diagonal Blvd.					
1	0.45	13.1	0.153	78.8	21.2
2	0.51	11.7	0.134	79.4	21.8
3	0.48	12.5	0.124	79.1	21.7
Rogers- CH 101					
1	0.20	21.4	0.859	72.5	20.9
2	0.32	22.6	0.899	71.9	21.3
3	0.64	22.3	0.952	72.2	20.6
Edina- Viking Dr.					
1	0.56	16.4	0.550	69.0	14.4
2	0.64	13.8	0.523	69.0	14.5
3	0.48	15.1	0.548	68.7	14.0
Edina- Washington Ave.					
1	0.36	14.6	0.839	67.6	16.7
2	0.58	14.9	0.794	67.3	16.7
3	0.64	14.8	0.944	67.5	17.1
Duluth- London Rd.					
1	0.46	13.5	0.823	47.1	20.6
2	0.66	12.0	0.888	46.9	20.3
3	0.52	12.2	0.836	47.7	20.8

Table 2.4. Soil test results.

Zone	Phosphorus[1,2]	Potassium[1]	Organic Matter	Soil pH
	mg/kg	mg/kg	% LOI	
Coon Rapids-CH 14				
1	13.8	52.8	3.1	7.9
2	13.0	67.3	3.1	7.9
3	17.8	69.0	3.6	7.6
Edina-Bass Lake Rd				
1	34.7	170.0	2.7	7.7
2	27.5	165.3	2.3	7.7
3	29.0	160.0	2.6	7.8
Maple grove-85th Ave.				
1	20.8	80.3	2.1	8.0
2	18.3	80.3	2.2	8.3
3	15.5	78.5	2.5	8.1
St. Paul-Maryland x 35 E				
1	34.3	88.5	5.8	7.0
2	19.3	64.8	6.3	7.1
3	31.0	69.0	5.2	7.0
Grand Rapids- SH 169				
1	4.0	40.3	3.2	7.4
2	24.7	61.7	3.6	7.2
3	4.0	63.3	2.5	7.4
Carver- Levi Griffin Rd.				
1	28.3	191.0	3.9	7.4
2	29.0	147.3	4.1	7.5
3	19.5	142.0	3.7	7.4
Saint Paul- English St.				
1	17.5	77.5	2.7	7.5
2	17.5	84.0	2.6	7.6
3	23.5	93.5	2.5	8.2
Minnetonka- Gatewood Dr				
1	82.3	787.0	6.9	8.1
2	63.3	635.0	5.8	7.8
3	61.3	714.7	7.0	7.8
Lindstrom West- SH 8				
1	37.5	163.0	1.8	7.8
2	35.0	161.0	2.4	7.6
3	28.0	123.0	1.3	7.8

[1] Represents soil available nutrients

[2] Bray extraction method used on samples with pH lower than 7.4 and Olsen extraction method used on samples with pH at or above 7.4

Table 2.4 (cont.) Soil test results

Zone	Phosphorus[1,2] mg/kg	Potassium[1] mg/kg	Organic Matter % LOI	Soil pH
Richfield- Diagonal Blvd.				
1	48.0	122.6	2.6	7.2
2	50.5	106.0	2.3	7.2
3	23.0	94.3	4.4	7.2
Rogers- CH 101				
1	21.4	100.5	2.8	8.3
2	24.0	117.7	3.1	8.1
3	16.7	90.0	2.7	8.1
Duluth- London Rd.				
1	12.0	98.3	3.3	7.8
2	8.7	89.0	2.3	8.1
3	10.3	96.0	2.7	8.1

[1] Represents soil available nutrients
[2] Bray extraction method used on samples with pH lower than 7.4 and Olsen extraction method used on samples with pH at or above 7.4

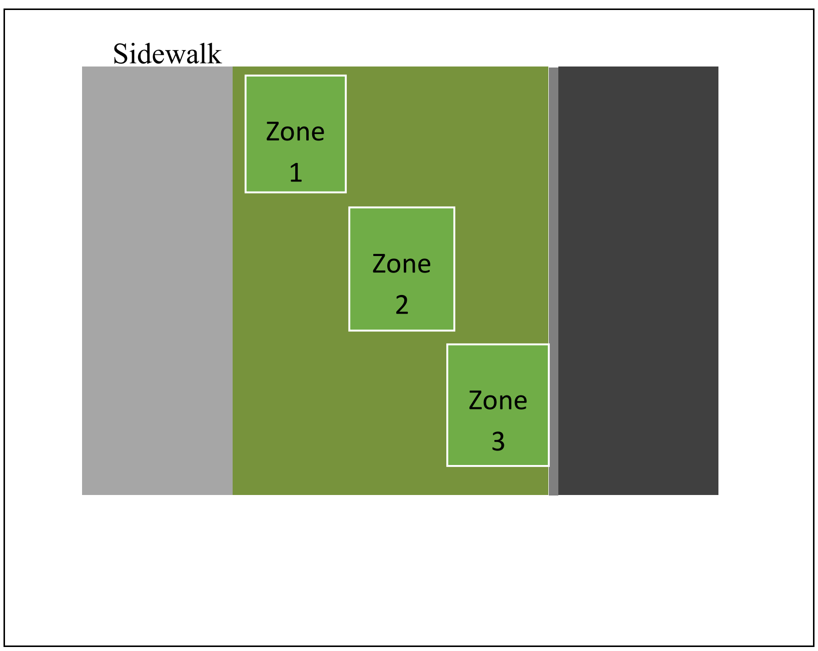

Figure 2.1. Diagram portraying layout of for site evaluation.

Figure 2.2. Image of a failed establishment that was evaluated in Stillwater, MN.

CHAPTER 3: EVALUATION OF SOIL AMENDMENTS TO INCREASE SUCCESS OF SEEDED AND SODDED MIXTURES OF TURFGRASSES FOR ROADSIDES

3.1 INTRODUCTION

Certain soil amendments have demonstrated the ability to hasten establishment in soils of varying quality (Linde and Hepner, 2005); this has also been reported as being true on roadsides in Rhode Island (Brown and Gorres, 2011) amended with either processed biosolids or compost. Roadsides are often disturbed or depleted soils that may benefit from the use of soil amendments during turf establishment. Some soil amendments may hasten establishment of turfgrasses from sod or seed, but little is known regarding the use of amendments in roadsides. Therefore, the objective of this experiment was to assess the use of 6 soil amendments for establishment of roadside both seeded and sodded turfgrasses.

3.2 MATERIALS AND METHODS

This experiment was conducted in two locations in both 2015 and 2016: St. Paul and Blaine, MN. Plots at the St. Paul location were on the north side of Larpenteur Ave. between Gortner Ave. and Larpenteur Ave. In Blaine, plots were located on the east side of Davenport St. NE between 105th Ave NE and 109th Ave. NE St. Paul and Blaine plots were established on August 24th and 25th 2015, respectively. In 2016, St. Paul and Blaine plots were established on August 31st and September 1st, respectively. The experiments were repeated immediately adjacent to the 2015 trial locations for both Blaine and St. Paul. For both locations, sites were prepped and maintained identically. In order to evaluate the effect of amendment treatment on establishment, separate but adjacent experimental areas were designated for seed and for sod. The plots at each location were 6 ft. by 6 ft. and were arranged in a randomized complete block design that ran parallel with the road using 4 replications.

Six amendment treatments and a single untreated control were used:

Treatment 1: Native soil (control)

Treatment 2. Native soil plus one-time synthetic slow-release fertilizer: The fertilizer used was a 22-5-10 Type 3 as defined by the MnDOT specifications. A Type 3 is as follows: (1) Specifically processed to release nitrogen at a slow rate over a growing season; (2) Containing nitrogen, phosphorous, and potassium; (3) The primary nitrogen sources shall be in a coated, prilled urea form; and (4) At least 70 percent of the nitrogen component shall be slow-release water-insoluble nitrogen. The 22-5-10 fertilizer was applied at 1.75 lbs. N/1000. This product is often specified by MnDOT and carried by many distributors in the area. We obtained this product from Twin City Seed.

Treatment 3: Native soil plus one-time natural-based fertilizer. Fertilizer used was a Type 4 as defined by the MnDOT specifications. A Type 4 is as follows: (1) With at least 50 percent of the mass and at least 50 percent of the macronutrients derived from natural or organic material; (2) Consisting of dry granulated nutrients with a moisture content of less than 10 percent; (3) Consisting of granules with an approximate size from No. 7 [2.8 mm] sieve to No. 30 [0.6 mm] sieve; (4) Derived from aerobically composted feed stock supplemented with ammonium sulfate, ferrous sulfate, and sulfate of potash to meet the ratios shown on the Plans; and (5) Free of sewage sludge, raw manure, or uncomposted organic matter. For this trial we used an 8-2-4 by Sustane applied at 1.75 lbs. N/1000. This product is often specified by MnDOT and carried by many distributors in the area. We obtained this product from Twin City Seed.

Treatment 4: Native soil plus biosolid fertilizer manufactured from wastewater treatment plant. This product was sourced from Blue Lakes Water Treatment plant in Shakopee, MN. This was a 5-8-0 applied at 1.75 lbs. N/1000. The product was advertised as a 5-4-0, but the phosphorous level can change from batch to batch based on the biosolids that are received. This product has not been previously used on MnDOT projects.

Treatment 5: Native soil plus MnDOT specs for Grade 1 compost. One inch (135 cu. yards/acre) of the physical compost was incorporated into the soil. This product is derived from animal material and was sourced from MN Soil and Mulch.

Treatment 6: Native soil plus MnDOT specs for Grade 2 compost (Figure 2). One inch (135 cu. yards/acre) was incorporated into the soil. This product was derived from leaves and yard waste and sourced from MN Soil and Mulch.

Treatment 7: Native soil plus hydraulic compost applied to the top. Hydraulic compost and seed was mixed together and applied by hand onto the seeded areas. Hydraulic compost alone will be placed on the soil just prior to sodding with the sod laid on top of the hydraulic compost. Verdyol Biotic Earth Black was used at a rate of 4,000 lbs./acre. The product was obtained from Twin City Seed located in Minneapolis, MN.

3.2.1 Soil Preparation

Glyphosate was applied 2 weeks prior to tilling the soil. Plot areas were tilled to a depth of 3-4 inches using a Toro Dingo (The Toro Co., Bloomington, MN) with the Power Box Rake attachment. Plants (mostly weeds) that were tilled into the soil profile were removed (hand raking and removal with Dingo bucket tool). Seeded plots were seeded at 4.0 lb. PLS /1000 ft^2, raked in, and covered with Futerra Blankets (Profile Products LLC, Buffalo Grove, IL.). Sodded plots were lightly raked and smoothed prior to sod installation.

3.2.2 Watering

Sodded plots were immediately watered based on MnDOT Specifications 2014 edition with a sod maintenance period of 30 calendar days. Water was applied within ½ hour after sod was laid on soil and provided 1 inch (2.5 cm) of water so that soil beneath sod was wet and soil 3 inches (10 cm) below surface was moist. Water was applied at a rate that prevented runoff. Water was supplied to sod daily for the first 10 calendar days at a rate that kept the soil surface below the sod moist. For the remainder of the 30 calendar days, sod was watered as needed to provide 1 inch (2.5 cm) per week. On days 2-10 water was applied to keep sod moist. On days 11-30, sodded areas were watered Monday, Wednesday and Friday at a rate of 0.33 inches. This met the MnDOT specification of 1.0 inch per week. This continued for 30 days after the sodding date. After the 30-day mark, supplemental water was no longer applied. Seeded plots were watered Monday, Wednesday and Friday in order to wet the Futerra blanket. There is no MnDOT specification for watering of seedings.

3.2.3 Data Collection

Turf Quality rating (TQ): Visual ratings were taken one time per month using a 1-9 scale (1=dead, 9=ideal turf).

Weed coverage: Data were collected 4 weeks after seeding and 8 weeks after seeding. A 100 (12"x12") intersect grid was used. The grid was randomly placed three times onto each plot for each rating date. If an intersection of the grid was immediately over a weed, that intersection counted as a percentage point for weed coverage. Due to little or no weed pressure in sodded plots, weed coverage data were only collected in seeded plots.

Turfgrass clipping biomass: Plots were mowed parallel with the street and made one pass in the middle of the plot. The edges running perpendicular to the street were mowed first to provide a uniform clipping area. A cloth bag was fit over the fabricated "shoot" on the 21" Toro walk behind mower. At clipping collection, plots were mowed at 3.25". Clippings were transferred from the cloth bag to a paper bag. Clippings in the bag were then transferred to the dryer. Clipping were weighed after dry.

Electroconductivity (EC): Data was collected using a FieldScout Direct Soil EC Meter with 24" T-Handle Probe (Item # 2265FSTP) (Spectrum Technologies, Aurora, IL).

3.2.4 Data Analysis

Data were analyzed in SAS (SAS Institute Inc., 2014, ver. 9.4, Cary, NC, USA) using PROC GLM. When treatment *F* tests were significant ($p \leq 0.05$), Duncan's multiple range test ($\alpha=0.05$) was used to separate means.

Although seeded and sodded plots were evaluated immediately adjacent to one another in Blaine and St. Paul, they could not be arranged within the same experimental design for logistical reasons. As a result, data for seeded and sodded plots will always be presented separately for the amendment trial. In some cases, it was not possible to combine data across locations, with the exception of turfgrass quality of the 2016 experiment (Tables 3.2 and 3.4), soil moisture (Tables 3.8 and 3.9) and electrical conductivity (Tables 3.10 and 3.11). No sodded plot had more than 5% weed coverage or less than 95% turf coverage at any time throughout the experiment, so weed coverage data are only presented for seeded plots.

3.3 RESULTS AND DISCUSSION

Soil amendment treatments had little effect on turfgrass quality, regardless if the plots were seeded (Tables 3.1 and 3.2) or sodded (Tables 3.3 and 3.4). Similarly, the soil amendments tested had no effect on weed coverage (Tables 3.5, 3.6, and 3.7) in seeded or sodded plots in either St. Paul or Blaine locations on any rating dates. In cases where statistical differences for weed coverage did exist, for instance, the November 2016 and May 2017 rating dates at Saint Paul, the differences were not agronomically important (less than 6% of a difference is very minor in this situation).

The lack of differences observed among treatments in turfgrass quality or weed coverage is somewhat surprising. Previous research has demonstrated the effectiveness of soil organic amendments for hastening establishment of turfgrasses in previous reports on roadsides (Brown and Gorres, 2011) and other turf systems (Linde and Hepner, 2005). Based on their data, Brown and Gorres (2011) suggested that soil amendments were more important for seeded roadside turf success than genetics. Our results in this and other studies clearly show a different result. There are a few reasons that this might be: (1) Brown and Gorres (2011) did not properly replicate amendment treatments but rather used what they referred to as "pseudoreplication" which reduces confidence in their results by putting all amended plots in one area and all non-amended plots in a different yet adjacent area (in our study, amendment treatments were properly replicated and randomized to ensure that location did not affect results); (2) Brown and Gorres conducted their research in Rhode Island where winters are not as harsh as Minnesota and the important traits for turf survival on those sites may be different than the traits needed in Minnesota; and (3) the Rhode Island study was done at two sites within the state in a single year while our trial was repeated in time and space (two locations, two years); as winters are quite variable, replicating in time is preferred to single year research.

One potential explanation for this lack of separation among amendment treatments could be attributed to the quality of soil at each experimental location. If the native soil fertility levels were sufficient throughout the duration of the study, the added benefit of the amendment treatments would have been muted. There were some differences in the amount of clippings collected from plots having various amendment treatments in September 2015 (Table 3.12). The plots that were amended with 8-2-4 or 5-8-0 fertilizers consistently resulted in the highest amount of clippings collected. The addition of extra nitrogen from these treatments likely is the contributing factor for this increase in yield. Given that there was no difference among treatments in turf quality in November 2015 and May 2016, the added benefit of the extra N was short-lived. Electrical conductivity was not significantly affected by soil amendment on any rating date or location and was not significantly related to turfgrass quality or weed coverage throughout the experiment.

3.4 CONCLUSIONS

Our recommendation is that soil amendments beyond starter fertilizer (applied at seeding or sodding) are not necessary. Consistent with sound agronomic practices and state law, public agencies should continue to base nutrient additions on soil testing data for any new establishment weather by seed or by sod.

Table 3.1. The effect of soil amendment on turfgrass quality of seeded plots established in in Blaine and St. Paul, MN in August 2015.

Amendment	Nov. 2015[1]	May 2016	June 2016	July 2016	Aug. 2016	Sept 2016	Oct. 2016	Nov. 2016
				Turf Quality (1-9)[2]				
Untreated Control	5.3	5.4	6.8	4.9	4.1	4.0	5.1	5.1
22-5-10	6.0	6.0	7.4	5.0	4.5	4.5	4.3	5.1
8-2-4	6.1	6.0	7.0	5.0	4.4	4.3	5.0	4.9
5-8-0	5.9	6.1	7.5	4.9	4.3	4.3	5.1	5.0
Grade 1 Compost	5.3	5.8	7.0	5.3	4.9	4.4	5.6	5.5
Grade 2 Compost	5.5	6.3	7.1	5.0	4.3	4.0	5.4	5.3
Verdyol Black	5.0	5.2	6.3	4.4	4.3	4.1	5.0	5.0

[1] Columns containing no letters resulted in no significant differences among treatments.

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6= acceptable, 9=ideal).

Table 3.2. The effect of soil amendment on turfgrass quality of seeded plots established in Blaine and St. Paul, MN in August 2016.

Amendment	Blaine			St. Paul		
	Oct. 2016[1]	Nov. 2016	May 2017	Oct. 2016	Nov. 2016	May 2017
	Turf Quality (1-9)[2]					
Untreated Control	3.3 a	3.8 a	4.5 a	4.8 a	5.3 a	4.5 ab
22-5-10	3.5 a	4.0 a	4.8 a	5.0 a	5.0 a	4.3 b
8-2-4	4.0 a	4.0 a	5.0 a	5.3 a	4.8 a	4.0 b
5-8-0	3.8 a	4.0 a	5.0 a	5.2 a	5.0 a	4.2 b
Grade 1 Compost	2.0 b	3.3 b	2.8 b	3.0 b	4.3 b	4.3 b
Grade 2 Compost	3.5 a	4.0 a	4.8 a	5.0 a	5.0 a	5.0 a
Verdyol Black	3.5 a	4.0 a	4.8 a	5.0 a	5.0 a	5.0 a

[1] Means within a sampling date followed by a similar letter are not significantly different (α=0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 3.3. The effect of soil amendment on turfgrass quality of sodded plots established in in Blaine and St. Paul, MN in August 2015.

Treatment	Nov. 2015	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Turf Quality (1-9)[2]				
Untreated Control	4.9	6.0 bc	7.0	4.6	4.0	4.6	5.0	4.6
22-5-10	5.9	6.4 ab	6.9	4.4	3.5	4.5	5.0	4.6
8-2-4	5.4	5.8 c	6.8	4.3	3.4	4.3	4.8	4.4
5-8-0	6.0	6.1 bc	7.3	4.4	3.9	4.6	5.1	4.6
Grade 1 Compost	5.4	6.0 bc	6.8	4.1	3.4	4.5	4.9	4.5
Grade 2 Compost	6.4	6.8 a	7.0	4.4	3.6	4.3	4.8	4.6
Verdyol Black	4.0	5.6 c	6.8	4.6	3.8	4.5	4.8	4.4

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 3.4. The effect of soil amendment on turfgrass quality of sodded plots established in Blaine and St. Paul, MN in August 2016.

Amendment	Blaine			St. Paul		
	Oct. 2016[1]	Nov. 2016	May 2017	Oct. 2016	Nov. 2016	May 2017
	Turf Quality (1-9)[2]					
Untreated Control	6.8	6.0	5.0	7.0 a	6.5	3.3 c
22-5-10	7.0	5.8	4.5	7.0 a	6.3	3.0 c
8-2-4	6.8	5.5	4.3	6.8 a	6.3	3.3 c
5-8-0	7.0	6.0	4.5	6.7 ab	6.0	3.3 c
Grade 1 Compost	7.0	5.8	4.8	5.8 b	5.5	4.5 a
Grade 2 Compost	7.0	5.8	5.0	6.8 a	6.0	3.3 bc
Verdyol Black	7.0	5.8	4.5	6.5 ab	5.8	4.3 ab

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 3.5. The effect of soil amendment on weed coverage of seeded plots established in Blaine, MN in August 2015.

Treatment	Oct. 2015[1]	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Weed coverage (%)[2]				
Untreated Control	3.9	12.4	13.9	14.6	12.5	12.0	14.4	13.9
22-5-10	3.2	10.6	12.5	13.3	15.5	14.5	16.6	12.2
8-2-4	4.4	14.3	10.9	16.9	13.8	13.8	15.0	13.7
5-8-0	3.8	13.3	11.7	15.2	16.7	15.4	14.7	16.4
Grade 1 Compost	5.1	16.1	16.6	11.8	14.1	14.0	15.2	15.1
Grade 2 Compost	4.7	14.2	12.3	14.2	13.0	16.4	14.2	12.3
Verdyol Black	4.6	12.9	9.6	11.1	12.2	13.7	13.8	13.0

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Weed coverage was estimated using the grid count method.

Table 3.6. The effect of soil amendment on weed coverage of seeded plots established in St. Paul, MN in August 2015.

Treatment	Oct. 2015[1]	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Weed coverage (%)[2]				
Untreated Control	3.5	9.7	9.5	6.4	12.0	11.2	10.2	8.7
22-5-10	4.2	13.0	7.8	7.6	5.3	8.4	8.1	6.2
8-2-4	5.7	7.7	5.6	5.5	4.6	7.1	6.8	5.2
5-8-0	3.7	13.2	7.5	7.0	12.3	11.6	11.0	9.5
Grade 1 Compost	5.5	7.7	7.6	6.3	5.4	7.9	7.0	5.5
Grade 2 Compost	4.4	6.9	5.3	7.0	6.7	8.8	7.9	6.3
Verdyol Black	4.6	16.5	12.6	13.6	9.2	13.4	13.0	11.2

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Weed coverage was estimated using the grid count method.

Table 3.7. The effect of soil amendment on weed coverage of seeded plots established in Blaine and St. Paul, MN in August 2016.

Amendment	Blaine			St. Paul		
	Oct. 2016[1]	Nov. 2016	May 2017	Oct. 2016	Nov. 2016	May 2017
	Weed coverage (%)[2]					
Untreated Control	6.4	3.1	12.4	2.5	3.0 c	3.1 b
22-5-10	4.3	2.9	6.8	2.8	3.2 c	3.7 b
8-2-4	5.4	5.2	5.8	2.8	5.0 ab	8.5 a
5-8-0	3.8	6.6	7.8	3.0	3.6 bc	4.1 b
Grade 1 Compost	7.8	4.8	13.4	5.3	5.4 a	5.0 b
Grade 2 Compost	6.0	3.8	8.5	2.0	2.3 c	2.9 b
Verdyol Black	7.5	4.1	9.6	2.8	3.3 c	4.9 b

[1] Means within a sampling date followed by a similar letter are not significantly different (α=0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Weed coverage was estimated using the grid count method.

Table 3.8. The effect of soil amendment on soil moisture of seeded plots established in Blaine and St. Paul, MN in August 2015.

Treatment	Oct. 2015[1]	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov 2016
				Soil Moisture (VWC)[2]				
Untreated Control	22.5	26.4	30.0	20.4	27.5	18.7	19.5	17.4
22-5-10	20.6	26.9	31.0	19.8	29.3	18.4	19.3	17.4
8-2-4	23.1	27.9	30.0	19.5	27.4	17.7	18.2	16.4
5-8-0	24.2	27.0	30.5	19.8	27.6	18.3	18.7	17.0
Grade 1 Compost	22.7	25.1	29.5	16.9	27.5	19.8	19.0	17.0
Grade 2 Compost	20.7	25.1	29.5	17.5	27.3	18.8	18.3	17.9
Verdyol Black	24.5	27.9	30.1	18.5	28.0	19.3	19.1	17.4

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 3.9. The effect of soil amendment on soil moisture of sodded plots established in Blain and St. Paul, MN in August 2015.

Treatment	Oct. 2015	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Soil Moisture (VWC)[2]				
Untreated Control	28.1	32.3	32.7	21.7	27.3	19.5	24.9	18.9
22-5-10	26.2	29.2	31.3	22.7	27.8	17.9	25.3	21.4
8-2-4	27.4	29.2	31.9	24.0	28.5	20.2	23.9	22.1
5-8-0	27.9	28.6	32.4	21.3	28.2	19.3	25.0	20.6
Grade 1 Compost	29.1	28.5	31.0	18.7	26.3	19.2	25.7	22.5
Grade 2 Compost	28.2	28.6	31.9	20.8	28.0	19.3	22.7	22.0
Verdyol Black	26.9	26.8	32.1	20.7	29.2	17.9	25.1	22.7

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 3.10. The effect of various soil amendment treatments on soil electrical conductivity (EC) of seeded plots established in in Blaine and St. Paul, MN in August 2015.

Treatment	Oct. 2015	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
					EC (mS cm)[2]			
Untreated Control	0.31	0.30	0.32	0.35	0.43	0.24	0.24	0.26
22-5-10	0.28	0.32	0.35	0.29	0.45	0.30	0.28	0.28
8-2-4	0.34	0.30	0.31	0.35	0.43	0.21	0.30	0.26
5-8-0	0.30	0.29	0.30	0.32	0.44	0.28	0.25	0.22
Grade 1 Compost	0.27	0.35	0.36	0.35	0.46	0.27	0.28	0.30
Grade 2 Compost	0.29	0.33	0.33	0.32	0.50	0.28	0.31	0.31
Verdyol Black	0.32	0.30	0.36	0.36	0.41	0.23	0.27	0.26

[1]Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Electrical conductivity was determined using a FieldScout Direct Soil EC Meter.

Table 3.11. The effect of various soil amendment treatments on soil electrical conductivity (EC) of sodded plots established in Blaine and St. Paul, MN in August 2015.

Treatment	Oct. 2015	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				EC (mS cm)[2]				
Untreated Control	0.28	0.30	0.32	0.27	0.40	0.24	0.48	0.37
22-5-10	0.29	0.34	0.33	0.33	0.37	0.23	0.36	0.32
8-2-4	0.32	0.35	0.33	0.33	0.44	0.28	0.46	0.43
5-8-0	0.27	0.30	0.29	0.26	0.39	0.20	0.39	0.38
Grade 1 Compost	0.23	0.28	0.34	0.31	0.43	0.24	0.38	0.36
Grade 2 Compost	0.32	0.27	0.33	0.30	0.46	0.25	0.38	0.37
Verdyol Black	0.34	0.36	0.31	0.27	0.38	0.31	0.47	0.39

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Electrical conductivity was determined using a FieldScout Direct Soil EC Meter.

Table 3.12. The effect of various soil amendment treatments on dry weight clipping yield of sodded plots established in Blaine and St. Paul, MN in August 2015.

Treatment	14 September 2015		30 September 2016	
	St. Paul[1]	Blaine	St. Paul	Blaine
	Clipping yield (g)			
Control	3.3 b	2.8 c	3.4 b	6.8 b
22-5-10	12.0 a	24.9 a	11.1 a	28.6 a
8-2-4	10.2 a	10.2 ab	10.1 a	17.0 ab
5-8-0	9.9 a	9.4 ab	9.5 a	14.7 ab
Grade 1 Compost	2.7 b	4.6 c	3.2 b	10.1 ab
Grade 2 Compost	5.6 ab	6.4 bc	4.1 ab	9.6 ab
Verdyol Black	1.1 b	2.4 c	1.5 b	4.5 b

[1] Means within a column that are followed by a similar letter on not significantly different from one another.

CHAPTER 4: DETERMINING BEST SEEDING AND SODDING DATE FOR A SALT-TOLERANT ROADSIDE GRASS MIXTURE

4.1 INTRODUCTION

Time of the year is an extremely important aspect of any turfgrass establishment as it can affect weed pressure, irrigation requirements, grass seed germination and establishment rates, and winter survival. Roadsides provide a unique growing environment that may require adjustments to establishment timing recommendations. Public land managers establish roadsides through both seed and sod. Currently, most roadside turfgrass seed and sod mixtures comprise a significant portion of Kentucky bluegrass. MNST-12, on the other hand, consists primarily (~%80 by seed weight) of fine fescue species. Understanding the differences between these two types of mixes (predominantly Kentucky bluegrass and predominantly fine fescues) will move us toward more successful roadside turf stands.

4.1.1 Sodding Date Research

The literature on methods for establishing Kentucky bluegrass is robust, while fine fescue sod has received only little attention from researchers. Kentucky bluegrass can be sodded at any point during the growing season, and has been shown to survive after being laid on frozen ground. Interestingly, Henderson et al. (2009) found that, in Connecticut, sod laid in December (whether covered with Green Evergreen covers or left uncovered) outperformed sod laid in either the following May, June, or July; the primary reason for this difference seemed to be that December-laid sod was able to produce a greater amount of roots during the season after establishment (this would be too late for root development in Minnesota, however). Although research on athletic fields might not translate easily to roadsides, this versatility makes Kentucky bluegrass sod a very popular option for projects that occur outside the optimal seeding or sodding time frame. Unfortunately, this species has been shown to not be an effective roadside grass in both field (Friell et al., 2011; Friell et al. 2015) and laboratory experiments (Friell et al., 2012).

The production of fine fescue sod is a recent development (Friell et al., 2016), as consumers, both homeowners and turfgrass professionals, have demanded lower-input turfgrasses. The sod industry has responded by growing an increasing amount of this specialty product. We have observed that fine fescue sod is deficient in a few ways: (1) rooting of new sod is very slow once installed (especially compared to Kentucky bluegrass), requiring smaller amounts of water during each irrigation event, but needing more frequent irrigation events during establishment; (2) fine fescue does not have a dormancy mechanism that is as effective as Kentucky bluegrass, so if establishment practices or the environment into which the sod is laid do not provide needed water, fertility, etc., the sod could die; (3) fine fescue appears to suffer severe damage when it is mowed under stressful conditions (high temperatures and/or moisture deficit). We want to stress that these are our observations, and for the most part, these observations are not confirmed in the scientific literature.

4.1.2 Seeding Date Research

In Minnesota and similar climates, seeding of turfgrasses is recommended to occur in the late summer (between about August 15 and September 15); this is a small window for roadside seeding. This has been confirmed by other researchers several times; for instance, Diesburg and Krausz (2013) evaluated the effect of seeding date for both Kentucky bluegrass and tall fescue and found that for these cool-season grasses, a September seeding (in Illinois) is ideal and that a dormant seeding can also be very effective.

In single species plots of tall fescue, Kentucky bluegrass, or Texas bluegrass x Kentucky bluegrass hybrids seeded in the spring in a European transition zone climate (and grown under low-input conditions), weed pressure was significantly higher (16%) two months after seeding compared to a fall seeding (6%); this difference was also reflected in turf quality scores (Fiorio et. al, 2012). In the same study, tall fescue, due to its drought avoidance characteristics, was able to outperform both of the other species for green turf cover regardless of seeding date, showing that species with better low-input characteristics can often overcome poor establishment conditions.

Fine fescues seem to prefer a fall seeding, but can also do well with a spring seeding under certain conditions. Larsen and Bibby (2005) showed that slender creeping red fescue is better able to germinate under cooler soil temperatures than either Kentucky bluegrass or perennial ryegrass, indicating that cooler soil temperatures in the spring should not hinder fine fescue establishment. They suggested that the difference between red fescue and Kentucky bluegrass would be even greater under “poor seedbed conditions”, which is analogous to the situation found on Minnesota roadsides.

It is clear that there is a need for more research on proper seeding and sodding dates for roadside turfgrass installations. Therefore, the objective of this experiment was to find the optimum seeding and sodding date that provides the highest amount of winter survival for salt-tolerant turfgrasses along Minnesota roadsides.

4.2 MATERIALS AND METHODS

The experiment was conducted at two roadside sites beginning in 2015: St. Paul and Blaine, MN. Plots at the St. Paul location were on the south side of Larpenteur Ave. between Gortner Ave. and Fairview Ave. (44°59'31.6"N, 93°11'05.1"W). In Blaine, plots were located on the east side of Davenport St NE between 105th Ave. NE and 109th Ave. NE (45°09'44.5"N 93°13'47.8"W). For both locations, sites were prepped and maintained identically (see description below). The plots at each location were 6 ft. by 6 ft. and were arranged in a randomized complete block design that ran parallel to the road using 4 replications. An additional experiment year was initiated throughout 2016 in identical conditions but adjacent to the 2015 plots.

4.2.1 Site Preparation

Sites were seeded or sodded as close to the first of the month starting in May and continuing through November, resulting in sodding and seeding dates of May 1, June 1, July 1, August 1, September 1, October 1 and November 1. Two weeks prior to sodding or seeding, plots were treated with glyphosate. The day before sodding or seeding a particular plot, the area was tilled to a depth of 3-4 inches using a walk-behind tiller. For the sodded plots, some soil needed to be removed after tilling to allow for the sod to be soil-level with the sidewalk. Immediately prior to site preparation, soil samples were taken from each plot. After this, fertilizer was applied at a rate of 1 lb. of P_20_5/1000 ft^2 using a 12-12-12 fertilizer to all seeded and sodded plots for that month. After fertilizer, plots were seeded or sodded. Seeded plots were seeded at 4.0 lb. PLS /1000 ft^2, raked in, and covered with Futerra F4 Blankets (Profile Products LLC, Buffalo Grove, IL.). The seed mixture was obtained from Twin City Seed and consisted of Celestial strong creeping red, Shoreline slender creeping red fescue, Bighorn GT hard fescue, Marco Polo sheep fescue and Moonlight SLT Kentucky bluegrass all 20% by weight of the mixture (following MNST-12 sod mixture specifications). Sodded plots were installed using salt-tolerant MNST-12 sod obtained from a local sod farm.

4.2.2 Plot Maintenance

Sodded plots were immediately watered based on MnDOT Specifications 2014 edition. The sod maintenance period was 30 calendar days. Water was applied within ½ hour after sod installation on soil to provide 1 inch (2.5 cm) of water so that soil beneath sod was wet and soil 3 inches (10 cm) below surface was moist. The sod was watered daily for the first 10 calendar days at a rate to keep soil surface below sod moist. For the remainder of the 30 calendar days, sod was watered as needed to provide 1 inch (2.5 cm) per week.

On day 1 (day of sodding or seeding), plots were immediately watered with 1 inch of water (MnDOT specifications). On days 2-10, water was applied to keep sod moist. On days 11-30, sodded areas were watered Monday, Wednesday and Friday at a rate of 0.33 inches, which met the MnDOT specification of 1.0 inch per week. This continued for 30 days after the sodding date. After the 30-day mark, supplemental water was no longer applied. Seeded plots were watered Monday, Wednesday and Friday in order to wet the Futerra blanket. There is no MnDOT watering specification for seed.

Sodded plots were mowed initially 2 weeks after installation and were mowed as needed thereafter. Mowing height was 3.25 inches with a Toro walk behind mower with clippings being collected. Seeded plots were mowed as needed. Data were collected based on 30-day intervals beginning in Fall 2015. Visual ratings of turfgrass quality and weed counts were conducted to assess establishment. Supplementary data of EC and soil volumetric water content were also collected at monthly intervals.

4.2.3 Data Analysis

Data were analyzed in SAS (SAS Institute Inc., 2014, ver. 9.4, Cary, NC, USA) using PROC GLM. When treatment *F* tests were significant ($p \leq 0.05$), Duncan's multiple range test ($\alpha = 0.05$) was used to separate means.

Planting location (Blaine or St. Paul) proved to be an important factor in seeding or sodding timing, as no data could be combined across locations for any rating dates or measurements. A significant establishment method (seed or sod) by planting date interaction existed for most rating types and dates, so data are presented within rating date for both planting years (2015 and 2016).

4.3 RESULTS AND DISCUSSION

Although planting date significantly affected turfgrass quality for seeded or sodded plots on most rating dates in both Blaine (Table 4.1) and St. Paul (Table 4.2), seeded plots were most affected by planting date at both locations. Sodded plots had very similar performance, as judged by either turfgrass quality or weed invasion, for all sodding dates; in fact, November-sodded (2015) plots always had a higher turfgrass quality rating than seeded plots, even though not always significantly higher, for all rating dates in 2016. Seeded plots showed some differences for performance based on date. The most noticeable difference was when comparing late summer (Aug 1 and Sept 1) with fall (Oct 1 and Nov 1) seeding dates. The May rating from each post-establishment year was most important, as it is critical for roadside turf to develop to a point that weed invasion later in the year is reduced because of high turf density in the spring. For the 2015 seedings, plots at Blaine seeded in fall were the poorest performing at the May rating date in 2016 (Table 4.1); both the October and November seeding dates were not only rated significantly lower than all other seeding dates, but they also were much lower in quality than the corresponding sodded plots. A similar trend was seen at St. Paul for the 2015 plots (Table 4.2), and at both locations for 2016 seeded plots (Table 4.3).

In a roadside setting, one of the most important quality characteristics of a turf is its ability to reduce weed pressure. In this study, no sodded plot had more than 3% weed coverage or less than 95% turf coverage at any time throughout the experiment. Plots seeded in May or November resulted in the highest coverage of weeds. The highest weed pressure in seeded plots occurred in plots seeded in October and November in St. Paul and November in Blaine. This difference between our two sites is probably because the October 1 seeding date is very close to the typical recommended cut-off date for seeding cool-season turfgrasses. A warm fall would allow for an October 1 seeding at some locations, while a cooler, shorter fall would result in poor establishment.

We also collected data on soil moisture (Tables 4.6, 4.7 and 4.8) and soil electrical conductivity (Tables 4.9, 4.10 and 4.11); these measurements did not explain results and are presented only for reference.

4.4 CONCLUSIONS

Based on our results, we suggest that (1) sodding at any time from spring through fall should work under conditions where soil moisture is not limiting; and (2) seeding can be performed until sometime in early September as later fall seedings (October 1 and later) do not establish well enough before winter to provide a fully functional roadside turf. These results are not surprising, as most turfgrass researchers in the northern U.S. would recommend seeding fine fescues prior to September 15; however, the fact that seeding in the summer was effective does go against typical turfgrass recommendations. It is important to note, that in these trials, soil moisture was not limiting during establishment, which is a major challenge when establishing new roadside turf areas. Other research by our group (including Chapter 5 in this report) can help address this issue. Based on our experience in other research trials and our observations, we would recommend avoiding seeding or sodding during hot dry summer months due to difficulties with currently-utilized irrigation application methods.

Based on these results, sodding with MNST-12 can be attempted from May to November, provided there is sufficient access to irrigation. If an area is to be seeded with MNST-12, seeding in August or September is ideal; seeding should be avoided during the heat of mid-summer and if spring seeding is necessary, a pre-emergent herbicide that is labeled for use on cool-season turfgrasses is recommended.

Table 4.1. The effect of planting date on turf quality of MNST-12 seeded or sodded plots established in Blaine, MN.

Planting date 2015	Establishment method	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Turf Quality (1-9)[2]				
May 1	Seed	6.0 bc	6.5 abc	4.8 a	2.8 c	4.0 b	5.3 ab	5.0
	Sod	7.3 a	6.0 bcd	3.8 b	3.0 c	3.5 b	5.3 ab	5.5
June 1	Seed	5.5 cd	6.0 bcd	4.3 ab	3.0 c	3.5 b	5.5 ab	4.5
	Sod	7.5 a	6.5 abc	4.0 b	3.5 bc	4.3 ab	5.5 ab	5.3
July 1	Seed	6.0 bc	5.3 de	4.5 a	3.3 c	3.5 b	5.3 ab	5.0
	Sod	7.5 a	7.3 a	3.5 bc	3.8 bc	5.3 a	6.0 ab	5.5
August 1	Seed	5.8 c	5.8 cd	4.3 ab	3.8 bc	3.5 b	4.8 b	5.3
	Sod	6.8 ab	6.3 abc	4.0 b	4.5 ab	4.5 ab	6.0 ab	5.8
September 1	Seed	4.8 d	4.8 e	4.5 ab	3.8 bc	4.0 b	5.0 ab	4.8
	Sod	7.5 a	7.0 ab	4.8 a	4.5 ab	5.3 a	6.5 ab	5.8
October 1	Seed	3.0 e	3.5 f	3.5 bc	3.8 bc	4.0 b	5.3 ab	5.0
	Sod	7.5 a	7.0 ab	5.3 a	5.0 a	5.5 a	6.8 a	6.3
November 1	Seed	2.3 e	3.3 f	3.3 c	3.0 c	3.3 b	4.8 b	4.8
	Sod	7.5 a	6.5 abc	4.3 ab	4.5 ab	5.3 s	5.8 ab	4.8

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6= acceptable, 9=ideal).

Table 4.2. The effect of planting date on turf quality of MNST-12 seeded or sodded plots established in St. Paul, MN.

Planting date 2015	Establishment method	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
		Turf Quality (1-9)[2]						
May 1	Seed	4.0 abc	3.8 abc	4.0 ab	3.8	3.3 ef	3.5 ef	3.5 cde
	Sod	4.3 ab	3.3 c	3.8 ab	3.0	3.0 f	3.3 f	3.3 de
June 1	Seed	3.0 def	3.0 c	3.3 abc	3.5	3.8 def	3.8 def	3.5 cde
	Sod	3.5 b-e	3.3 c	3.3 abc	3.5	3.8 def	3.5 ef	3.0 e
July 1	Seed	2.8 ef	3.0 c	2.8 bc	3.8	3.3 ef	3.3 f	3.5 cde
	Sod	3.3 c-f	3.3 c	3.0 abc	2.5	3.8 def	3.5 ef	3.3 ed
August 1	Seed	4.0 abc	3.5 bc	4.3 a	4.5	4.5 bcd	4.5 bcd	4.5 c
	Sod	3.8 a-d	3.8 abc	3.8 ab	3.8	4.3 cde	4.3 cde	4.3 cd
September 1	Seed	4.5 a	4.3 ab	4.3 a	3.8	4.3 cde	5.0 abc	5.0 ab
	Sod	4.0 abc	4.5 a	4.3 a	5.0	6.3 a	5.8 a	5.5 a
October 1	Seed	4.0 abc	3.8 abc	2.8 bc	3.8	4.0 def	5.0 abc	5.0 ab
	Sod	4.0 abc	4.3 ab	3.8 ab	5.0	5.5 ab	5.3 ab	4.8 ab
November 1	Seed	2.5 f	3.0 c	2.0 c	3.8	3.5 def	3.5 ef	3.8 cde
	Sod	3.8 a-d	3.8 abc	3.5 ab	4.5	5.3 abc	4.8 bc	4.0 b-e

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.
[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 4.3. The effect of planting date on turf quality rated in May 2017 of MNST-12 seeded or sodded plots established throughout 2016 in St. Paul, MN and Blaine, MN.

Planting date 2016	Establishment method	Blaine[1]	St. Paul
		Turf Quality (1-9)[2]	
May 1	Seed	2.8 de	3.5 d
	Sod	3.6 cd	4.0 cd
June 1	Seed	3.8 bcd	4.5 abc
	Sod	3.8 bcd	4.5 abc
July 1	Seed	4.5 ab	4.3 bc
	Sod	4.8 ab	5.0 a
August 1	Seed	5.0 a	4.8 ab
	Sod	4.3 abc	4.8 ab
September 1	Seed	4.8 ab	5.0 a
	Sod	4.8 ab	4.0 cd
October 1	Seed	3.3 cd	4.3 bc
	Sod	4.5 ab	4.5 abc
November 1	Seed	2.0 e	2.0 e
	Sod	5.0 a	4.8 ab

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.
[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 4.4. The effect of planting date on weed coverage of MNST-12 seeded plots established in Blaine and St. Paul, MN.

Planting date 2015	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
Blaine				Weed coverage (%)[2]			
May 1	26.1	39.9 b	8.6 b	26.2	28.8	27.2	23.0
June 1	28.3	31.2 bc	5.3 b	26.3	30.3	28.7	24.3
July 1	45.0	37.5 b	8.2 b	28.4	35.7	34.1	29.1
August 1	32.1	42.0 ab	7.3 b	18.8	32.6	31.0	26.4
September 1	20.2	24.0 bc	8.7 b	13.6	23.7	22.1	18.6
October 1	43.9	11.3 c	9.1 b	20.2	25.3	23.8	20.3
November 1	21.0	64.5 a	20.5 a	33.8	41.6	40.0	34.3
St. Paul							
May 1	38.1 b	39.9 b	50.6 b	77.8 ab	65.0 a	59.6 a	49.6 a
June 1	22.1 cd	23.1 cd	28.9 cd	50.1 bc	32.7 abc	31.1 bcd	25.9 bcd
July 1	27.9 cb	29.3 bc	37.1 bc	63.3 ab	32.3 abc	40.9 abc	34.2 abc
August 1	2.9 e	3.1 e	3.9 e	17.8 d	13.2 bc	40.9 d	9.1 d
September 1	10.0 de	10.5 de	13.2 ed	22.4 cd	6.8 c	11.9 d	9.9 d
October 1	37.2 bc	39.1 bc	48.8 bc	62.2 ab	18.1 bc	16.9 cd	14.1 cd
November 1	63.8 a	66.9 a	84.5 a	92.4 a	51.9 ab	48.0 ab	39.9 ab

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Weed coverage was estimated using the grid count method.

Table 4.5. The effect of planting date on weed coverage rated in May 2017 for MNST-12 seeded or sodded plots established in Blaine and St. Paul, MN.

Planting date 2016	Blaine	St. Paul
	Weed coverage (%)[2]	
May 1	7.1 b	17.4 b
June 1	3.9 b	7.3 b
July 1	8.5 b	5.7 b
August 1	13.2 b	20.0 b
September 1	5.0 b	13.1 b
October 1	55.3 a	14.0 b
November 1	61.3 a	61.9 a

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Weed coverage was estimated using the grid count method

Table 4.6. The effect of planting date on soil moisture of MNST-12 seeded or sodded plots established in Blaine, MN.

Planting date 2015	Establishment method	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Soil Moisture (%)[2]				
May 1	Seed	12.3	14.5	12.9 c	15.8	15.6	14.5	14.7
	Sod	15.2	15.8	16.2 abc	16.0	18.2	16.9	17.2
June 1	Seed	14.1	16.0	14.3 bc	17.4	18.4	17.1	17.4
	Sod	14.7	16.9	16.0 abc	15.3	16.8	15.6	15.9
July 1	Seed	14.7	16.4	15.2 abc	16.1	16.4	15.2	15.6
	Sod	16.6	17.0	16.8 ab	17.6	19.7	18.4	18.8
August 1	Seed	13.0	16.0	15.0 abc	16.8	16.3	15.2	15.5
	Sod	17.5	17.3	17.0 ab	18.0	17.0	15.8	16.1
September 1	Seed	15.2	18.5	15.6 abc	18.1	16.5	15.4	15.7
	Sod	16.7	18.9	17.6 ab	18.2	20.2	18.8	19.2
October 1	Seed	13.7	16.2	16.1 abc	17.0	15.9	14.8	15.1
	Sod	16.2	18.5	18.3 a	19.8	18.5	17.2	17.5
November 1	Seed	14.3	16.6	14.3 bc	16.4	16.0	14.9	15.2
	Sod	15.1	19.0	18.1 a	17.6	18.3	17.0	17.4

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 4.7. The effect of planting date on soil moisture of MNST-12 seeded or sodded plots established in St. Paul, MN.

Planting date 2015	Establishment method	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
					Soil Moisture (%)[2]			
May 1	Seed	17.9 ab	20.6 a	19.5 c	29.7 a-d	16.2	17.7 bc	16.7 bc
	Sod	15.2 bcd	16.5 bc	21.9 abc	33.9 ab	14.8	14.6 de	15.5 bc
June 1	Seed	14.3 cd	15.4 bc	23.1 abc	26.4 d	11.9	15.0 de	15.4 bc
	Sod	17.3 ab	19.1 ab	24.4 ab	34.6 a	15.7	17.0 bcd	16.1 bc
July 1	Seed	17.0 abc	16.4 bc	24.7 ab	32.2 abc	13.6	16.6 bcd	12.5 d
	Sod	19.1 a	17.7 abc	25.7 a	30.8 a-d	15.1	17.7 bc	17.5 b
August 1	Seed	18.8 a	16.0 bc	19.2 c	32.6 abc	19.8	17.5 bc	14.2 cd
	Sod	18.9 a	17.5 abc	19.7 c	32.7 abc	13.5	18.6 ab	18.2 b
September 1	Seed	19.5 a	16.8 bc	19.7 c	28.8 a-d	16.4	19.1 ab	15.3 bc
	Sod	19.2 a	17.9 abc	20.6 c	34.6 a	16.4	20.2 a	21.1 a
October 1	Seed	17.3 ab	16.2 bc	20.1 c	28.8 bcd	13.7	15.9 cde	15.7 bc
	Sod	18.3 a	17.0 abc	24.9 ab	34.6 a	17.5	16.9 bcd	17.5 b
November 1	Seed	12.5 d	14.1 c	19.7 c	27.9 cd	17.3	13.5 e	14.1 cd
	Sod	17.2 ab	15.9 bc	21.4 bc	31.1 a-d	14.4	14.7 ed	16.0 bc

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 4.8. The effect of planting date on soil moisture of MNST-12 seeded or sodded plots established in Blaine and St. Paul, MN rated in May 2017.

Planting date 2016	Establishment method	Blaine	St. Paul
		Soil Moisture (%)[2]	
May 1	Seed	30.8	22.3
	Sod	30.5	23.6
June 1	Seed	27.8	23.3
	Sod	32.2	22.1
July 1	Seed	27.4	23.7
	Sod	30.1	22.9
August 1	Seed	30.2	22.0
	Sod	28.3	21.2
September 1	Seed	28.2	21.5
	Sod	30.3	22.3
October 1	Seed	27.3	21.4
	Sod	32.3	23.3
November 1	Seed	25.1	20.9
	Sod	28.2	22.6

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 4.9. The effect of planting date on soil electrical conductivity of MNST-12 seeded or sodded plots established in Blaine, MN.

Planting date 2015	Establishment method	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Electrical Conductivity (mS cm)[2]				
May 1	Seed	0.22	0.09	0.17	0.20	0.20	0.30	0.27
	Sod	0.22	0.16	0.20	0.33	0.30	0.40	0.36
June 1	Seed	0.20	0.10	0.14	0.28	0.18	0.29	0.25
	Sod	0.14	0.10	0.15	0.26	0.23	0.33	0.29
July 1	Seed	0.20	0.09	0.18	0.21	0.14	0.25	0.21
	Sod	0.16	0.16	0.20	0.27	0.20	0.30	0.26
August 1	Seed	0.13	0.19	0.13	0.20	0.17	0.27	0.24
	Sod	0.18	0.16	0.16	0.16	0.16	0.26	0.23
September 1	Seed	0.22	0.13	0.14	0.32	0.21	0.31	0.27
	Sod	0.20	0.07	0.12	0.17	0.17	0.27	0.22
October 1	Seed	0.15	0.07	0.14	0.21	0.15	0.25	0.22
	Sod	0.22	0.13	0.14	0.22	0.16	0.26	0.22
November 1	Seed	0.19	0.14	0.19	0.22	0.16	0.27	0.23
	Sod	0.22	0.11	0.11	0.14	0.15	0.26	0.22

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Electrical conductivity was determined using a FieldScout Direct Soil EC Meter.

Table 4.10. The effect of planting date on soil electrical conductivity of MNST-12 seeded or sodded plots established in St. Paul, MN.

Planting date 2015	Establishment method	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016
				Electrical Conductivity (mS cm) [2]				
May 1	Seed	0.21	0.19	0.31	0.41	0.16	0.13	0.13 d
	Sod	0.26	0.20	0.24	0.41	0.13	0.17	0.28 ab
June 1	Seed	0.24	0.22	0.30	0.53	0.10	0.17	0.16 cd
	Sod	0.19	0.14	0.33	0.50	0.11	0.20	0.21 bcd
July 1	Seed	0.23	0.21	0.35	0.62	0.12	0.23	0.15 d
	Sod	0.28	0.14	0.33	0.56	0.11	0.20	0.30 ab
August 1	Seed	0.29	0.24	0.26	0.55	0.11	0.30	0.22 bcd
	Sod	0.26	0.24	0.39	0.56	0.16	0.25	0.28 ab
September 1	Seed	0.34	0.26	0.22	0.47	0.14	0.29	0.36 a
	Sod	0.27	0.25	0.35	0.41	0.15	0.21	0.29 ab
October 1	Seed	0.21	0.21	0.29	0.54	0.14	0.17	0.23 bcd
	Sod	0.26	0.15	0.29	0.62	0.14	0.20	0.28 ab
November 1	Seed	0.24	0.20	0.28	0.47	0.16	0.27	0.26 abc
	Sod	0.25	0.19	0.41	0.53	0.14	0.19	0.27 ab

[1]Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Electrical conductivity was determined using a FieldScout Direct Soil EC Meter.

Table 4.11. The effect of planting date on soil electrical conductivity (EC) of MNST-12 seeded or sodded plots established in Blaine and St. Paul, MN rated in May 2017.

Planting date 2016	Establishment method	Blaine	St. Paul
		Electrical Conductivity (mS cm) [2]	
May 1	Seed	0.23	0.44 abc
	Sod	0.23	0.38 bcd
June 1	Seed	0.19	0.51 ab
	Sod	0.23	0.34 cd
July 1	Seed	0.23	0.56 a
	Sod	0.21	0.47 abc
August 1	Seed	0.21	0.37 bcd
	Sod	0.20	0.46 abc
September1	Seed	0.23	0.38 bcd
	Sod	0.21	0.50 ab
October 1	Seed	0.22	0.48 abc
	Sod	0.25	0.27 d
November 1	Seed	0.24	0.40 bcd
	Sod	0.20	0.45 abc

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments.

[2] Electrical conductivity was determined using a FieldScout Direct Soil EC Meter.

CHAPTER 5: EVALUATION OF WATERING REGIMES ON KENTUCKY BLUEGRASS AND MNST-12 SOD

5.1 INTRODUCTION

Sod is a preferred establishment method in many cases because of its ease of use, rapid establishment, erosion prevention, and aesthetics. Historically, Kentucky bluegrass is the dominant species used for establishing roadsides by sod in the state of Minnesota. However, due to its poor salt tolerance (Friell et al., 2013), turfgrass scientists at the University of Minnesota have been researching optimum mixtures of salt tolerant grasses to replace Kentucky bluegrass (Friell et al., 2015). One sod mixture that has shown some promise is MNST-12, a mixture (by weight) of approximately 80% fine fescues and 20% Kentucky bluegrass.

Currently, MnDOT provides watering recommendations to contractors for sod, but because these recommendations have been based on Kentucky bluegrass sod, they are likely inaccurate for fine fescue sod like MNST-12. Furthermore, these watering recommendations have been based on anecdotal experiences of contractors or other turfgrass professionals and not rooted in science. Modern, science-based approaches that have investigated optimum watering regimes have centered on replacing the amount of water lost via evapotranspiration, or ET (Ervin and Koski, 1998; Fry and Butler, 1988). This particular method ensures the optimum amount of water needed by the plants and thus can be a tremendous tool for saving water resources. However, despite the extended use of basing irrigation on ET replacement rates, relatively little is known for the requirements of fine fescue, especially with how it compares to Kentucky bluegrass.

As a result, more research is needed to determine the optimum watering practices for newer sod mixtures like MNST-12 and how they might compare to a traditional sod choice like Kentucky bluegrass. Therefore, the objective of this study is to identify the optimum watering regime for successful Kentucky bluegrass and MNST-12 sod establishment.

5.2 MATERIALS AND METHODS

This study was located at the University of Minnesota campus in St. Paul MN under an automated rainout shelter for both years of the experiment (Figure 5.1). The automated rainout shelter was equipped with a rain sensor and a track system so that it could automatically move over the trial area when rain was detected. Once the rain event ended, the shelter could be automatically moved off of the trial area. The rainout shelter allowed for complete control over watering, which provided the worst-case scenario for sod establishment on a roadside.

5.2.1 Site Preparation

Sod was established under the rainout shelter on April 30th, 2015 and on May 3rd, 2016. Kentucky bluegrass sod and MNST-12 salt-tolerant sod were harvested from the same sod farm and on the same day as establishment to the trial area (the Kentucky bluegrass sod served as a control as it has been traditionally used along roadsides in Minnesota). The MNST-12 sod is prescribed to contain around 80% fine fescue and 20% Kentucky bluegrass plants, but based on our own visual estimates, the actual coverage of Kentucky bluegrass was around 30%. Individual plot areas measured 6 feet long by 6 feet wide. Prior to establishment, the individual plot areas were isolated to a depth of 5.325 inches below the soil surface with an aluminum barrier from the neighboring plot area with the barrier extending 0.625 inches above the soil surface to prevent any surface movement into the neighboring plot. This was needed as each plot area received a different amount of water on a daily basis and thus prevented water from migrating to a neighboring plot. After sod installation, initial watering of all plot areas was implemented based on the MnDOT Standard Specification for Construction 2014 edition. One inch of water was applied within ½ hour after sod was laid so that soil beneath the sod was wet and soil 3 inches below the surface was moist.

In order to prevent runoff from the plots, water was applied to the plot areas in two ½-inch increments. After this initial watering, 7 different watering regimes were implemented for both Kentucky bluegrass and MNST-12 sod and began on the first full day after establishment for each year's experiment:

> *Treatment #1*: No pre-wetting of soil prior to sod installation and then watering to replace 60% evapotranspiration (ET) over a 24 hour period. Plots were watered for 60 days beginning the day after each year's establishment.
>
> *Treatment #2*: No pre-wetting of soil prior to sod installation and then watering to replace 100% ET over a 24 hour period. Plots were watered for 60 days beginning the day after each year's establishment.
>
> *Treatment #3*: No pre-wetting of soil prior to sod installation and then watering based on MnDOT Standard Specifications for Construction 2014 edition. This included watering sod daily on days 2-10 at a rate to keep soil surface below sod moist. For this trial, 0.175 inches were applied daily on days 2-10 to adequately keep the soil below sod moist. Starting on day 11 and continuing to day 30, sod was watered to supply 1 inch of moisture per week. This was done by applying 0.33 inches of water on Monday, Wednesday and Friday. Plots were watered for the first 30 days and then received no additional water on days 31-60 after establishment.
>
> *Treatment #4*: Pre-wetting of soil and then watering to replace 60% evapotranspiration (ET) over a 24 hour period. Pre-wetting consisted of applying 0.125 inches of water to dry soil just before sod installation. Plots were watered for 60 days beginning the day after each year's establishment.
>
> *Treatment #5*: Pre-wetting of soil and then watering to replace 100% ET over a 24 hour period. Pre-wetting consisted of applying 0.125 inches of water to dry soil just before sod installation. Plots were watered for 60 days beginning the day after each year's establishment.
>
> *Treatment #6*: Pre-wetting of soil and then watering based on MnDOT Standard Specifications for Construction 2014 edition as outlined above. Plots were watered for the first 30 days and then received no additional water on days 31-60 after establishment.
>
> *Treatment #7*: No pre-wetting of soil prior to sod installation and then receiving no additional water after the April 30th water application, as outlined above, for the remainder of the study period.

Each day, estimated ET was determined for the previous day from the University of Wisconsin Extension Ag Weather website (http://agwx.soils.wisc.edu/uwex_agwx/sun_water/et_wimn) (this website is no longer funded, but was during the project period; similar sources of ET data can be found online). The ET data was determined using atmospheric observations from Automated Surface Observing System (ASOS) stations and satellite-derived isolation estimates to predict water use by plants. Once the ET was determined, water was applied to treatments 1, 2, 4 and 5 to replace the previous day's ET loss. Treatments 3 and 6 were watered strictly based on water amounts specified by the MnDOT Standard Specifications as outlined above. Water was applied and measured using a Sotera Systems 850 model flow meter (Tuthill Corporation, Burr Ridge, IL) fitted with a nozzle to provide the exact amount of water needed to each individual plot area. Water was applied to these plot areas between 1100 and 1300-h each day for the duration specified in the treatments. Plot areas were initially mowed with a rotary mower (Toro Heavy Duty 21" OHV Push, The Toro Company, Bloomington, MN) two weeks after sod establishment and continued weekly at a height of 3.25 inches.

5.2.2 Data Collection

Turfgrass cover was used to quantify percent green turfgrass coverage by analyzing digital pictures taken weekly (Richardson et al., 2001). A visual rating of turfgrass quality using a 1-9 scale, (1=dead, 6=minimum acceptable, 9=ideal) was taken every 7-14 days after establishment. Turf shear strength was determined using Shear Vane Tester (Turf-Tec International, Tallahassee, FL) by measuring shear resistance in three locations per plot. Soil moisture was quantified weekly using a FieldScout TDR 300 Soil Moisture Meter (Spectrum Technologies, Aurora, IL) to determine volumetric soil water content of each plot.

Root samples were also taken using the Miltona Soil Profiler (Miltona Turf Tools and Accessories) to a depth of 7". Approximately 90 days after sod establishment, two root measurement samples were taken per plot and placed into their own individual container and placed into the coolers in Alderman 201. The protocol followed to wash the soil off the roots of the samples was taken from. After 48 hours, soil was washed from the roots and placed into paper bags and placed in the dryer in Alderman 201 for 48 hours at which time samples were weighed (two samples per location averaged).

5.2.3 Data Analysis

Data were analyzed in SAS (SAS Institute Inc., 2014, ver. 9.4, Cary, NC, USA) using PROC GLM. When treatment *F* tests were significant ($p \leq 0.05$), Duncan's multiple range test ($\alpha = 0.05$) was used to separate means. In order to better explain differences among irrigation treatments, Dunnett's test ($\alpha = 0.05$) was used to compare individual water treatments with the Initial watering only treatment.

Pre-wetting the soil prior to sod establishment had no impact at any point during the study for either year, so data were pooled across pre-wetting treatments. Several species × water treatment interactions (a species in combination with a particular water treatment occasionally had higher cover) existed for turfgrass cover for various rating dates. As a result, data are presented within rating date by species for each water treatment (Table 5.1). In general, sod species selection did not affect turf quality (Tables 5.2 and 5.3) or root weight (Table 5.4), so data were pooled across sod species for each rating date. Sod species selection alone affected soil moisture on particular rating dates (Table 5.5 and 5.6).

5.3 RESULTS AND DISCUSSION

The watering treatment that consistently resulted in the lowest turfgrass coverage or quality was the initial watering at establishment only treatment (Tables 5.1, 5.2, and 5.3). However, given that the scope of this experiment was to examine various water regimes, the majority of this results and discussion will focus on differences among the other water regime treatments. Watering according to MnDOT specifications resulted in reduced turfgrass coverage of MNST-12 sod compared to Kentucky bluegrass sod between 51 and 71 days after planting (Table 5.1), indicating that the specifications may need to be adjusted based on sod type chosen for installation.

Turfgrass quality was similarly affected by watering treatment compared to turfgrass coverage (Tables 5.2 and 5.3), given that watering according to MnDOT recommendations resulted in reduced turf coverage compared to replacing 60 or 100% ET, regardless if it was sodded with Kentucky bluegrass or MNST-12. Surprisingly, similar turfgrass coverage was observed regardless if water was used to replace 60 or 100% of ET when establishing MNST-12 sod. Relatively little is known regarding optimum ET replacement rates for fine fescues. Fry and Butler (1988) observed reduced hard fine fescue turf quality when irrigated to replace 50% ET but not for 75 or 100% ET, which agrees with what we observed in this study. More research has been dedicated towards identifying optimum ET replacement rates in Kentucky bluegrass. Ervin and Koski (1998) evaluated numerous rates of ET for Kentucky bluegrass and reported 60% was sufficient for maintaining acceptable turfgrass quality.

The lack of differences in green cover at 74 or 90 days after planting (DAP) (Table 5.1) are likely the result of increased weed coverage in voids created by reduced turf coverage earlier in the experiment. If the hue of green is similar among weed species to that of the Kentucky bluegrass or fine fescues, the computer program that analyzes the images will be unable to distinguish between a weed leaf and a grass leaf. This is supported by the reduced turf quality (which takes into account weed cover) throughout the duration of the experiment in both years (Tables 5.2 and 5.3)

Despite the fact that there were significant differences among water treatments for turfgrass coverage and quality, water treatment had no effect on turf rooting (Table 5.4). This was somewhat surprising given that root weights have been positively associated with irrigation quantity (Baldwin et al., 2006). This lack of separation among water treatments may demonstrate the difficulty of obtaining undisturbed root samples from a native soil rootzone.

Soil moisture was significantly affected by watering treatment (Tables 5.5 and 5.6). Not surprisingly, the water treatments that resulted in more frequent irrigation occurrences resulted in higher soil moisture. In general, the water treatments that resulted in consistently higher soil moisture were among the water treatments that resulted in higher turf coverage and quality. Within several rating dates turfgrass species (Kentucky bluegrass or fine fescue) significantly affected soil moisture. However, the maximum difference in soil moisture between species on any rating date was less than %3, which is negligible. In addition to resulting in reduced turf coverage and quality, the treatment of watering only at establishment also resulted in reduced shear strength across both species (Table 5.7)

By calculating the amount of water applied for each watering regime for the duration of the experiment, it is possible to calculate the total amount of water needed to irrigate a similar site of turf. The initial watering at establishment only, watering based off of MnDOT recommendations, watering to replace 60% ET and watering to replace 100% ET used 27,104; 155,969; 101,761; and 169,521 gallons of water per acre of sod, respectively. Given the large differences among water applied, it's important to also consider other costs such as labor and transportation that may not be directly accounted for in the cost of the water.

5.4 CONCLUSIONS

Based off of data from this experiment and our own observations, turfgrass professionals establishing MNST-12 from sod will need to adjust their watering regime from MnDOT's recommendations in order to ensure a successful establishment. A water savings (and other potential economic savings) may be realized if the sod is watered to replace 60% ET. Further investigation is likely needed to determine the feasibility and effectiveness of watering programs for roadsides based on ET rates. Across the two experimental years of 2015 and 2016, pre-wetting the soil prior to sod establishment did not improve establishment of either Kentucky bluegrass or MNST-12 sod.

Figure 5.1. Rainout shelter used to evaluate water regime treatments in St. Paul, MN.

Table 5.1. The effect of water regime treatment on turfgrass coverage of Kentucky bluegrass and MNST-12 sod established in 2015 and 2016.

Water regime treatment		2015[1]			2016		
	Sod type[2]	51 DAP[3]	66 DAP	74 DAP	60 DAP	71 DAP	90 DAP
		Turf Cover (%)[4]					
MnDOT	MNST-12	68.0 b*	72.4 b*	83.0 *	64.0 b*	66.9 b*	80.5 *
MnDOT	KBG	78.4 a*	78.6 ab*	84.5 *	81.8 a*	78.8 a*	82.5 *
60% ET	MNST-12	82.2 a*	83.9 a*	84.2 *	85.0 a*	76.5 a*	80.8 *
60% ET	KBG	84.4 a*	83.4 a*	85.5 *	88.6 a*	82.4 a*	84.5 *
100% ET	MNST-12	85.5 a*	86.7 a*	84.3 *	86.4 a*	80.5 a*	85.4 *
100% ET	KBG	87.0 a*	88.6 a*	88.1 *	89.6 a*	82.8 a*	85.4 *
Only initial watering	MNST-12	8.2	38.7	59.5	3.4	36.7	63.5
Only initial watering	KBG	12.2	47.8	69.9	10.5	58.6	73.6

[1] Means within a column that are followed by a similar letter on not significantly different from one another (α =0.05). Asterisks indicate a treatment that was different from the initial 1-inch treatment according to Dunnett's test (α =0.05).

[2] MNST-12= mixture of approximately 80% fine fescues + 20% Kentucky bluegrass; KBG = Kentucky bluegrass.

[3] DAP = Days after planting.

[4] Turf cover was determined by analyzing digital images for the amount of green area.

Table 5.2. The effect of water regime treatment on turfgrass quality of Kentucky bluegrass and MNST-12 sod established on April 30th, 2015.

Irrigation Treatment	11 May 2015	11 June 2015	18 June 2015	25 June 2015	1 July 2015	8 July 2015	23 July 2015	31 July 2015
				Turf Quality (1-9)[2]				
MNDOT	8.0 *	7.5 b*	7.3 b*	7.1 b*	6.1 b*	5.6 c*	5.3 c*	5.5 b*
60%	7.9 *	8.3 a*	8.1 a*	8.4 a*	7.5 a*	7.0 b*	6.3 b*	6.8 a*
100%	7.9 *	8.3 a*	8.1 a*	8.5 a*	7.9 a*	7.9 a*	7.4 a*	7.3 a*
Initial 1 inch (control)	7.0	4.5	4.4	4.5	3.4	3.5	3.9	3.8

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments. Asterisks indicate a treatment that was different from the initial 1-inch treatment according to Dunnett's test (α =0.05).

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 5.3. The effect of water regime treatment on turfgrass quality of Kentucky bluegrass and MNST-12 sod established on May 3rd, 2016.

Irrigation Treatment	23 May 2016[1]	7 June 2016	21 June 2016	5 July 2016	19 July 2016	21 Aug. 2016	23 Aug. 2016	22 Sept. 2016
				Turf Quality (1-9)[2]				
MNDOT	8.3 a*	7.6 a*	7.1 *	6.7 *	6.3 *	5.4 *	6.9 *	7.0 *
60%	5.9 b*	6.3 b*	6.9 *	6.9 *	6.4 *	6.0 *	6.3 *	7.0 *
100%	8.3 a*	7.7 a*	7.1 *	7.2 *	6.6 *	5.5 *	6.5 *	7.2 *
Initial 1 inch	2.4	2.3	2.0	2.0	2.3	2.5	2.0	2.0

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments. Asterisks indicate a treatment that was different from the initial 1-inch treatment according to Dunnet's test (α =0.05).

[2] Turf quality is a visual rating based on a 1-9 scale (1=dead, 6=acceptable, 9=ideal).

Table 5.4. The effect of water regime treatment on Kentucky bluegrass (KBG) and MNST-12 sod root weights in 2015 and 2016.

Treatment	2015[1]	2016
	Root weight (g)[2]	
MNDOT	0.240	0.240
60%	0.238	0.238
Pre 100%	0.234	0.235
Initial 1 inch	0.148	0.209

[1] There were no significant differences among water treatments for the amount of root weighed.

[2] Roots were harvested approximately 90 days after establishment.

Table 5.5. The effect of watering regime on soil moisture of sodded Kentucky bluegrass and MNST-12 of sod established on April 30th, 2015.

	14 May 2015[1]	21 May 2015	28 May 2015	3 June 2015	11 June 2015	18 June 2015	25 June 2015	12 July 2015	18 July 2015	23 July 2015	31 July 2015
	Soil Moisture (VWC)[2]										
Irrigation Treatment											
MNDOT	40.9 a*	41.1 a*	37.6 a*	26.0 c*	14.8 c*	14.9 c*	10.6 c*	13.0 c*	30.0 c*	15.4 b*	22.9 b*
60%	32.4 c	34.9 c*	33.0 b*	30.1 b*	35.5 b*	34.6 b*	31.9 b*	27.5 b*	35.4 b*	19.0 a*	24.5 a*
100%	38.0 b*	39.9 b*	36.9 a*	35.3 a*	42.3 a*	44.9 a*	43.6 a*	38.4 a*	37.9 a*	19.7 a*	24.7 a*
Initial 1 inch	32.4	21.6	17.6	17.6	12.9	12.3	9.6	10.2	30.3	16.0	23.1
Species											
KBG	38.5 a	39.3 a	36.1	31.6 a	32.5 a	32.2	29.2	26.8	35.2 a	18.4	24.7 a
MNST-12	35.7 b	38.0 b	35.5	29.4 b	30.1 b	31.2	28.2	25.9	33.6 b	17.6	23.4 b

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments. Asterisks indicate a treatment that was different from the initial 1-inch treatment according to Dunnett's test (α =0.05).

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 5.6. The effect of watering regime on soil moisture of sodded Kentucky bluegrass and MNST-12 of sod established on May 3rd, 2016.

	24 May 2016	2 June 2016	8 June 2016	15 June 2016	22 June 2016	29 June 2016	2 July 2016	6 July 2016	13 July 2016	20 July 2016	27 July 2016
					Soil Moisture (VWC)[2]						
Irrigation Treatment											
MNDOT	32.2 c*	39.7 b*	32.0 c*	27.0 c*	19.4 c*	16.7 c*	14.4 c*	35.6 c*	38.3 c	28.2 b*	32.7 b*
60%	28.6 b*	38.8 b*	39.3 b*	44.9 b*	35.1 b*	34.1 b*	30.5 b*	44.3 b*	41.3 b	29.9 b	33.8 ab*
100%	42.8 a*	51.8 a*	51.6 a*	56.3 a*	47.3 a*	47.8 a*	46.4 a*	48.8 a*	46.6 a*	33.6 a*	35.6 a
Initial 1 inch	24.5	24.3	22.2	21.1	16.6	15.6	13.8	40.3	41.8	31.3	37.9
Species											
KBG	34.6	43.6	41.8 a	43.8 a	34.9	33.5	31.8 a	43.8 a	42.6	31.1	34.9 a
MNST-12	34.4	43.3	40.1 b	41.7 b	32.9	32.2	29.0 b	42.0 b	41.5	30.0	33.2 b

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments. Asterisks indicate a treatment that was different from the initial 1-inch treatment according to Dunnett's test (α =0.05).

[2] Soil moisture was determined using a TDR soil moisture probe that measured the soil volumetric water content (VWC).

Table 5.7. The effect of water regime treatment on Kentucky bluegrass and MNST-12 sod shear strength in 2015 and 2016.

	2015[1]	2016
	Shear strength (N m)[2]	
Irrigation Treatment		
MNDOT	31.8 *	31.8 *
60%	31.5 *	31.5 *
100%	31.5 *	31.5 *
Initial 1 inch	28.5	24.3
Species		
KBG	31.9	29.7
MNST-12	31.0	29.4

[1] Means within a sampling date followed by a similar letter are not significantly different (α =0.05). Columns containing no letters resulted in no significant differences among treatments. Asterisks indicate a treatment that was different from the initial 1-inch treatment according to Dunnett's test (α =0.05).

[2] Shear strength was quantified using a Shear Vane Tester.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

This report documents the need for establishment and maintenance recommendations that are based on sound agronomic and scientific principles. Establishment is the most difficult and critical period of maintenance for a turfgrass area, and this is no truer than in roadsides where conditions are very challenging.

Soil amendments had minimal impact on establishment of MNST-12 from seed or sod. Our recommendation is that soil amendments beyond starter fertilizer are typically not necessary. Consistent with sound agronomic practices and state law, continue to base nutrient additions on soil testing data for any new establishment whether by seed or sod.

Planting date, species selection, and establishment method are all important factors necessary for consideration when attempting to establish a roadside with turf. Assuming sufficient access to irrigation, sodding with MNST-12 can be attempted from May to November. If an area is to be seeded with MNST-12, seeding in August or September is preferred.

This research also demonstrated that irrigation recommendations may need to be specific for species of sod used. Current MnDOT standard specifications for irrigating sod result in lower turfgrass coverage and quality compared to those based on replacing 60% or 100% ET. Watering to replace 60% ET had similar turf cover and quality as watering to replace 100% ET. Basing irrigation approaches on ET could result in reducing water consumption and ultimately the cost of establishing areas with sod. Further investigation is likely needed to determine the feasibility and effectiveness of watering programs for roadsides based on ET rates. Furthermore, additional research is needed to identify more efficient methods for delivering irrigation during the critical establishment period.

6.1.1 Recommended Changes to MnDOT Specifications

Based on the results of this research report, we recommend the following MnDOT specification changes:

1. No soil amendments are necessary, though poor sites may benefit from their addition. Ensure adequate seedbed preparation to ensure appropriate seed-to-soil or sod-to-soil contact. This may include removing existing plant debris and large stones, smoothing the soil surface, and use appropriate germination blanket or sod staples when establishing on a slope.
2. Seeding is a preferred option between August 15 and September 15.
3. Sodding should be permitted at any time throughout the year, provided the installer is able to supply frequent irrigation in amounts necessary for successful fine fescue sod rooting.

4. When watering in sod, attention should be given towards which species is being used and local evapotranspiration rates.
5. Installers of sod can anticipate using between 100,000 and 170,000 gallons of water per acre to ensure a successful establishment.
6. Mowing of fine fescue sod can be mowed as soon as sufficient root growth prevents an operator from manually pulling up sod pieces by hand. Fine fescue sod should not be mowed if it is wilting from heat or drought.

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