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Cool-season turfgrass species mixtures for roadsides in Minnesota

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A R T I C L E I N F O

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Roadside turfgrass mixtures are subject to a wide variety of extreme stresses including heat, drought, low nutrient availability, ice cover, and road salt exposure. The currently specified turfgrass seed mixtures for roadsides in Minnesota have not been based on the results of recent, designed experiments. A quantitative approach to evaluating turfgrass species mixtures for roadsides in Minnesota is needed in order to improve the current mixture recommendation. The objectives of this experiment were to (1) assess the performance of several mixtures of cool-season turfgrass for survival on roadsides in central Minnesota, (2) quantitatively evaluate the influence of individual species on the survival of turfgrass mixtures on roadsides, and (3) identify a suitable mixture of cool-season turfgrass species for roadsides in central Minnesota. In fall 2011, three replications of 51 cool-season turfgrass mixtures, comprising nine species of turfgrass, were established at two roadside locations in the metropolitan area surrounding St. Paul, MN, USA. Survival of the established mixtures was assessed using digital image analysis to determine percent living ground cover during both spring and summer 2012, and again using a grid-intersect method during spring 2013. Several mixtures were identified that performed significantly better than the current specified mix during spring or summer 2012. The log-odds of a plot retaining at least 60% living turfgrass cover in spring 2013 decreased by 1.78 for mixtures including tall fescue (*Festuca arundinacea* L.). Hard fescue [*Festuca trachyphylla* (Hack.) Krajina] and sheep fescue (*Festuca ovina* L.) increased the log-odds of success by 0.95 and 0.96, respectively, and both estimates were significant at the 90% confidence level. Quantitative analysis of survival percentage in spring 2013 indicated that the best mixture for roadsides in central Minnesota comprises 20% slender creeping red fescue, 40% hard fescue, and 40% sheep fescue. These results can be used by public works officials to implement and improve roadside turfgrass mixtures in Minnesota.

1. Introduction

Roadsides present substantial and unpredictable challenges to maintaining vegetative cover due to stressful conditions that can be extreme. Drought, low nutrient availability, disease, ice cover, and exposure to road salt are just a few examples of the many stresses placed on roadside vegetation. Moreover, mid-continental positions of many locations in the United States where road salt is necessary, including Minnesota, exhibit highly variable environments including a wide range of temperature, humidity, and soil moisture conditions. These conditions necessitate vegetation with a distinct set of plant community characteristics that must be considered when identifying proper vegetative cover.

Turfgrasses are typically implemented on roadsides to avoid contrast with adjacent land use, prevent erosion, and enhance visibility for drivers without the need for extensive mowing. Their use as roadside vegetation first became of interest during the 1930s due to the construction of a number of large-scale highway projects including the United States Numbered Highway System and the Autobahnen in Germany (Hottenstein, 1969; Weingroff, 2013). However, no single species of turfgrass possesses a superlative tolerance to all of the concurrent stresses experienced by roadside vegetation. It is well documented that multi-species assemblages are needed to maintain a high-functioning ecosystem (Tilman et al., 2001; Zavaleta et al., 2010; Isbell et al., 2011). Watschke and Schmidt (1992) reviewed the literature showing that, indeed, this concept extends to turfgrass communities. It is therefore likely that a mixture capable of taking advantage of the unique tolerances of several species will produce the most sustainable and functional roadside turfgrass.

Selection of the proper species proportions for use on roadsides, however, has been troublesome. Many early attempts to provide a

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suitable grass mixture for roadsides resulted in overly complicated mixtures including between five and fifteen grasses, three to four legumes, and two herbs (Boeker, 1970). Since that time, grass mixtures for roadsides have been improved and refined to use as few as four well-chosen species (Boeker, 1970). Some basic principles for creating cool-season turfgrass mixtures for roadsides were laid out by Blaser (1963) who concluded that seed mixtures should not contain any species with aggressive seedlings such as ryegrasses or cereals, and found that all mixtures containing tall fescue (*Festuca arundinacea* L.) and Kentucky bluegrass (*Poa pratensis* L.) performed well in roadside trials. Henensal et al. (1980) conducted a roadside study of polystands in a clay soil outside of Paris, France in what was described as a "marine climate, altered to some extent." The authors reported that including more than 10% perennial ryegrass (*Lolium perenne* L.) in the mixture impeded growth of all species in the mixture and that performance over time was generally poor. Moreover, they noted that polystands consisting of 'Dawson' slender creeping red fescue (*Festuca rubra* L. ssp. *litoralis*), 'Biljart' hard fescue [*Festuca trachyphylla* (Hack.) Krajina], and 'Tracenta' colonial bentgrass (*Agrostis capillaris* L.) performed best. They concluded that, in that environment, roadside mixtures should be based on those three species. Butler et al. (1974) identified individual species as being salt tolerant, but did not evaluate mixtures and concluded that there was great need for further research focused on salt-related plant problems. Brown and Gorres (2011) evaluated the effect of soil amendments on several monocultures and one experimental species mixture from the Rhode Island Department of Transportation on roadsides in Rhode Island. The mixture exhibited variable performance across experimental locations and soil amendments. At one location the mixture maintained the greatest amount of turf cover among all trial entries, and was similar to monostands of strong creeping red fescue (*Festuca rubra* L. ssp. *rubra*), when established in a biosolids-amended soil. At the other experimental location, the mixture maintained the greatest amount of turf cover among all entries when established in a compost-amended soil.

Today, several states have specified turfgrass mixtures for roadsides with the goal of providing basic ecosystem services required of roadside turfgrass such as providing safe driving conditions, preventing soil erosion, and filtering runoff water. In addition, it is ideal that the mixtures should maximize persistence over time. Those mixtures make use of several species, but given the demonstrated difficulty in the design and analysis of roadside mixture trials, they are seldom based on results of recent, designed experiments. This is, in part, because, most recent mixture experiments have focused on evaluating the effects of treatments such as golf cart or foot traffic, mowing frequency and height, and fertilizer regime. These factors, while important in other contexts, are not entirely relevant in roadside ecosystems. Moreover, such practices are neither easily specified nor often followed in roadside vegetation maintenance practices. Recent trials have, however, shown that significant changes in performance can be generated by altering mixture species proportions (Engel and Trout, 1980; Shildrick, 1980, 1982; Brede and Duich, 1984a, 1984b; Hsiang et al., 1997; Dunn et al., 2002; Larsen et al., 2004).

It is clear that there is a need for designed experiments aimed at improving cool-season turfgrass mixtures for roadsides. Such experiments would include quantitative, *in situ* evaluations of mixture performance and a method to identify superior turfgrass species mixtures. Such a method should: (1) systematically define mixtures to be included in the trial, (2) quantify the effect of each species on the success of a mixture including any synergisms or interferences with other species that may be present, and (3) identify the best possible mixture composition based on the quantitative effects of each species.

In the present study we have taken a system-level statistical approach, similar to that suggested by Friell et al. (2013b), which allowed us to identify a best mixture of cool-season turfgrass species for roadside establishment in central Minnesota, USA based on carefully designed entries and quantitative measures of survival. We selected cultivars based on both their ability to establish and survive on roadsides in central Minnesota (Friell et al., 2012) and direct assessments of their salt tolerance during vegetative growth (Friell et al., 2013a). Although our results are applicable under the environmental conditions of the study, our approach is generalizable such that the wide range of stressful conditions and maintenance practices, which cannot be consistently well defined on roadsides, may be accounted for at any given location. Implementation of this novel approach to cool-season turfgrass seed mixture experimentation provided a sound methodology by which to accomplish the objectives of our study: (1) assess the performance of several mixtures of cool-season turfgrass for survival on roadsides in central Minnesota, (2) quantitatively evaluate the influence of individual species on the survival of turfgrass mixtures on central Minnesota roadsides, and (3) identify a suitable mixture of cool-season turfgrass species for central Minnesota roadsides.

2. Materials and methods

2.1. General approach

First we identified mixtures of cool-season turfgrass that performed well on roadsides in central Minnesota. We then quantified the extent to which individual species were responsible for the superior performance. Finally we used that information to define the best possible turfgrass seed mixture for roadside environments like those in the study.

The mixtures included in the trial were designed using an extreme vertices simplex design (Snee and Marquardt, 1974). Extreme vertices designs systematically identify mixtures to be design points in a trial based on the total number of species in the trial and the constraints placed on proportion of each species. Each of those mixtures, in effect, becomes a treatment for the experiment and is seeded into a plot. Given a large number of species included in the trial, the set of identified treatments is likely to exceed the physical space available for the trial. In such a case, a design optimization algorithm is used to select a subset of the design points that allow for the greatest amount of information to be gained from the experiment. In this type of experiment, the total number of seeds per unit area is held constant so as to avoid confounding the effects of total seeding rate with effects of individual species seeding rate.

The response data were examined in three ways. First, the effects of mixture, time, and weed cover on percent living ground cover were assessed using linear mixed effects modelling. The purpose of this was simply to identify any obvious trends in mixture performance and provide a check for the results of the second and third analysis steps. Second, logistic regression was used to quantify the extent to which the presence or absence of a species in an applied seed mixture increased or decreased the success of the plot after two years. This allowed for the identification of species that may be considered important to the success of a plot. Finally, a polynomial function specifically designed for simplex experiments (Scheffé, 1963) was fit to survival response data. The fitting was done in a least squares sense, using the species proportions as the independent variables. Fitting the polynomials was equivalent to carrying out multiple linear regression with the intercept term forced to be equal to zero. The resulting regression equation defined a response surface for the survival of all possible mixtures in the design space, from which, the best possible mixture was predicted.