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Review

The performance of native and non-native turfgrass monocultures and native turfgrass polycultures: An ecological approach to sustainable lawns

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Abstract

As environmental impacts and life-cycle costs (water use, water, fertilizer, pesticides and mowing) of the constructed landscape come under increasing scrutiny, the development of methods to reduce resource inputs for managed turf are increasingly important. While the use of a number of native turfgrass species as alternatives to non-natives has been previously examined, only a few are presently commercially available, and many species have been perceived as failing to perform to the level required by industry and consumers. Furthermore, the use of polycultures of native turfgrasses has not been extensively investigated, but could offer an alternative to the conventional lawn. We hypothesize that because native short grass species would be expected to be well-adapted to climate and soil conditions in areas with infrequent and erratic rainfall, their performance in terms of drought resistance, resilience to disturbance, and efficient resource use, will exceed that of a non-native species. Moreover, ecological theory predicts that a polyculture of coexisting native species may exhibit additional performance benefits. One native (*Bouteloua dactyloides*) and one commonly-used, non-native monoculture (*Cynodon dactylon*) and two native polyculture assemblages (two and seven species including *B. dactyloides*, *Bouteloua gracilis*, *Bouteloua rigidiseta*, *Hilaria belangeri*, *Erioneuron pilosum*, *Bouteloua hirsuta*, *Sporobolus vaginiflorus*) were compared for leaf density and weed resistance under two irrigation regimens, traffic regimes and mowing intensities. The native turfgrass and turfgrass assemblages generally had 30% higher leaf densities in the early growing season, and up to 50% lower weed density than the non-native monoculture. There was no difference among species tested in response to traffic or irrigation regimens, suggesting that all assemblages could be subjected to both higher traffic frequencies and reduced water inputs. Even though native species can have slower growth rates compared to the non-native species they maintained a higher or equivalent leaf density than the non-native turfgrass. This is a potentially important finding because of the large impact that mowing has on the total carbon footprint of turfgrass, and the corresponding reduction in that carbon footprint that could be realized through a reduced mowing frequency and corresponding reduction in life-cycle cost. This study suggests that regionally adapted native grass species are worth investigating as mono- and polycultures for performance advantages and lower resource inputs, and consequently may be suitable alternatives to conventional non-native turfgrasses in many applications.

Introduction

Turfgrasses comprise a large portion of residential and commercial landscapes, particularly in the United States, where turfgrasses taken together constitute the largest irrigated crop in America, covering over 16 million hectares of which 10 million hectares is residential lawn (Bormann et al., 2001; The Lawn Institute, 2010). Historical, horticultural performance expectations of turfgrasses include: ease of propagation and aesthetic qualities such as color, textural density and homogeneity; and depending on application, an ability to cope with foot and/or light vehicular traffic. There has been considerable horticultural research over the last 50 years which has focused on the selection of species to fulfill these demanding performance requirements, through breeding or genetically modifying a single, frequently non-native species, to meet the desired criteria. Recently, the public and many regulatory agencies have expressed concern over the high life-cycle costs of managed turf stemming from high pesticide, fertilizer and water use, high mowing rates, and problems with pathogens (Robbins and Birkenholtz, 2003). It is estimated that every year lawns in the United States use between 30% and 60% of municipal potable water, over $5.2 billion of fossil fuel derived fertilizers, 800 million gallons of gasoline and $700 million of pesticides (Bormann et al., 2001). Additionally, as more grass species and varieties are tested and marketed for the wide range of turfgrass applications throughout the United States, there is a potential increase in economic and ecological cost associated with the risk that many of these improved grasses could become invasive outside of the lawn environment. For example, bermudagrass (*Cynodon dactylon* (L.) Pers), due to its widespread commercial use and consequent escape, is now considered a problematic weed in Texas and other southern US states (Duble, 1996, Invasive Plant Atlas, 2010), and the USDA lists this species as a noxious weed in Arkansas, California and Utah (USDA, 2010). For these reasons there has been increasing attention toward the selection and propagation of native turfgrasses which have demonstrated a variety of other beneficial traits, including low nutrient requirements and drought tolerance (Bormann et al., 2001, Duble, 1996, McAfee and Leps, 2001, McKernan et al., 2001).

Several species native to North America have been examined for turfgrass applications, including warm season grasses such as buffalograss (*Bouteloua dactyloides* (Nutt.)), blue grama (*Bouteloua gracilis* (Kunth.) Lag. Ex Griffiths), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), native paspalums (*Paspalum* spp.) and lovegrasses (*Eragrostis* spp.); as well as cool season grasses including red fescue (*Festuca rubra* L.), velvet bentgrass (*Agrostis canina* L.) and native bluegrass species (*Poa* spp.) (Casler, 2006, Frank et al., 2004, Jenkins et al., 2004, Mintenko et al., 2002). These studies demonstrate the potential suitability of the species under examination, but acknowledge (e.g. Jenkins et al., 2004) that significant horticultural development would be necessary before commercial application.

One species in particular, *B. dactyloides*, a short, stoloniferous warm-season grass native to the Great Plains of North America, has been increasingly used for low-traffic turfgrass applications, and has been widely tested in southern states as a potential substitute for the more commonly used non-native warm–season species such as *C. dactylon*, St. Augustine (*Stenotaphrum secundatum* (Walter) Kuntze) and zoysia (*Zoysia japonica* (Steud.)) (Huang, 1999, Mintenko et al., 2002). While the native grass *B. dactyloides* has been demonstrated to have good drought tolerance, slow growth rate and low nutrient requirements (Casler, 2006, Duble, 1996, McAfee and Leps, 2001, Timmons, 1950), it has compared less favorably with non-native counter parts with respect to foot traffic (Duble, 1996), resistance to invasion by unwanted grasses and forbs (Anonymous, 2003, Geren et al., 2009), and, due to its grey-green hue, lower aesthetic appeal (McAfee and Leps, 2001). Consequently, *B. dactyloides* is considered an inferior substitute for most residential and commercial applications despite the conceptual appeal of using a regionally native species. Some negative aspects of this species' performance, however, may have been a result of poor installation and management. Specifically, inadequate soil preparation, over-mowing, and high use of water and fertilizer, which may be appropriate for many commonly used turfgrasses, but can have negative effects on the performance of *B. dactyloides* (Duble, 1996, McAfee and Leps, 2001). Other native grasses have also demonstrated considerable potential as turfgrasses due to high leaf density and drought resistance, and performed as well if not better than some commonly used non-natives (McKernan et al., 2001, Mintenko et al., 2002, Romani et al., 2002) and with further breeding efforts could result in an acceptable monocultural turfgrass.

However, this "horticultural approach" to the selection and creation of turf monocultures from native grassland species presupposes a theoretical method which may need to be questioned. The horticultural approach focuses on the selection or modification of individual species to fit a wide range of performance requirements which may rely on considerable, potentially unsustainable management inputs to maintain targeted performance characteristics. But as ecological engineering can be defined as the design of sustainable systems consistent with ecological values (Bergen et al., 2001, Gosselin, 2008), we suggest that, following these principles, an alternative "ecological approach" would be more appropriate. Such an approach would takes into account multiple biotic and abiotic processes and interactions, of both existing and hypothetical plant communities to address the same targeted performance values. While application of this approach in the constructed landscape has not been empirically tested, it has been widely used in forage science (e.g. Smith and Allcock, 1985) and ecological restoration (e.g. Jackson et al., 1995). Theory suggests ecological design could provide significant value for turfgrass applications through the mimicry or replication of the attributes of native plant communities.

Natural grasslands offer a case in point. Under natural conditions few grasses occur as monocultures. Most occur in assemblages with other grasses and forbs, where their individual performance is affected by coexistence and competition with other species. Indeed, most natural grasslands are species-rich systems maintained in this state by the dynamics of rainfall patterns, pathogens, soil heterogeneity, wildfire, grazing and other ecological inputs and disturbances. Disturbance regimes and the resulting species response and interactions may result in fluctuation over time in frequency of a single species population within the community, but the plant community as a whole is resilient, maintaining a consistent population over time (Begon et al., 1996). As such, plant communities with high species richness tend to exhibit greater stability, both spatially and temporally (Tilman et al., 2006a). McKernan et al. (2001) demonstrated that grass species mixes were better at weed resistance than single species due to a proposed 'synergistic effect'. Addition of species for weed suppression is also employed in agriculture where 'non-crop' species are added to reduce the potential competitive effect of weed on target crop and even erode seed bank over time (Blackshaw et al., 2000, Nice et al., 2001, Roberts et al., 2001, Picasso et al., 2008). This suggests that there may be potential advantages of multi-species mixes of co-occurring native species with similar traits, appearance and habitats to create lawns with greater residence to traffic, drought and weed invasion while requiring fewer maintenance inputs. To some extent this has is already practiced with non-native species. Grass mixes are recommended for specific turfgrass applications: to either maintain a year-round green or shade-sun situation, but these usually comprise one or more non-native species (e.g. rye grass *Lolium perrenne* and Kentucky bluegrass *Poa pratensis*). We suggest that this principle should be tested further by examining the relative performance of native and non-native species and as selected multi-species combinations.

This study tests the following hypotheses:

H1

Leaf densities, of polycultures of turf grasses are greater than single native or non-native turfgrass species.

H2

Weed densities, in polycultures of turf grasses are less than single native or non-native turfgrass species.

H3

Leaf densities, of polycultures of turf grasses under high traffic conditions are greater than single native or non-native turfgrass species.

Section snippets

Site description

Experimental plots were established in a former pasture in Austin, Texas (30°11′N, 97°52′W; elevation 247 m; mean annual rainfall 810 mm). Climate is subhumid, subtropical with a bimodal rainfall pattern peaking in spring (April–June) and fall (September–October). Soils are highly disturbed, remnant spoil excavated for an adjacent highway derived from clayey, mixed thermic, lithic argiustolls of the Speck series (10–50 cm deep) (USDA, 1974). In March 2007 prior to seed sowing, soil was modified …

Results

Concentrations of principal plant nutrients following addition of supplemental fertilizer were high and probably not limiting to growth by the end of the season (Table 3). The watering treatments resulted in the higher than average rainfall treatment receiving 12% more than the annual mean with only 1 month (May) showing a total less than the mean (Fig. 1). The below average treatment received 18% less than annual with 3 months exceeding the monthly mean (Fig. 1).

Total weed cover was …

Weeds suppression

The most common weeds in turfgrass in Texas are cool and warm season species of grasses (e.g. *Digitaria* sp., *Bromus* spp.) and forbs (e.g. *T. officinale*, *Dichondra* spp.) and mainly occur in the wetter, cooler months of spring and early summer. This trial demonstrated that turf leaf densities were highest in the spring for the native species but *C. dactylon* density peaked in July. If weed suppression is a function of leaf density then this would explain the greater weed resistance of the native …

Conclusion

The concept of the evenly-green, close-cropped, landscaped lawn is a highly desirable and entrenched part of the modern constructed landscape, but its design origins are from the native temperate grasslands of Europe. There, intense grazing pressure from livestock and other herbivores created an herbaceous layer comprising low growth-form, but highly diverse, grasses and forbs. Such a complex of plant species features an assortment of life histories which occupy a range of ecological niches. As …

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