Low-input turfgrass species as a pest management strategy

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Dedication

This thesis is dedicated to my family who fostered my passion and enthusiasm for plant science and to my friends who have supported me throughout this research project.

Abstract

A number of alternative grass species, not widely used as turf, show significant potential for use as turf in the United States northern Midwest. Many alternative species have also exhibited better adaptation to low-maintenance conditions than traditionally used species, and it is also probable that these alternative species may have superior tolerance to common turf pests, specifically diseases. Yet, the use of alternative grass species as a novel integrated pest management strategy has not been explicitly evaluated. In this research, three experiments were conducted to evaluate the use of alternative turfgrass species as an integrated pest management strategy in Minnesota.

The objective of the first experiment was to evaluate the field performance of four alternative turfgrass species including hard fescue (*Festuca trachyphylla* (Hackel) Krajina), colonial bentgrass (*Agrostis capillaris* L.), tufted hairgrass (*Deschampsia caespitosa* (L.) P. Beauv.), and prairie junegrass (*Koeleria macrantha* (Ledeb.) Schult.), under different low-input management regimes in Minnesota. Species were evaluated for turfgrass quality, weed cover, live cover, and disease resistance at two locations in Minnesota over two years. Fertilizer treatment and mowing height significantly affected species performance, and the results indicate that alternative grasses, specifically hard fescue, can be excellent options for lower-input landscapes.

Two additional experiments were conducted to determine the economic viability of using alternative grass species as a pest management strategy. First, a choice experiment with real products was conducted to investigate the willingness to pay (WTP) of Minnesota homeowners for maintenance attributes of turfgrasses. Homeowners were willing to pay significant premiums for turfgrasses with reduced irrigation and mowing requirements. Secondly, conjoint analysis was used to further investigate the consumer preferences of Minnesota homeowners for aesthetic and maintenance attributes of turfgrasses, as well as identify potential market segments in the residential turfgrass market. The results suggest that maintenance attributes significantly influence consumer purchasing behavior, and they also identify a strong consumer preference for reduced irrigation and mowing requirements. The analysis also identified four potential consumer segments: the "Price Conscious" segment (consumers who value low cost), the "Shade Adaptation" segment (consumers who value grasses that can grow in the shade), the "Mowing Conscious" segment (consumers who value reduced mowing requirement), and the "Water Conscious" segment (consumers who value grasses with reduced water-use requirements). Overall, the results support that the introduction and use of alternative, low-input turfgrasses would be an economically viable pest management strategy in the residential landscape.

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LITERATURE REVIEW

Urbanization in the United States over the past 30 years has prompted the examination of the ecological impacts of widespread turfgrass acreage as well as associated management practices. Milesi et al. (2005) estimated that turfgrass, including golf courses, parks, residential and commercial lawns covers 1.9% of the continental U.S. Thus raising concerns about the irrigation requirements of such a large turfgrass area. Additional concerns about the ecological impacts of turfgrass management practices include the effects of potential nutrient runoff and leaching from fertilizer applications (Eason and Petrovic, 2004; Soldat and Petrovic, 2008), as well as the effects on soil biota (Cheng et al., 2008). In the U.S., both state and local governments have responded to public concerns by instituting regulations on lawn care practices, such as municipal water restrictions concerning home lawn irrigation and state-wide restrictions on phosphorous containing lawn fertilizers (Boer and Ripp, 2008; MassDEP, 2010; State of Minnesota, 2010; State of Wisconsin, 2011). Nevertheless, healthy turfgrass does provide environmental benefits such as carbon sequestration (Qian et al., 2010), reduced soil erosion and surface runoff from urban areas (Krenitsky et al., 1998), mitigation of urban heat island effects (Peters et al., 2011), as well as functional and aesthetic benefits to society (Beard and Green, 1994).

Turfgrass managers and professionals have adopted integrated pest management (IPM) strategies in an effort to reduce pesticide use. IPM is an ecology-based pest management strategy which utilizes cost-effective methods that minimize negative impacts on society and the environment (Kogan, 1998). Disease forecasting and the use of economic thresholds in decision making have been employed to increase the efficiency of pesticide applications (Nyrop et al., 1995; Uddin et al., 2003). The use of biological controls of turfgrass pests has also been explored as an integrated pest management strategy, such as the use of the bacterial strain (*Stenotrophomonas maltophilia* strain C3) for the suppression of brown patch disease (*Rhizoctonia solani* Kuhn) (Yuen and Zhang, 2001), the use of compost applications for the suppression of dollar spot disease (*Sclerotinia homoeocarpa* F.T. Bennett) (Boulter et al., 2002), and the use of entomopathogenic nematodes in combination with insecticides for improved white grub (Coleoptera: Scarabaeidae) control (Koppenhofer and Kaya, 1998). Cultural practices may also be modified to reduce pesticide use. Davis and Dernoden (1991) observed that mowing height, irrigation schedule and nitrogen source all significantly affected the development of summer patch disease (*Magnaporthe poae* Landschoot & Jackson) on Kentucky bluegrass (*Poa pratensis* L.). Similarly, Fidanza and Dernoden (1996) observed that morning irrigation and a slow release nitrogen source (sulfur-coated urea) significantly reduced the development of brown patch disease on perennial ryegrass (*Lolium perenne* L.) when compared to evening irrigation and a quick release nitrogen source (sodium nitrate). Although methods such as disease forecasting, biological control, and the modification of cultural practices can significantly decrease damage inflicted by turfgrass pests, they cannot eliminate the use of pesticides entirely.

Genetic resistance remains one of the most effective and sustainable methods of pest management. Extensive improvement in turfgrass disease resistance has been achieved through breeding efforts (Bonos et al., 2006). Reinert et al. (2004) highlight the importance of selecting cultivars resistant to insect predation. Richmond et al. (2006) demonstrate the importance of both proper cultivar and species selection as a weed management strategy. Out of the 10,000 species in the Poaceae family, only a few grass species are used for turf purposes. Grasses belonging to this family exhibit an extremely wide range of adaptation to different environments, and this variation remains a relatively underutilized resource (Wang et al., 2001). Although species selection is well known as a critical component of pest management, little effort has been dedicated to investigating the use of novel, alternative grass species as an IPM strategy.

Low-input, alternative turfgrass species for the U.S. northern Midwest

Interest in lowering resource inputs initiated the search for alternative grass species which were better adapted to low-input maintenance. One of the first field trials aimed at identifying alternative, low-input turfgrass species adapted to the northern Midwest region evaluated eleven alternative grass species at three mowing heights under low-input conditions (i.e. no supplemental irrigation and 49 kg N ha^{-1} yr^{-1}) (Diesburg et al., 1997). Species performance was evaluated over a three year period in 7 states throughout the northern Midwest. Although there was a significant species by location interaction, tall fescue (*Festuca arundinacea* Schreb.), sheep fescue (*Festuca ovina* L. ssp. *hirtula* (Hackel *ex* Travis) M. Wilkinson), hard fescue (*Festuca trachyphylla* (Hackel) Krajina), and colonial bentgrass (*Agrostis capillaris* L.) exhibited the greatest potential of the eleven grass species for use as low-input turfgrass. Although pesticide use over the three year period was minimal, one herbicide application each year was necessary. A similar trial was conducted to evaluate the performance of alternative, cool-season grass species under low-input conditions in Canada (McKernan et al., 2001). Nineteen different species, along with ten mixtures, were evaluated at two locations over three years. The plots were maintained at a height of 7.6 cm and received no supplemental irrigation, fertility, or pesticide applications, with the exception of one herbicide application in the first year. Blue grama (*Bouteloua gracilis* (Willd. *ex* Kunth) Lag. *ex* Griffiths) provided excellent drought tolerance and percent turf cover. The fine-leaf fescues (hard fescue and sheep fescue) exhibited moderate tolerance to drought, excellent percent turf cover, and superior resistance to weed encroachment. Additionally, mixtures provided superior resistance to weed encroachment compared to monocultures.

Attention has also been focused on identifying alternative, native grass species that exhibit potential for use as low-input turf. Although native grasses are not generally well adapted to intensive management, a number of species have shown potential for use as turf in areas receiving minimal resource and management inputs (Johnson, 2008). A four year trial was conducted at two locations in Canada to evaluate twelve native grass species for use as low-input turf (Mintenko et al., 2002). Irrigation was only applied during the summer of the first year to alleviate drought stress, and the trial received minimal fertility and herbicide applications over the four year period. Two blue gramma entries and the prarie junegrass cultivar, 'Barkoel', provided the highest turf quality across years. Tufted hairgrass (*Deschampsia caespitosa* (L.) P. Beauv.) exhibited exceptional turf quality in the spring, but quality significantly declined during the summer. It is worth noting that the prairie junegrass cultivar 'Barkoel' did not originate from native germplasm. The most recent low-input, alternative grass species trial was conducted using the results of previous regional trials (Watkins et al., 2011). Twelve turfgrass species (both native and non-native) were evaluated across eight states in the U.S. northern Midwest. Trials were maintained with no supplemental irrigation or fertility and a single herbicide application in the first year. Although species performance varied by year and location, hard fescue, tall fescue, sheep fescue, and colonial bentgrass were recommended for use as low-input turfgrass in the northern Midwest. Tufted hairgrass, prairie junegrass, blue grama, and hybrid bluegrass (*Poa arachnifera* Torr. × *Poa pratensis* L.) also exhibited potential for use as low-input turfgrass throughout the region.

The species by location interactions observed in previous trials suggest that further research on a state or local scale is necessary for specific recommendations. Also, further research on intraspecific differences in performance will also help refine recommendations for alternative, low-input turfgrasses. Limited disease and pest occurrence was reported in the four regional trials, which indicates that the use alternative, low-input grass species may have potential as an IPM strategy.

Hard fescue (*Festuca trachyphylla* [Hackel] Krujina)

Hard fescue is a perennial, slow-growing, bunch-type grass that is native to central Europe and is well-adapted to the climate in the U.S. northern Midwest. It is also tolerant of shade and low fertility and prefers well drained, sandy soils (Beard and Beard, 2005; Christians, 2004; Hubbard, 1984). Hard fescue exhibits superior drought tolerance relative to Kentucky bluegrass, perennial ryegrass, and tall fescue (Aronson et al., 1987; Brar and Palazzo, 1995) and has maintained excellent turf quality in low-input trials throughout the northern Midwest (Diesburg et al., 1997; McKernan et al., 2001; Watkins et al., 2011). Newer cultivars exhibit enhanced resistance to disease, including read thread (*Laetisaria fusiformes* [McAlp.] Burdsall), dollar spot, and Microdochium patch (*Microdochium nivale* [fr. Samuels and Hallet]) (Meyer, 1982; Ruemmele et al., 2003).

Some hard fescue cultivars, including ‘Reliant II’ have also shown excellent wear tolerance (Bonos et al., 2001).

Hard fescue possesses a number of natural methods for dealing with pests. Endophyte-mediated resistance to both pest predation and disease has been reported in hard fescue. Endophyte infected hard fescue cultivars exhibit superior resistance to predation by fall armyworm (Lepidoptera:Noctudiae) and chinch bug (Hemiptera:Lygaeidae) populations (Breen, 1993; Funk et al., 1993)., Endophyte-mediated resistance to dollar spot disease has also been observed among hard fescue cultivars (Clarke et al., 2006). ‘Reliant II’ hard fescue has demonstrated enhanced natural weed suppressive ability in field conditions which may be linked to allelopathy, or the natural suppression of weed encroachment through the exudation of weed-suppressive chemicals by plant roots (Bertin et al., 2009). Additionally, varying degrees of natural tolerance to glyphosate has been observed in the species. Hart et al. (2005) reported that ‘Aurora Gold’ hard fescue, which was the product of a recurrent selection program to increase glyphosate tolerance, could withstand rates up to 0.8 kg ha^{-1}. Natural tolerance to glyphosate, an herbicide with low environmental impact, tolerance to insect predation, disease, and weed infestation, in combination with excellent performance in low-input, regional trials indicate that the use of hard fescue in the urban landscape should be considered as an IPM strategy.

Colonial bentgrass (*Agrostis capillaris* L.)

Colonial bentgrass is native to Europe and temperate Asia and was originally used on closely mown sports greens, tennis courts and lawns (Hubbard, 1984). Colonial bentgrass is a perennial, bunch-type grass that often forms short rhizomes and stolons, has excellent cold tolerance and moderate tolerance to heat, drought, and low fertility (Beard and Beard, 2005; Ruemmele, 2000; Ruemmele, 2003). Although the suggested mowing height for colonial bentgrass is 1.0 to 1.5 cm (Christians, 2004), results from recent studies suggest that it may also provide acceptable quality when maintained at mowing heights up to 10.2 cm (Diesburg et al., 1997; Watkins et al., 2011). Colonial bentgrass is known for having superior resistance to dollar spot compared to creeping bentgrass (*Agrostis stolonifera* L.), and interspecific hybrids between the two species exhibit enhanced resistance to dollar spot (Belanger et al., 2004; Chakraborty et al., 2006). Gregos et al. (2011) found that colonial bentgrass provided better resistance to snow mold than creeping bentgrass under fairway conditions. Yet, brown patch susceptibility is one of the current limitations to the use of colonial bentgrass (DaCosta and Huang, 2006; Ruemmele, 2003). Although, newer cultivars exhibit improved quality and resistance to both brown patch and Microdochium patch (NTEP, 2011). The aggressive growth habit, tolerance to abiotic stresses, resistance to common diseases observed in the northern Midwest, and performance of recent colonial bentgrass cultivars in regional trials, suggest that increased use of this species should be investigated as an IPM strategy.

Tufted hairgrass (*Deschampsia caespitosa* (L.) P. Beauv.)

Tufted hairgrass is a perennial, native, bunch-type grass which has mainly been used for forage or reclamation, although recent efforts have been initiated to develop turf cultivars (Brilman and Watkins, 2003). It is widely distributed throughout the northern hemisphere in arctic and alpine environments; it is tolerant of shade, low fertility, and heavy metal contamination (Davy, 1980; von Frenckell-Insam and Hutchinson, 1993).

Extensive ecotypic variation has been observed in this species (Davy, 1980). In recent efforts to breed tufted hairgrass for turf uses, the major obstacles encountered have been resistance to insect predation, rust disease (*Puccinia* spp.), and low tolerance to heat stress (Watkins and Meyer, 2005; Watkins et al., 2007; Watkins et al., 2011; Mintenko et al., 2002). One of the first tufted hairgrass cultivars, 'Nortran', originated from Alaskan and Icelandic germplasm collections and was bred for re-vegetation, forage, and low-input ground cover and exhibited improved resistance to rust (Mitchell, 1988). Regional trials (Mintenko et al., 2002; Watkins et al., 2011) indicate the use of tufted hairgrass should be considered as an IPM strategy, and additional investigation into species and cultivar performance in Minnesota will provide useful information to breeding programs.

Prairie junegrass (*Koeleria macrantha* (Ledeb.) Schultes)

Prairie junegrass is a native, perennial, bunch-type grass which, like tufted hairgrass, has only recently been considered for use as turf. This species is widely distributed throughout the temperate regions of North America, from Canada to Mexico, and Eurasia (Dixon 2000). Prairie junegrass has become a target species for use as a native, low-input turfgrass because it exhibits wide variation in environmental adaptation, moderate drought tolerance and quick recovery after re-watering, slow vertical growth, and tolerance to low fertility (Dixon, 2000; Clark and Watkins, 2010a; Clark and Watkins, 2010b; Looman, 1978; Milnes et al., 1998). One of the first cultivars of prairie junegrass released was the Estonian cultivar 'Ilo' (Soovali and Bender, 1997).

Wang et al. (2011) observed varying levels of salinity tolerance among prairie junegrass cultivars and native populations, noting that the European cultivar 'Barleria' exhibited the highest level of salinity tolerance. The European cultivar 'Barkoel' performed exceptionally well in the low-input turf trial conducted by Mintenko et al. (2002). Several incidents of rust diseases, including *Puccinia graminis* Pers., have been reported on prairie junegrass (Dixon, 2000; Clark and Watkins, 2010a; Looman, 1978; Mains, 1933). In addition to rust resistance, current breeding goals consist of improving mowing quality, turf quality, and seed production (Clark and Watkins, 2010a; Clark and Watkins, 2010b). Further information about intraspecific variation among prairie junegrass germplasm will be useful in the improvement of this species. Identifying the optimal management practices for this species when grown in the U.S. northern Midwest will also be useful in determining the potential of the utilization of prairie junegrass as an IPM strategy.

Economic potential of alternative, low-input turfgrasses

The majority of urban turf acreage is comprised of residential and commercial lawns. Vinlove and Torla (1994) estimated total U.S. home lawn acreage to be approximately 14 to 18 million acres, and there is an estimated 872,660 acres of home lawns in the state of Minnesota alone (Meyer et al., 2001). The use of alternative, low-input turfgrasses as an IPM strategy could have a huge impact on turfgrass management practices in the urban landscape. In order for this IPM strategy to be viable, alternative grasses must not only provide an acceptable turf surface under fewer resource inputs, their introduction to the market must also be economically feasible. With the exception of the limited availability of fine-leaved fescues, the majority of seed available to homeowners in the northern Midwest is Kentucky bluegrass and perennial ryegrass.

Conjoint analysis is commonly used to investigate consumer preferences for novel products not yet available on the market. It is based on the idea that consumer satisfaction for a product as a whole is determined by the value placed on each of the product's individual attributes (Baker, 1999; Green et al., 2001). By allowing consumers to evaluate multiple combinations of product attributes (i.e. alternatives), the value (i.e. utility) of each attribute can be estimated using regression methods. The relative importance of each attribute, which represents the magnitude of importance an attribute contributes to a consumer's overall valuation of a product, can then be estimated from utility values. Additionally, if individual regression models are fit instead of an aggregate model for an entire sample, participants with similar preferences can be grouped together using cluster analysis. Not only does this method help identify potential market segments, but it also reduces bias introduced when consumers have differing preferences (Green and Helsen, 1989). Conjoint analysis in combination with cluster analysis has been used to examine consumer preferences and identify potential market segments for many horticultural products, such as consumer preferences for various attributes of bell peppers (Frank et al., 2001), tabletop Christmas trees (Behe et al., 2005b), Satsuma mandarins (Campbell et al, 2004), asparagus (Behe, 2006), biodegradable containers (Hall et al., 2010) and geraniums (Behe et al., 1999). Utilizing conjoint analysis, Behe et al. (2005a) found that an appealing landscape added 5-11% to the perceived value of a home. In a conjoint analysis of consumer preferences for ornamental plants, Townsley-Brascamp and Marr (1995) found that consumers placed the most importance on the health of a plant and the suitability of a plant for his or her garden when purchasing ornamental plants. Studies suggest that certain consumer segments are environmentally conscious and consequently make more ecologically-minded purchasing decisions (Yue et al., 2010).

In recent years, the choice experiments have been widely used to elicit consumer preferences as well as willingness to pay (WTP) for product attributes which can reveal additional information about the economic viability of a novel product (Gao et al., 2010). In conjoint analysis consumers are asked to rank or rate product alternatives with different combinations of attributes, whereas in choice experiments consumers are asked to make purchasing decisions between product alternatives with varying combinations of attributes. Choice experiments have been used to identify consumer preference and willingness to pay for organic, natural, and locally grown foods (Gil et al., 2000; Onken et al., 2011; Yue and Tong, 2009) and biodegradable flower pots (Yue et al., 2010). Using a choice experiment, Helfand et al. (2006) found that consumers were willing to pay a price premium for environmentally-friendly landscapes with differing levels of native plantings relative to a traditional, monoculture lawn. To eliminate potential bias introduced by the hypothetical nature of choice experiments, real products and experimental auctions have been used in choice experiments to model purchasing decisions and elicit WTP (Alfnes et al., 2006; Yue et al., 2011; Yue and Tong, 2009). Lusk and Shroeder (2004) demonstrated that marginal WTP was equivalent between hypothetical and non-hypothetical experiments when real products were used. Although previous research shows that there is economic potential for environmentally-friendly goods and services (Hu et al., 2009; Laroche et al., 2001; Schegelmilch et al., 1996; Straughan and Roberts, 1999; Engel and Potschke, 1998; Guagnano et al., 1994), there has been limited research on consumer preferences for maintenance attributes of turfgrasses.

SUMMARY

Hard fescue, colonial bentgrass, tufted hairgrass, and prairie junegrass all exhibit desirable low-input characteristics such as tolerance of drought and low fertility, and studies indicate they are well-adapted to the U.S. northern Midwest. The adaptation of these grasses to low-input conditions in the northern Midwest suggests they may also be viable candidates for use as an integrated pest management strategy. Alternative grass species must not only have superior pest resistance under low-input conditions to be an effective pest management strategy. Their introduction to the turfgrass market must also be economically viable, meaning there must be consumer demand for alternative, low-input grasses and their production must be economically feasible for the turfgrass seed industry. The objectives of this research were to (1) evaluate the field performance and pest resistance of hard fescue, colonial bentgrass, tufted hairgrass, and prairie junegrass in Minnesota, and (2) determine the economic potential of alternative, low-input turfgrasses in the residential turfgrass market. This information will be useful in providing specific species and cultivar recommendations for low-input turfgrasses in Minnesota and in the development of effective urban pest management strategies.

Alternative Cool-Season Turfgrasses as a Pest Management Strategy in Minnesota

INTRODUCTION

The demand for low-input, sustainable urban landscapes in the United States is increasing due to public attitudes, environmental concerns, as well as state and municipal regulations (Robbins et al., 2001; Robbins and Birkenholtz, 2003; State of Minnesota, 2010; State of Wisconsin, 2011). Turfgrass comprises a significant portion of the urban landscape (Milesi et al., 2005), and despite concerns about the negative impacts of turfgrass management practices, turfgrass does provide benefits to society and the environment (Beard and Green, 1994; Krenitsky et al., 1998; Qian et al., 2010; Peters et al., 2011). Turfgrass professionals have responded to these concerns and regulations by adopting integrated pest management (IPM) strategies. While species and cultivar selection is a crucial component of turfgrass management, the use of alternative turfgrass species as an IPM strategy has not been widely explored.

Traditional turfgrass species such as Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.) dominate the landscape in the U.S. northern Midwest., but they require significant inputs to maintain acceptable cover and quality (Turgeon, 2005). There are alternative, cool-season grass species that are better adapted to low-maintenance management (Diesburg et al., 1997; Mintenko et al., 2002; Watkins et al., 2011), such as sheep fescue (*Festuca ovina* L. ssp. *hirtula* (Hackel *ex* Travis) M. Wilkinson), tall fescue (*Festuca arundinacea* Schreb.), hard fescue (*Festuca trachyphylla* (Hackel) Krajina), and colonial bentgrass (*Agrostis capillaris* L.) (Diesburg et al., 1997; Watkins et al., 2011). Several native grasses have also shown potential for use as low-input turfgrasses, including blue grama (*Bouteloua gracilis* (Willd. *ex* Kunth) Lag. *ex*

Griffiths), prairie junegrass (*Koeleria macrantha* (Ledeb.) Schult.), and tufted hairgrass (*Deschampsia caespitosa* (L.) P. Beauv.) (Mintenko et al., 2002; Watkins et al., 2011).

Additional research is required to determine whether the use of alternative, low-input turfgrasses could be an effective IPM strategy. Prior regional studies investigating low-input, alternative grass species noted significant interactions between species and location, suggesting that species and cultivar recommendations as well as recommended management practices should be based on data generated on a state or local scale. Four alternative species, hard fescue, colonial bentgrass, prairie junegrass, and tufted hairgrass were selected based on previous regional trials to be evaluated for use as an IPM strategy in Minnesota.

Hard fescue is a slow-growing, bunch-type grass adapted to cooler climates and is tolerant of shade, low fertility, and drought (Beard and Beard, 2005; Christians, 2004; Hubbard, 1984). Newer cultivars have reportedly improved turfgrass quality (color, density, etc.), tolerance to extreme temperatures, as well as improved disease resistance (National Turfgrass Evaluation Program, 2011). Substantial tolerance to glyphosate, up to 0.8 kg ha^{-1}, has been observed in some hard fescue cultivars (Hart et al., 2005). Endophyte infected hard fescue cultivars exhibit superior resistance to insect predation (Breen, 1993; Funk et al., 1993) and disease (Clarke et al., 2006). Natural resistance to weed encroachment through the exudation of weed-suppressive chemicals by plant roots, or allelopathy, has also been observed among hard fescue cultivars (Bertin et al., 2009).

Colonial bentgrass is a dense, bunch-type grass that often forms short rhizomes and stolons, has excellent cold tolerance, moderate heat and drought tolerance, and varying tolerance to low fertility (Beard and Beard, 2005; Ruemmele, 2000; Ruemmele, 2003). Although it has traditionally been used for lower-cut turf, such as golf greens and tennis courts, recent research suggests it may also be used as a low-input, higher-cut turfgrass (Watkins et al, 2011). The performance of recent colonial bentgrass cultivars in recent regional trials, suggest that increased use of this species should be investigated as an IPM strategy (Belanger et al., 2004; Chakraborty et al., 2006; Gregos et al., 2011).

Tufted hairgrass is a bunch-type, wetland grass adapted to northern environments. It has tolerance to shade, low fertility, and heavy metal contamination (Von Frenckell-Insam and Hutchinson, 1993; Brilman and Watkins, 2003). Current tufted hairgrass germplasm has shown poor resistance to insect predation, rust disease (*Puccinia* spp.), and low tolerance to heat stress (Watkins and Meyer, 2005; Watkins et al., 2007; Watkins et al., 2011; Mintenko et al., 2002). Yet, results of regional trials indicate that tufted hairgrass has potential for use as a low-input turfgrass provided further germplasm improvement (Mintenko et al., 2002; Watkins et al., 2011).

Prairie junegrass is a bunch-type grass widely distributed throughout the northern hemisphere (Dixon, 2000). Like tufted hairgrass, prairie junegrass has only recently been considered for use as turf. It has desirable low-input characteristics such as slow vertical growth, moderate drought tolerance, and tolerance to low-fertility (Clark and Watkins, 2010; Mintenko et al., 2002; Watkins et al., 2011). The European cultivar 'Barkoel' performed exceptionally well in the Canadian low-input trial conducted by Mintenko et al. (2002), and information on the performance of native germplasm will be useful in the genetic improvement of this species.

The objectives of this study were to 1) evaluate the performance (i.e. quality, functionality, and pest resistance) of colonial bentgrass, hard fescue, tufted hairgrass, and prairie junegrass when maintained under low-input conditions in Minnesota, 2) examine intraspecific variation in performance among four turfgrass species, and 3) compare species performance under various low-input management regimes (i.e. mowing height and nitrogen rate) when grown in Minnesota. These results can be used in conjunction with results from regional trials to make recommendations for the use of low-input turfgrasses for parks, residential and commercial lawns, as well as golf course roughs in Minnesota to reduce pesticide and fertilizer use as well as irrigation.

MATERIALS AND METHODS

Experimental design

The trial was seeded in the fall of 2009 at two locations, the Turfgrass Research Outreach and Education Center at St. Paul, MN [44°99'45" N, 93°18'54" W] (seeded August 18) and at the University of Minnesota Landscape Arboretum at Chaska, MN [44°86'40" N, 93°61'63" W] (seeded September 3). The soil at the St. Paul site was a Waukegan silt loam (pH 7.5, 38 ppm phosphorous, 292 ppm potassium, 3.4% organic matter). The trial at Chaska was planted on an urban soil (pH 7.9, 6 ppm phosphorous, 153 ppm potassium, 1.7% organic matter) that consisted of a mixture of construction material sourced from an excavation site nearby and a Lester Kilkenny loam. Before seeding at Chaska, the site was amended with compost derived from leaf litter and yard waste at a depth of 7.62 cm. Seventeen turfgrass entries were included in the study. The entries included four cultivars each of hard fescue and colonial bentgrass, three cultivars of tufted hairgrass, and four entries of prairie junegrass which included one cultivar and three native populations developed from germplasm collections made in Colorado (CO), North Dakota (ND), and Minnesota (MN). One cultivar each of Kentucky bluegrass and perennial ryegrass were also included to provide comparisons to higher-input turfgrasses. Cultivar and selection names as well as seeding rates are shown in Table 1.1.

The experiment was set up as a split-split plot design with four replications. Mowing height was the main plot, nitrogen rate was the sub plot, and cultivar was the sub-sub plot (individual plot size 1.0×1.5 m). A starter fertilizer was applied at a rate of 24.5 kg N ha^{-1}, 49 kg P_2O_5 ha^{-1}, and 49 kg K_2O_5 ha^{-1}, at seeding, and plots were irrigated during establishment. After establishment in the fall of 2009 plots received no supplemental irrigation or pesticide applications over the following two year period. Plots were mowed once or twice a week during the growing season at one of three mowing heights: 3.2 cm, 5.7 cm, or 8.3 cm. Fertilizer treatments were applied using Renaissance ® All Natural Organic fertilizer at one of three rates: 1) 0 g N m^{-2}, 0 g P_2O_5 m^{-2} , 0 g K_2O_5 m^{-2}; 2) 4.9 g N m^{-2}, 0 g P_2O_5 m^{-2}, 4.9 g K_2O_5 m^{-2} applied in early September; and 3) 9.8 g N m^{-2}, 0 g P_2O_5 m^{-2} , 9.8 K_2O_5 g m^{-2} (applied as a split application with 4.9 g N m^{-2} applied in late May and 4.9 g N m^{-2} applied in early September).

Data collection

Visual ratings of turf quality were taken on a 1-9 scale (1 = poor, 5 = minimally acceptable, 9 = excellent) twice a month from May through October in 2010 and 2011. Turf quality ratings were based on color, uniformity, density, and texture. The same 1-9 scale was used to rate disease severity, establishment, and spring green-up with 9 representing the best turfgrass characteristic. Disease severity ratings were taken after the onset of disease symptoms. Establishment ratings were taken in the fall of 2009, and green-up ratings were taken in the spring of 2010 and 2011. Quantitative data were collected on percent live turfgrass cover and percent weed cover in the spring and fall of 2010 and 2011 using the grid intersect method by placing a 0.3×0.9 m grid with 33 intersects twice at random on each plot. Live turfgrass cover and weed cover were scored at each intersect and converted into a percentage.

Data analysis

Data from each location were analyzed separately, and all statistical analyses were calculated in R version 2.13.1 (R Development Core Team, 2011). Establishment ratings were analyzed by species with the exception of 'Barkoel' prairie junegrass which was analyzed separately from the native prairie junegrass populations. Large morphological and genetic variability exists among prairie junegrass germplasm. Cultivars derived from European germplasm, including ‘Barkoel’, differ considerably from U.S. germplasm (Clark and Watkins, 2010; Dixon, 2000; Mintenko et al., 2002). Establishment ratings were analyzed as a randomized complete block design and subjected to analysis of variance (ANOVA). Mean separation was conducted using Fisher's protected Least Significant Difference (LSD). Turf quality data were split by year and averaged among season due to highly significant interaction effects between time and cultivar, mowing height, and fertilizer treatment. Durability is a necessary characteristic of a low-input turfgrass. Therefore, only the analysis of turf quality data from 2011 is presented. Significant interactions between cultivar and mowing height and cultivar and fertilizer treatment were detected among turf quality data in 2011, so data were further divided into two management regimes. Disease ratings were taken regularly during 2010 and 2011, but due to confounding effects with additional biotic and abiotic stresses, the analysis was limited to single rating dates at the onset of disease. Spring green-up, disease severity, and turf quality by season were analyzed with a linear mixed effects model, using the *lme* function from the 'nlme' package in R (Pinheiro and Bates, 2000). Cultivar, mowing height, fertilizer treatment, and their interactions were specified as fixed effects, and random intercepts were specified for replication, mowing height (whole plot), and fertilizer treatment (sub plot) to account for the random effects at different levels of grouping. For each response, the significance of the fixed effects was assessed by starting with a model including all fixed effects and their interactions (using maximum likelihood estimation) and then simplified by removing non-significant terms. The best combination of fixed effects was selected based upon log-likelihood ratio tests, and the final models were fit using restricted maximum likelihood estimation. The best combination of random effects was also chosen for each model using log-likelihood ratio tests. Heteroscedasticity and normality of residuals was assessed using plots of predicted and fitted values and quantile plots (Q-Q plots). Differences in disease severity and spring green-up between cultivars were tested with Tukey contrasts using the *glht* (general linear hypothesis testing) function in the 'multcomp' package in R (Hothorn et al., 2008). Significant interactions between cultivar, mowing height and fertilizer treatment regarding turf quality were detected among the seasons in 2011, so the data were further subset into two management regimes. The first management regime, or the high-input regime, consisted of plots maintained at the 3.2 cm mowing height receiving 9.8 g N m^{-2} nitrogen per year. The second management regime, or the low-input regime, consisted of plots maintained at the 8.3 cm mowing height receiving 0 g N m^{-2} nitrogen per year. Turf quality ratings within each management regime and season were treated as randomized complete block designs and subjected to ANOVA and mean separation using Fisher's protected LSD.

Percent live cover and percent weed cover were analyzed by species with the exception of ‘Barkoel’ prairie junegrass, which was analyzed independently from the native prairie junegrass populations. A linear mixed effects model was used to analyze percent live cover and percent weed cover. In addition to the three main treatment effects (i.e. cultivar, mowing height, and fertilizer treatment), season, year, and their interactions were included as fixed effects. The random effects of plot and plot by year interaction were included to account for repeated measures on the same plot. Log-likelihood ratio tests were used to identify the best combinations of fixed and random effects. When heteroscedasticity was present, the use of a variance function in the form *varIdent* in the ‘nlme’ package in R (Pinheiro and Bates, 2000) was explored to estimate within group variance and account for unequal variances among different stratification levels in the data (e.g. year, season, cultivar, etc.).

RESULTS

Establishment and Spring Green-Up

Differences in mean establishment of species at each site are provided in Table 1.2. Perennial ryegrass was the fastest to establish at both locations, but the mean establishment of colonial bentgrass and tufted hairgrass in Chaska were statistically equivalent to that of perennial ryegrass ($\alpha = 0.05$).

The native populations of prairie junegrass were not rated for spring green-up due to poor establishment. There was a significant year by cultivar interaction ($\alpha = 0.05$), so spring green-up was analyzed separately within each year (Table 1.3). In 2010, mowing height and fertilizer treatment did not significantly ($\alpha = 0.05$) affect spring green-up. In 2011, the main effects of cultivar, mowing height, and fertilizer treatment were significant at both locations. In Chaska in 2011, the interactions between cultivar and mowing height and cultivar and fertilizer treatment were significant. In 2010 'MSP 3769' Kentucky bluegrass exhibited excellent spring green-up at both locations, but in 2011 the four hard fescue cultivars exhibited the quickest green up at both locations. At both locations in 2011, spring green-up was the quickest for plots mowed at 3.2 cm and for plots receiving 9.8 g m-2 nitrogen per year (Table 1.4).

Disease Severity

Several diseases caused significant damage to turfgrass plots over the two year period including, Microdochium patch (*Microdochium nivale*), Typhula blight (*Typhula incarnata* and *Typhyla ishikariensis*), brown patch (*Rhizoctonia solani*), leaf spot (*Bipolaris* spp. and *Drechslera* spp.), and rust (unknown *Puccinia* spp.), but the analysis of disease severity was limited to single ratings of snow mold and rust.

Snow mold did not develop during the winter of 2010 at either location, but there was significant snow mold damage observed in 2011. Snow mold severity was rated as the combined effect of both Microdochium patch and Typhula blight. The native populations of prairie junegrass were not rated for snow mold in St. Paul due to heavy weed encroachment (≥ 70%). Cultivar had the largest effect on snow mold severity at both sites. Fertilizer treatment did not significantly affect ($\alpha = 0.05$) snow mold severity at either location, and the main effect of mowing height was only significant in St. Paul. The interaction between cultivar and mowing height was significant at both locations, therefore mean comparisons between cultivars were conducted separately within each mowing height (Table 1.5). In Chaska, the estimated coefficients (data not shown) of the cultivar by mowing height interaction indicated that the effect of increased mowing height on the snow mold severity of 'Arctic Green' was significantly ($\alpha = 0.05$) greater in comparison with all other cultivars in Chaska.

Rust (unidentified *Puccinia* spp.) developed on plots at both locations during mid-July of 2010 and 2011 and persisted through the fall. Rust severity was greatest in St. Paul in 2010, and the mean rust severity in July 2010 for each cultivar and selection is presented in Table 1.6. Multiple species of rust have been reported on Kentucky bluegrass, perennial ryegrass, tufted hairgrass, and prairie junegrass, including crown rust (*Puccinia coronata*) and stem rust (*Puccinia graminis*) (Bonos et al., 2006; Davy, 1980; Looman, 1978; Mains, 1933; Watkins and Meyer, 2005). Separate ratings were not taken for different species of rust; therefore it is probable that the rating of rust severity encompasses multiple types of rust depending on species. Cultivar, mowing height, nitrogen rate, and their interactions significantly ($\alpha = 0.05$) affected rust severity. Due to significant interactions between cultivar, mowing height and fertilizer treatment, comparisons of cultivars were conducted within each mowing height and fertilizer treatment. Rust severity generally decreased with reduced mowing height and increasing nitrogen rates. 'Barkoel' prairie junegrass had the least rust development across mowing heights and nitrogen rates, and rust severity was greatest on the tufted hairgrass cultivars. The prairie junegrass populations from Minnesota and North Dakota exhibited greater resistance to rust than the Colorado population.

Turf Quality

Significant interactions between cultivar and mowing height and cultivar by fertilizer treatment were detected among all three seasons (Table 1.7). Therefore, the turf quality data from 2011 were further divided into two management regimes per season (Table 1.8).

St. Paul. The four hard fescue cultivars maintained the highest turf quality through 2011 in St. Paul under both management regimes, and ‘MN HD’ hard fescue was the top performing cultivar. Most cultivars were able to maintain acceptable quality throughout the spring, summer, and fall of 2011 under the high-input regime, with the exception of the native prairie junegrass populations and the tufted hairgrass cultivars. In contrast to the high-input regime, the four hard fescue cultivars were the only entries able to maintain acceptable quality throughout the spring, summer, and fall of 2011 under the low-input regime. 'Glory' and 'SR 7150' colonial bentgrass also exhibited acceptable quality during the summer under the low-input regime.

Chaska. Turfgrass quality was significantly lower in Chaska. All four hard fescue cultivars, 'Barkoel' prairie junegrass, 'SR 3150', 'Glory', and 'Alister' colonial bentgrass, and 'Barcampsia' tufted hairgrass had acceptable turf quality in the spring of 2011 in Chaska under the high-input regime. With the exception of 'MSP 3769' Kentucky bluegrass in the summer under the high-input regime, no turfgrass cultivar was able to maintain acceptable quality during the summer or fall under either management regime. In fact, in the fall no entry had an average turf quality rating above 3.0, which was likely due a combination of moisture stress and the edaphic characteristics of the

Chaska site considering there was a total rainfall of 2.95 in the fall of 2011, compared to a total of 15.47 cm in 2010.

Percent Live Turfgrass Cover and Percent Weed Cover

The ANOVA of percent live turfgrass cover and percent weed cover in Chaska and St. Paul are presented in Table 1.9. In St. Paul, the main effect of species accounted for the greatest variation in percent live cover and percent weed cover followed by the main effects of year and season. In Chaska, the interaction between year and season and their main effects explained the greatest portion of the variation in percent live cover and percent weed cover followed by the main effect of species. Mowing height significantly affected percent live cover and percent weed cover at both locations. Fertilizer treatment had a significant effect on percent live cover and percent weed cover in Chaska but not in St. Paul.

In general, 'Barkoel' prairie junegrass, hard fescue, and colonial bentgrass maintained the highest percent live turfgrass cover across years, locations, and fertilizer regimes, while the native populations of prairie junegrass had the lowest average percent live turfgrass cover (Figure 1.1). The effect of increased fertility on percent live cover was largest in 2010 in Chaska. The average percent cover of perennial ryegrass and Kentucky bluegrass dropped from 2010 to 2011, especially for Kentucky bluegrass recieving no fertility. In Chaska in the fall of 2011, the percent live cover of each species substantially decreased as reflected in the turf quality ratings, but the greatest percent live cover was provided by hard fescue.

Weed pressure was much stronger in Chaska than in St. Paul (Figure 1.2), and consequently the effect of mowing height on percent weed cover was greater in Chaska.

Increased mowing height was generally associated with increased weed cover. The native praririe junegrass populations had the highest percentage of weed cover. In St. Paul, the least weed encroachment was observed on perennial ryegrass and colonial bentgrass across both years and mowing heights. Weed encroachment in hard fescue and tufted hairgrass plots was also minimal in St. Paul. In Chaska colonial bentgrass provided superior competition against weed encroachment, although tufted hairgrass, 'Barkoel' prairie junegrass, and hard fescue plots had levels of weed encroachment equivalent to or less than Kentucky bluegrass and perennial ryegrass.

DISCUSSION

It is likely that edaphic differences between locations contributed to the reduced turf quality in Chaska, and the results demonstrate that the level of resource inputs required to maintain alternative grasses is site specific. Compared with the effects of mowing height and fertilizer treatment, cultivar and species had the largest effect on differences observed among all measured responses. Significant intraspecific differences in performance were also detected. These results support that proper species and cultivar selection based on local data is critical for the successful establishment of low-input turfgrass stands. Diesburg et al. (1997) define a low-input turfgrass as one that is durable, able to provide functional quality and acceptable aesthetic quality, as has tolerance to both abiotic and biotic stresses when maintained with minimal resource inputs. The alternative turfgrass species exhibited desirable low-input characteristics, but hard fescue was best able to provide the functions listed above.

Hard fescue provided the best overall turf quality and performance across both management regimes during the two year period. Although the use of hard fescue has been limited in part because of disease susceptibility, more recent cultivars exhibit resistance to diseases such as red thread (*Laetisaria fuciformis*), leaf spot (*Drechslera* spp.), and Microdochium patch (Ruemmele et al., 2003), and in this study, the hard fescue cultivars were the least affected by disease. Recent studies have identified potential allelopathy, or natural weed suppression (Bertin et al., 2009), as well as endophyte-mediated disease resistance among hard fescue cultivars (Clarke et al., 2006). Additionally, Quian et al. (2010) recently proposed that fine fescue species may have greater carbon sequestering capacity than Kentucky bluegrass. The results from this study suggest that the utilization of modern hard fescue cultivars would be a viable option as an integrated pest management strategy in Minnesota, leading to the reduction of irrigation, fertilizer, and pesticide applications in the urban landscape, and future studies exploring topics such as allelopathy might lead to further reductions in management inputs.

In general, the colonial bentgrass cultivars had unacceptable quality under the low-input management regime, but they had consistently acceptable quality under the high-input management regime in St. Paul. Colonial bentgrass is best adapted to mowing heights of approximately 1.25 cm, and increased mowing height was a major contributor to the decrease in quality of colonial bentgrass between management regimes. These results do not support the use of colonial bentgrass as a higher-cut turf, but instead indicate that colonial bentgrass should be maintained at heights at or below 3.2 cm. Colonial bentgrass exhibited excellent competition against weed infestation. Carpenter and Meyer (1999) surveyed homeowners in the city of Edina, Minnesota and found that the majority were willing to tolerate 10% weed coverage on their home lawn. In spite of the strong weed pressure in Chaska, colonial bentgrass was able to maintain an average weed cover of 10.56% when mowed at 3.2 cm. Colonial bentgrass also provided more live turfgrass cover relative to Kentucky bluegrass and perennial ryegrass, especially under lower fertility. These results indicate that the use of colonial bentgrass may be a viable strategy to reduce herbicide use. The major limitation of the colonial bentgrass cultivars was susceptibility to disease. Brown patch, snow mold, and leaf spot caused significant damage to colonial bentgrass plots, and the results suggest that the colonial bentgrass cultivars included in this study would not provide an acceptable turf stand in Minnesota under low-maintenance conditions without the use of fungicides.

The native prairie junegrass populations did not provide acceptable turf quality, predominantly due to poor establishment and subsequent weed encroachment. Poor establishment of prairie junegrass, and native grasses in general, has been previously reported (Leinauer et al., 2010; McKernan et al., 2001; Watkins et al., 2011). Although slow establishment may currently limit the use of prairie junegrass as a turfgrass, it may also help facilitate the adaptation of prairie junegrass to infertile soils (Smith and Whalley, 2002). In fact, percent live cover of both the native prairie junegrass populations and 'Barkoel' actually decreased in St. Paul in 2011 as fertility increased. Poor mowing quality due to leaf shredding is also a current limitation to the use of prairie junegrass as a turfgrass (Clark and Watkins, 2010). Unlike the native populations, 'Barkoel' provided superior turf quality and functionality, especially when maintained with moderate fertility (4.9 to 9.8 g N m^{-2}) and mowed at a height of 3.2 cm. The differences in performance observed between the native populations of prairie junegrass and Barkoel demonstrate the extensive genetic variability present in this species which will be valuable to the development of improved, low-input cultivars (Clark and Watkins, 2010; Dixon, 2000). Although most of the current cultivars of prairie junegrass originate from European germplasm, the results support that native germplasm may be useful to breeding programs concerning traits such as resistance to local rust races and tolerance to lower fertility.

Tufted hairgrass has desirable characteristics such as low fertility and light requirements and tolerance to wear and heavy metal contamination which make it promising for use as a low-input turfgrass, but it has only become a focus of turfgrass breeding programs in recent years (Beatrix et al., 1993; Brilman and Watkins, 2003). The tufted hairgrass cultivars had acceptable quality in the spring but were not able to maintain adequate turf quality through the summer and fall mainly due to rust development and summer stress. This was not unexpected, as the main breeding goals for tufted hairgrass cultivars include improved tolerance to summer stress, specifically heat stress, and improved resistance to rust and insect predation (Brilman and Watkins, 2003; Watkins and Meyer, 2005; Watkins et al., 2007). Tufted hairgrass, like prairie junegrass, is a widespread, complex species with wide genetic and phenotypic variation which can be utilized for the development of improved cultivars (Davy, 1980). Most studies investigating insect and disease resistance as well as tolerance to heat and drought stress have screened non-native germplasm. Regional germplasm collections of tufted hairgrass should be screened to investigate whether improved resistance to biotic and abiotic stresses exists among native germplasm.

CONCLUSIONS

The results suggest that the use of alternative, low-input turfgrasses, specifically hard fescue, could be an effective integrated pest management strategy in Minnesota. Future studies should explore cost effective ways to utilize alternative, low-input turfgrasses in the urban landscape. Turfgrasses maintained under low-input conditions are subject to greater abiotic stress, making them more susceptible to disease and insect predation. Therefore, improved disease and pest resistance of alternative, low-input turfgrasses should be a major goal of breeding programs. Additionally, regional germplasm collections of native grasses may contain valuable resistance to disease. Given that this trial was only conducted over two years, future studies should evaluate the long-term performance of alternative species under low-input management. In this experiment, only the use of monocultures of alternative species was examined. The potential of using mixtures of alternative grasses as a pest management strategy may also warrant attention (Simmons et al., 2011).

Table 1.1 Turfgrass cultivar or selection entries and seeding rates planted in St. Paul and Chaska, MN in fall 2009.

Species	Seeding rate	Cultivar/Selection
Colonial bentgrass	5.33 g m^{-2}	Alister, Barking, Glory, SR 7150
Hard fescue	16.67 g m^{-2}	Spartan II, Reliant IV, MN HD†, SR 3150
Prairie junegrass	13.33 g m^{-2}	DCS†, DCM, Barcampsia
Tufted hairgrass	13.33 g m^{-2}	MN pop.†, ND pop.†, CO pop. † Barkoel
Perennial ryegrass	16.67 g m^{-2}	Arctic Green†
Kentucky bluegrass	10.00 g m^{-2}	MSP 3769†

† From the University of Minnesota breeding program.

Table 1.2 Mean establishment of turfgrass species in fall 2009 in St. Paul and Chaska, MN.

	Establishment†	
Species	**St. Paul**	**Chaska**
Perennial ryegrass	8.89 a	6.56 a
Colonial bentgrass	7.38 b	6.29 a
Tufted hairgrass	6.58 c	6.24 a
Prairie junegrass (Barkoel)	5.05 d	5.03 b
Hard fescue	4.94 d	3.78 c
Kentucky bluegrass	3.61 e	3.81 c
Prairie junegrass (native)	2.22 f	1.67 d

† Establishment was rated visually on a 1-9 scale (9 = best establishment) on Septemeber 29, 2009 in St. Paul and Chaska. Means within the same column with the same letter are not significantly different ($\alpha = 0.05$) according to Fisher's protected LSD.

Table 1.3 Spring green-up of cultivar/selection entries in 2010 and 2011 in St. Paul and Chaska, MN.

Cultivar/ Selection	St. Paul				Chaska			
	2010		2011		2010		2011	
Arctic Green	3.92	f	3.39	de	8.03	a	2.56	d
MSP 3769	7.69	a	2.97	de	7.17	b	2.92	cd
Barcampsia	4.14	ef	4.00	c	6.06	c	3.36	Bd
Barking	5.92	b	1.67	f	6.00	c	3.06	Cd
Glory	5.44	bc	1.81	f	5.83	c	3.22	Bc
SR 7150	4.00	f	1.75	f	5.72	cd	2.72	Cd
Alister	5.06	cd	1.75	f	5.53	ce	3.14	Cd
DCS Bulk	3.14	g	2.94	e	5.33	ce	2.86	Cd
Reliant IV	5.97	b	6.06	a	5.28	ce	4.94	A
MN HD	6.00	b	5.72	ab	5.25	ce	4.44	A
DCM	4.22	ef	3.64	cd	5.00	def	3.39	Bc
Spartan II	5.86	b	5.86	ab	4.89	ef	4.28	B
SR 3150	2.72	g	5.39	ab	4.78	ef	4.61	a
Barkoel	4.72	de	3.50	ce	4.39	f	3.31	bc

Means within the same column with the same letter are not significantly different (α = 0.05) within year and location.

Table 1.4 Spring green-up in 2011 by mowing height and fertilizer treatment.

	St. Paul		Chaska	
Mowing Height (cm)				
3.2	4.24	a	3.93	a
5.7	3.52	b	3.34	ab
8.3	3.07	b	3.19	b
Fertilizer treatment (g N m^{-2})				
0	3.31	b	3.18	b
4.9	3.70	a	3.62	ab
9.8	3.83	a	3.66	a

Means with the same letter are not significantly different (α = 0.05) within year and location.

Table 1.5 Mean overall snow mold severity of turfgrass cultivars and selections by mowing height in St. Paul and Chaska, MN in spring 2011.

		Snow Mold Severity†					
		St. Paul			Chaska		
Cultivar/ Selection	Species‡	3.2 cm	5.7 cm	8.3 cm	3.2 cm	5.7 cm	8.3 cm
DCS	TH	9.00 a	9.00 a	9.00 a	8.83 a	9.00 a	9.00 a
Barcampsia	TH	8.67 a	8.50 a	8.67 a	9.00 a	9.00 a	8.92 a
Spartan II	HF	8.42 a	8.50 a	7.83 a	8.83 a	9.00 a	8.83 a
Reliant IV	HF	8.42 a	8.58 a	8.18 a	8.92 a	9.00 a	9.00 a
DCM	TH	8.42 a	8.42 a	8.58 a	9.00 a	9.00 a	9.00 a
SR 3150	HF	8.00 a	8.42 a	8.00 a	9.00 a	8.67 ac	8.58 ab
MN HD	HF	7.67 a	8.08 a	8.42 a	8.83 a	8.75 ab	8.33 ab
Barkoel	PJ	5.58 b	5.50 b	5.75 b	8.75 a	7.75 ad	8.33 ab
MSP 3769	KBG	5.50 b	3.83 bc	3.00 c	8.75 a	8.08 ad	8.42 ab
MN pop.	PJ	--	--	--	8.75 a	7.67 ad	8.25 ab
CO pop.	PJ	--	--	--	7.75 ab	7.00 cd	7.75 ab
ND pop.	PJ	--	--	--	7.92 ab	7.00 cd	7.67 ab
Arctic Green	PR	4.45 b	4.08 bc	3.25 c	6.50 bc	3.75 f	3.75 c
SR 7150	COL	2.92 c	1.42 d	1.08 d	8.17 a	7.83 ad	7.33 ab
Glory	COL	2.75 c	2.00 d	1.08 d	7.83 ab	7.17 bcd	7.50 ab
Alister	COL	2.67 c	1.42 d	1.67 d	7.75 ab	6.83 de	7.00 b
Barking	COL	2.17 c	1.42 d	1.00 d	5.50 c	5.25 ef	4.17 c

† Snow mold severity ratings (combined gray and pink snow mold) were taken on a 1-9 scale (9 = no snow mold) on April 8 and April 7, 2011 in St. Paul and Chaska, respectively. Means within the same column with the same letter are not significantly different (α = 0.05).

‡ Colonial bentgrass (COL); Hard fescue (HF); Kentucky bluegrass (KBG); Prairie junegrass (PJ); Perennial ryegrass (PR); Tufted hairgrass (TH)

Table 1.6 Mean overall rust severity by mowing height and by fertilizer treatment on turfgrass culitvars and selections in St. Paul, MN, 2010.

Cultivar/ Selection	Species ‡	Mowing Height (cm)†			Fertilizer Treatment (g N m^{-2})†		
		3.2	**5.7**	**8.3**	**0**	**4.9**	**9.8**
MNHD	HF	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
SR 3150	HF	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
Spartan II	HF	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
Reliant IV	HF	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
Barking	COL	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
Glory	COL	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
Alister	COL	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
SR 7150	COL	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a
Barkoel	PJ	9.00 a	8.67 a	8.92 ab	8.83 a	8.83 ab	8.92 a
MSP 3769	KBG	8.50 ab	7.50 ab	7.67 bc	8.00 ab	7.67 ab	8.00 ab
Arctic Green	PR	7.75 bc	5.83 cd	5.17 d	6.33 ce	6.00 cd	6.42 cde
MN pop.	PJ	7.67 bc	7.42 abc	7.67 bc	7.67 ac	7.33 bc	7.75 abd
ND pop.	PJ	7.58 bc	7.50 ab	7.42 c	7.75 ac	7.33 bc	7.42 bc
DCM	TH	7.00 c	5.92 bd	5.92 d	6.00 de	5.83 cd	7.00 bcf
Barcampsia	TH	6.92 c	5.00 d	4.92 d	5.75 e	4.83 d	6.25 ce
CO pop.	PJ	6.83 c	5.42 d	5.73 d	7.33 bcd	5.25 d	5.36 e
DCS	TH	6.67 c	4.58 d	4.75 d	5.00 e	5.25 d	5.75 ef

† Overall rust severity was rated on a 1-9 scale (9 = no rust) on July 26, 2010 in St. Paul, MN. Means within the same column with the same letter are not significantly different (α = 0.05).

‡ Colonial bentgrass (COL); Hard fescue (HF); Kentucky bluegrass (KBG); Prairie junegrass (PJ); Perennial ryegrass (PR); Tufted hairgrass (TH)

Table 1.7 Analysis of variance (ANOVA) of turf quality by season as influenced by cultivar, mowing height, and fertilizer treatment in St. Paul and Chaska, MN in 2011.

	Turf Quality†											
	Spring				Summer				Fall			
Source of Variation	St. Paul		Chaska		St. Paul		Chaska		St. Paul		Chaska	
Intercept	172.64	***	1872.37	***	381.83	***	568.92	***	533.76	***	571.59	***
Cultivar (C)	136.75	***	99.67	***	352.53	***	128.85	***	285.89	***	112.78	***
Mowing Height (MH)	2.21		5.92	*	0.82		7.68	*	21.16	**	6.42	*
Fertilizer Treatment (F)	12.15	***	40.27	***	11.91	***	25.52	***	21.50	***	5.46	***
C×MH	2.51	***	2.52	***	1.43		2.63	***	2.04	***	4.84	***
C×F	0.77		2.17	***	1.79	**	2.24	***	0.76		0.95	
MH×F	0.76		1.13		0.19		3.09	*	0.37		1.40	
C×MH×F	0.29		1.08		0.38		0.98		0.38		0.81	

The single asterisk (*), double asterisks (**), and triple asterisks (***) denote significance at the 0.05, 0.01, and 0.001 levels respectively.

† Turf quality in 2011 was rated twice a month on a 1-9 scale (9 = best turf quality) from May through October and averaged over season.

Table 1.8 Mean turf quality of cultivars and selections by location, season, and management regime in St. Paul and Chaska, MN in 2011.

		Turf Quality in St. Paul, MN†						Turf Quality in Chaska, MN†					
		Spring		Summer		Fall		Spring		Summer		Fall	
Cultivar/Selection	Species§	High-input‡	Low-input	High-input	Low-input	High-input	Low-input	High-input	Low-input	High-input	Low-input	High-input	Low-input
MNHD	HF	7.13	6.38	7.75	6.56	7.38	6.19	5.25	3.63	4.69	3.69	2.38	2.81
Reliant IV	HF	6.88	5.88	7.25	6.19	6.88	6.06	6.00	3.63	4.69	3.31	2.38	2.19
Barkoel	PJ	6.75	4.56	5.81	4.75	5.81	4.06	5.69	2.81	3.63	2.13	1.69	1.25
SR 3150	HF	6.56	6.00	7.06	6.31	7.00	5.81	5.63	3.06	4.56	2.63	2.00	2.19
Spartan II	HF	6.38	5.94	6.75	6.00	6.50	5.56	5.44	3.94	4.56	3.69	2.50	2.50
Glory	COL	6.31	3.56	5.25	5.13	5.19	3.88	5.56	4.25	3.63	3.44	1.25	1.31
DCS	TH	6.19	4.56	4.00	3.00	3.81	2.25	4.13	2.69	3.63	2.75	1.81	1.56
Arctic Green	PR	5.81	4.50	5.63	3.69	5.81	3.75	4.56	2.38	4.63	2.06	2.44	1.50
SR 7150	COL	5.81	3.81	5.31	5.13	4.88	3.69	4.56	3.25	2.69	2.75	1.06	1.19
Barcampsia	TH	5.81	4.44	3.75	3.13	3.38	2.63	5.00	3.25	3.63	2.50	1.81	1.44
Alister	COL	5.63	3.56	5.31	4.75	5.13	3.75	5.31	3.25	3.88	2.50	1.50	1.25
MSP 3769	KBG	5.44	4.38	5.75	3.63	5.44	3.38	4.00	2.38	5.00	3.00	2.44	2.06
Barking	COL	5.38	3.06	4.94	4.69	5.13	3.13	4.63	2.94	3.00	2.56	1.19	1.13
DCM	TH	5.06	4.69	3.44	3.63	3.13	2.81	4.75	3.38	3.56	2.81	1.94	1.81
ND POP	PJ	2.44	2.56	1.50	1.63	1.00	1.63	2.56	1.69	1.38	1.38	1.00	1.00
CO POP	PJ	1.94	1.94	1.38	1.50	1.00	1.06	2.38	1.69	1.31	1.38	1.00	1.00
MN POP	PJ	1.69	2.25	1.13	1.69	1.50	1.13	2.19	1.94	1.19	1.06	1.00	1.00
	LSD¶ =	1.096	1.058	0.757	0.782	0.867	0.854	0.624	0.932	0.803	1.125	0.560	0.762

† Turf quality was rated on a 1-9 scale (9 = best turf quality) twice a month from May through October in St. Paul and Chaska, MN and averaged over season.

‡ The high-input management regime includes plots that were maintained at 3.2 cm and received 9.8 g N m^{-2} per year. The low-input management regime includes plots that were maintained at 8.3 cm and recieved 0 g N m^{-2} per year.

§ Colonial bentgrass (COL); Hard fescue (HF); Kentucky bluegrass (KBG); Prairie junegrass (PJ); Perennial ryegrass (PR); Tufted hairgrass (TH)

¶ Indicates Fisher's protected least significant difference (LSD) at $\alpha = 0.05$ within columns.

Table 1.9 Analysis of variance (ANOVA) of percent live turfgrass cover and percent weed cover in St. Paul and Chaska, MN as influenced by mowing height, fertilizer treatment, species, season, and year.

			Percent Live Cover†				Percent Weed Cover†			
			St. Paul		Chaska		St. Paul		Chaska	
Source	Num. df	Den. df	F-value		F-value		F-value		F-value	
Intercept	1	1206	69714.33	***	14723.48	***	2616.84	***	8721.41	***
Replication	3	546	1.42		61.03	***	2.55	*	86.60	***
Mowing Height (MH)	2	546	14.19	***	55.66	***	15.67	***	116.84	***
Fertilizer Treatment (F)	2	546	1.70		97.69	***	0.39		76.29	***
Species (SP)	6	546	957.30	***	148.94	***	909.93	***	133.63	***
Season (S)	1	1206	241.49	***	476.12	***	70.91	***	247.45	***
Year (Y)	1	577	399.86	***	389.50	***	316.52	***	389.95	***
MH×F	4	546	0.97		2.44	*	1.17		3.94	**
MH×SP	12	546	2.42	**	1.70		4.32	***	1.70	
MH×S	2	1206	0.19		20.24	***	1.53		5.59	**
MH×Y	2	577	3.36	*	14.04	***	2.15		17.25	***
F×SP	12	546	0.95		0.71		0.89		1.00	
F×S	2	1206	2.24		0.13		0.58		11.81	***
F×Y	2	577	0.01		12.20	***	0.01		0.46	
SP×S	6	1206	24.34	***	24.46	***	20.87	***	23.14	***
SP×Y	6	577	60.01	***	36.80	***	83.39	***	42.24	***
S×Y	1	1206	181.35	***	4175.98	***	106.74	***	513.03	***
MH×F×SP	24	546	0.98		1.19		1.00		0.91	
F×SP×Y	12	577	1.66		0.89		1.61		1.37	
MH×SP×Y	12	577	5.15	***	1.54		5.10	***	0.74	
SP×S×Y	6	1206	8.66	***	76.07	***	9.17	***	7.04	***

The single asterisk (*), double asterisks (**), and triple asterisks (***) denote significance at the 0.05, 0.01, and 0.001 levels, respectively.
† Percent live cover and percent weed cover were calculated using the grid intersect method. Measurements were taken in the spring and fall of 2010 and 2011 in St. Paul and Chaska, MN.

Figure 1.1 Percent live turfgrass cover in 2010 and 2011 in St. Paul and Chaska, MN as influenced by species and nitrogen rate.

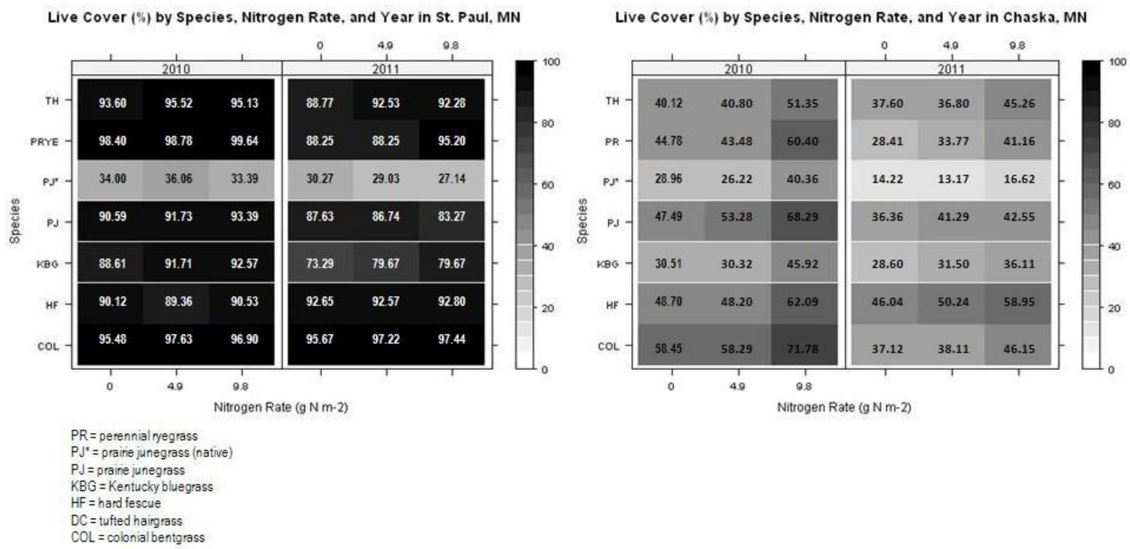
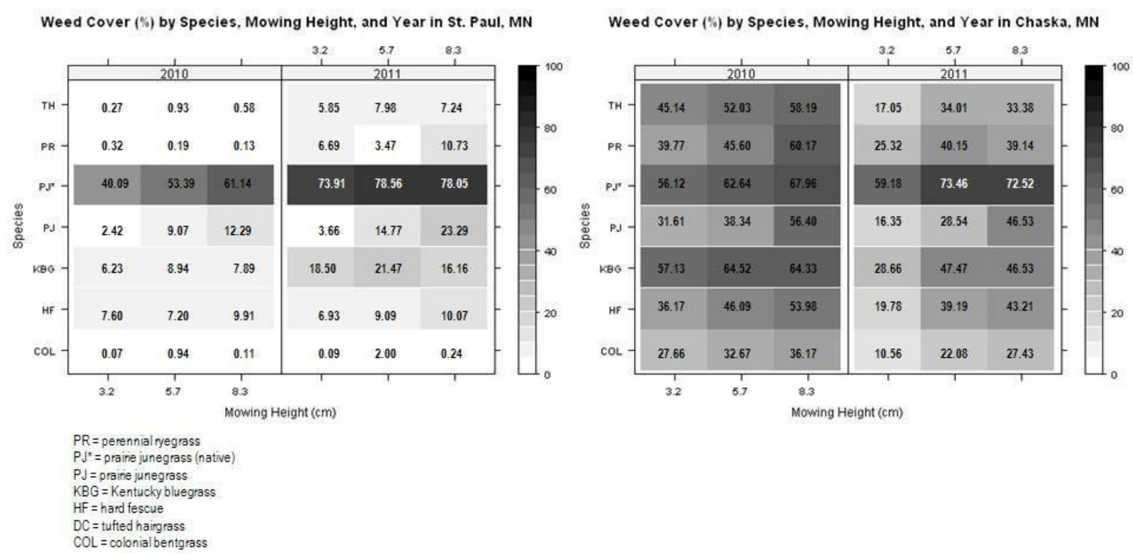


Figure 1.2 Percent weed cover in 2010 and 2011 in St. Paul and Chaska, MN as influenced by species and mowing height.



Are consumers willing to pay more for low-input turfgrasses on residential lawns?

Evidence from choice experiments

INTRODUCTION

Widespread urban development has led to substantial growth in lawn acreage and the subsequent increase in the amount of resource inputs (fertilizer, water, etc.) used for residential turfgrass management (Alig et al., 2004). Fresh water conservation is a universal issue, and in the United States, turfgrass covers an area larger than that of any irrigated crop (Milesi et al., 2005). In addition to the impact of water use for irrigation, concerns have also arisen about the potential negative impacts of turfgrass management practices on the environment and human health, such as the risks of pesticide exposure and fertilizer runoff (Robbins and Birkenholtz, 2003; Robbins and Sharp, 2003; Milesi et al., 2005). These concerns have prompted regulations on urban lawn care practices. A few examples of such regulations are statewide restrictions on the use of fertilizers containing phosphorous on home lawns (State of Minnesota, 2010; State of Wisconsin, 2011), pesticide bans on home lawns in numerous municipalities and provinces of Canada (Government of Quebec, 2006), and municipal water regulations (Boer and Ripp, 2008; MassDEP, 2010).

Despite potential drawbacks, healthy residential lawns provide important environmental benefits such as urban heat dissipation, water quality protection, erosion control, and carbon sequestration, as well as functional and aesthetic benefits to society (Quian et al., 2010; Krenitsky et al., 1998; McPherson et al., 1989; Beard and Green, 1994). One potential strategy to reduce resource inputs without sacrificing the environmental and societal benefits provided by turfgrass is to use non-traditional, alternative grass species better adapted to low maintenance conditions, or low-input turfgrasses. Over the past few decades researchers have identified and developed alternative grass species suited for low maintenance sites (Brilman and Watkins, 2003; Duncan, 2003; Engelke and Anderson, 2003; Hanna and Liu, 2003; Riordan and Browning, 2003; Ruemmele et al., 2003). There has also been interest in developing turfgrass varieties from grass species that are native to North America. Native grasses have evolved in North American conditions over a long period of time and may be better adapted to specific environments in the U.S. in comparison to introduced, non-native grasses (Johnson, 2008). The use of low-input turfgrass species on residential lawns could be a viable strategy to reduce the rising economic costs of maintenance inputs as well as satisfy public concerns about the environmental impacts of urban turfgrass management practices. Additionally, more stringent regulations on lawn care practices could further increase the demand for low-input turfgrasses.

Regardless of the advances in the development of low-input turfgrasses, production and availability remain limited across much of the United States. Several alternative, low-input turfgrass species, for example, colonial bentgrass(*Agrostis capillaris* L.) and hard fescue (*Festuca trachyphylla* [Hack.] Krujina), have provided acceptable quality and performance in regional trials throughout the United States Upper Midwest under little or no supplemental irrigation, fertility or pesticide applications, and reduced mowing regimes (Diesburg et al., 1997; Watkins et al., 2011). A few grass species native to North America, including tufted hairgrass (*Deschampsia caespitosa* [L.] P. Beauv.) and prairie junegrass (*Koeleria macrantha* [Ledeb.] Shult.), have also shown potential in regional trials for use as low maintenance turfgrasses (Mintenko et al., 2002;

Watkins et al., 2011). Yet, Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.), which are more resource intensive to maintain, are still the most commonly used turfgrasses for residential lawns in the Upper Midwest (Christians, 2004). Little is known about consumer preference regarding alternative, low-input turfgrasses. Gaining information about the market potential of low-input turfgrasses could help bridge this gap between research progress and the turfgrass seed market.

Previous research shows there is market potential for environmentally-friendly goods and services (Hu, et al., 2009; Laroche et al., 2001; Schegelmilch et al., 1996; Straughan and Roberts, 1999; Engel and Poetschke 1998; Guagnano et al., 1994; Yue et al., 2010). Although most research indicates that consumers who are willing to pay a price premium for environmentally-friendly products share similar attitudes, environmental concerns vary widely among consumers (Gladwin et al., 1995; Purser et al., 1995). Consumers often respond differently to new ideas and products, and it is necessary to conduct valid research to explore how consumers will react to a new product, in this case, low-input turfgrasses for residential lawns. To our knowledge, little research has been done in this area. Helfand et al. (2006) found that consumers were willing to pay a premium for environmentally-friendly landscapes with differing levels of native plantings compared to a traditional monoculture lawn, but there has been no information published on consumer preferences for maintenance attributes of turfgrasses or on potential barriers to consumer adoption of low-input turfgrasses.

Several questions arose when considering the market potential of low-input turfgrasses: 1) Will consumers be willing to pay premiums for low-input turfgrasses? 2) If yes, what are the premiums? 3) Will the premiums they are willing to pay be the same for different low-input characteristics such as reduced water use, reduced fertilizer use, etc.? 4) If not, which characteristics glean higher premiums? To answer these questions, we conducted a survey with homeowners in the Minneapolis—St. Paul, Minnesota metropolitan area. The main component of the survey was a choice experiment to investigate consumer preference and estimate willingness to pay (WTP) for several low-input attributes (e.g. water use) as well as aesthetic attributes, origin, and shade adaptation of turfgrasses. Choice experiments have been used to identify consumer preference and WTP for various attributes of novel products (Mtimet and Albisu, 2006; Brooks and Lusk, 2010) as well as for genetically modified (GM), organic, natural, and locally grown products (Burton and Pearse, 2002; Carlsson et al., 2007; Hu et al., 2004; Onken et al., 2011). The results presented in this study provide important implications and insights about the market potential of low-input turfgrass species to plant breeders and professionals in the Upper Midwest turfgrass seed industry.

In the following section we describe the methodology including the product attributes, sampling methods, choice experiment, questionnaire and statistical models used for the study. In the next section we present the results, specifically, the WTP estimates. The paper then concludes with the discussion and implications of our findings.

METHODOLOGY

Product Attributes

Pre-survey focus groups conducted in April 2010 helped identify a key set of nine turfgrass attributes to include in the study (Table 1). Aesthetic quality is important to homeowners, and the three aesthetic attributes included in the study were color, texture, and weed infestation. Many home lawns have a significant amount of shaded area, thus shade adaptation was included in the set of attributes. Consumers have shown interest in native plants for landscaping (Helfand et al., 2006), so origin was also included as an attribute, which was defined as being native to the United States or non-native. Each of the aesthetic attributes, shade adaptation, and origin had two categories. The focus groups also helped identify three turfgrass maintenance practices of foremost importance to homeowners, specifically, irrigating, fertilizing, and mowing. Therefore, these three maintenance attributes were included in the choice experiment, and each had three input categories corresponding to low, moderate, and high. Price points were determined based on turfgrass seed prices obtained from consulting with various seed sales professionals in the Minneapolis—St. Paul, Minnesota metropolitan area. To reduce error in participant estimation, price was given as the cost to seed an area 1,000 ft^2, and prices ranged between $5.00 and $20.00 with $5.00 as the incremental interval.

Lusk and Shroeder (2004) demonstrated that marginal WTP was equivalent between hypothetical and non-hypothetical experiments when real products were used. To capture the effects of aesthetic characteristics on consumer choice behavior, we gave participants the opportunity to see and evaluate actual turfgrass plots instead of seed. Although showing a sample turfgrass plot is not typical for turfgrass varieties in retail stores, plots of new varieties are commonly tested in various public displays. Although consumers purchase seed, the turfgrass is the ultimate product that determines the demand for new turfgrass varieties (McCluskey et al., 2007). Therefore, having participants evaluate turfgrass plots allowed us to evaluate the market potential for several novel, low-input turfgrass varieties.

The choice experiment was conducted on field plots at the Turfgrass Research, Outreach, and Education Center at the University of Minnesota in St. Paul, Minnesota in June 2010. The turfgrass field plots (1.52 m × 0.91 m each) were seeded in August 2009; each species was seeded at the recommended seeding rate; and typical turfgrass establishment procedures were followed. The following six turfgrass species from the field plots were used in the study: colonial bentgrass, hard fescue, tufted hairgrass, prairie junegrass, perennial ryegrass, and Kentucky bluegrass. Additionally, multiple cultivars of each species were available for the choice experiment. The six different species and the multiple cultivars of each provided the necessary combinations of aesthetic attributes.

Sampling Methods

Participants were recruited by placing an advertisement in 13 local newspapers in and around the Minneapolis—St. Paul metropolitan area including both urban and suburban communities, and also from minneapolis.craigslist.org. Participants were compensated $30.00 each for their time. To ensure that the sample was representative of the consumer market, only those consumers who had a home lawn and only members of the household who were able to make lawn care decisions and purchases were allowed to participate. One hundred thirty-six people participated in the experiment and 128 provided enough information for analysis. There were five separate sessions of the choice experiment and each session included between 20 and 30 participants.

Choice Experiment

The choice experiment was conducted to elicit consumer preference and WTP for the nine turfgrass attributes. Participants were presented with a series of choice scenarios, which consisted of adjacent or nearly adjacent turfgrass plots. To lessen the cognitive burden on participants, only two turfgrass plots were included in each scenario. The two turfgrass plots in each scenario varied in aesthetic quality. For example, if plot A was dark green, fine in texture, and had weeds, then plot B was light green, coarse in texture, and had no weeds. The two plots in each scenario also varied in shade adaptation and origin, levels of maintenance inputs, and price which were displayed on labels in front of each turfgrass plot. Participants were asked to choose which alternative (i.e. turfgrass plot) in each choice scenario they would rather purchase. They were also given the option to choose "Neither" (i.e. the opt-out alternative) for each scenario, indicating they would not purchase either alternative. The opt-out alternative was included in the experimental design to make the choice situation more realistic (Carlsson et al., 2007). When an opt-out alternative is a viable option in the real choice situation, failure to allow for non-demanders could result in overestimates of participation (Ryan and Skatun, 2004). An example of one choice scenario is shown in Table 2.

Since it was not practical to ask each participant to choose from all possible scenarios, a fractional factorial design was developed to minimize scenario number and maximize profile variation. The design was developed based on four principles: 1) level balance (levels of an attribute occurred with equal frequency), 2) orthogonality (the occurrence of any two levels of different attributes were uncorrelated), 3) minimal overlap (cases where attribute levels did not vary within a scenario were minimized), and 4) utility balance (the probabilities of choosing alternatives within a scenario were as similar as possible) (Louviere et al., 2000). After four clearly dominating alternatives were eliminated[1], the resulting fractional factorial design consisted of a set of 16 scenarios to evaluate. For further discussion of fractional factorial designs, see Louviere et al. (2000). The choice scenarios were designed using JMP® 8 software (SAS Institute Inc, Cary, NC, USA).

Before the experiment began, pricing was explained to participants as the price to seed 1,000 ft^2, and an area adjacent to the experiment equivalent to 1,000 ft^2 was marked off for participants to use as a reference during the experiment. To avoid order effects, turfgrass plots were presented in the field so that participants could start from any scenario and walk around freely while completing the choice experiment. The turfgrass plots were labeled clearly to ensure that participants matched the correct plots with each choice scenario in the survey. First, a practice round of choice scenarios was conducted to familiarize participants with the experiment, but in the practice round, neither the maintenance information nor origin were labeled on the turfgrass plots. Therefore, in the practice round participants made their choice based solely on the difference in turfgrass appearance, shade adaptation and price. Labels including information about maintenance requirements and origin were then added to the turfgrass plots before the formal choice experiment was conducted. In the formal experiment, participants made their choice based not only on the appearance, shade adaptation, and price of a turfgrass alternative, but also based on maintenance requirements (irrigation, fertilizer, and mowing requirement) and origin (U.S. native or non-native).

Questionnaire

After completing the choice experiment, participants were asked to fill out a short questionnaire which included questions regarding demographics, home lawn characteristics, current maintenance practices, as well as attitudes about low-input lawn care. The questionnaire was designed to identify potential relationships between participant demographics or attitudes and stated preferences, as well as potential barriers to consumer acceptance of low-input turfgrasses.

Statistical Model

A mixed logit model was used to estimate the probability of a consumer's choice of certain turfgrasses and the WTP for different attributes. Unlike the standard logit model, the mixed logit model allows for correlation in factors (Train, 2003). We used the mixed logit model to capture all possible correlations for responses from the same participant. The statistical model was

$$U_{nis} = \beta x_{nis} + \eta_i + \gamma_s + \varepsilon_{nis} \qquad (1)$$

where U_{nis} was the utility of individual *n* from choosing alternative *i* in scenario *s*; x_{nis} were vectors of observed variables relating to alternative *i* and individual *n* which included the attributes of an alternative turfgrass; β was a vector of fixed coefficients; η_i was a vector of normally distributed random terms with mean zero and standard deviation σ_η, which was used to capture the possible correlations; γ_s was a vector of fixed scenario effects; and ε_{nis} was an identical and independent extreme value error term. The standard logit model is a special case of the mixed logit model where η has zero variance.

The density of η was denoted by $f(\eta \mid \Omega)$, where Ω was the fixed parameter vector of the distribution. For a given η, the conditional choice probability of alternative *i* was a standard logit:

$$L_i(\eta) = \frac{e^{\beta x_i + \gamma + \eta}}{\sum_{j \in J} e^{\beta x_j + \gamma + \eta}} \qquad (2)$$

J is the total number of alternatives and *j* refers to *j*th alternative, where *j*=1, 2, …*J*. Consequently, the unconditional choice probability *P* in the mixed logit model was the logit formula integrated over all values of η with density of η as weights:

$$P_i = \int L_i(\eta) f(\eta \mid \Omega) d\eta \qquad (3)$$

This integral was approximated through simulation (Alfnes, et al., 2006; Brownstone and Train, 1999). The maximum likelihood estimation method was used to estimate coefficients with Stata 10.0 software (StataCorp, College Station, TX, USA).

RESULTS

Summary statistics of the participants' socio-demographic background are shown in Table 3. On average, participants were approximately 45 years old, and 51% of the participants were female. Sixteen percent of participants had a high school diploma or less; approximately 63% of them had some college or a college diploma, and 21% had some graduate school or had a graduate degree. Twenty percent of participants had children under 12 years old. Thirty one percent of the participants' household income was less than or equal to $50,000; 47% of participants' household income was greater than $50,000 and less than $100,000; and about 23% of participants' household income was over $100,000.

Eighteen percent of participants' home lawns were larger than 8,000 ft^2, and when asked 'what type of grass do you currently have on your lawn?' 61.8% indicated they did not know. Twelve percent of participants stated that they had Kentucky bluegrass on their lawn, and only 6.9% stated that they had perennial ryegrass. The lawn care practices of the participants varied widely. When participants were asked how often they watered their lawn during June, July, and August, 20.7% watered their lawn every other week or less; 35.1% watered their lawn once or twice a week; and 19.1% watered their lawn more than three times per week. Twenty-four percent of participants stated they watered their lawn 'only when stressed'. Sixty-six percent of participants mowed their lawn once or twice per week; 29.0% mowed their lawn every other week; and only 2.3% mowed their lawn once a month. When participants were asked the amount of fertilizer applied to their lawn per year, over half indicated that they did not know. Participants were more familiar with the frequency at which fertilizer was applied to their lawn per year. Twenty-four percent of participants fertilized their lawn three or more times per year; 51.9% fertilized one or two times per year; and 20.6% of participants never fertilized their lawn.

To investigate consumer WTP for turfgrass attributes, a mixed logit model[2] was used to estimate the probability of participant choice. Specifically, we used the "xtlogit" command in Stata to run the analysis. Log-likelihood ratio tests were conducted to compare the full model, which had both low-input attributes and the aesthetic attributes (log-likelihood of -2464.66), the model which had only the low-input attributes (log-likelihood of -2494.95), and the model that only had the aesthetic attributes (log-likelihood of -2575.29). The p-values of the log-likelihood ratio test statistics were < 0.05, and the test results showed that the full model had the best goodness of fit. The low-input attributes did significantly affect participants' preference and WTP for turfgrasses. We also tested for relationships between participants' lawn care practices and their stated preferences, but we did not detect any significant relationships.

The estimation results of the mixed logit model are shown in Table 4. The coefficient of price (*Price*) was negative and significant, meaning that the higher the price, the less likely that a choice alternative was chosen. The coefficients of the low irrigation requirement (*Waterlow*) and the moderate irrigation requirement (*Watermedium*) were positive and significant indicating that, compared to the high irrigation requirement, low and moderate irrigation requirements increased the likelihood that a turfgrass choice alternative was chosen. The coefficients of the low mowing requirement (*Mowinglow*) and the moderate mowing requirement (*Mowingmedium*) were also positive and significant, meaning that compared to the high mowing frequency, low and moderate mowing requirements increased the likelihood that a choice alternative was chosen[3]. Turfgrasses with fine leaf texture, dark green color and no weed encroachment were more likely to be chosen. The presence of weeds in a plot strongly discouraged participants from choosing the turfgrass. Being native to the U.S. did not increase the likelihood of a turfgrass choice alternative being chosen because the main effect of origin (*Native*) was not significant. However, it did decrease participant sensitivity to price because the interaction between price and origin (*Native***Price*) was positive and significant. The scenario fixed effects were controlled in the model. The random individual effect was significant, which indicated there was a significant correlation between the choices made by the same participants. The random individual effect effectively controlled the differences in socio-demographic backgrounds among participants.

The price premium participants were willing to pay for an attribute was estimated by dividing the corresponding attribute's coefficients by the absolute value of the coefficient of price, and these premiums represent the extra cost participants were willing to pay to seed an area of 1,000 ft^2. The price premiums for low-input attributes are shown in Table 5. Compared to the high irrigation requirement, participants were willing to pay \$9.70 1,000 ft^{-2} more for a turfgrass with a low irrigation requirement and \$5.85 1,000 ft^{-2} more for a turfgrass with a moderate irrigation requirement. Compared to the most frequent mowing requirement, participants were willing to pay \$3.92 1,000 ft^{-2} more for a turfgrass requiring infrequent mowing and \$2.97 1,000 ft^{-2} more for a turfgrass requiring moderately frequent mowing. Compared to the high fertility requirement, the premiums for turfgrasses with low and moderate fertility requirements, \$2.00 and \$1.10 1,000 ft^{-2} respectively, were not significant. We conducted tests to investigate if there were any significant differences between the WTP for low and moderate levels of irrigation, mowing, and fertilizer requirements. The WTP for the low irrigation requirement was significantly higher than that for the moderate irrigation requirement (p-value=0.027); the WTP for the low mowing requirement was not significantly different from that for the moderate mowing requirement (p-value=0.482); and the WTP for the low fertilizer requirement was not significantly different from that for the moderate fertilizer requirement (p-value=0.140).

DISCUSSION AND CONCLUSIONS

Turfgrass is an important and beneficial component of urban landscapes, and approximately 75% of the total U.S. turfgrass coverage is home lawn acreage (Hull et al., 1994). As public concerns about the environment continue to grow and costs of natural resources rise, the demand for low maintenance landscapes will also increase. Additional regulation of lawn care practices may also increase this demand. The use of low-input turfgrasses could be a viable strategy to meet these demands, but the success of this strategy will be largely determined by the market potential of low-input turfgrasses.

The primary goal of this research was to explore how low-input attributes of turfgrasses might affect consumer demand. Choice experiments with turfgrass plots were used to elicit the WTP for turfgrasses with various attributes to accomplish this objective. Our results suggest that the maintenance attributes of turfgrasses greatly affect consumer demand. Although aesthetic characteristics played a significant role in consumer choice, our results indicate that low-input characteristics are equally important marketing points for turfgrasses. These results also provide direction for future efforts of plant breeders in developing more low-input, sustainable turfgrass varieties.

Irrigation requirement was the most influential maintenance attribute affecting consumer choice behavior, followed by mowing requirement, and lastly fertility requirement. Likewise, participants were willing to pay the highest premium for a turfgrass with a low irrigation requirement. It is likely that the strong preference for water conservation is not only due to cost savings but also due to environmental concerns. Over 75% of participants slightly-to-strongly agreed with the statement “water use on home lawns is an environmental concern.”

Mowing requirement was the second most influential input attribute on choice behavior. Although participants did not indicate a significant preference between having to mow every other week versus once or twice a week, they did indicate a strong preference for mowing on a monthly basis. The results indicate there is great market potential for some turfgrass species (e.g. fine fescues) that can provide acceptable quality when mowed on a monthly basis or only twice per year (Meyer and Pedersen, 2000; Watkins et al., 2011).

Fertilizer requirement did not affect consumer WTP. Participants’ responses to the questionnaire show that approximately half of participants did not know the total amount of fertilizer applied to their home lawn per year. Previous research has also found that most homeowners are unfamiliar with the recommended fertility practices (Carpenter and Meyer, 1999). This lack of knowledge could be a potential reason for the lack of significance of fertility requirement. Another possible explanation for why fertility requirement did not affect choice behavior is that participants already perceived their fertility practices to be low-input, considering over 70% of participants fertilized their lawn two times per year or less.

Even though native origin decreased consumer sensitivity to price, species origin was not an important driver of WTP. While origin may affect the choice behavior of consumers concerning other landscape plants (Helfand et al., 2006; Zadegan et al., 2008), our results suggest that currently there may not be significant demand for native turfgrasses in residential landscapes. Rather, participants placed higher importance on aesthetic and maintenance attributes.

Participants preferred turfgrasses with dark green color and fine leaf texture, and the most important aesthetic characteristic was the absence of weeds. Efforts should be focused on developing cultivars that are competitive against weed encroachment. We also found more than 80% of participants agreed with statement "pesticide use is harmful to human health and the environment." These results suggest that future plant breeding efforts could be directed to increasing the aggressiveness or allelopathy (i.e. natural weed suppression) of turfgrass varieties as a means of providing non-chemical weed control for low-input or organic lawns.

The development of low-input turfgrasses deserves further consideration as a strategy to reduce the environmental and economic costs of home lawn maintenance. These results suggest that changes in residential turfgrass management could potentially benefit the turfgrass seed industry because of the large price premiums associated with low-input attributes. Low-input turfgrasses could also provide a means for the industry to take advantage of increased regulatory action. As environmental concerns continue to manifest, the turfgrass industry may develop a greater interest in producing and marketing low-input turfgrasses.

There are some limitations to the methods and analysis employed in this study. Participants were recruited from in and around the Minneapolis--St. Paul, Minnesota metropolitan area, so the results may not be representative of other regions of the United States. Compared with other hypothetical surveys, the sample size was relatively small. These limitations suggest the results should be interpreted carefully, but the results also identify directions for future research for the improvement of low-input turfgrasses and their introduction to the lawn care industry and to consumers.

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[1] In the choice experiments, there were two alternatives (A or B) and one opt-out option (Neither). If A is a dominating alternative, that means A is strictly better than B. For example, alternative A has a low irrigation requirement, low mowing requirement, low fertilizer requriement, and is dark green, fine textured, has no weeds and it only costs $5, but B has a high irrigation requirement, high mowing requirement, high fertilizer requirement, and is light green, coarse textured, has weeds and it costs $15. It is obvious that participants would choose alternative A. In this case, it is hard to estimate which particular attribute(s) drive participants' decisions. Therefore, these dominating alternatives should be eliminated.

[2] Both a probit model and logit model were used for the statistical analysis, and the resulting WTP estimates were nearly identical.

[3] The fertilizer attribute levels were both insignificant. It is possible that there was a correlation between fertilizer attribute levels and mowing requirement (i.e. greater fertilizer application could lead to more frequent growth and therefore mowing). We tried to avoid this correlation in the experimental design in order to obtain the separate effects of the fertilizer attributes and mowing frequency attributes on participants' preference. When tested, the correlation between the two attributes was very low. Specifically, the correlation between *Mowinglow* and *Fertilizerlow* was 0.07; the correlation between *Mowingmedium* and *Fertilizermedium* was 0.08; and the correlation between *Mowinglow* and *Fertilizermedium* was -0.02.

Table 2.1 Turfgrass attributes and the attribute categories in the choice experiment.

Attributes	**Category**
Texture	*Fine*
	Coarse
Color	*Dark green*
	Light green
Weed presence	*Yes*
	No
Native	*Native (U.S.)*
	Non-native
Shade adaptation	*Sun*
	Sun or Shade
Irrigation requirement	*Low (Less than once a week)*
	Medium (1 to 2 times a week)
	High (3 to 5 times a week)
Fertility requirement	*1 lb nitrogen 1,000* ft^{-2} *per year*
	2 lbs nitrogen 1,000 ft^{-2} *per year*
	3 lbs nitrogen 1,000 ft^{-2} *per year*
Mowing requirement	*Once a month*
	Every other week
	1 to 2 times per week
Price	*$5 per 1,000* ft^2
	$10 per 1,000 ft^2
	$15 per 1,000 ft^2
	$20 per 1,000 ft^2

Table 2.2 An example of the choice scenarios[a]

Consider a situation where you are provided two turfgrass choices. From the following pairs of turfgrasses please choose which turfgrass you would prefer to purchase (you may choose "neither" if you would not purchase either).

Scenario 1	**Alternative A**	**Alternative B**	**Alternative C**
Price:	\$5.00/ 1,000 ft^2	\$10.00/ 1,000 ft^2	Neither A Nor B
Mowing requirement:	Every other week	Once a month	
Fertilizer requirement:	3 lbs nitrogen/ 1,000 ft^2 per year	1 lb nitrogen/ 1,000 ft^2 per year	
Shade adaptation:	Sun	Sun or Shade	
Irrigation requirement:	Less than once a week	1 to 2 times a week	
Origin:	Non-native	Native (U.S.)	
Choose only one option.	☐	☐	☐

[a]Although aesthetic attributes were not labeled, alternatives in each scenario also varied in color, texture, and weed infestation.

Table 2.3 Summary statistics of choice experiment participants' background information (n=128).

Variable	**Description of variables**	**Mean**	**Std. Dev.**
Age	Participants' age	44.778	14.005
Education			
Edulow	1 if high school diploma or less; 0 otherwise	0.156	0.363
Edumedium	1 if some college or college diploma; 0 otherwise	0.625	0.484
Eduhigh	1 if some graduate school or graduate degree	0.211	0.408
Gender	1 if female; 0 if male	0.512	0.5
Child	1 if having children under 12 years old at home; 0 otherwise	0.197	0.398
Income			
Incomelow	1 if household income is ≤ \$50,000; 0 otherwise	0.305	0.46
Incomemedium	1 if household income is > \$50,000 and ≤ \$100,000; 0 otherwise	0.469	0.499
Incomehigh	1 if household income is >\$100,000; 0 otherwise	0.227	0.419
Lawnsize	The size of home lawn; 1 if lawn size is more than 8,000 ft^2; 0 otherwise	0.18	0.384

Table 2.4 The estimation results of the mixed logit model (n=6,144)[a].

Independent variables	Coefficient		Std. Error
Price	-0.155	***	0.059
Waterlow	1.505	***	0.173
Watermedium	0.906	***	0.156
Fertilizerlow	0.31		0.214
Fertilizermedium	0.17		0.169
Mowinglow	0.607	***	0.216
Mowingmedium	0.46	*	0.287
Native	0.825		0.58
Sun	0.805	**	0.387
Fine	1.36	**	0.547
Dark	0.413	*	0.26
Weeds	-1.161	***	0.337
*Native*Price*	0.055	***	0.022
*Sun*Fine*	-0.509		0.625
Intercept	0.179		0.512
Random individual effect			
σ_η	0.203	***	0.031

[a] There were 128 participants and each of them evaluated 16 alternatives, which gives 6,144 (128*16) observations in total.

A single asterisk (*), double asterisks (**), and triple asterisks (***) denote significance at the α = 0.05, 0.01, and 0.001 levels, respectively.

Table 2.5 WTP premium estimates for low-input attributes from the mixed logit model (n=6,144).

Attribute	Mean ($ per 1,000 ft^2)	Std. Error
Waterlow	9.70	3.52
Watermedium	5.85	1.95
Fertilizerlow	2.00	0.78
Fertilizermedium	1.10	0.83
Mowinglow	3.92	2.18
Mowingmedium	2.97	1.90

Consumer Preferences for Low-Input Turfgrasses: A Conjoint Analysis

INTRODUCTION

Lawns are an important part of American culture and are nearly universal throughout urban and suburban residential landscapes. As a result, turfgrass covers more acreage in the U.S. than any other irrigated crop (Milesi et al., 2005). Over half of U.S. households participate in lawn care practices and spend an average of $213 annually on lawn care services and products (Butterfield, 2003). Haydu et al. (2006) estimated the total value added to the U.S economy from the lawn care industry in 2002 was approximately $13.3 billion.

If managed properly, turfgrass benefits both society and the environment. Turfgrass can reduce soil erosion and surface runoff (Krenitsky et al., 1998), mitigate urban heat island effects (Peters et al., 2011), sequester carbon (Qian et al., 2010), as well as provide recreational and aesthetic benefits to society (Beard and Green, 1994). However, turfgrass culture and management practices in the urban landscape have come under scrutiny for potential negative impacts on the environment, such as freshwater contamination from fertilizers and pesticides and irrigation practices (Robbins et al., 2001; Robbins and Birkenholtz, 2003; and Milesi et al., 2005). Consequently, restrictions have been placed on residential lawn care practices in several states, such as restrictions on phosphorus containing lawn fertilizers and municipal water restrictions regarding lawn irrigation, (State of Minnesota, 2010; State of Wisconsin, 2011; MassDEP, 2010) which are likely to become more stringent as the availability of natural resources becomes more limited.

In response to public concerns and regulations, researchers and turfgrass managers have focused on strategies to reduce resource inputs. A few of these strategies include the use of deficit irrigation to reduce water use (Dacosta and Huang, 2006; Devitt et al., 2008), the use of economic thresholds to govern pesticide applications for turfgrass pests (Castle and Naranjo, 2009), breeding for turfgrass cultivars with improved drought tolerance and pest resistance (Abraham et al., 2003; Bonos et al., 2006; and Karcher et al., 2008), as well as the initiation of community educational programs about sustainable lawn care (Carpenter and Meyer, 1999).

Another promising strategy is the use of non-traditional turfgrass species that require fewer resource inputs, or low-input turfgrass species. For example, Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.) are the most widespread grass species found in residential landscapes in the northern Midwest, but they require considerable amounts of resource inputs to maintain a lawn of satisfactory quality (Turgeon, 2005). Several non-traditional grass species that provide acceptable, even superior, quality when maintained with fewer resource inputs have been identified in studies conducted throughout the northern Midwest. Diesburg et al. (1997) established field trials in seven states throughout the northern Midwest to evaluate alternative grass species under minimal fertility and no irrigation over a three year period. Although they observed some variation in species performance between sites, in general tall fescue (*Festuca arundinacea* Schreb.), sheep fescue (*Festuca ovina* L.), and colonial bentgrass (*Agrostis capillaris* L.) performed well across the region. Watkins et al. (2011) observed similar results in a two year, regional alternative grass species field trial that received no fertility or irrigation and minimal mowing. Watkins et al. reported that hard fescue

(*Festuca trachyphylla* [Hack.] Krujina), tall fescue, sheep fescue, and colonial bentgrass provided an acceptable turfgrass stand throughout the region under the low-maintenance regime. Additionally, several native grass species, including tufted hairgrass (*Deschampsia caespitosa* [L.] P. Beauv.) and prairie junegrass (*Koeleria macrantha* [Ledeb.] Shult.), have also shown potential in regional trials for use as low-input turfgrasses (Mintenko et al., 2002; Watkins et al., 2011).

There have been multiple studies conducted investigating residential landscape preferences, but most have focused on homeowner preferences for xeriscapes (Yabiku et al., 2008; Spinti et al., 2004; and Larsen and Harlan, 2006). Results from these studies are currently most relevant in arid regions where the strain on freshwater resources is greater than in the humid northern Midwest. Homeowners generally value traditional, well-groomed residential landscapes (Zheng et al., 2011), and an aesthetically pleasing landscape can even enhance the perceived value of homes (Behe et al., 2005). Studies also suggest consumers are becoming more environmentally conscious and making more ecologically-minded purchasing decisions (Yue et al., 2010). Helfand et al. (2006) found that consumers in the northern Midwest were likely to adopt more environmentally beneficial landscape designs. Previous research suggests that consumers are likely to adopt environmentally beneficial landscape designs and a potential market may exist for low-input turfgrasses in residential landscapes (Helfand et al., 2006; Wolfe and Zajicek, 1998), but there have been no formal studies investigating consumer preferences for turfgrass attributes. In order for the use of non-traditional, low-input turfgrasses to be a successful strategy to reduce resource inputs in the urban landscape, the consumer market for low-input turfgrasses as well as consumer preferences for aesthetic and maintenance attributes of turfgrasses must first be investigated and characterized. Therefore, the objectives of this study were to 1) characterize the relative importance of both aesthetic and maintenance attributes of turfgrasses with residential homeowners, and 2) identify and characterize potential market segments within the residential turfgrass market. This information is not only useful for marketing and sales professionals to identify the target consumer market, but it also provides valuable information and direction for turfgrass breeders and seed producers.

MATERIALS AND METHODS

Consumer satisfaction for a product as a whole is determined by the value placed on each of the various attributes that comprise the product (Baker, 1999), and conjoint analysis utilizes regression methods to estimate how much individual attributes and attribute levels contribute to overall consumer satisfaction. Conjoint analysis is widely used for marketing research (Green et al., 2001) and has been used to examine consumer preferences for many horticultural products (Behe, 2006; Behe et al., 1999; Behe et al., 2005; Campbell et al., 2004; Frank et al., 2001; and Hall et al., 2010). In this study, conjoint analysis was used to characterize consumer preferences for turfgrass attributes as well as determine their relative importance.

Attributes

Focus groups were conducted in April 2010 to help determine the set of turfgrass attributes to include in the conjoint analysis. Key attributes of most concern to consumers were price, shade adaptation, aesthetic characteristics (e.g. color), and maintenance characteristics (e.g. mowing requirement). Based on the results from the focus group discussions, the following nine attributes were included in the conjoint analysis: price, shade adaptation, color, texture, amount of weed infestation, irrigation requirement, fertility requirement, mowing requirement, and origin. Other potential attributes such as pest resistance and wear tolerance were determined to have less importance to homeowners and were excluded.

The difference in the price of turfgrass seed is highly dependent on species. Four representative price points were chosen for the study ($5.00, $10.00, $15.00, and $20.00), and to ensure ease of interpretation, price was expressed as the cost to seed 1000 ft^2. The appropriate price range was determined by observing the market price of turfgrass seed and consulting with turfgrass seed professionals throughout the Minneapolis-St. Paul metropolitan area. Aesthetic attributes of turfgrass also influence consumer preference. Traditionally, consumers value dark, finer textured turfgrass stands with no weed infestation. Two levels of color (‘*dark’* and ‘*light’*), texture (‘*coarse’* and ‘*fine’*), and weed infestation (‘*yes’* or ‘*no’*) were chosen for the conjoint design. Maintenance requirements are also likely to influence consumer preference, not only due to interest in cost savings but also due to increasing interest in environmental stewardship. Three levels of irrigation, fertility, and mowing requirements were chosen for the conjoint design. Irrigation requirement was expressed as frequency of irrigation required during June, July, and August (‘*low: less than once a week*’, ‘*moderate: 1 to 2 times per week*’, and ‘*high: 3 to 5 times per week*’), and mowing requirement was also expressed as a frequency (‘*once a month*’, ‘*every other week*’, and ‘*1 to 2 times per week*’). Fertility requirement was expressed as pounds of nitrogen required annually (‘*1 lb N/1000 ft^2/year*’, ‘*2 lbs N/1000 ft^2/year*’, and ‘*3 lbs N/1000 ft^2/year*’). Many home lawns have shaded areas, and consumers have shown an interest in native plants for landscapes

(Helfand et al., 2006). Thus, two levels of shade adaptation (‘*sun only*’ and ‘*sun and shade*’) and origin (‘*U.S. native*’ and ‘*non-native*’) were also included in the conjoint design.

Survey

The total number of possible attribute combinations was 3,456. Therefore, it was impractical to have respondents evaluate all combinations, so a fractional-factorial design was used. The fractional-factorial design was generated using JMP® 8 software (SAS Institute Inc, Cary, NC, USA), and non-realistic profiles were eliminated from the design (Green and Srinivasan, 1978). For example, native grasses are typically more expensive than non-native grasses (Smith and Whalley, 2002). Therefore, profiles that were $5.00 and native were eliminated. The final set of profiles consisted of 32 combinations which maximized orthogonality and level balance (levels of an attribute occurred with equal frequency).

Turfgrass plots were used as the stimuli in order to estimate the relative importance of aesthetic attributes as well as the other turfgrass attributes. Plots were used as stimuli because estimations from both verbal questions and photographs may not accurately represent true preferences (Zheng et al., 2011), and the use of real products may allow for more accurate estimation of consumer preference (Alfnes et al., 2006; Yue and Tong, 2009). Turfgrass plots were 1.0 m × 1.5 m, and consisted of monostands of Kentucky bluegrass, perennial ryegrass, hard fescue, colonial bentgrass, tufted hairgrass, and prairie junegrass. There were 648 turfgrass plots at the study site, which varied in color, texture, and natural weed presence from which the 32 turfgrass plots (i.e. stimuli) were chosen. Turfgrass plots were chosen so that differences in color and texture could be clearly differentiated. Plots that were categorized as absent of weeds had no weeds, and plots that were categorized as having weeds had approximately 10-20% natural weed encroachment. The 32 turfgrass plots included in the study were clearly labeled and delineated. Signs were placed in front of each turfgrass plot and were labeled with one level of price, shade adaptation, origin, and specific maintenance requirements. Color, texture and weed presence were not labeled on the signs so consumer valuation of aesthetic attributes was based solely on participants' observations. Because price was expressed as the cost per area, an area adjacent to the turfgrass plots equivalent to 1000 ft^2 was marked off for participants to use as a reference.

Participants were recruited by placing advertisements in 13 local newspapers throughout the Minneapolis-St. Paul metropolitan area as well as advertisements on minneapolis.craigslist.org. Participants came to the study site located at the University of Minnesota Turfgrass Research, Outreach, and Education Center located in St. Paul, MN and were compensated $30.00 each for completing the on-site survey. To ensure the results were representative of the consumer market, only subjects with a home lawn and the ability to make lawn care decisions were allowed to participate in the study. The survey was conducted on June 12, 2010. In order to reduce the number of participants taking the survey at one time, there were five separate sessions throughout the day, and there were 20 to 30 participants in each session for a total of 136 participants. Participants were asked to rate each turfgrass plot on a 5-point Likert scale (1= extremely dislike, 5= extremely like). They were also asked to fill out a short questionnaire about demographic and lawn care specific information, including age, gender, level of education, income, household size, and current lawn care practices. In the questionnaire participants were also asked questions about their attitudes and preferences about home lawn maintenance practices. The study protocol was approved by the University of Minnesota Institutional Review Board prior to implementation.

Data analysis

Preference ratings were analyzed using CONJOINT in SPSS 19.0 (SPSS, Inc., Chicago, Ill.). For the conjoint model, a part-worth functional form was selected for each attribute except for price, which was represented with an ideal point (quadratic) model. Vector (linear) and ideal point models for price were evaluated using the method described by Green and Srinivasan (1990), and the ideal point model was determined to have the smallest prediction error. Ordinary least squares regression was used to estimate each participant's part-worth and ideal coefficients (i.e. utilies), for each attribute level. Each variable, except for price, was effects coded so the utilities of each level within an attribute summed to zero. Individual regression models were fit to each participant instead of using an aggregate model, which not only reduces potential bias due to differences in preferences among individuals, but also allows participants to be grouped into consumer segments by clustering individuals with similar coefficients (Green and Helsen, 1989). The relative importance of each attribute was also calculated for each individual using the following formula:

$$RI_i = \left(\frac{RG_i}{\sum_{i=1}^{9} RG_i}\right) \times 100$$

where RI_i is the relative importance of the *i*th attribute and RG is the range of the utility coefficients for attribute *i*. Relative importance represents the magnitude of importance an attribute contributes to a consumer's valuation and purchasing decision.

Cluster analysis was performed in SPSS 19.0 (SPSS, Inc., Chicago, Ill.) using the estimated coefficients for each participant. Multiple clustering algorithms were used to determine the ideal number of clusters, namely Ward's Minimum Variance and Complete Linkage (Hall et al., 2010; Frank et al., 2001; and Campbell eta l., 2004). A four cluster solution was selected based on distinctness and interpretability (Kotler and Armstrong, 1994). Mean utility values as well as the mean response to questions about attitudes toward lawn care practices for each of the four segments were tested against the overall sample mean using two-tailed *t* tests. Additionally, multiple pair-wise comparisons between segments were also conducted on utility and relative importance estimates as well as demographic and behavioral variables using Dunnett's C test in SPSS 19.0 (SPSS, Inc., Chicago, Ill.).

RESULTS AND DISCUSSION

Overall sample

One hundred and thirty-six participants completed the survey. However, only 116 participants were used in the conjoint and cluster analyses due to missing values. Participants' age ranged from 19 to 77 years old, and the average age of the sample was 44.7 years old. Approximately half of the sample was female (50.9%). Eleven percent of participants earned $25,000 or less annually, 35.3% of participants earned between $25,001 and $50,000, 28.4% earned between $50,001 and $80,000, and 25.0% earned more than $80,000. Forty nine percent of participants worked full time, 15.5% worked part time, 5.2% were students, 13.8% were retired, and 9.5% were unemployed (6.9% of responses were missing values). Fourteen percent of participants had earned a high school diploma or less, 62.1% had completed some college or earned a college diploma, and 23.3% had completed some graduate school or earned a graduate degree. Only 16.4% of participants hired an external lawn care service, and 81.0% of participants had purchased turfgrass seed in the past 10 years. Approximately twenty-two percent of participants spent less than $100 on lawn care annually, 43.1% spent between $100 and $300, and 24.1% of participants spent more than $300 on annual maintenance (11.2% of responses were missing values).

The mean utility for each attribute level, standard error, relative importance, and R^2 for the overall sample and each consumer segment are reported in Table 3.1, as well as mean comparisons between each segment and the overall sample and multiple pair-wise comparisons between consumer segments. Higher utility values indicate a greater preference, and relative importance represents the extent to which an attribute contributes to consumers' overall valuation of the product. The conjoint model accounted for 77% of the variation in participant response. Overall, participants placed the highest relative importance on irrigation requirement (15.98%) and price (15.45%), followed by mowing requirement (13.74%) and fertility requirement (12.06%). Less relative importance was placed on shade adaptation, aesthetic attributes, and origin. Due to the elimination non-realistic profiles, there may have been an interaction effect between price and origin.

Participants preferred dark, fine textured turfgrasses with no weed infestation, low (less than once a week) and moderate (1 to 2 times per week) irrigation requirements, as well as the low (once a month) mowing requirement. Preferences for shade adaptation, texture, color, fertility, and origin varied widely, as indicated by the large standard errors for the utilities. Estimated statistics from the entire sample provide useful insight, but the presence of groups of participants whose preferences differ from the overall sample can lead to biased results (Green and Krieger, 1991). Four consumer segments, the Price Conscious, Shade Adaptation, Mowing Conscious, and Water Conscious segments, were identified through cluster analysis by grouping participants with similar preferences. Each segment had characteristically different importance values as well as preferences in comparison to each other and the overall sample. Mean comparisons between segments and the overall sample and multiple pair-wise comparisons between consumer segments regarding demographics and attitudes are presented in Table 3.2. Although there were significant ($\alpha = 0.05$) differences in attitudes between the four segments, there were no significant differences in demographics between consumer segments.

Segment I

Participants in the first segment, the "Price Conscious" participants, comprised 20.69% of the sample. Participants in this group placed significantly higher relative importance on price (18.97%) compared to the Water Conscious segment and the overall sample, as well as turfgrass plots with no weed infestation (13.84%) relative to the other three consumer segments. The Price Conscious segment strongly preferred the low irrigation requirement and was the only group that disliked the moderate irrigation requirement. These participants also highly favored the moderate fertility requirement and had a strong preference for non-native grasses, which could be a result of the potential interaction effect between origin and price.

In comparison to the overall sample, participants in the Price Conscious segment spent significantly less on lawn maintenance and also indicated they would be less willing to sacrifice the aesthetic appeal of their lawn in order to reduce maintenance inputs. Turfgrasses most likely to appeal to these participants are low-cost grasses with an aggressive growth habit making them likely to out-compete weeds. Most participants in this segment, like the overall sample, slightly-to-strongly agreed (rating ≥ 5) that pesticides were harmful to human health (87.5%) and the environment (91.7%), so naturally weed-suppressive, allelopathic turfgrasses (Bertin et al., 2009) may also strongly appeal to these consumers.

Segment II

Participants in the second segment, the "Shade Adaptation" segment, represented 31.03% of the sample. They placed significantly higher relative importance on shade adaptation relative to the overall sample and the Water Conscious segment, and they had a significantly stronger preference for turfgrasses adapted to both sun and shade compared to the other three consumer segments. This group also placed significantly more importance on texture than the overall sample, but their preferences for fine and coarse textured turfgrasses were not significantly different from the other segments. The Shade Adaptation segment placed significantly lower relative importance on irrigation requirement compared to the overall sample and the Water Conscious segment, and the presence of weeds was the least important turfgrass attribute to these participants. Turfgrass advertized as a ‘sun and shade mix’ would more likely appeal to these participants compared to turfgrass advertized for aesthetic or low maintenance attributes.

Segment III

Participants in Segment III, the "Mowing Conscious" participants, comprised 28.45%. These participants placed the greatest importance on mowing requirement and placed significantly less relative importance on the presence of weeds compared to the overall sample. They were also the only consumer segment that favored the low fertility requirement. Unlike the other three segments, the average coefficients for price were positive as was the utility for native origin. Considering the potential interaction effect between price and origin, this may indicate that participants in the Mowing Conscious segment were not as sensitive to price and preferred native grasses. This group also had the highest percentage of women. This segment may indicate a potential market for more expensive, native turfgrasses that are slow-growing and low-maintenance.

Segment IV

The fourth segment, the "Water Conscious" participants, comprised 19.83% of the sample and placed an extremely high relative importance on irrigation requirement (30.12%). Mowing requirement was the second most important attribute. Participants in this segment placed a significantly lower relative importance on price and texture relative to the overall sample, but they strongly preferred darker grasses.

The Water Conscious segment had the highest percentage of men and a significantly higher level of education than the overall sample. The defining characteristic of participants in this segment was their strong concern for water conservation. Compared to the overall sample, the Price Conscious segment, and the Shade Adaptation segment, these participants indicated they would be more likely to purchase low-input turfgrasses. Low-maintenance, drought-tolerant turfgrasses which remain green throughout the dry periods of the growing season would likely strongly appeal to this group of participants.

CONCLUSIONS

The ecological impact of urban and suburban lawn care practices has become a major concern in recent decades. The use of non-traditional, low-input turfgrasses for home lawns may help reduce resource inputs and environmental impacts associated with residential lawn care. This study characterizes consumer preferences for nine attributes of turfgrass and identifies four distinct potential market segments. Although preferences differed between segments, in general participants placed more importance on maintenance attributes than on aesthetic attributes. These results suggest that information about the maintenance requirements of turfgrass significantly influence consumer purchasing decisions, and that non-traditional, low-input turfgrasses would likely be accepted in the residential turfgrass market.

With the exception of price, irrigation requirement was the most important turfgrass attribute overall, and only slight importance was placed on shade adaptation, color, texture, presence of weeds, and origin. However, clear differences in preference and relative importance among these attributes became apparent after participants were clustered into segments. The Price Conscious and Shade Adaptation segments were more sensitive to price and placed less overall importance on maintenance attributes than participants in the Mowing Conscious and Water Conscious segments. Still, it is evident that reduced irrigation requirement is the most valued low-maintenance attribute of turfgrasses by homeowners in the Minneapolis--St. Paul metropolitan area. Participants' responses to statements about water use indicated that the cost of water was not a major motivation behind the strong preference for turfgrasses with a low irrigation requirement, but instead that environmental concern was a likely motivation. These results strongly suggest that the introduction of low-input turfgrasses to the market might be a viable strategy to reduce water use in the urban landscape.

Preferences for mowing and fertility requirements were not as consistent as the preference for irrigation requirement. Of the three maintenance attributes, the second most importance was placed on mowing requirement. Approximately 70% of participants agreed with the statement 'reducing how often I mow will benefit the environment', suggesting participants' motivations behind placing high importance on reduced mowing were not only based upon cost and time savings but also potentially on environmental concerns about fossil fuel use.

More than 75% of participants agreed that fertilizers were harmful to the environment, which is similar to the findings of Meyer et al. (2001). Yet all participants, except for those in the Mowing Conscious segment, preferred the moderate fertility requirement. The University of Minnesota Extension program recommends 2 lbs N 1000 ft^{-2} per year for moderately maintained home lawns in (Mugaas, 1995). Considering recommendations and restrictions on phosphorus containing lawn fertilizers currently in effect in Minnesota, it is probable that most homeowners believe that a moderate amount of fertility is not detrimental to the environment.

Previous research suggests that consumers prefer native plants in residential landscapes (Helfand et al., 2006; Zadegan et al., 2008). These results suggest the same preference may not exist for turfgrasses, although inference on consumer preference for turfgrass origin is limited due to the potential interaction between origin and price. Only participants in the Mowing Conscious segment preferred native turfgrasses, yet they still placed little relative importance on origin compared to other attributes. These results do support that there is consumer demand for turfgrasses adapted to shade, which are already available on the market. Among the aesthetic attributes, participants had the strongest preference for turfgrass plots without weeds. Given that herbicides are the most commonly used pesticides on home lawns (Meyer et al., 2001) and a majority of participants (68.9%) indicated they would likely purchase a different type of grass if it required fewer pesticide applications, the development and introduction of allelopathic turfgrasses for the residential market may warrant further investigation.

Participants in the Water Conscious segment had the highest level of education, which has previously been reported as significant socio-demographic predictor for environmentally-conscious consumer behavior (Samdahl and Robertson, 1989). Although, more recent studies have failed to find connections between environmentally-conscious purchasing behavior and consumer demographics, which is likely due to more widespread knowledge about environmental issues (Roberts, 1996). This may help explain the lack of significant differences in demographics between consumer segments in this study. Roberts (1996) suggested that demographics and an individual's concern for the environment were much less accurate at predicting consumer behavior in comparison to perceived consumer effectiveness, which is a measure of consumers' belief in the ability of the actions of an individual to significantly affect environmental problems. There is a relatively high level of perceived consumer effectiveness in regard to environmental issues surrounding residential lawn care given that the majority of Minnesota homeowners believe their lawn care practices can have a significant effect on the environment (Meyer et al., 2001). This additionally supports the likelihood of consumers adopting non-traditional, low-input turfgrasses.

The vast majority of participants (95.7%) indicated that they would be more likely to purchase low-input turfgrasses if provided more information. Efforts to increase public knowledge about sustainable lawn care practices and awareness of low-input turfgrasses may also be an effective, long-term, strategy to reduce resource inputs used in residential landscapes (Carpenter and Meyer, 1999 and Hurd, 2006). Although the results presented in this study highlight the importance of maintenance attributes of turfgrass to consumers, the results should also be interpreted with caution. It is also worth noting that there are different ways to segment participants, and that the number of clusters chosen is, to some extent, subjective. We could have further segmented participants into sub-segments, likely identifying areas of differing preference within each of the four segments. The sample size for the conjoint analysis (n=116) was relatively small compared with other conjoint studies, and the results may not be representative of other states and regions of the U.S. Despite these limitations, the results do imply that the introduction of low-input turfgrasses to the residential consumer market warrants further consideration.

Table 3.1 Relative importance and utilites for nine turfgrass attributes in a conjoint study of consumer preference for low-input turfgrasses among 116 homeowners in Minneapolis—St. Paul, Minnesota.

	Price Conscious segment 24		**Shade Adaptation segment** 36		**Mowing Conscious segment** 33		**Water Conscious segment** 23		**Overall Sample** 116	
Attributes and levels	Part-worth	(Std. error)	Part-worth	(Std. error)	Part-worth	(Std. error)	Part-worth	(Std. error)	Part-worth	(Std. error)
Shade tolerance										
Sun and shade	- 0.131 b	(0.086)	'0.190* a	(0.089)	- 0.09 b	(0.071)	- 0.141 b	(0.060)	- 0.022	(0.067)
Sun only	0.131 b	(0.086)	- 0.190* a	(0.089)	0.09 b	(0.071)	0.141 b	(0.060)	0.022	(0.067)
Relative importance (%)		9.36 ab		12.64* a		8.78 ab		7.56 b		9.86
Texture										
Fine	0.092 a	(0.075)	- 0.01 a	(0.078)	0.083 a	(0.062)	0.043 a	(0.053)	0.048	(0.059)
Coarse	- 0.092 a	(0.075)	0.01 a	(0.078)	- 0.083 a	(0.062)	- 0.043 a	(0.053)	- 0.048	(0.059)
Relative importance (%)		5.23* b		10.80* a		7.97 ab		4.77* b		7.65
Color										
Dark	0.143 a	(0.091)	- 0.213* b	(0.095)	0.103 a	(0.075)	0.206* a	(0.064)	0.034	(0.071)
Light	- 0.143 a	(0.091)	0.213* b	(0.095)	- 0.103 a	(0.075)	- 0.206* a	(0.064)	- 0.034	(0.071)
Relative importance (%)		6.53 a		9.82 a		9.18 a		8.08 a		8.61
Weed infestation										
No	'0.352* a	'(0.077)	- 0.001* b	(0.080)	0.005* b	(0.064)	0.184 a	(0.054)	0.11	(0.060)
Yes	- 0.352* a	(0.077)	0.001* b	(0.080)	- 0.005* b	(0.064)	- 0.184 a	(0.054)	- 0.11	(0.060)
Relative importance (%)		13.84* a		7.27 b		6.28* b		6.45 b		8.19
Irrigation requirement										
Low	0.352 b		- 0.015* c		0.112* c		0.86* a	(0.067)	0.27	(0.074)

		(0.095)		(0.099)		(0.079)				
Moderate	- 0.143* b	(0.079)	0.039 a	(0.082)	0.070 a	(0.065)	0.088 a	(0.055)	0.02	(0.061)
High	- 0.209 a	(0.087)	- 0.024* a	(0.090)	- 0.182 a	(0.072)	- 0.948* b	(0.061)	- 0.29	(0.068)
Relative importance (%)		13.00 b		11.27* b		13.43 b		30.12* a		15.98
Fertility requirement										
Low	- 0.137 bc	(0.082)	- 0.266* c	(0.086)	0.192* a	(0.068)	- 0.033 b	(0.058)	- 0.063	(0.064)
Moderate	0.234* a	(0.081)	0.173* ab	(0.084)	- 0.163* c	(0.067)	0.066 b	(0.057)	0.069	(0.063)
High	- 0.097 b	(0.094)	0.094 a	(0.097)	0.028 ab	(0.077)	- 0.033 ab	(0.066)	- 0.006	(0.073)
Relative importance (%)		11.95 a		12.70 a		15.05 a		6.86* b		12.06
Mowing requirement										
Low	'0.135 a	'(0.073)	0.115 a	(0.076)	0.237 a	(0.060)	0.381 a	(0.051)	0.194	(0.057)
Moderate	- 0.186* b	(0.104)	- 0.219* b	(0.109)	0.142* a	(0.086)	0.167* b	(0.074)	- 0.033	(0.081)
High	0.050* a	(0.108)	0.014* a	(0.112)	- 0.379* b	(0.089)	- 0.485* b	(0.076)	- 0.161	(0.084)
Relative importance (%)		11.12 a		11.65 a		16.02 a		16.44 a		13.74
Origin										
Native to U.S.	- 0.258* c	(0.094)	- 0.097 b	(0.098)	0.075* a	(0.078)	- 0.007 ab	(0.066)	- 0.064	(0.073)
Non-native	'0.258* c	'(0.094)	0.097 b	(0.098)	- 0.075* a	(0.078)	0.007 ab	(0.066)	0.064	(0.073)
Relative importance (%)		9.96 a		8.46 a		7.95 a		7.59 a		8.46
Price										
Estimate	- 0.264* c		- 0.112 bc		0.028* a		- 0.048 ab		- 0.091	
$5.00/1000 ft^2	- 1.023	(0.264)	- 0.441	(0.275)	0.117	(0.219)	- 0.185	(0.186)	- 0.352	(0.206)
$10.00/1000 ft^2	- 1.453	(0.398)	- 0.644	(0.415)	0.184	(0.330)	- 0.257	(0.281)	- 0.499	(0.310)
$15.00/1000 ft^2	- 1.291	(0.416)	- 0.609	(0.433)	0.201	(0.344)	- 0.217	(0.293)	- 0.442	(0.324)

$20.00/1000 ft^2	- 0.537	(0.368)	- 0.337	(0.383)	0.169	(0.304)	- 0.063	(0.259)	- 0.18	(0.287)
Relative importance (%)		18.97* $_{a}$		15.37 $_{ab}$		15.29 $_{ab}$		12.12* $_{b}$		15.45
Adjusted R^2	0.64		0.41		0.69		0.95		0.77	

*Significant at the 0.05 level when compared to the overall sample in a two-tail *t* test.

Segment means within the same row with the same letter are not significantly different (α = 0.05) according to Dunnett's C test.

Table 3.2 Demographic characteristics and mean responses to statements about attitudes and perceptions of tufgrass of each consumer segment.

Demographic variable	Segment I		Segment II		Segment III		Segment IV		Overall Sample
Age (years)	47.38		42.34		46.12		47.45		44.70
Gender (% female)	0.46		0.50		0.67		0.36		0.51
Education[a]	3.63		3.64		3.82		4.41	*	3.80
Annual income[b]	4.25		4.78		5.21		5.43		4.92
Employment status[c]	2.29		2.42		1.90		1.87		2.13
Size of home lawn[d]	3.25		3.35		3.48		3.30		3.16
Do you hire a lawn maintenance service? (% yes)	0.08		0.17		0.24		0.13		0.16
How much do you spend on lawn maintenance annually?[e]	2.04	*	2.68		2.93		2.48		2.56
Have you purchased seed in the past 10 years? (% yes)	0.87		0.78		0.88		0.77		0.82
Statements[f]									
I would like to be able to see what the grass looks like before purchasing it.	5.92	a	6.14	a	5.94	a	6.39	a	6.09
I would be more likely to purchase a low-input grass if I were better informed about it.	5.79	ab	5.92	b	5.97	ab	6.35	a*	5.99
I don't want my yard to look different from my neighbors.	3.00	a	2.80	a	3.64	a	3.17	a	3.16
I would be willing to sacrifice some of the aesthetic appeal of my lawn in order to reduce maintenance inputs.	3.75	b*	5.11	ab	5.00	ab	5.04	a**	4.78
I would be more likely to use a low-input grass if it were advertised well.	4.17	b**	4.42	b	4.82	ab	4.70	a*	4.53
If low-input grasses were more available, I would be more likely to purchase them.	4.88	b	5.08	b	5.15	ab	5.61	a**	5.16

I would purchase a different type of grass if I only had to mow twice a year.	4.33	a**	5.25	a	5.72	a	5.78	a	5.25
Reducing how often I mow will benefit the environment.	5.26	a	5.19	a	5.31	a	5.78	a	5.31
I would purchase a different type of grass if it required less water.	4.75	b	5.08	b	5.30	ab	6.17	a***	5.29
Water use on home lawns is an environmental concern.	5.33	b	5.78	ab	5.27	b	6.43	a***	5.67
I would buy a differenty type of grass if it required less fertilizer.	4.29	b*	4.75	ab	5.06	ab	5.57	a*	4.91
Fertilizer use on home lawns is harmful to human health.	5.29	a	5.11	a	5.64	a	5.22	a	5.32
Fertilizer use on home lawns is harmful to the environment.	5.42	a	5.31	a	5.76	a	5.96	a	5.59
I would purchase a different type of grass if it required less pesticide use.	5.39	a	5.19	a	5.03	a	6.09	a*	5.37
Pesticide use on home lawns is harmful to human health.	6.04	a	5.78	a	6.12	a	6.13	a	6.00
Pesticide use on home lawns is harmful to the environment	6.13	a	5.89	a	6.06	a	6.35	a	6.08

[a]Education was reported on a 1 to 6 scale: 1= some high school or less; 2= high school diploma; 3= some college; 4= college diploma; 5= some graduate school; 6= graduate degree.

[b]Income was reported on a 1 to 8 scale: 1= $15,000 or under; 2= $15,001 - $25,000; 3= $25,001 - $35,000; 4= $35,001 -$50,000; 5= $50,001 - $65,000; 6= $65,001 - $80,000; 7= $80,001 - $100,000; 8= Over $100,000.

[c]Employment was reported on a 1 to 5: 1= full time; 2= part time; 3= student; 4= retired; 5= unemployed.

[d]Size of home lawn was reported on a 1 to 5 scale: 1= less than 1,000 ft^2; 2= 1,000 - 2,999 ft^2; 3= 3,000 - 4,999 ft^2; 4 = 5,000 - 8,000 ft^2; 5 = more than 8,000 ft^2.

[e]Annual expenditure was reported on a 1 to 5 scale: 1= less than $100.00; 2= $100.00 - $199.00; 3= $200.00 - $299.00; 4= $300.00 - $400.00; 5= more than $400.00.

[f]Participants were asked to indicate on a scale of 1 to 7 which best described their attitude toward the statements (1= strongly disagree and 7= strongly agree).

Single asterisk (*), double asterisks (**), and triple asterisks (***) denote significance at 0.10, 0.05, and 0.01 levels, respectively when compared to the overall sample in a two-tail *t* test.

Means within the same row with the same letter are not significantly different ($\alpha = 0.05$) according to Dunnett's C test.

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APPENDIX A

Sample of homeowner questionnaire distributed in St. Paul, MN in June, 2010.

ID: ___________

INSTRUCTION BOOKLET

Please do not look at or read pages in this INSTRUCTION BOOKLET until directed to by a monitor or a monitor may ask you to leave and you will forfeit any money you would have received.

Voluntary Consent Form

Dear Participant:

You are invited to be a part of a research study investigating the attitudes and preferences of home owners concerning the use of alternative turfgrasses. Please read through this form and feel free to ask any questions you may have before agreeing to participate in the study.

This study is being conducted by:
Kari Hugie, Master Student, Applied Plant Sciences
Chengyan Yue, PhD., Assistant Professor, Horticultural Science and Applied Economics

We would like you to take about 40-50 minutes (including the time you spend reading this page) to help us evaluate your preferences for alternative turfgrass species. You will be presented with various scenarios for turfgrass plots and asked to mark your preference. You will also be asked to fill out a short questionnaire about your socio- demographics and attitudes toward alternative turfgrass species.

The following measures will be taken to ensure confidentiality to the extent permitted by law: you will be randomly assigned a unique code to be used on all forms instead of your name; your name will never be associated with this code; only the project investigators will have access to the information you provide; this information will be held confidential through password protected computer files; and your identity will remain confidential in any published results.

There are no foreseeable risks from participating in this study.

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to withdraw at any time without affecting those relationships.

You may ask any questions you have now. If you have questions later, **you are encouraged** to contact:

Chengyan Yue	Kari Hugie
1970 Folwell Ave.	1970 Folwell Ave.
St. Paul MN 55108	St. Paul MN 55108
(612) 626-3974	(662) 820-5000
yuechy@umn.edu	hugi0006@umn.edu

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact:

Research Subjects' Advocate Line
D528 Mayo
420 Delaware St. Southeast
Minneapolis MN 55455
(612) 625-1650

Thank you for taking part in this experiment on alternative turfgrass preferences. It is important for the quality of this research that you take your time and answer this questionnaire as best as you can.

Questionnaire on Turfgrasses for Home Lawns

Please follow the instructions in this booklet carefully. If you have any questions during the experiment, please direct them to a monitor.

OVERVIEW

The purpose of this experiment is to better understand homeowners' preferences for different grasses on home lawns. To accomplish this, you will be asked to consider the scenarios and complete the survey questions within this booklet.

The experiment will proceed in 3 sections:

SECTION 1: Choice Scenarios (in the field)
SECTION 2: Maintenance Practices and Turfgrass Preferences for Home Lawns
SECTION 3: Socio-Demographics

These instructions will guide you through the experiment one section at a time.

**Thank you for taking part in this experiment on consumer behavior and preferences. It is very important for the quality of this research that you *take your time and answer this questionnaire as best as you can*. Thanks!

SECTION 1. Choice Scenarios

Round 1

Instructions: *This section will involve actual plots of turfgrass. Consider a situation where you are provided two turfgrass choices. From the following pairs of turfgrasses please rate your preference for each choice, and then choose which turfgrass you would prefer to purchase (you may choose "neither" if you would not purchase either).*

On a 1-5 scale, please rate your preference for each Choice A and Choice B (1= extremely dislike, 5= like very much). Circle the number that best reflects your preference. Then please mark which choice you would rather purchase (mark "neither" if you would not purchase either). Choose only one option.

Scenario 1					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 2					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 3					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 4					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 5					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 6					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 7					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 8					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 9					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 10					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 11					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 12					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 13					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 14					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 15					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 16					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	◻ Choice A		◻ Choice B		◻ Neither

Round 2

Instructions: *Now consider the same choice scenarios when you are provided additional information about water use, fertilizer requirements, mowing requirements, and origin (U.S. native versus non-native). Again, please rate your preference for each choice, and then choose which turfgrass you would prefer to purchase (you may choose "neither" if you would not purchase either) considering the additional information.*

On a 1-5 scale, please rate your preference for each Choice A and Choice B (1= extremely dislike, 5= like very much). Circle the number that best reflects your preference. Then please mark which choice you would rather purchase (mark "neither" if you would not purchase either). Choose only one option.

Scenario 1					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 2					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 3					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 4					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 5					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 6					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 7					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 8					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 9					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 10					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 11					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 12					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 13					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 14					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 15					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Scenario 16					
	Extremely dislike	**Dislike**	**Neutral**	**Like**	**Like very much**
Choice A	1	2	3	4	5
Choice B	1	2	3	4	5
Which would you rather purchase?	□ Choice A		□ Choice B		□ Neither

Please proceed to finish the rest of the questions until you are finished.

SECTION 2. Maintenance Practices and Turfgrass Preferences for Home Lawns

Instructions: The following questions are directed toward your lawn maintenance practices and attitudes towards them as well as turfgrass preferences for your home lawn. Please take time to thoroughly read and answer the questions to the best of your ability.

1. My lawn is approximately ______.

(Please check only one response)

- ❑ Less than 1,000 ft^2
- ❑ 1,000 - 2,999 ft^2
- ❑ 3,000 - 4,999 ft^2
- ❑ 5,000 - 8,000 ft^2
- ❑ more than 8,000 ft^2
- ❑ I don't know

2. What type of grass do you currently have on your lawn?

(Please check only one response)

- ❑ Kentucky bluegrass
- ❑ Perennial ryegrass
- ❑ Fescue
- ❑ Bentgrass
- ❑ Other
- ❑ NA
- ❑ I don't know

3. Are you the primary caretaker of your home lawn?

- ❑ Yes
- ❑ No

4. Do you have a shaded lawn?

- ❑ Yes
- ❑ No

5. Do you hire a lawn maintenance service?

- ❑ Yes
- ❑ No

6. Have you purchased grass seed in the past 10 years?

- ❑ Yes
- ❑ No

7. If you answered "no" to question 5, please proceed to question 7. If you answered "yes" to question 5, please answer the following.

a. How many times have you purchased seed in the past 10 years?

(Please check only one response)

- ❑ 1-3 times
- ❑ 4-7 times
- ❑ 7-10 times
- ❑ More than 10 times

b. Where did you purchase the seed?

- ❑ Online
- ❑ Store (please indicate the store name or store type ____________________)
- ❑ Other

c. What type of seed did you purchase?

❑ ______________________ ❑ I don't know

8. Approximately how much do you spend on lawn maintenance yearly? (water, fertilizer, etc.)

(Please check only one response)

- ❑ Less than $100.00
- ❑ $100 -- $199
- ❑ $200 -- $299
- ❑ $300 -- $400
- ❑ More than $400
- ❑ I don't know

9. Labels on bags of seed display different information. Please indicate which of the following you look for (or would look for) when purchasing seed.

(*Check all that apply.)*

- ❑ Function (e.g. shade, repair)
- ❑ Grass variety(s)
- ❑ Care instructions
- ❑ Water requirement
- ❑ Pesticide requirement
- ❑ Fertilizer requirement
- ❑ Mowing requirement
- ❑ Speed of establishment
- ❑ Shelf life
- ❑ Wear tolerance
- ❑ Special adaptations (e.g. slopes, soil type)
- ❑ Other (please specify)________________________

10. Please answer the following questions regarding mowing practices to the best of your knowledge.

a. On average, I mow my lawn _____ .

(Please check only one response)

- ❑ More than once a week
- ❑ Once a week
- ❑ Once every two weeks
- ❑ Once a month
- ❑ Less than once a month
- ❑ NA

b. In your opinion, which of the following best describes "low-input" maintenance in terms of mowing frequency?

(Please check only one response)

- ❑ More than once a week
- ❑ Once a month

❑ Once a week
❑ Once every two weeks
❑ Less than once a month

c. Please indicate which best describes your attitude toward the following statements (1=strongly disagree, 7=strongly agree). (*Please circle only one response for each item*)

Statement	strongly disagree	somewhat disagree	slightly disagree	neither	slightly agree	somewhat agree	strongly agree
Attitude Towards Mowing							
(a) I wish I didn't need to mow my lawn as often.	1	2	3	4	5	6	7
(b) I would purchase a different type of grass if I only had to mow once every two weeks.	1	2	3	4	5	6	7
(c) I would purchase a different type of grass if I only had to mow once a month.	1	2	3	4	5	6	7
(d) I would purchase a different type of grass if I only had to mow twice a year.	1	2	3	4	5	6	7
(e) Reducing how often I mow will benefit the environment.	1	2	3	4	5	6	7

11. Please answer the following questions regarding water use to the best of your knowledge.

a. On average, how often do you water lawn during June, July and August?

(Please check only one response)

❑ Every day
❑ Three times a week
❑ Twice a week
❑ Once a week
❑ Every other week
❑ Less than every other week
❑ Only when it looks stressed
❑ Never
❑ NA

b. On average, how much water do you apply to your lawn weekly during June, July and August?

❑ _______________ inches
❑ I don’t know

c. In your opinion, which of the following best describes "low-input" maintenance in terms of water use?

(Please check only one response)

- ❑ Every day
- ❑ Three times a week
- ❑ Twice a week
- ❑ Once a week
- ❑ Every other week
- ❑ Less than every other week
- ❑ Only when it looks stressed
- ❑ Never

d. Please indicate which best describes your attitude toward the following statements (1=strongly disagree, 7=strongly agree). (*Please circle only one response for each item*)

Statement	strongly disagree	somewhat disagree	slightly disagree	neither	slightly agree	somewhat agree	strongly agree
Attitude Towards Water Use							
(a) My lawn requires too much water.	1	2	3	4	5	6	7
(b) My water bill gets too high in the summer because of having to water my lawn.	1	2	3	4	5	6	7
(c) I would purchase a different type of grass if it required less water than my current lawn.	1	2	3	4	5	6	7
(d) Water use on home lawns is an environmental concern.	1	2	3	4	5	6	7

12. Please answer the following questions regarding fertilizer use to the best of your knowledge.

a. I fertilize my lawn _______ .

(Please check only one response)

- ❑ More than 5 times per year
- ❑ 5 times per year
- ❑ 4 times per year
- ❑ 3 times per year
- ❑ 2 times per year
- ❑ 1 time per year
- ❑ Never
- ❑ NA

b. Approximately, how much total fertilizer do you apply to your lawn per year?

_____________lbs

❑ I don’t know

c. In your opinion, which of the following best describes "low-input" maintenance in terms of fertilizer use?

(Please check only one response)

❑ More than 5 times per year
❑ 5 times per year
❑ 4 times per year
❑ 3 times per year
❑ 2 times per year
❑ 1 time per year
❑ Never
❑ NA

c. Please indicate which best describes your attitude toward the following statements (1=strongly disagree, 7=strongly agree). (*Please circle only one response for each item*)

Statement	strongly disagree	somewhat disagree	slightly disagree	neither	slightly agree	somewhat agree	strongly agree
Attitude Towards Fertilizer Use							
(a) My lawn requires too much fertilizer.	1	2	3	4	5	6	7
(b) I would buy a different type of grass if I didn't have to fertilize as often.	1	2	3	4	5	6	7
(c) Fertilizer use on home lawns is harmful to human health.	1	2	3	4	5	6	7
(d) Fertilizer use on home lawns is harmful to the environment.	1	2	3	4	5	6	7

13. Please answer the following questions regarding pesticide <u>(e.g. weed, insect and disease control)</u> use to the best of your knowledge.

a. How often do you apply pesticides to your lawn?

(Please check only one response)

❑ More than 5 times per year
❑ 5 times per year
❑ 4 times per year
❑ 3 times per year
❑ 2 times per year
❑ 1 time per year
❑ Never
❑ NA

b. In your opinion, which of the following best describes "low-input" maintenance in terms of pesticide use?

(Please check only one response)

❑ More than 5 times per year
❑ 5 times per year
❑ 2 times per year
❑ 1 time per year

- ❑ 4 times per year
- ❑ 3 times per year
- ❑ Never

c. Please indicate which best describes your attitude toward the following statements (1=strongly disagree, 7=strongly agree). (*Please circle only one response for each item*)

Statement	strongly disagree	somewhat disagree	slightly disagree	neither	slightly agree	somewhat agree	strongly agree
Attitude Towards Pesticide Use							
(a) I would like to reduce the amount of pesticides I apply to my lawn.	1	2	3	4	5	6	7
(b) I would purchase a different type of grass if it required fewer pesticide applications.	1	2	3	4	5	6	7
(c) Pesticide use on home lawns is harmful to human health.	1	2	3	4	5	6	7
(d) Pesticide use on home lawns is harmful to the environment.	1	2	3	4	5	6	7

14. Different grasses have different characteristics both functionally and aesthetically. Please rate the following characteristics from 1-7 indicating their importance to you, where 1= extremely unimportant and 7 = extremely important. *(Please circle only one response for each item).*

Characteristic	Extremely un-important	quite un-important	slightly un-important	neither	slightly important	quite important	extremely important
Color	1	2	3	4	5	6	7
Uniformity	1	2	3	4	5	6	7
Density	1	2	3	4	5	6	7
Height of cut	1	2	3	4	5	6	7
Mowing frequency	1	2	3	4	5	6	7
Water requirement	1	2	3	4	5	6	7

Characteristic	Extremely un-important	quite un-important	slightly un-important	neither	slightly important	quite important	extremely important
Fertility requirement	1	2	3	4	5	6	7
Pesticide requirement	1	2	3	4	5	6	7
Origin (U.S. native vs. non native)	1	2	3	4	5	6	7
Speed of establishment	1	2	3	4	5	6	7
Price	1	2	3	4	5	6	7

15. How would the following scenarios increase the likelihood of you purchasing a certain type of grass for your lawn? (1= extremely unlikely, 7 = extremely likely) (*Please circle only one response for each item*)

	Statement	extremely unlikely	quite unlikely	slightly unlikely	Neither	slightly likely	quite likely	extremely likely
(a)	The grass is native to the U.S., but it costs \$15-20 more per 1000 ft^2.	1	2	3	4	5	6	7
(b)	The grass is more expensive upfront, but it requires fewer inputs and would save money long term.	1	2	3	4	5	6	7
(c)	The grass requires fewer inputs, but it costs \$5-10 more per 1000 ft^2.	1	2	3	4	5	6	7
(d)	The grass requires less water, but it takes longer to establish.	1	2	3	4	5	6	7
(e)	The grass requires less fertilizer, but my lawn won't be as green.	1	2	3	4	5	6	7
(f)	I will not have to mow as often, but my lawn won't look as uniform.	1	2	3	4	5	6	7
(g)	The grass requires fewer pesticide applications, but I will have to tolerate a few weeds.	1	2	3	4	5	6	7

16. How much do you agree with the following statements (1=strongly disagree, 7=strongly agree)? (*Please circle only one response for each item*)

	Statement	strongly disagree	somewhat disagree	slightly disagree	neither	slightly agree	somewhat agree	strongly agree
(a)	I don't apply chemicals to my lawn because of health concerns.	1	2	3	4	5	6	7
(b)	I don't apply chemicals to my lawn because of environmental concerns.	1	2	3	4	5	6	7
(c)	I spend too much time maintaining my lawn.	1	2	3	4	5	6	7
(d)	My lawn requires too many inputs (fertilizer, water, etc.).	1	2	3	4	5	6	7
(e)	I am not aware that native turfgrasses are available.	1	2	3	4	5	6	7
(f)	I am not aware that low-input grasses are available.	1	2	3	4	5	6	7
(g)	I would like to be able to see what the grass looks like before purchasing it.	1	2	3	4	5	6	7
(h)	I would be more likely to purchase a low-input grass if I were better informed about it.	1	2	3	4	5	6	7
(i)	I don’t want my yard to look different from my neighbors.	1	2	3	4	5	6	7
(j)	I would be more willing to purchase low-input grasses if I knew other homeowners were purchasing them.	1	2	3	4	5	6	7
(k)	I would prefer to have a grass on my lawn that is native to the U.S.	1	2	3	4	5	6	7

(l)	I would be willing to sacrifice some of the aesthetic appeal of my lawn if I could reduce maintenance inputs.	1	2	3	4	5	6	7
(m)	I would rather purchase grass as sod than as seed.	1	2	3	4	5	6	7
(n)	I would be more likely to use a low-input grass if it were advertised well.	1	2	3	4	5	6	7
(o)	If low-input grasses were more available, I would be more likely to purchase them.	1	2	3	4	5	6	7
(p)	I doubt that low-input grasses will perform as well on my lawn as traditional grasses.	1	2	3	4	5	6	7
(q)	I would be more likely to purchase low-input grass if I was given an estimate of savings over time.	1	2	3	4	5	6	7
(r)	I would be more willing to purchase a low-input grass if I had a referral from a trusted source.	1	2	3	4	5	6	7
(s)	I would be more willing to purchase a low-input grass if there were monetary incentives (e.g. rebate program, tax break).	1	2	3	4	5	6	7

SECTION 3. Socio-Demographics

Instructions: We would like you to answer just a few more survey questions about you and your household. Your completion of the survey is extremely important for the results of this study. ***Remember that your responses are confidential.***

17. What is your AGE? (very important information)

____

18. What is the highest level of EDUCATION you have completed?

(*Please check only one response*)

- ☐ Some High School or Less
- ☐ High School Diploma
- ☐ Some College
- ☐ College Diploma
- ☐ Some Graduate School
- ☐ Graduate degree

19. What is your GENDER?

- ☐ Male
- ☐ Female

20. What is your marital status?

a. Not married / single
b. In a relationship
c. Married
d. Divorced / separated
e. Widow / widower

21. Do you have children under 12 years old at home?

- ☐ Yes
- ☐ No

22. Do you have pets that play on your lawn?

- ☐ Yes
- ☐ No

23. How many people live in your household? Include yourself, your spouse, and any dependents. Do not include your roommates:

(*Please check only one response*)

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 or More

24. Please circle the category below that describes the total amount of INCOME earned in 2008 by the people in your household (as "household" is defined in question 18).

(*Please check only one response*)

Consider all forms of income, including salaries, tips, interest and dividend payments, scholarship support, student loans, parental support, social security, alimony, and child support.

- ☐ $15,000 or under
- ☐ $15,001 - $25,000
- ☐ $25,001 - $35,000
- ☐ $50,001 - $65,000
- ☐ $65,001 - $80,000
- ☐ $80,001 - $100,000

- ☐ $35,001 - $50,000
- ☐ Over $100,000

25. What is your current employment status?

(*Please check only one response*)

- ☐ Full time
- ☐ Part time
- ☐ Student
- ☐ Retired
- ☐ Unemployed
- ☐ NA

26. Please share any additional comments you have about turfgrass and what the industry can do to improve the performance of the grasses that can be used on your homelawn.

____
____
____
____
____
____
____

This concludes the questionnaire portion of this experiment. Please hand in your INSTRUCTION BOOKLET. Following the collection of your materials, you will receive $30 for your participation in this experiment. We appreciate your participation and your contribution to our research.