Investigating the Practices and Challenges for Turfgrass Breeders and Distributors

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Abstract. An online survey was conducted to investigate the current practices of and challenges for turfgrass breeders and turfgrass seed distributors (or sales staff) in the United States. We found that turfgrass seed breeders rated producers/growers and consumers as more important parties compared with other interested parties. However, variations in ratings were found for breeders/distributors according to different program characteristics. The volume of seed sales of the species was the most highly rated technical consideration for both breeders and distributors. Compared with distributors, breeders considered the following technical factors more important than others: funding, labor, field trial performance, diversity in working priorities, availability of germplasms, scheduling, and staff training. Costs, followed by resource allocation and resource availability, were rated as the most challenging factors when breeders were implementing priorities. Our findings provide important insight regarding breeding and distribution practices and management in the turfgrass industry.

Increased urban development and the concomitant increase in turfgrass acreage have resulted in increased research of turfgrass breeding and associated management

practices. In the United States, turfgrasses occupy 1.9% of the continental surface and cover an area three-times larger than any irrigated crop (Milesi et al., 2005, 2009). Turfgrasses provide functional benefits such as water quality protection, soil erosion control, and water microclimate moderation (Boyd and Wainger, 2002; Krenitsky et al., 1998; McPherson et al., 1989). Residential lawns have become one of the most fundamental landscape components providing recreational and aesthetic benefits for numerous consumers (Beard and Green, 1994). However, researchers and the public have shown growing concerns about the increasing use of resources (water, pesticides, fertilizer, etc.) for lawn maintenance and the resulting envi-

ronmental problems such as soil runoff and excess nutrients and pesticides in the watershed (Alig et al., 2004; Gilliom et al., 2006; Robbins and Birkenholtz, 2003).

To fulfill the needs of consumers and to contribute to environmental sustainability, turfgrass breeding programs evaluate, develop, and introduce turfgrasses with superior traits. Previously, various turfgrass species have been assessed for pest and disease resistance (Bonos et al., 2006; Cisar, 2010; Watkins et al., 2014), climatic region adaptation (Mintenko et al., 2002), drought tolerance, and reduced nitrogen requirements (Bonos and Huff, 2013; Johnson, 2008; Watkins et al., 2014). A previous study (Yue et al., 2012) investigated priorities for North American rosaceous crop breeding programs and found that breeders regarded the two ends of the supply chain (producer/growers and the consumers) as the most important parties when setting trait priorities. Turfgrass breeding, like other product development activities, determines the inherent physical characteristics of the turfgrass variety and creates value for stakeholders in the supply chain (Solomon and Stuart, 2003). Because of the substantial evidence suggesting that market-driven businesses are more likely to be economically successful, it is useful to investigate whether turfgrass suppliers adopt a market-driven approach.

To our knowledge, no study has investigated the practices and challenges of turfgrass breeders and distributors. Our specific objectives were as follows: 1) to identify the primary parties influencing how turfgrass breeders and distributors prioritize turfgrass traits; 2) to evaluate how technical considerations influence how these priorities are set; 3) to identify challenges turfgrass breeders encounter when determining and implementing target traits for breeding; and 4) to investigate differences in the practices and challenges encountered by breeders/distributors when breeding/distributing turfgrasses with different uses and how demographics profiles and program characteristics affect such differences.

Materials and Methods

An online survey was conducted to investigate the current practices of and challenges encountered by turfgrass breeders and turfgrass seed distributors (or sales staff) in the United States. The survey asked questions about species, targeted regions, and major uses of the turfgrasses that are bred/distributed. The survey included questions about the importance level of interested parties (consumers, producers/growers, wholesalers, marketing companies, university colleagues, sales staff, professional peers, turfgrass scientists, extension specialists, and public officials/policymakers), technical considerations (such as the volume of seed sales of the species, availability of technologies, and speed of production), and socioeconomic challenges (such as resource availability,

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niche market potential, and awareness of environmental changes) affecting the determination and implementation of turfgrass priorities for breeders and distributors. Other background information such as program size, program location, affiliation (university, government, or private company), years of working experience in the turfgrass industry, and the sex and education level of respondents were also collected.

We obtained a total of 54 responses, but several were incomplete; therefore, they were excluded from this study. Eleven complete responses from turfgrass breeders and 34 complete responses from turfgrass seed distributors were used for this study. Breeders and distributors rated the importance of factors affecting the selection of turfgrass priorities using a continuous scale of 0 to 10 (0 = very unimportant and 10 = very important). Factors such as the importance of the needs of interested parties and technical considerations were examined from the viewpoints of breeders and distributors. Breeders were also asked about the challenges they encountered when determining or implementing breeding trait priorities. We conducted *t* tests to evaluate if the ratings of interested parties/technical considerations differed significantly between each of the analyzed factors.

The variables included the breeders' and distributors' ratings of the importance of interested parties, technical considerations, and challenges encountered when determining and implementing priorities. To identify the main factors that influence the ratings of breeders, we used double-bounded Tobit models (ratings range, 0 to 10; left-censored at 0 and right-censored at 10). An unobservable underlying latent variable (Y^*) was used to express the observed dependent variable (Y) (Greene, 2007). The unobserved dependent variable Y^* is expressed as a function of a vector of the independent variable X by the following specification:

$$Y^* = X\beta + \varepsilon; \varepsilon \sim \text{Normal}(0, \sigma^2)$$

where β is the vector of the unknown coefficient and ε is the error term assumed to follow a normal distribution with a mean of zero and standard deviation of σ . The observed dependent variables are represented by:

$$Y = \max(0, Y^*) \text{ and } Y = \min(Y^*, 10)$$

The dependent variables included measures of the importance of the needs of interested parties, technical considerations, and challenges that breeders encounter when setting priorities. The independent variable vector X included information regarding program characteristics such as the targeted regions of turfgrasses, program size, years of working experience in the turf industry, and the education level and sex of respondents.

Results

*Summary statistics and pairwise *t* test results of breeder and distributor ratings.*

Summary statistics for demographics of surveyed breeders and distributors are listed in Table 1. More than 70% of the surveyed turfgrass breeders and more than 90% of the turfgrass seed distributors were male. On average, breeders and distributors had a similar number of years of working experience (between 19 and 20 years). The program size was approximately six full-time equivalent staff members for breeders and 23 for distributors. The average education level for breeders was a Master's degree, whereas the average distributor had a Bachelor's degree.

Table 2 shows the summary statistics for ratings of importance of interested parties and technical considerations for both breeders and distributors. The most important parties influencing priority settings for breeders were producers/growers and consumers, followed by distributors or sales staff, turfgrass scientists, and wholesalers. Other parties such as public officials, marketing companies, professional peers, extension specialists, and university specialists were considered less important. Distributors, however, considered consumers as the most important party, followed by distributors/sales staff, producers/growers, and wholesalers. Similar to the turfgrass breeders, turfgrass seed distributors considered public officials, marketing companies, professional peers, as well as university and extension specialists as less important parties. We also conducted pairwise *t* tests and found that the ratings for consumers, followed by those for producers/growers, were significantly higher than those for other parties. Technical considerations such as the volume of seed sales of the species, perceived market demand for specific traits, labor, availability of technologies, profit margins, field trial performance, ease of production, popularity/use of species, and availability of the germplasm were the most important factors when breeders were setting program priorities. Pairwise comparisons using a *t* test also suggested that the volume of seed sales of the species and perceived market demand for specific traits were rated significantly higher than other factors.

Table 3 presents the summary statistics for ratings of the challenges encountered by breeders when determining and implementing turfgrass trait priorities. The summary statistics of ratings together with the pairwise *t* test results indicated that breeders rated resource availability such as financial and labor/personnel resources (technicians, breeders, etc.) as the most challenging when determining the program priorities. Additionally, when comparing the challenges encountered when implementing program priorities, breeders and distributors gave the highest ratings to costs, followed by resource allocation across different projects.

Estimation results of Tobit models. We used double-bounded Tobit models to identify the major aspects affecting turfgrass breeders' and distributors' ratings of interested parties, technical considerations, and challenges encountered. In total, 55 Tobit models were used, and the results are pre-

sented in Tables 4–7. Table 4 includes 11 dependent variables of interested parties (consumers, producers/growers, wholesalers, marketing companies, university colleagues, sales staff, distributors, professional peers, turfgrass scientists, extension specialists, and public officials/policymakers) rated according to importance. Table 5 shows the results of 24 regressions for dependent variables that were rated according to importance and the following technical considerations: volume of seed sales of the species, perceived market demand for specific traits, labor, availability of technologies, profit margins, field trial performance, ease of production, popularity/use of species, availability of the germplasm, funding, cost of development, speed of production, scheduling, maximization of economic returns, information/feedback from consumers, diversity in working priorities, information regarding new markets, unique germplasm with interesting traits, consistency of traits of the species, the need to withstand the test of time, species specifications, staff training ahead of seasonal changes, collaboration opportunities, and university research. Independent variables for Tobit models in Tables 4 and 5 included the target regions (West, Midwest, South, Northeast, and Canada) where turfgrasses would be used, the program size, years of experience, respondents' sex and education level, and a dummy variable indicating whether the respondent was a breeder or a distributor.

Tables 6 and 7 present the results of Tobit models including dependent variables that were different challenges breeders encountered when determining and implementing the program priorities. Nine dependent variables in Table 6 represent the challenges breeders encountered when determining priorities; these included resource availability (financial, labor/personnel, space/land), niche market potential, knowing environmental changes, availability in the marketplace, identifying new sources of genes (germplasm) to reach breeding goals, not doing too much (future royalties/unknown funding), and practicality of targeting the trait of the species of interest. Eleven dependent variables (cost, resource allocation across different projects, resource availability, being the first to do something/lack of technological ability to do something, consistency of the trait of the species, collecting germplasm resources, evaluating new resources of germplasm, grower support, poor documentation of existing germplasm, coordination/timing in terms of training seasonal/part-time staff, budgeting of past royalties) in Table 7 are challenges that breeders encountered when implementing program priorities. The following independent variables for the last two sets of models were the same: program size, number of years of working experience as a turfgrass breeder, and breeder's education level and sex. For all of the regressions, each effect discussed was *ceteris paribus*, meaning that the estimated coefficient describes the effect of the variable

Table 1. Summary statistics of the background information of a national survey distributed to turfgrass breeders and distributors (n = 45).

Variables	Description	Breeders (n = 11)		Distributors (n = 34)	
		Mean	(SD)	Mean	(SD)
Male	1 if the respondent is male; 0 if the respondent is female	0.73	(0.47)	0.94	(0.24)
Work years	Number of years the breeder or distributor professional has been involved in the turfgrass industry	19.20	(9.29)	19.79	(11.35)
Program size	Size of the program in terms of number of full-time equivalent staff	5.91	(4.48)	22.62	(45.21)
Education	Highest level of education 1 = some high school; 2 = high school degree; 3 = some college; 4 = Bachelor's degree; 5 = Master's degree; 6 = PhD degree	4.73	(1.01)	3.91	(0.67)

Table 2. Summary statistics of turfgrass breeders' and distributors' ratings of the importance of interested parties and technical considerations when selecting priorities based on a survey distributed to a national sample of turfgrass breeders and distributors (n = 45).

Importance of interested parties that influence priorities (0 = very unimportant, 10 = very important)	Breeders		Distributors		Importance of technical considerations that influence priorities (0 = very unimportant, 10 = very important)	Breeders		Distributors	
	Mean	(SD)	Mean	(SD)		Mean	(SD)	Mean	(SD)
Producers/growers	8.91	(0.94)	6.75	(2.74)	Volume of seed sales of the species	8.64	(1.12)	7.76	(1.99)
Consumers	8.55	(1.13)	8.47	(1.83)	Perceived market demand for the specific trait	7.90	(2.23)	7.13	(2.05)
Distributors	6.78	(2.64)	6.88	(2.80)	Labor	7.89	(2.03)	4.30	(2.32)
Turfgrass scientists	6.57	(1.40)	5.76	(2.85)	Availability of technologies	7.86	(1.57)	5.58	(3.17)
Sales staff	6.50	(3.02)	6.44	(2.39)	Profit margins	7.64	(2.62)	7.70	(1.73)
Wholesalers	6.27	(2.80)	6.00	(3.01)	Field trial performance	7.55	(2.73)	7.62	(2.19)
Public officials/policymakers	6.00	(3.12)	4.57	(3.16)	Ease of production	7.50	(2.37)	6.52	(2.49)
Marketing companies	5.88	(3.00)	4.14	(2.22)	Popularity/use of species	7.44	(2.24)	7.67	(2.07)
Professional peers	5.80	(2.17)	5.44	(2.64)	Availability of germplasm	7.38	(1.41)	5.52	(2.48)
Extension specialists	5.00	(2.38)	5.86	(2.83)	Funding	7.25	(2.92)	4.62	(3.14)
University colleagues	4.29	(1.25)			Costs of development	7.00	(2.37)	5.65	(2.35)
					Speed of production	6.80	(3.08)	6.20	(2.35)
					Scheduling: staying ahead of seasonal changes (e.g., pollen and harvest windows)	6.71	(2.56)	5.00	(2.56)
					Maximization of economic returns/royalties	6.44	(3.64)	5.15	(3.44)
					Information/feedback from consumers	6.30	(2.11)	7.54	(2.19)
					Diversity in working priorities	6.25	(2.38)	5.50	(2.69)
					Information regarding new markets	6.22	(2.86)	5.46	(2.41)
					Unique germplasm with interesting traits	6.22	(2.54)	6.63	(2.37)
					Consistency of the trait of the species	6.00	(2.67)	7.08	(2.21)
					Need to withstand the test of time	6.00	(2.56)	7.11	(2.33)
					Species specifications	5.78	(3.03)	6.88	(2.28)
					Staff training ahead of seasonal changes	5.43	(2.88)	5.58	(2.73)
					Collaboration opportunities	5.13	(2.80)	5.57	(2.04)
					University research	4.29	(1.98)	6.81	(2.18)

of interest with other conditions remaining the same.

Importance of the interested parties influencing the settings of priorities. Table 4 shows that turfgrass breeders and distributors targeting different geographical regions had different ratings for each interested party. For instance, breeders and distributors targeting the west regions rated the needs of consumers, sales staff, and professional peers as more important compared with the needs of those who did not target these regions. Extension specialists were rated as a more important party by those who were targeting the Midwest. Public officials/policymakers were considered more important, and professional peers were considered less impor-

tant by breeders/distributors targeting the southern United States. Turfgrass breeders and distributors targeting Canada tended to rate producers/growers and wholesalers as more important parties, but they rated extension specialists as less important.

Program size also affected breeders' and distributors' ratings of the important parties. Programs with larger sizes rated consumers as less important parties, but they considered professional peers and turfgrass specialists as more important. Breeders and distributors with more working experience rated the producers/growers as less important parties. More educated respondents considered public officials/policymakers as more important and professional peers as less important.

Compared with their female counterparts, male respondents rated the importance of marketing companies higher. The differences in ratings between breeders and distributors were not significant for most parties. However, the significant coefficient of the breeder variable for the professional peers model suggested that breeders thought of professional peers as a more important party compared with distributors.

Importance of the technical considerations influencing priorities. Table 5 presents the Tobit model results for different technical considerations. Respondents targeting the west regions considered information/feedback from consumers, consistency of the trait of the species, the need to withstand the test

Table 3. Summary statistics of breeders' ratings of challenges encountered when determining and implementing priorities when selecting a trait for inclusion in a breeding program based on a survey distributed to a national sample of turfgrass breeders and distributors (n = 11).

Challenges you face when determining priorities (0 = very unchallenging 10 = very challenging)	Mean	(sd)	Challenges you face when implementing priorities (0 = very unchallenging 10 = very challenging)	Mean	(sd)
Resource availability: financial	8.91	(0.94)	Costs	8.40	(2.41)
Resource availability: labor/personnel (technicians, breeders, etc.)	8.55	(1.13)	Resource allocation across different projects	7.10	(2.60)
Niche market potential	6.78	(2.64)	Resource availability	6.44	(2.51)
Knowing environmental changes	6.57	(1.40)	Being the first/lack of technological ability to do something (e.g., not having the technology to perform genetic marker research)	6.20	(2.62)
Availability in the marketplace	6.50	(3.02)	Consistency of the trait of the species	5.33	(3.50)
Resource availability: space/land	6.27	(2.80)	Collecting germplasm resources	5.00	(3.07)
Identifying new sources of genes (germplasms) to reach breeding goals	5.88	(3.00)	Evaluating new sources of germplasms	4.82	(2.36)
Not doing too much (future royalties/funding is unknown)	5.80	(2.17)	Grower support	4.75	(3.58)
Practicality of targeting the trait of the species of interest	4.29	(1.25)	Poor documentation of existing germplasm	4.33	(2.65)
			Coordination/timing in terms of training seasonal/part-time staff	4.33	(3.28)
			Budgeting of past royalties	4.11	(3.79)

Table 4. Tobit model estimation results regarding the importance of interested parties influencing priorities for turfgrass breeders and distributors based on a survey distributed to a national sample of turfgrass breeders and distributors (n = 45).^z

	Consumers	Producers/ growers	Wholesalers	Marketing companies	University colleagues ^y	Sales staff members	Distributors	Professional peers	Turfgrass scientists	Extension specialists	Public officials/ policymakers
West ^y	3.05** (2.30)	-0.63 (0.40)	-0.26 (0.13)	0.45 (0.25)	—	3.95** (2.43)	1.69 (0.77)	4.01** (2.69)	0.45 (0.24)	-1.86 (0.92)	2.07 (0.73)
Midwest ^y	-0.16 (0.14)	-1.77 (1.41)	-0.25 (0.15)	-2.02 (0.98)	—	1.15 (0.85)	2.70 (1.56)	2.03 (1.67)	0.48 (0.31)	7.34*** (3.25)	0.42 (0.17)
South ^y	-1.36 (1.13)	0.48 (0.33)	0.75 (0.42)	0.51 (0.34)	—	0.40 (0.25)	0.05 (0.02)	-4.33** (2.80)	-1.06 (0.59)	2.87 (1.38)	5.61* (1.77)
Northeast ^y	-0.32 (0.30)	-1.14 (0.99)	-1.53 (0.93)	-0.02 (0.01)	—	0.39 (0.34)	0.07 (0.04)	0.51 (0.49)	-1.01 (0.76)	4.45** (2.67)	-1.63 (0.85)
Canada ^y	0.07 (0.05)	4.68** (2.72)	5.65** (2.41)	3.16 (1.02)	—	0.64 (0.33)	2.37 (1.13)	0.28 (0.17)	1.26 (0.61)	-7.69** (2.31)	7.17 (1.73)
Program size	-0.02** (2.35)	0.00 (0.29)	0.00 (0.42)	0.00 (0.01)	0.17 (1.43)	0.01 (0.93)	0.00 (0.34)	0.02** (2.32)	0.02** (2.16)	0.00 (0.37)	0.01 (1.04)
Work years	0.00 (0.13)	-0.10* (2.03)	0.04 (0.50)	-0.07 (1.30)	0.04 (1.36)	-0.04 (0.79)	-0.04 (0.70)	-0.01 (0.27)	-0.08 (1.51)	-0.01 (0.12)	0.01 (0.13)
Education	0.22 (0.40)	0.17 (0.26)	0.57 (0.68)	0.67 (0.48)	0.66 (1.86)	-1.20 (1.41)	-0.79 (0.90)	-1.81** (2.78)	-0.38 (0.46)	-1.59 (1.07)	3.09* (1.84)
Male ^x	-0.21 (0.19)	1.44 (1.17)	2.54 (1.61)	2.89* (2.06)	-2.00 (2.30)	0.91 (0.53)	0.19 (0.09)	0.42 (0.28)	-0.06 (0.03)	1.25 (0.85)	-0.75 (0.29)
Breeder ^w	-0.67 (0.54)	0.94 (0.70)	-1.90 (1.07)	-0.08 (0.04)	—	1.35 (0.80)	-0.95 (0.47)	3.62** (2.54)	1.58 (0.92)	-0.77 (0.34)	-4.06 (1.44)
Intercept	9.19*** (3.24)	7.15** (2.19)	1.95 (0.46)	0.27 (0.04)	1.18 (0.50)	12.70*** (3.09)	11.30** (2.38)	12.50*** (3.85)	7.59* (1.83)	11.60 (1.75)	-5.68 (0.75)

^zDependent variables for Tobit models in this table are the rated importance levels of interested parties as listed in each column, ranging from 0 to 10. The base group for these Tobit regressions comprised female distributors. Absolute t statistics are in parentheses. ***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level. Some climatic condition variables (for example, cool-arid or warm climate conditions) are also included in the model as control variables.

^yRegional variables (west, midwest, south, northeast, and Canada) represented the target region where grasses will be used.

^xMale was a dummy variable that equaled 1 if the respondent was a male (0 if a female).

^wBreeder was a dummy variable that equaled 1 if the respondent was a breeder (0 if not a breeder).

^vThis regression was based on turfgrass breeder samples because only breeders rated the importance of university colleagues.

of time, and the availability of the germplasm as more important technical considerations; however, those who targeted the Midwest tended to rate collaboration opportunities as more important and volume of seed sales as less important. For those respondents targeting the regions, technical considerations such as the cost of development and collaboration opportunities were rated as more important, whereas funding, feedback from consumers, consistency of traits of the species, diversity in working priorities, availability of the germplasm, and scheduling and staff training ahead of seasonal changes were regarded as

less important. In fact, many warm-season grasses in the south are vegetatively propagated; therefore, seed yield would not be an issue. It is possible that the cost of development is regarded as an important technical consideration because people are producing and selling more sod than seed. Respondents targeting the northeast United States rated considerations such as unique germplasms with interesting traits, diversity in working priorities, and availability of the germplasm as more important. Respondents targeting Canada assigned lower ratings to more than half of the technical consid-

erations in terms of their importance in setting trait priorities.

Programs with larger sizes rated the need to withstand the test of time as a less important consideration. Respondents with more years of working experience rated the profit margins, species specifications, and staff training ahead of seasonal changes as more important considerations. However, the speed of production was rated as less important.

Education levels were found to have significant effects on some of the technical considerations. For example, respondents

Table 5. Tobit model estimation results for the importance of technical considerations that influence priorities for turfgrass breeders and distributors based on a survey distributed to a national sample of turfgrass breeders and distributors (n = 45).^z

	Volume of seed sales of the species	Perceived market demand for the specific trait	Funding	Labor	Costs of development	Profit margins	Species specifications	Field trial performance	Information about new markets	Information/feedback from consumers	Speed of production	Ease of production	Availability of technologies
West ^y	1.30 (1.08)	1.59 (1.10)	1.57 (0.65)	0.15 (0.09)	0.41 (0.24)	0.90 (0.82)	2.25 (1.51)	1.33 (0.86)	1.76 (1.22)	2.13* (1.85)	2.00 (1.47)	0.63 (0.42)	2.70 (1.21)
Midwest ^y	-2.35** (2.08)	-0.62 (0.47)	-1.81 (0.71)	-2.67 (1.68)	-1.63 (1.17)	0.35 (0.33)	-1.72 (1.13)	-1.86 (1.41)	-0.56 (0.47)	-0.71 (0.64)	-1.61 (1.23)	-2.15 (1.50)	1.19 (0.55)
South ^y	-1.20 (0.99)	-1.51 (1.10)	-3.76* (1.77)	2.14 (1.29)	2.44* (1.92)	0.11 (0.10)	-2.26 (1.44)	-1.89 (1.35)	0.50 (0.30)	-2.48** (2.13)	0.27 (0.18)	0.78 (0.48)	-2.27 (0.97)
Northeast ^y	-1.03 (0.96)	1.60 (1.34)	1.68 (0.90)	-0.092 (0.07)	0.21 (0.19)	0.59 (0.62)	0.79 (0.63)	0.14 (0.13)	-0.45 (0.44)	0.60 (0.57)	1.27 (1.05)	-0.03 (0.02)	-2.38 (1.38)
Canada ^y	-1.44 (0.94)	-3.59** (2.26)	-10.7*** (3.47)	-2.07 (0.88)	0.43 (0.25)	0.95 (0.72)	-5.19** (2.52)	-8.02*** (4.41)	-0.77 (0.49)	-5.51*** (3.78)	-3.77** (2.27)	-0.04 (0.02)	1.97 (0.75)
Program size	-0.01 (0.43)	0.00 (0.52)	0.00 (0.09)	0.01 (1.55)	0.00 (0.18)	0.00 (0.34)	0.0 (0.05)	0.01 (0.76)	0.00 (0.38)	-0.01 (0.92)	0.00 (0.04)	-0.01 (0.82)	0.01 (0.59)
Work years	-0.04 (1.03)	0.02 (0.52)	0.00 (0.04)	-0.07 (1.45)	-0.07 (1.63)	0.09** (2.45)	0.15** (2.82)	0.06 (1.28)	0.08 (1.67)	0.01 (0.31)	-0.09** (2.10)	0.02 (0.41)	0.04 (0.58)
Education	-0.062 (0.12)	-0.80 (1.25)	-4.24*** (3.48)	-0.85 (0.94)	-0.74 (1.00)	0.18 (0.38)	-2.02** (2.71)	-3.38*** (4.14)	1.02* (1.75)	-1.02* (1.73)	0.13 (0.23)	0.30 (0.48)	1.08 (1.11)
Male ^x	0.33 (0.31)	-0.40 (0.32)	1.79 (1.02)	0.93 (0.83)	1.83 (1.65)	-0.18 (0.18)	-0.0053 (0.00)	-0.30 (0.25)	0.89 (0.82)	-0.21 (0.22)	-1.25 (1.13)	-0.61 (0.51)	1.98 (0.79)
Breeder ^w	0.93 (0.80)	2.18 (1.60)	7.38*** (3.51)	3.91** (2.66)	1.19 (0.88)	-1.00 (0.92)	2.38 (1.55)	5.46*** (3.53)	0.43 (0.31)	1.40 (1.27)	-0.34 (0.26)	-0.79 (0.53)	2.00 (0.94)
Intercept	8.77*** (3.17)	10.1*** (3.19)	17.5*** (3.31)	7.62* (1.87)	10.3*** (3.01)	5.76** (2.21)	11.0*** (3.03)	19.4*** (5.23)	-1.69 (0.54)	11.3*** (3.97)	8.00** (2.67)	6.22* (1.90)	-3.12 (0.60)

with higher education levels rated most technical considerations (such as funding, field trial performance, unique germplasms with interesting traits, consistency of the trait of the species, diversity in working priorities, staff training ahead of seasonal changes, information/feedback from consumers) as less important, whereas the information regarding new markets was rated as more important. Male respondents considered the maximization of economic returns and availability of the germplasm as more important, and they considered the consistency of traits of the species as less important. Being a breeder significantly affected the respondent's ratings of many technical considerations. Compared with distributors, breeders gave higher ratings to the importance of funding, labor, field trial performance, working priority diversities, germplasm availability, scheduling, and staff training; however, their ratings for considerations such as the need to withstand the test of time and collaboration opportunities were lower.

Challenges breeders encountered when determining priorities and when selecting traits for inclusion in their breeding programs. The Tobit results for challenges that breeders encountered when determining priorities are listed in Table 6. The program size had a significant influence on the ratings of challenges. Keeping other variables constant, turfgrass breeders from larger programs considered challenges such as resource availability, labor/personnel, and space/land as more challenging factors, whereas other aspects such as identifying new sources of genes to reach breeding goals and niche market potential were considered to be less challenging. Years of working experience only affected breeders' ratings

of resource availability; these breeders considered the availability of labor/personal (technicians, breeders, etc.) as a more challenging factor. Breeders with higher education levels rated the availability of space/land and the availability in the marketplace as more challenging factors when determining priorities. Male breeders also thought of the availability of space/land as more challenging; however, they regarded the niche market potential as a less challenging factor.

Challenges breeders encountered when implementing priorities when selecting traits for inclusion in their breeding programs. When implementing priorities, breeders with larger program sizes considered factors such as poor documentation of existing germplasms and evaluating new sources of germplasms as less challenging. Breeders with more working experience considered collecting germplasm resources, evaluating new sources of germplasm, consistency of the trait of the species, and coordination/timing in terms of training seasonal/part-time staff as more important challenges when implementing priorities. More educated breeders considered collecting germplasm resources to be more challenging, and male breeders considered costs to be more challenging when implementing turfgrass priorities.

Discussion and Conclusions

The results presented in this study are useful for turfgrass researchers, breeders, distributors, and policymakers. Our findings provide important implications and insight about breeding/distributing practices and management in the turfgrass industry. Overall, we found that turfgrass seed breeders rated the producers/growers and consumers

as more important parties compared with other interested parties. This finding, similar to the results of a previous study of rosaceous fruit breeding programs (Yue et al., 2012), suggests that breeders are aware that the turfgrass industry is a market-driven industry and that they recognize consumers' needs and acceptance as the most important indicators for market success. Furthermore, breeders care about the benefits of the producers/growers; therefore, their breeding efforts should aim to provide producers/growers with more profits. This aspect may be unique to turfgrass because breeders need to develop products that will provide profits for the growers/producers (i.e., higher seed yield) and benefits for the consumers (turfgrass quality, drought tolerance, disease resistance, etc.). Breeding programs for agronomic crops (for example, maize and wheat), however, mainly focus on improving production efficiency to increase yield and grain quality (Carena, 2013); therefore, both producers and consumers obtain more surplus from yield increases (Nogueira et al., 2015).

Unlike breeders who regularly conduct field trials with growers and interact with producers to determine research progress and who care about the grower/producer benefits, turfgrass distributors might only consider market-related factors (consumers, distributors/sales staff, producers/growers, and wholesalers) as more important. In our survey, distributors cared most about the yield of turfgrass seeds, profit margins, and consumer acceptance.

However, variations in ratings were found for breeders/distributors with different program characteristics. For example, programs with larger sizes were more likely to

Table 5. Continued

	Maximization of economic returns/royalties	Popularity/use of species	Unique germplasm with interesting traits	Consistency of the trait of the species	Need to withstand the test of time	Diversity in working priorities	Availability of the germplasm	Scheduling: staying ahead of seasonal changes (e.g., pollen and harvest windows)	Staff training ahead of seasonal changes	University research	Collaboration opportunities
West ^y	-0.21 (0.08)	0.79 (0.54)	2.10 (1.51)	3.31** (2.80)	2.47* (1.82)	-0.10 (0.06)	1.93* (1.87)	0.075 (0.05)	0.070 (0.05)	1.37 (0.89)	-1.39 (1.11)
Midwest ^y	1.46 (0.52)	-0.63 (0.47)	1.37 (1.03)	1.17 (1.03)	-1.05 (0.81)	-0.85 (0.43)	1.46 (1.40)	0.22 (0.14)	0.24 (0.17)	1.21 (0.87)	4.09*** (3.01)
South ^y	3.11 (1.32)	0.24 (0.14)	-0.70 (0.47)	-3.41** (2.63)	-0.058 (0.03)	-3.12* (1.83)	-3.91*** (3.65)	-2.64* (1.93)	-4.86*** (4.15)	0.29 (0.17)	2.46* (1.98)
Northeast ^y	3.34 (1.59)	1.44 (1.22)	2.54* (1.91)	1.51 (1.46)	0.40 (0.32)	4.02** (2.87)	2.33** (2.75)	1.60 (1.31)	1.38 (1.32)	0.11 (0.10)	1.50 (1.40)
Canada ^y	-1.82 (0.49)	-1.26 (0.77)	-7.99*** (3.62)	-4.87*** (3.18)	-6.54*** (3.76)	-5.40** (2.68)	-4.82** (2.95)	-6.70*** (3.41)	-10.1*** (6.07)	-1.01 (0.64)	-1.39 (0.94)
Program size	-0.01 (0.74)	-0.01 (1.30)	0.01 (0.66)	0.01 (1.02)	-0.02** (2.45)	0.01 (1.29)	0.00 (0.33)	-0.01 (0.77)	-0.01 (1.13)	0.01 (1.22)	0.01 (0.78)
Work years	0.02 (0.31)	0.02 (0.43)	0.03 (0.65)	0.00 (0.04)	-0.01 (0.16)	0.05 (1.01)	0.06 (1.71)	0.05 (1.20)	0.11** (2.64)	0.07 (1.55)	-0.04 (1.06)
Education	0.32 (0.23)	-0.30 (0.48)	-1.13* (2.07)	-1.09** (2.17)	-0.13 (0.22)	-1.86** (2.54)	-0.26 (0.40)	-1.14 (1.39)	-2.04** (2.96)	-0.46 (0.75)	0.43 (0.94)
Male ^x	3.71** (2.16)	1.58 (1.25)	1.56 (1.29)	-1.99* (2.05)	-0.83 (0.74)	-0.28 (0.19)	1.85* (1.93)	1.60 (1.17)	0.13 (0.11)	-0.088 (0.07)	1.34 (1.29)
Breeder ^w	-2.63 (1.16)	-0.86 (0.57)	0.037 (0.03)	1.35 (1.22)	-2.61* (1.93)	3.06* (2.16)	3.05** (2.66)	2.77* (2.03)	3.41** (3.00)	-1.56 (1.13)	-3.03** (2.79)
Intercept	-1.14 (0.18)	7.02** (2.23)	5.07 (1.64)	12.9*** (5.01)	6.49** (2.20)	11.1*** (3.11)	1.90 (0.61)	2.93 (0.81)	7.75** (2.51)	7.96** (2.64)	1.19 (0.50)

^yThe dependent variables for Tobit models in this table are the rated importance of technical considerations as listed in each column, ranging from 0 to 10. The base group for these Tobit regressions comprised female distributors. Absolute t statistics are in parentheses. ***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level. Some climatic condition variables (for example, cool-arid or warm climate conditions) were also included in the model as control variables.

^yThe regional variables (west, midwest, south, northeast, and Canada) represented the target region where grasses will be used.

^xMale was a dummy variable that equaled 1 if the respondent was a male (0 if a female).

^wBreeder was a dummy variable that equaled 1 if the respondent was a breeder (0 if not a breeder).

Table 6. Tobit model estimation results for challenges breeders encountered when determining priorities when selecting a trait for inclusion in a turfgrass breeding system based on a survey distributed to a national sample of turfgrass breeders and distributors (n = 11).^z

	Resource availability: labor/personnel (technicians, breeders, etc.)	Resource availability: financial	Resource availability: space/land	Identifying new sources of genes (germplasm) to reach breeding goals	Practicality of targeting the trait in the species of interest	Availability in the marketplace	Niche market potential	Not doing too much (future royalties/funding is unknown)	Knowing environmental changes
Program size	0.22** (2.89)	0.25 (1.09)	0.82*** (4.09)	-0.38*** (3.94)	-0.18 (0.91)	-0.12 (0.77)	-0.63** (3.50)	-0.090 (0.33)	0.14 (0.67)
Work years	-0.10** (3.24)	-0.099 (1.03)	-0.056 (0.70)	0.066 (1.62)	0.057 (0.68)	0.11 (1.79)	0.10 (1.48)	-0.035 (0.35)	0.14 (1.84)
Education	0.25 (1.03)	0.80 (1.06)	1.36* (2.19)	0.13 (0.35)	-0.75 (1.02)	1.94** (3.48)	1.01 (1.58)	-0.41 (0.45)	1.14 (1.57)
Male ^y	0.55 (0.82)	3.39 (1.67)	6.37*** (3.85)	-1.21 (1.32)	-1.49 (0.79)	-1.19 (0.86)	-3.16* (1.97)	2.67 (1.17)	-2.11 (1.24)
Intercept	8.00*** (4.98)	2.87 (0.59)	-7.02 (1.72)	7.94** (3.36)	10.9* (2.24)	-5.04 (1.37)	3.96 (0.94)	4.86 (0.82)	-2.83 (0.59)

^zDependent variables for Tobit models in this table are the challenges breeders encountered when determining priorities in a breeding program as listed in each column, ranging from 0 to 10. The base group for these Tobit regressions comprised females. Absolute t statistics are in parentheses. ***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level.

^yMale was a dummy variable that equaled 1 if the respondent was a male (0 if a female).

rate professional peers and turfgrass scientists as important parties because of their existing or potential collaborations. Additionally, breeders were more likely to rate professional peers higher than distributors, indicating that breeders may have more interactions with other professional peers. The volume of seed sales was the most highly rated technical consideration for both breeders and distributors. Compared with distributors, breeders considered technical factors (such as funding, labor, field trial performance, diversity in working priorities, availability of the germplasm, scheduling, and staff training) as

more important because they had to bear a higher proportion of production costs.

The influence of program characteristics varied for different technical and societal challenges when breeders were determining or implementing priorities. In general, resource availabilities were rated as the most challenging when determining the program priorities; costs, followed by resource allocation and resource availability, were rated as the most challenging factors when breeders were implementing priorities. Although turfgrass breeders encounter a variety of challenges different from those of breeding

programs for rosaceous crops (Yue et al., 2012), resource-related challenges were still among the most influential factors when making decisions about selecting traits. Breeding programs with larger sizes were less concerned with the technical challenges (such as identifying new sources of genes, documentation of existing germplasms, and evaluating new sources of germplasms) and societal challenges (for example, finding niche market potential); however, resource-related challenges were considered more important. Moreover, breeders with more experience found technical challenges (such

Table 7. Tobit model estimation results for challenges breeders encountered when implementing priorities when selecting a trait for inclusion in a turfgrass breeding system based on a survey distributed to a national sample of turfgrass breeders and distributors (n = 11).²

	Costs	Budgeting of past royalties	Being the first/lack of technological ability to do something (e.g., not having the technology to perform genetic marker research)	Resource availability	Resource allocation across different projects	Collecting germplasm resources	Poor documentation of existing germplasm	Evaluating new sources of germplasm	Consistency of the trait in the species	Coordination/timing in terms of training seasonal/part-time staff	Grower support
Program size	0.16 (0.70)	0.23 (0.61)	0.065 (0.28)	0.36 (1.56)	0.11 (0.43)	0.028 (0.14)	-0.51** (2.98)	-0.36** (3.27)	-0.031 (0.10)	0.12 (0.59)	0.10 (0.25)
Work years	-0.039 (0.42)	0.072 (0.52)	0.030 (0.34)	-0.13 (1.54)	0.12 (1.24)	0.19* (2.32)	0.10 (1.69)	0.18*** (3.94)	0.38** (2.70)	0.21** (2.65)	0.12 (1.00)
Education	1.38 (1.71)	1.56 (1.30)	0.57 (0.74)	1.10 (1.53)	-0.12 (0.13)	1.46* (2.01)	-0.013 (0.02)	0.34 (0.84)	2.72 (1.73)	0.60 (0.84)	0.58 (0.35)
Male ³	4.37* (2.09)	4.47 (1.45)	-0.56 (0.27)	3.36 (1.79)	2.66 (1.17)	0.57 (0.31)	-1.50 (1.07)	0.24 (0.23)	3.27 (1.30)	5.23** (2.98)	2.89 (1.02)
Intercept	-0.89 (0.16)	-9.36 (1.18)	3.09 (0.61)	-0.64 (0.14)	3.13 (0.51)	-6.22 (1.30)	6.44 (1.41)	1.71 (0.63)	-16.5 (1.45)	-6.83 (1.42)	-3.03 (0.27)

²Dependent variables for Tobit models in this table are the challenges breeders encountered when implementing priorities in a breeding program as listed in each column, ranging from 0 to 10. The base group for these Tobit regressions comprised females. Absolute t statistics are in parentheses. ***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level.

³Male was a dummy variable that equaled 1 if the respondent was a male (0 if a female).

as collecting germplasm resources, evaluating new sources of germplasms, and consistency of the traits in the species) and societal challenges (such as coordination of staff training) to be more important factors and resource availabilities to be less challenging. These results are in line with those of Yue et al. (2012), because some technical and societal challenges may be considered especially important for breeding programs with certain characteristics and resource availability. We suggest that these societal challenges could be addressed by strengthening the coordination and work of similar breeding programs and evaluating supply chain stakeholder perceptions of successful cultivars.

In conclusion, this study provided insight for the turfgrass industry by investigating the technical and socioeconomic challenges encountered by breeders and distributors when prioritizing traits. The findings suggested that market-driven programs were actually in need of both turfgrass breeders and distributors. With the information from this study, breeders, distributors, funding agencies, and policymakers can gain a better understanding of how market-based evaluations can benefit breeding programs and how breeding systems are constrained by technical and societal challenges. Future studies are needed to examine the reasons for the differences across programs and to explore effective ways of overcoming different challenges encountered by breeders.

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