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Extension event attendance increases adoption of weed management practices by sports field managers

Research Article

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Abstract

Data from a national survey of 348 U.S. sports field managers were used to examine the effects of participation in Cooperative Extension events on the adoption of turfgrass weed management practices. Of the respondents, 94% had attended at least one event in the previous 3 yr. Of this 94%, 97% reported adopting at least one practice as a result of knowledge gained at an Extension turfgrass event. Half of the respondents had adopted four or more practices; a third adopted five or more practices. Nonchemical, cultural practices were the most-adopted practices (65% of respondents). Multiple regression analysis was used to examine factors explaining practice adoption and Extension event attendance. Compared to attending one event, attending three events increased total adoption by an average of one practice. Attending four or more events increased total adoption by two practices. Attending four or more events (compared to one event) increased the odds of adopting six individual practices by 3- to 6-fold, depending on the practice. This suggests that practice adoption could be enhanced by encouraging repeat attendance among past Extension event attendees. Manager experience was a statistically significant predictor of the number of Extension events attended but a poor direct predictor of practice adoption. Experience does not appear to increase adoption directly, but indirectly, via its impact on Extension event attendance. In addition to questions about weed management generally, the survey asked questions specifically about annual bluegrass management. Respondents were asked to rank seven sources of information for their helpfulness in managing annual bluegrass. There was no single dominant information source, but Extension was ranked more than any other source as the most helpful (by 22% of the respondents) and was ranked among the top three by 53%, closely behind field representative/local distributor sources at 54%.

Introduction

Sports field areas (including athletic fields, school grounds, parks, and recreational areas) provide several environmental, economic, psychological, and social benefits. Examples include moderating temperature to counter urban heat island effects, improving groundwater recharge and reducing soil erosion through reduced surface water runoff, contributing to child cognitive and creative skills, and providing safe playing surfaces for sports and exercise (Brosnan et al. 2020a). Weeds, however, can reduce the aesthetic quality of turfgrass and reduce the safety of playing surfaces (Bartholomew et al. 2015; Brosnan et al. 2014), including creating uneven surfaces that contribute to tripping and jarring injuries (Otago et al. 2007; Sorate 2015).

Integrated weed management strategies in sports fields are often limited by specific use factors and regulations regarding human health. Because turfgrasses are generally perennial, some options used for weed control in annual agronomic crops, such as tillage (Carroll et al. 2021; Munshaw et al. 2017) or planting cover crops (Elford et al. 2008; Larsen et al. 2004), are poor options. Concerns over human exposure to agricultural chemicals, especially among children on school grounds, have led to additional regulation of herbicides in sports fields (Bartholomew et al. 2015; Hurley et al. 2014; Kowalewski et al. 2016). Herbicide use has also been complicated by the rapid spread of herbicide-resistant weeds (including those that exhibit cross- and multiple resistance) in turfgrass systems across multiple states (Brosnan et al. 2020b, 2020c, McCurdy et al. 2023). The use of diverse chemical and nonchemical tactics is seen as a crucial strategy to delay resistance (Brosnan et al. 2020b, 2020c).

Resistance to multiple herbicides in annual bluegrass (*Poa annua* L.) in turfgrass systems has become an area of specific concern and investigation (Allen et al. 2022; Brosnan et al. 2020b, 2020c; Carroll et al. 2021). In an earlier survey, conducted by the Weed Science Society of America, respondents ranked annual bluegrass as the most troublesome turfgrass weed and the third most common turfgrass weed in the United States and Canada (Van Wychen 2020).

Cooperative Extension has been seen as an important vehicle for transferring knowledge on herbicide resistance and sustainable weed management generally (Coble and Schroeder 2016; Ervin and Frisvold 2016; Shaw et al. 2018) and in turfgrass systems in particular (Allen et al. 2022; Klein and Green 2002). One study of school grounds employees found that they wanted information on weed management and herbicide use more than any other training topic (Kowalewski et al. 2016). Ervin et al. (2019) found that farmers who relied more on Extension for weed management advice were more likely to be concerned about herbicide resistance and more willing to speak with neighboring farmers about it. Extension workshop attendance has been found to contribute to greater adoption of urban water conservation practices (Borisova and Useche 2013) and environmental landscape management practices (Knox and Israel 1996).

This study used data from a national survey (developed and implemented by this research team) to determine the influence of Extension event attendance on adoption of weed management practices on turfgrass sports fields. It also determined sports field manager reliance on Extension for information specifically for management of annual bluegrass.

Materials and Methods

The research team implemented a national survey of U.S. turfgrass managers about weed management challenges and practices. This was carried out in August through September of 2020. Along with questions about weed management in sports fields in general, the survey included some questions specifically about management of annual bluegrass. Previous studies surveying turfgrass managers have often been state- or region-specific, rather than national (e.g., Barnes et al. 2018; Klein and Green 2002; Wallace et al. 2016).

The present survey was designed and implemented as part of a large multi-state research and education project supported by the USDA-NIFA Specialty Crops Research Initiative conducted by a team of 16 university faculty in 14 states (resistpoa.org/). The survey data included responses from sports field managers in 37 continental U.S. states that represent 95% of the population and 79% of the land area of the continental United States (Figure 1). The 14 states with project researchers accounted for 73% of respondents. Of these, most came from Arizona (9% of total), Florida (10%), North Carolina (10%), and Texas (11%). Among states without project researchers, 7% of respondents were from New York, 5% were from California, and 15% were distributed across the remaining 21 states.

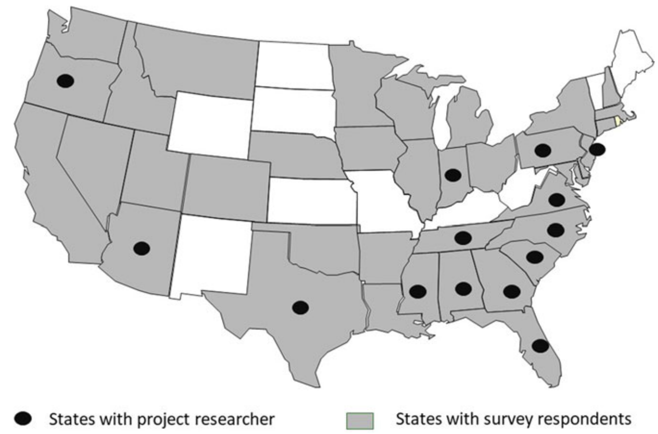

Figure 1. States with survey responses and project researchers.

The current study focused on managers of sports fields (comprising athletic fields, school fields, urban parks, and other recreational areas). The Internet survey instrument was developed in collaboration with Great Lakes Marketing Research (glm.com), who administered the survey. Respondents were recruited from state, regional, and national organizations that serve sports and recreational turfgrass professionals (e.g., Sports Field Management Association (and its affiliated chapters), university turfgrass management blogs, and listservs). These organizations announced the survey to their members and invited those who self-identified as sports field managers to complete the online survey. Responses were also requested from Cooperative Extension turfgrass manager contact lists.

The survey asked sports field managers to rank their top three information sources in terms of how helpful they were for managing annual bluegrass, specifically. Respondents were provided with seven choices:

- Professional consultants/turf advisors
- Field representative for local distributor
- Extension agents or university specialists
- Sports turf company representatives
- STMA––Sports Turf Managers Association (national or local chapter)
- Other sports turfgrass managers
- Family member

They could rank information sources first, second, and third in terms of helpfulness for annual bluegrass management, while leaving other sources unranked.

The survey also asked about the role of Extension in weed management practice adoption generally, and not solely for annual bluegrass management. In the survey, respondents were asked, "In the past 3 years, how many University research or Extension turfgrass or integrated pest management workshops, seminars, field days, webinars, etc. have you attended?" Throughout, we will refer to these as "Extension events." The survey was administered in August through September of 2020; thus, "the past 3 yr" from August through September 2017 to August through September 2020. There were five response options: none, one, two, three, and four or more events attended. The sample consisted of 348 respondents, with 325 of these attending one or more Extension event. Respondents who attended one event or more were then asked to indicate if they had "adopted any of the following turfgrass management or integrated pest management practices as a result of attending and learning about topics at University research or Extension turfgrass or integrated pest management workshops, seminars, meetings, webinars, or other events." The respondents could choose any number of the following nine options (respondents could select more than one option):

1) Used a new herbicide
2) Rotated herbicide from what was previously used
3) Implemented a weed control program with varying herbicide modes of action (MOA)
4) Improved cultural practices (mowing, cultivation, fertilization, irrigation, hand weeding, overseeding, resodding/replanting)
5) Changed turfgrass cultivar or species
6) Changed plant growth regulators
7) Improved soil physical/chemical properties
8) Scouted and mapped plants that escaped control
9) Used site-specific weed management/precision turf management

They also had the option of writing in an additional "other" practice.

Different regression equations were estimated to examine which manager and facility attributes were associated with (a) adopting a greater total number of management practices as a result of Extension attendance in the past 3 yr as well as, (b) a greater probability of adopting individual management practices as a result of attending Extension turfgrass events.

There is an extensive literature providing reviews and meta-analyses of factors influencing practice adoption for agronomic crops and livestock production (Baumgart-Getz et al. 2012; Liu et al. 2018; Lu et al. 2022; Prokopy et al. 2008), but the literature is sparse for adoption in turfgrass systems. Explanatory variables used in regression analysis were categorical variables for factors hypothesized to affect practice adoption (Table 1). These included:

- Type of facility managed. This variable tests the hypothesis that management practices may differ across facilities managed. For example, some have noted greater regulation of weed control practices on school grounds than in other settings or environments (Bartholomew et al. 2015; Hurley et al. 2014; Kowalewski et al. 2016).
- Number of employees. Studies of agronomic crops have often found positive associations between (larger) scale of operation and practice adoption, although this is not a universal finding (Liu et al. 2018; Lu et al. 2022; Prokopy et al. 2008).
- Turfgrass acres (hectares) managed. Acres (hectares) managed, along with number of employees, captures scale effects.
- Number of Extension events attended. Extension workshop attendance has been found to contribute to greater adoption of urban water conservation practices (Borisova and Useche 2013) and environmental landscape management practices (Knox and Israel 1996).
- Respondent age. Lu et al. (2022) hypothesized that greater age would have a negative effect on adoption, but their meta-analysis found support for this hypothesis in only 53% of

Table 1. Descriptive statistics for variables used in multiple regression analyses of adoption of turfgrass weed management practices.

	Percentage of observations used in adoption regression analysis (*n* =325)	Percentage of observations Full sample (*n* = 348)
Type of facility managed by respondent	%	%
Parks & recreation	29.5	29.6
Elementary/middle school	3.4	3.4
High school	15.7	16.1
College/university	24.9	25.3
Professional facility	22.2	21.3
Other	4.3	4.3
Number of employees at facility		
≤4	23.1	23.9
5–9	20.9	21.3
10–19	17.2	16.7
20–49	15.7	15.2
50–99	9.5	9.5
100–249	6.8	6.6
≥250	6.8	6.9
Number of turfgrass acres (hectares in parentheses) managed at facility		
<3 (<1.2)	6.2	6.0
3–4 (1.2 – 1.6)	6.8	7.2
5–10 (1.7 – 4.0)	19.4	20.1
11–14 (4.1 – 5.7)	12.6	12.6
15–50 (5.8 – 20.2)	31.1	31.0
> 50 (>20.2)	24.0	23.0
Extension turfgrass events attended by respondent in the past 3 yr		
Unanswered	0.0	0.3
None	0.0	6.0
1	12.9	12.1
2	21.5	20.4
3	23.4	21.8
≥4	42.2	39.4
Respondent age in years		
≤29	5.2	4.6
30–39	25.2	24.7
40–49	36.6	37.4
50–59	22.8	23.6
≥60	10.2	9.8
Respondent experience (years working in industry)		
<6	8.0	8.0
6–10	19.7	20.1
11–15	19.4	18.4
16–20	17.8	17.8
≥21	35.1	35.6
Respondent education level		
High school graduate or less	7.4	7.2
Vocation/Extension certificate	7.7	7.2
2-yr college degree	11.7	12.1
Some college	10.2	9.5
4-yr college degree	38.5	39.4
Some graduate school	3.7	3.4
Graduate degree	20.9	21.3
Respondent female		
Yes	5.2	5.0
Unanswered	0.0	0.6

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studies. Baumgart-Getz et al. (2012) found an overall negative effect of age.

- Years of experience working in the industry. Lu et al. (2022) hypothesized that more years of experience would have a negative effect on adoption but found support for this in only 42% of studies. Baumgart-Getz et al. (2012) found an overall negative effect of years of experience.
- Education. In their meta-analysis of studies of practice adoption, Baumgart-Getz et al. (2012) found "education is discussed in almost every study included in this analysis as a positive measure of individual capacity." Baumgart-Getz make a distinction between formal education (years of schooling) and Extension training. They found that whereas formal education did not have a significant impact on adoption, Extension training did have a positive impact on adoption.
- Gender. Gender has not been considered in formal meta-analyses, but reviews find mixed results with some studies finding females either more or less likely to adopt (Liu et al. 2018).

Two regression specifications were used for total practices adopted: a standard ordinary least squares (OLS) model and a Poisson regression model. Our dependent variable is an example of count data: All observations were positive integers (specifically 0, 1, 2 . . . 8). Applying OLS to count data can introduce biases in estimation (Cameron and Trivedi 2013), especially if the distribution of the data were skewed to higher or lower integers (e.g., skewed toward zero). Our data (among attendees) were not especially skewed, however, with the mode at a center value. Hence, the assumption of normality under OLS may be an acceptable approximation. Further, OLS results are easier to interpret than those of Poisson regressions. For example, coefficients of the Poisson regression affect the marginal probabilities of jumping from one integer to the next, whereas the OLS coefficients measure the direct change in number of practices adopted.

Table 1 reports respondent characteristic proportions for both the full sample ($n = 348$) and for observations used in the adoption regression equations ($n = 325$). The practice adoption question asked about adoption "as a result of Extension" attendance. Only those who attended events answered the adoption questions. Note, the proportions for characteristics (aside from Extension event attendance) were virtually identical for just the attendees and for the full sample (Table 1).

Separate logistic regression equations were run to examine the influence of manager and facility attributes on adoption of individual management practices. The dependent variables in the regressions equaled 1 if the practice was adopted and 0 otherwise. The individual management practice adoption regressions included the same explanatory variables as the total practice adoption equations.

The adjusted count R^2 (ACR^2) was reported for each logistic regression for practice adoption, using Equation 1:

$$ACR^2 = \frac{(\text{Total correct predictions from regression model} - \text{Count of most common response})}{(\text{Total number of observations} - \text{Count of most common response})} \quad [1]$$

Output from the logistic regression predicted adoption or nonadoption for each observation. The ACR^2 compares the logistic regression predictions to a "naive" model where one predicts that all responses were the same as the most common response. For example, suppose 80% of observations were "yes," for adoption. If someone naively predicted that all observations were yes, they would be correct 80% of the time. The ACR^2 measures the percentage reduction in prediction error from using the regression model relative to this naive model. If the regression predictions were no better than the naive model, then $ACR^2 = 0$. If the regression predicts perfectly, then $ACR^2 = 1$.

Odds ratios (ORs) and their significance levels were reported for variables in the logistic regressions. In the context of this study, the OR measures how a respondent being in a particular category (e.g., age category, education category) changes their odds of practice adoption relative to a reference category. The odds are the probability of adoption divided by the probability of nonadoption (UCLA 2023). An OR = 1 means that being in that category has no effect on the odds of adoption relative to the reference category. An OR = 2, for example, means that being in the category doubles the odds of adoption, whereas an OR = 0.5 means that being in the category halves the odds of adoption. Likelihood-ratio tests of the joint significance of *groups* of categorical variables were also conducted. The null hypotheses were that coefficients for all variables in a particular group equal zero (e.g., coefficients for all types of facility variables equal zero, all age variables equal zero, all education variables equal zero, etc.).

Ordered logistic regression analysis was also carried out to examine how manager and facility attributes influenced Extension turfgrass event attendance. The dependent variable, number of events attended, has reported values of 0 to 3 and ≥4. As all responses were not strictly numerical, but ordinal (i.e., "4 and above" is not strictly a number), ordered regression was used (Jussaume Jr et al. 2022; Llewellyn, et al. 2009). This regression included both respondents that attended and did not attend Extension events. Three observations had missing data on respondent attributes and were dropped from the regression, leaving a sample size of 345. All regressions in this study were run using STATA version 17 (StataCorp LLC, College Station, TX, USA).

Results and Discussion

Information Sources for Annual Bluegrass Management

Extension was ranked as the most helpful source of information most frequently (by 22% of the respondents) (Figure 2). Yet, this was closely followed by other turfgrass managers (19%), professional consultants/turf advisors (18%), and field representatives for local agricultural chemical distributors (16%). Extension was ranked in the top three most helpful information sources by 53% of the respondents, just behind field representative/local distributor source, at 54%. This also means that Extension was *not* ranked among the top three sources by 47% of respondents, illustrating that sports field managers' views of helpful information sources for annual bluegrass were highly varied. Studies have found that urban populations traditionally have low awareness of Extension (Fox et al. 2017; Henning et al. 2014; Raison 2014).

Adoption of Weed Management Practices Resulting from Extension Attendance

One respondent did not answer the question about Extension attendance. Whereas 6% of the respondents attended no Extension events in the previous 3 yr, 12% attended one, 20% attended two, 22% attended three, and 39% attended four or more events (Table 1). Respondents were asked if they adopted specific

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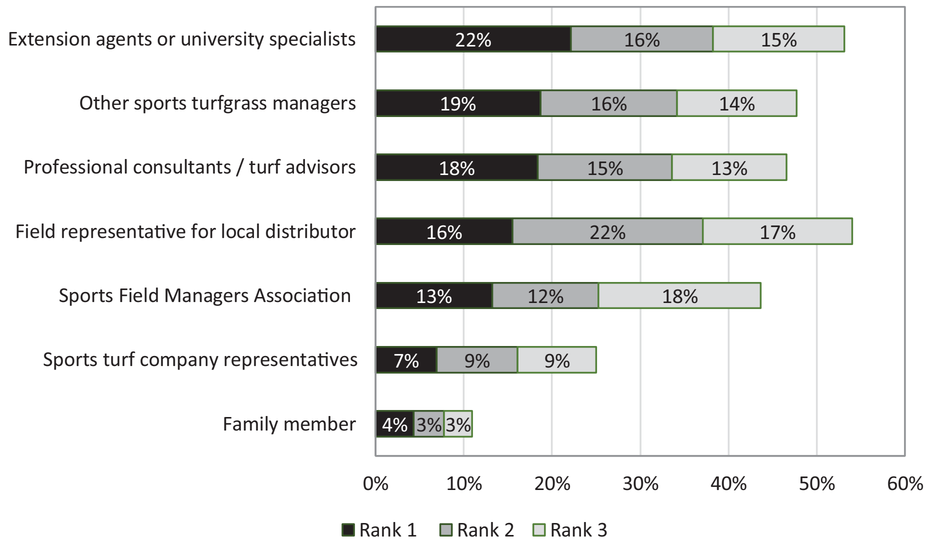

Figure 2. Top three sources of information for their helpfulness in managing annual bluegrass based upon survey of turfgrass sports field professional managers.

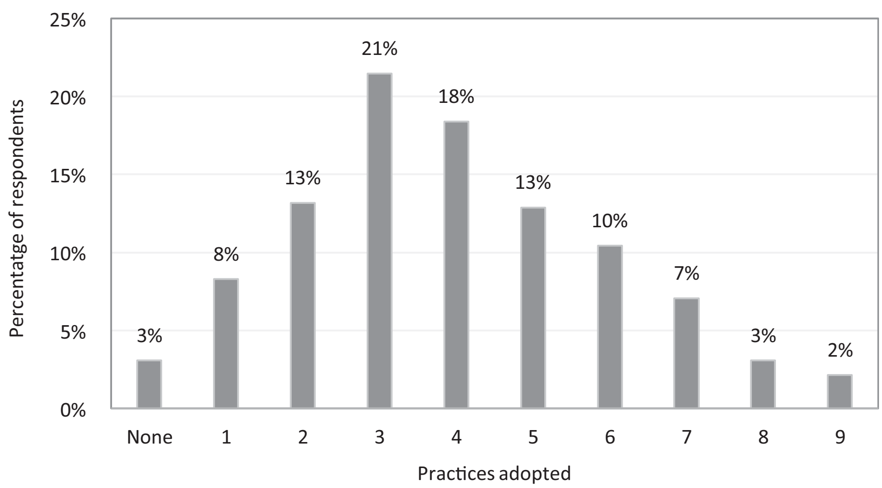

Figure 3. Total number of practices adopted as a result of attending Extension turfgrass events in the previous 3 yr.

turfgrass management practices "as a result of attending and learning about topics at" Extension events. Respondents who did not attend Extension events did not answer questions about adoption "as a result of" attendance. Although responses ranged between zero and nine different practices, 52% of respondents adopted between two and four practices (Figure 3). The mode response was adopting three practices (21% of those answering). Of those attending an Extension turfgrass event in the previous 3 yr, 97% adopted one or more practice, 89% adopted two or more practices, and 76% adopted three or more. More than half of the attendees adopted four or more practices, and more than a third adopted five or more.

The most adopted management practice was some form of improved cultural practice (i.e., mowing, cultivation, fertilization, irrigation, hand weeding, overseeding, resodding/replanting), with 65% of respondents adopting a cultural practice (Figure 4). This was followed by using a new herbicide (53%), adopting practices to improve soil physical/chemical properties (50%), varying herbicide MOA (i.e., using diverse MOAs within the year) (50%), rotating herbicide MOAs across years (49%), and site-specific or precision techniques (44%). Less frequently adopted practices included changing cultivars, changing plant growth regulators, and scouting and mapping plants that escaped control (27% or less).

Production inputs can be sold as products, allowing private firms to capture gains from technology transfer. Historically, a role of Extension has been to provide public goods–type information that the private sector may undersupply (Anderson and Feder 2007; Birkhaeuser et al. 1991). The relatively higher rate of adoption of improved cultural practices could result from an Extension emphasis on such practices. Use of cultural practices may also be due to lack of new active ingredients and MOAs (Allen et al. 2022; Elmore et al. 2023; Hahn et al. 2020; McDougall 2016).

Respondents attending one Extension turfgrass event in the previous 3 yr adopted 2.9 management practices as a result of attendance (Figure 5). Average adoption increased with attendance: 3.1 practices for those attending two, 4.1 practices for three events, and 4.6 practices for four or more events.

Factors Affecting Practice Adoption

Table 2 reports regression results determining factors affecting the total number of practices adopted as a result of attending Extension

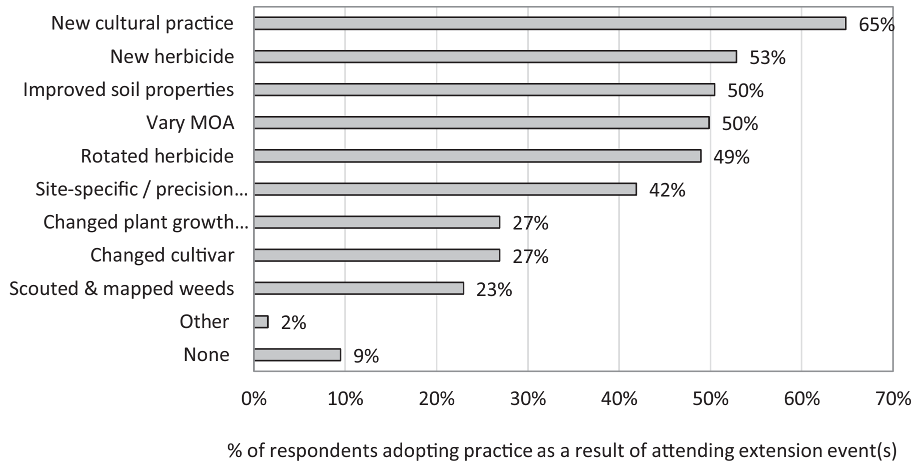

Figure 4. Specific practices adopted as a result of attending Extension turfgrass event. MOA, mode of action.

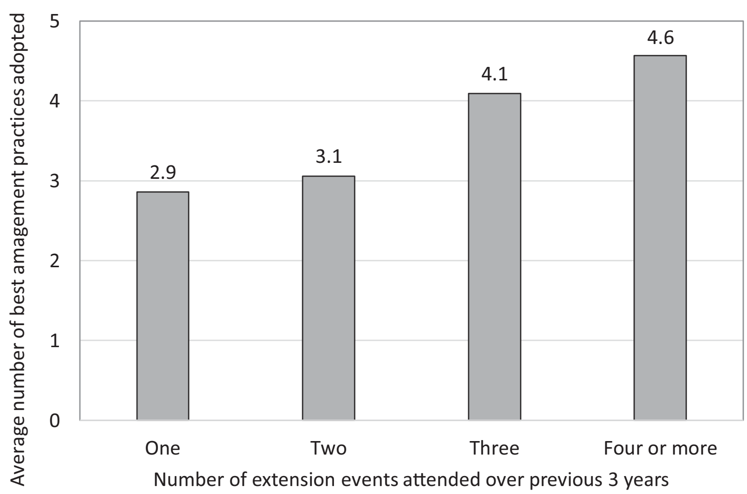

Figure 5. Average number of management practices adopted for each level of Extension event attendance.

turfgrass events over the previous 3 yr. Only variables that were statistically significant ($\alpha \leq 0.10$) in the regression results are reported (Table 2). Relatively few variables capturing respondent personal or facility characteristics were significant. People operating facilities of more than 50 acres (20.2 hectares) adopted roughly one additional practice (OLS coefficient of 0.938) than others managing fewer hectares. Similarly, companies with 50 to 99 and 100 to 249 employees adopt almost one more practice than others (OLS coefficients of 0.863 and 0.972, respectively). Compared to the respondents with low education levels (i.e., high school or less), those with vocational/Extension certificate or graduate degrees adopted approximately one more practice. Other education levels (relative to the lowest) have positive, but statistically insignificant, effects.

The most significant predictor of practice adoption was Extension event attendance over the previous 3 yr. Coefficients for attending three times and four or more times were highly significant. The OLS results can be interpreted as follows. The omitted, default variable is attending one event. The coefficient for attending twice was not statistically different from zero, implying no incremental effect of moving from attending one to two events. The coefficient for three events was 1.34, suggesting that moving from attending one to three events would increase the total number of practices adopted by slightly more than one on average. The coefficient for four or more events was 1.95, suggesting that moving from attending one to four events would increase the total number of practices adopted by roughly two practices.

The influence of Extension event attendance over the previous 3 yr and manager characteristics on the adoption of individual practices was considered via logistic regressions for each individual practice option from the survey (Table 3). Regressions included all the variables used in the total practice adoption equations (Table 1). However, we only reported variables where the odds ratio was significantly different from one at $\alpha \leq 0.10$. The adjusted count R^2 (ACR^2) measures reduction in prediction error. For new herbicide use, $ACR^2 = 0.238$, meaning that the regression reduced prediction error (relative to the naive model) by 23.8%. For rotated herbicide, it reduced prediction error by 35%.

Based on odds ratios, attendance at four or more Extension turfgrass events increased the odds of adopting six different practices. For six practices, attendance at four or more events in the past 3 yr (compared to the reference case of one time) increased the

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Table 2. Multiple regression of total turfgrass management practices adopted as a result of attending Extension turfgrass events. Regression coefficients and statistics are only reported for variables that are statistically significant at the ≤10% significance level.[a]

Dependent variable: total management practices adopted as a result of attending Extension turfgrass events in the past 3 yr	Poisson regression			Ordinary least squares		
	Cragg & Uhler's $R^2 = 0.209$			Adjusted $R^2 = 0.119$		
No. of observations: 325	Coefficient	Standard error	P value	Coefficient	Standard error	P value
Number of employees						
50–99	0.219	0.125	0.079	0.863	0.481	0.074
100–249	0.225	0.138	0.104	0.972	0.547	0.077
Number of turfgrass acres (hectares) managed						
>50 (>20.2)	0.240	0.144	0.096	0.933	0.526	0.077
Number of Extension turfgrass events attended						
3	0.373	0.115	0.001	1.327	0.403	0.001
≥4	0.529	0.110	0.000	1.944	0.381	0.000
Education level						
Vocation/Extension certificate	0.282	0.154	0.068	1.086	0.579	0.062
Graduate degree	0.331	0.144	0.021	1.155	0.511	0.024

[a]Default categories for categorical variables are working at an "other" facility type, with fewer than five employees, fewer than 3 acres (1.2 hectares), attending only one Extension turfgrass event in the previous 3 yr, aged ≤29 yr, with ≤5 yr experience, with a high school education or less, and male.

odds of adoption 2.9 to 6 times (see odds ratios, Table 3), depending on practice. Attendance at three events increased the likelihood of adopting three practices (relative to attending once) 2.9 to 6.1 times (Table 3), depending on practice. Increasing attendance from one to two events (not shown) did not have a statistically significant effect on practice adoption.

There is some evidence for scale effects in adoption of some practices. Those operating larger acreages were associated with greater odds of rotating herbicides across years and with using herbicides with different MOAs, whereas those with more employees were associated with greater odds of changing cultivars and greater odds of using of plant growth regulators. There was not a clear pattern between education and adoption across practices. More years of work experience were associated with greater use of new herbicides. This may be because more new herbicides become available (or resistance to older herbicides develops) over greater spans of time. The time taken to register new products has risen above 11 yr in recent years (McDougall. 2016).

For the OLS and Poisson regressions of total practices adopted, only the Extension variables were jointly significant (Table 4). Extension variables were also jointly significant for six of eight individual practices. Coefficients for the type of facility were jointly significant for four practices (changed cultivars, changed plant growth regulators, changed practices to improve soil properties, and implemented site-specific/precision techniques). Age and experience coefficients were not jointly significant in any regression. To address possible collinearity between age and experience (as both tend to increase together), regressions were also run with age, but not experience variables, and vice versa. Results did not qualitatively change, however. The number of employees at a facility significantly affected the odds of changing cultivars or use of plant growth regulators. Education was a significant predictor for rotating herbicides and weed scouting/mapping. Hectares managed was a significant predictor for varying herbicide MOA.

Factors Affecting Extension Event Attendance

The responsiveness of practice adoption to Extension event attendance over the previous 3 yr begs the question, "what factors explain more frequent attendance?" Table 5 reports the results of the ordered logistic regression analysis. The dependent variable, the number of Extension turfgrass events attended in the past 3 yr, has reported values of 0, 2, 3, and ≥4. Most variables did not significantly influence the number of Extension events attended. However, those working at high schools and sports facilities were less likely to attend Extension events, whereas those with more years of experience (>5 yr) had an increased odds of attending more events.

Extension was ranked as the most helpful source of information for annual bluegrass management by only 22% of the respondents. However, this 22% was greater than for any other information source. Extension was ranked in the top three most helpful information sources by half of respondents, but not in the top three by half of respondents. Thus, Extension is an important, but not dominant, source of information for annual bluegrass management among sports field managers. Many respondents were not relying on Extension directly as an information source, yet they were not relying much on any other single alternative source either. Asmus and Schroeder (2016) discuss similar results regarding Extension and weed management for agronomic crops, whereas Frisvold and Deva (2012) report similar results for Extension and irrigation management. The survey results suggest there is no "one-stop shopping" for annual bluegrass management information.

One reason Extension was not a dominant source of information for annual bluegrass management may be that not all states have a turfgrass Extension specialist. In a survey with 31 responding U.S. states, 26 reported having a turfgrass Extension specialist (Patton et al. 2013). Of those 26 states, only 14 had weed scientists with turfgrass Extension responsibilities. As such, the lack of Extension presence may diminish its impact. This lack of on-call expertise is one of several documented challenges to Extension delivery in urban settings (Collins and Gaolach 2018; Fox et al. 2017; Gaolach et al. 2017; Henning et al. 2014; Raison 2014).

Turfgrass managers were seeking out multiple and diverse sources of information to manage annual bluegrass. This raises two questions for future research and Extension programs. First, are these various sources providing consistent messages on herbicide resistance and other weed management topics? Earlier studies have emphasized the importance of consistent messaging for resistance management (Allen et al. 2022; Johnson et al. 2009; Shaw et al. 2018) and for urban turfgrass management (Allen et al. 2022; Borisova et al. 2011; Ervin et al. 2022). Second, how much are

Table 3. Logistic regressions for adoption of individual turfgrass management practices (all variables in Table 1 were included in each regression; only results for variables with P values < 0.1 are reported here).

Practice adopted (adjusted count R^2)	Odds ratio	P value	Odds ratio: 95% lower confidence level	Odds ratio: 95% upper confidence level
New herbicide (0.238)				
Attended ≥4 Extension turfgrass events	4.2	0.001	1.78	9.79
6–10 yr of experience	2.7	0.084	0.88	8.12
16–20 yr of experience	2.9	0.097	0.83	9.95
≥21 yr of experience	3.9	0.039	1.07	14.04
Rotated herbicide (0.35)				
Manages 15–50 acres (5.8 – 20.2 hectares)	3.0	0.065	0.94	9.56
Manages >50 acres (>20.2 hectares)	2.9	0.086	0.86	9.63
Attended 3 Extension turfgrass events	3.6	0.007	1.42	9.33
Attended ≥4 Extension turfgrass events	6.0	0.000	2.42	15.07
2-yr college degree	5.6	0.007	1.60	19.38
Graduate degree	3.7	0.032	1.12	12.41
Vary mode of action (MOA) (0.309)				
Manages 5–10 acres (1.7 – 4.0 hectares)	3.3	0.064	0.93	11.94
Manages 11–14 acres (4.1 – 5.7 hectares)	5.2	0.015	1.38	19.74
Manages 15–50 acres (5.8 – 20.2 hectares)	6.9	0.002	2.01	23.35
Manages >50 acres (>20.2 hectares)	6.4	0.004	1.79	22.63
Attended 3 Extension turfgrass events	2.9	0.023	1.16	7.30
Attended ≥4 Extension turfgrass events	5.2	0.000	2.15	12.70
Some graduate school	12.6	0.015	1.65	95.73
New cultural practice (0.165)				
>250 Employees	0.3	0.090	0.09	1.19
Attended ≥4 Extension turfgrass events	3.7	0.003	1.58	8.83
Changed cultivar (0.08)				
20–49 employees	4.5	0.003	1.65	12.52
50–99 employees	11.8	0.000	3.37	41.50
100–249 employees	5.6	0.013	1.43	21.68
<250 employees	6.5	0.010	1.55	27.59
Attended ≥4 extension turfgrass events	2.9	0.047	1.01	8.08
16–20 yr of experience	3.8	0.093	0.80	17.92
Changed plant growth regulator (0.125)				
Elementary/middle school	20.8	0.022	1.55	279.30
20–49 employees	6.3	0.001	2.19	18.01
50–99 employees	5.6	0.006	1.62	19.53
100–249 employees	6.4	0.007	1.65	25.16
≥250 employees	5.5	0.020	1.31	22.75
Improved soil properties (0.296)				
College/university	0.3	0.100	0.09	1.23
Attended 3 Extension turfgrass events	6.1	0.000	2.36	15.90
Attended ≥4 Extension turfgrass events	3.5	0.006	1.44	8.59
Vocational/Extension Certificate	3.4	0.067	0.92	12.91
Scouted/mapped weeds (0.053)				
100–249 employees	3.4	0.065	0.92	12.81
Graduate degree	3.6	0.088	0.82	16.09
Site-specific/precision techniques (0.146)				
Vocational/Extension certificate	3.9	0.06	0.97	15.48
2-yr college degree	3.5	0.05	1.02	12.28
Some college	5.4	0.01	1.50	19.58
4-yr college degree	2.9	0.06	0.97	8.97

professional consultants, turfgrass advisors, and other information sources relying on Extension to get *their* information? Extension may be acting as a "wholesaler" rather than a "retailer" or direct provider of information (Stock et al. 2020).

Among Extension event attendees, more frequent attendance over the previous 3 yr was significantly associated with adopting more weed management practices. Stock et al. (2020) found that practice adoption rates for school grounds managers were higher for those returning for additional Extension training than for those attending for the first time. This suggests that practice adoption could be enhanced by encouraging repeat attendance among past Extension event attendees. This might be attempted by maintaining lists of past attendees, then sending previous participants personalized follow-up invitations to new events. Personalized follow-up invitations could emphasize new topics or information to be covered, compared to previous events.

There was also some evidence of scale effects where managers working for larger operations (in terms of hectares or employees) were more likely to adopt certain practices. Elmore et al. (2023) note that employee turnover and finding skilled, knowledgeable labor are barriers to the adoption of integrated weed management practices. The turfgrass and landscape industry is known to have high employee turnover (Mathers et al. 2010; Patton and Reicher 2011), and it may be that larger organizations are able to invest in training through attendance at Extension events to reduce the impact of employee turnover (Elmore et al. 2023).

Practical Implications

Turfgrass managers seek out multiple, diverse sources of information to manage annual bluegrass. Extension is an important, but not dominant, information source for annual bluegrass management.

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Table 4. χ^2 tests of joint significance of grouped categorical variables in regressions of turfgrass practice adoption (e.g., null hypothesis is that regression coefficients for all education variables equal zero).[a]

	Type of facility	Number of employees	Hectares managed	Extension attendance in past 3 yr	Age	Experience	Education
Used a new herbicide				0.0002			
Rotated herbicides				0.0003			0.0316
Varied herbicide MOA[b]			0.0146	0.0001			
Used new cultural practice				0.0005			
Changed cultivar(s)	0.0726	0.0010		0.0442			
Changed plant growth regulators	0.0549	0.0098					
Improved soil properties	0.0238			0.0005			
Scouted/mapped plants							0.0162
Used site-specific or precision techniques							
Total practices adopted (OLS regression)				0.0000			
Total practices adopted (Poisson regression)				0.0000			

[a]Reported values are P values. Cells are blank for cases where the null hypothesis was not rejected (P > 0.10).
[b]Abbreviation: MOA, mode of action.

Table 5. Ordered logistic regression of the number of Extension turfgrass events attended in the past 3 yr. Regression coefficients and statistics are only reported for variables that are statistically significant at the 10% significance level or lower.

Dependent variable = No. of Extension turfgrass events attended (none, one, two, three, or four or more)

No. of observations: 345; pseudo R^2: 0.073

	Odds ratio	P value	Odds ratio: 95% lower confidence level	Odds ratio: 95% upper confidence level
Type of facility managed				
High school	0.3	0.043	0.074	0.957
Professional facility	0.3	0.072	0.084	1.111
Experience (years working in industry)				
6–10	2.8	0.012	1.254	6.311
11–15	5.1	0.000	2.173	12.130
16–20	4.7	0.001	1.852	11.845
≥21	4.6	0.002	1.778	11.714

This highlights the need for diverse information sources to provide consistent messages on important topics such as herbicide resistance management. The use of multiple, diverse weed management practices is frequently recommended to delay herbicide resistance. More frequent attendance of Extension turfgrass events over the previous 3 yr was associated with greater adoption of more weed management practices in general (not just for annual bluegrass management). This suggests that practice adoption could be enhanced by encouraging repeat attendance among past Extension event attendees. This might be attempted by maintaining lists of past attendees, then sending previous participants personalized follow-up invitations to new events. Personalized follow-up invitations could emphasize new topics or information to be covered, compared to previous events.

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