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Preferred information and delivery methods for weed management extension in Virginia

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Abstract

The goal of weed science extension efforts are to encourage and accelerate adoption of diverse, effective, and economical management tactics. To be most successful and efficient, extension personnel need to know how growers prefer to receive information, the format in which the information is delivered, and areas that future extension research should focus on. To this end, surveys were distributed at crop and forage extension meetings in Virginia. The results from 249 responses indicate that both crop and forage producers have similar preferences. Agribusiness personnel (e.g., co-ops, suppliers, vendors, crop consultants, sales representatives) had the greatest influence on herbicide-purchasing decisions and were the primary source of information for producers who make weed management decisions, and thus should be a target audience of extension. Respondents said that economic assessments, weed control data, and yield data are most likely to influence changes in their management practices and that they would prefer to receive that information through traditional extension formats (presentations, publications, and on-farm demonstrations). Generally, respondents also indicated that they wanted extension efforts to focus on evaluating new herbicides for weed control and crop safety in the future over alternative nonherbicidal weed control methods. Therefore, extension personnel are likely to be more successful by including herbicides in the practice of integrated weed management rather than relying solely on nonchemical approaches.

Introduction

The farm extension system in the United States was designed to disseminate research-based information and new technologies to the public, to facilitate their adoption, and thereby improve farming outcomes (Harvey 1954). Access to information and its quality are likely to have the largest impact on adoption of new practices or techniques (Baumgart-Getz et al. 2012). So, by tailoring the delivery format to a style the audience prefers, extension personnel could facilitate the adoption of new practices. However, the extension format is shifting from a top-down format in which personnel from land-grant universities share research with growers to one in which extension personnel become a middleman; that is, they pass information from researchers to growers and concomitantly pose questions to researchers from growers, and thereby influence new research ideas (Franz and Townson 2008; Harvey 1954; Knake 1987). Such two-way communication is expected to affect weed management decisions (Doohan et al. 2010).

Weed management practices are changing and will continue to change to address ongoing problems such as herbicide resistance and to promote the development and adoption of emerging technologies for weed management (Bajwa et al. 2015; Heap 2022; Kniss 2018; Mortensen et al. 2012; Westwood et al. 2018). Current recommendations among weed management experts are to adopt integrated weed management (IWM) plans (Norsworthy et al. 2012; Young et al. 2017). Although awareness and adoption of IWM is increasing on-farm (Young et al. 2017), previous research has found that a lack of information could be slowing the adoption of IWM. For example, many situations might be considered IWM, but some extension personnel believe that the standard can be too low (such as including rotations of herbicide modes of action) (Harker and O'Donovan 2013; Young et al. 2017). Such inconsistent messaging may limit IWM adoption; a grower may believe his or her current practices are sufficient and will not adopt additional practices. Looking ahead, researchers are calling for more integrated methods that focus on managing specific weeds with precision methods, thus moving beyond a traditional IWM system (Young et al. 2017). More advanced IWM programs rely on knowledge-intensive practices rather than a saleable product, making education an important component in effectively implementing these practices (Mortensen et al. 2012; Young et al. 2017).

Previous surveys of weed management practices have focused on technology or practice adoption (e.g., Bish and Bradley 2017; Givens et al. 2009; Prince et al. 2012); weed prevalence,

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including herbicide-resistant weeds (e.g., Kruger et al. 2009; Rankins et al. 2005; Scott and VanGessel 2007); and perspectives on these by growers and consultants (e.g., Godar and Stahlman 2015; Riar et al. 2013; Schwartz-Lazaro et al. 2018;). Literature also exists on grower demographics (i.e., education level, size of operation, what a grower produces, etc.) and their likeliness to adopt new or additional practices that often include recommendations for extension personnel (e.g., Baumgart-Getz et al. 2012; DeDecker et al. 2014; Dong et al. 2016; Frisvold et al. 2009; Hammond et al. 2006). But few surveys exist that directly ask growers what information sources and information preferences for weed management they find most influential.

To improve the diffusion of information that will promote adoption of new practices, change agents must know how to best reach their audience. To accomplish that, we surveyed audiences at Virginia extension meetings. The objectives of the surveys were to evaluate grower preferences in extension programming, determine whether differences existed in preferences between row crop producers/supporters and forage producers/supporters (supporters are people directly related to producers such as extension agents, advisors, or sales representatives), evaluate grower preferences in extension programming, and determine research topics that crop and forage producers/supporters would like Virginia Cooperative Extension to focus on. This aligns with Virginia Cooperative Extension's overall goal of maximizing weed management outcomes and programmatic efficiency. By better understanding who influences growers' decisions and what information will drive changes in their practices, we aim to increase the adoption of new weed management strategies and decrease the time between awareness and adoption.

Materials and Methods

Two surveys were created with one targeting row crop producers/supporters and the other targeting forage producers/supporters. The surveys were distributed at extension meetings and were available online between 2015 and 2017. Each survey was divided into three sections: 1) demographic information, 2) preferences in extension programming, and 3) future research. Both surveys contained the same questions pertaining to demographics and preferences in extension programming. The extension programming portion focused on source of information (i.e., from whom), research or educational topics (i.e., what information), and presentation format (i.e., how the information is delivered). Since the targeted survey audience differed for the crop and forage surveys, the questions for future research differed. All questions and answer choices are listed in figures or Appendix 1.

For both surveys, respondents were organized into farmer and "farmer advisor" occupations, which included sales representatives, crop advisors, and county extension agents. Data were analyzed using JMP Pro 16 software (SAS Institute, Inc., Cary, NC). Data were first analyzed to determine whether responses could be pooled across occupation (farmer and farmer advisors), and if so, data were analyzed again to determine whether they could be pooled across production system (crop and forage). If there was not a significant interaction ($P > 0.05$) between answer choice and survey audience (crop or forage), then responses were pooled. ANOVA was used to determine significant interactions using JMP software. Subsequently, means were separated by using Tukey's honestly significant difference test ($\alpha = 0.05$). Means and standard errors were obtained using JMP software and presented using Prism 9.0.0 software (GraphPad Software, San Diego, CA).

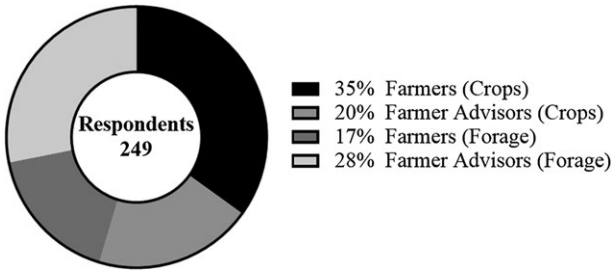

Figure 1. Demographic information indicating the agricultural profession of survey respondents. Respondents were divided into farmers and farmer advisors from both crop survey (136 respondents) and forage survey (113 respondents).

Some respondents reported being both a farmer and a farmer advisor. Those responses were not used in the analysis.

Results and Discussion

Survey Responses and Demographics

Overall, 136 individuals responded to the crop survey and 113 responded to the forage survey, for a total of 249 respondents. Some respondents left some survey questions unanswered because responses to every question were not mandatory. Therefore, the sample size varies by question, and in some cases, response within a question. Sample size is reported in each table and figure.

The occupation of survey respondents was 52% farmers and 48% farmer advisors (Figure 1). Of the 126 farmers who listed the number of acres they farmed the median size was 400 acres. Crop farmers reported farming a median size of 450 acres, whereas forage farmers farmed 250 acres. The median farm size in Virginia was 66 acres in 2017, so the respondents' farm sizes were generally larger than the reported median farm size (USDA-NASS 2017).

Although differences in responses existed (see below), they largely could be pooled across occupation but not across crop and forage surveys. Other research has reported similar preferences for communication type across various audiences (i.e., crop and forage producers) but differences between audiences based on time spent farming. Survey data from North Carolina found that beef producers and government workers had similar preferences for some extension delivery methods such as newsletters, personal visits, and method demonstrations. In the North Carolina survey, government officials preferred newspapers and workshops more than beef producers did, and compared to their county government counterparts, beef producers were more likely to attend field days (Clement et al. 1995). A similar survey conducted in Virginia noted differences in extension preferences between full-time and part-time beef cattle producers. Full-time producers preferred visits to experiment stations, phone calls, and bulletins, whereas part-time producers preferred on-farm demonstrations, workshops, and farm visits for receiving extension information (Obahayujie and Hillison 1988). Our survey did not include questions about the amount of time spent farming and the audience was not as diverse as it was in the Clement et al. (1995) survey because both groups in our survey were producers.

Source of Information

When asked about the primary source of weed management information, responses varied depending on the respondent

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Table 1. Survey responses to the question about who or what serves as the primary source of information for making weed management decisions.[a]

Response option	Crop farmers	Forage farmers	Crop farmer advisors	Forage farmer advisors
			%	
Co-op, supplier, or vendor	38	23	35	19
University extension or researcher	16	28	41	27
Crop consultant or advisor	19	2.4	14	16
Sales representative	16	7.3	8.1	22
Internet	6.9	7.3	2.7	9.9
Neighbor, friend, colleague, or family	5.2	15	0.0	2.7
Magazines or commercial publications	0.0	17	0.0	3.6
			n	
Total responses	58	82	37	111

[a]Survey respondents were asked "What is the primary source of weed management information for farmers? Choose only one."

Table 2. Survey responses to the question about who makes the largest impact when making herbicide-purchasing decisions.[a]

Response option	Crop farmers	Forage farmers
	%	
Co-op, supplier, or vendor	35	28
University extension or researcher	10	30
Crop consultant or advisor	12	4.5
Sales representative	16	7.5
Myself (no outside impacts)	16	4.5
Neighbor, friend, colleague, or family member	6.9	7.5
Other[b]	5.2	1.5
Magazines or commercial publications	0.0	12
Internet	0.0	4.5
	n	
Total responses	58	67

[a]Survey respondents were asked "Who or what has the largest impact when making herbicide purchasing decision? Choose only one."
[b]Other responses included cost, availability, and herbicides are not used on my operation.

group. Despite the variance, co-ops, suppliers, and vendors and university extension or researcher ranked high as main sources of information with an average of 29% and 28% of the total responses, respectively (Table 1). Sales representatives and crop consultants or advisors followed as a source of information with an average of 13% and 13% of the total responses, respectively. When combining persons affiliated with an agribusiness (co-op, supplier, or vendor + crop consultant or advisor + sales representative), farmers identified this group as having the largest impact of those surveyed. Thus, agribusiness personnel should be a target of extension. Extension personnel and peers ranked highly as a source of weed management information, although self-biases may exist in these data.

Both crop and forage surveys asked who or what has the greatest impact on a farmer when making herbicide-purchasing decisions. Based on an average across both surveys, 32% said that co-ops, suppliers, and vendors have the most influence, and 20% said that university extension and researchers have the largest impact on their decision (Table 2). After that, sales representatives and myself (no outside impact) follow with 12% and 10% of responses, respectively. Again, these data indicate that agribusiness personnel are an important audience for extension. That is, extension can expand its audience indirectly to farmers via agribusiness personnel.

Previous research has shown that often the most influential source of weed management information is the agricultural input network of chemical, seed, and equipment manufacturing companies, distributors, and retail outlets (Coble and Schroeder 2016; Givens et al. 2011; Johnson et al. 2009), which was also evident in our surveys. Arbuckle (2014) reported that 78% of farmers in Iowa relied on their agricultural chemical retailer for advice on weed management decisions. Contrary to this hierarchy, a survey distributed in Iowa, Illinois, Indiana, Mississippi, North Carolina, and Nebraska asking where growers receive their information on glyphosate resistance indicated that more than 50% of respondents in each state received information from farm publications. Less than 25% of respondents per state said they received information from dealers/retailers or university/extension personnel (Johnson et al. 2009).

While our findings are similar to those reported in previous surveys, responses for university extension or researchers as influences on weed management and herbicide-purchasing decisions are inflated compared to reports in other surveys. This could be because of the method of survey distribution. These surveys were distributed at extension meetings where university extension or researchers were giving presentations, which likely increased responses for this group.

Nonetheless, these findings echo calls to have more collaboration across groups of influencers to provide a clear and consistent message to farmers regarding herbicide resistance and weed management tactics (Asmus and Schroeder 2016; Barrett et al. 2016; Coble and Schroeder 2016; Hurley and Frisvold 2016). In a recent report of listening sessions with various agricultural stakeholders across regions of the United States, participants from the Midwest, Northeast, and Southeast said they wanted more education and collaborative communication for managing herbicide resistance (Schroeder et al. 2018).

Information Preferences

When asked to rank types of information that would directly influence a farmer to change their weed management strategies, responses could be pooled across farmer and farmer advisors for both crop and forage surveys, however, responses between the two surveys could not be pooled. Survey respondents from the crop survey ranked weed control efficacy data, economic assessment, and yield data as more likely to affect how their approach might change (Figure 2). Weed population shifts over time and on-farm demonstrations and at agricultural research and extension centers (ARECs) ranked as least likely to influence how they might change their weed management strategies. Respondents in the forage survey ranked economic assessment, weed control efficacy data, yield data, and weed population shifts over time as most likely things to affect a change in their herbicide practices (Figure 3). On-farm demonstrations and at ARECs followed in a lower statistical grouping.

Respondents were asked to rank their preferred extension delivery formats from worst (1) to best (10). Responses from farmers and farmer advisors could be pooled, and so could responses from both surveys. Traditional methods such as extension presentations, extension publications, and on-farm demonstrations or at ARECs ranked as the best places for receiving information (Figure 4). Websites were less favored as a way of obtaining information.

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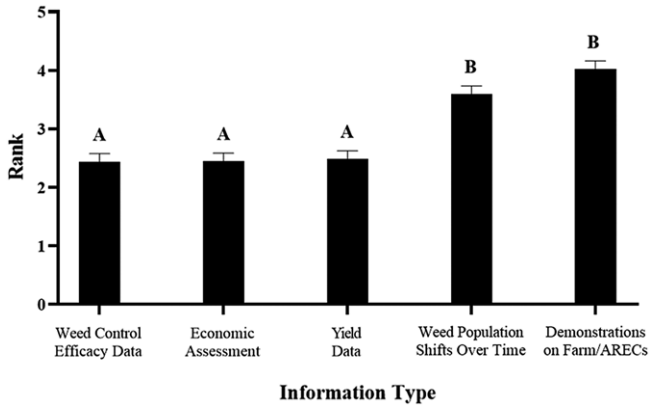

Figure 2. Information types ranked on a scale from 1 (most important) to 5 (least important) as to how likely these are to influence growers to change their weed management strategies, pooled across farmers and farmer advisors within the crop survey (n = 82). Abbreviation: ARECs, agricultural research and extension centers.

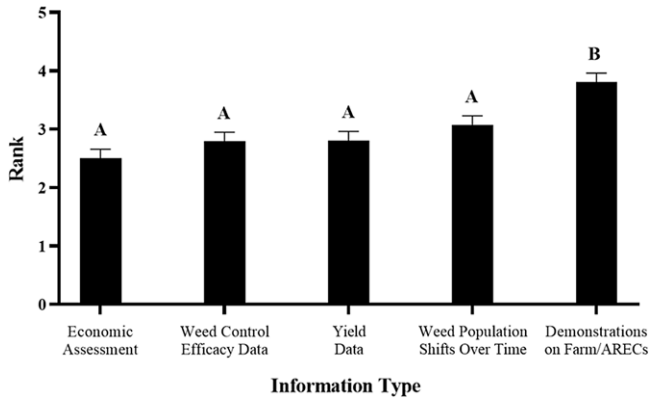

Figure 3. Information types ranked on a scale from 1 (most important) to 5 (least important) as to how likely these are to influence growers to change their weed management strategies, pooled across farmers and farmer advisors within the forage survey (n = 79). Abbreviation: ARECs, agricultural research and extension centers.

Nontraditional methods such as YouTube videos, social media, and blog posts were ranked as the worst way to obtain information. Although these ranked below traditional methods, there was still some interest in these formats. Much like previous advances in technology, these web-based methods provide new tools for presenting and distributing information and can take time to be accepted (Eberle and Shroyer 2000; Lineberger 1998). The nature of social media and blog posts could detract from sole reliance on these methods. These are meant for shorter communications and are more difficult to find as time passes. Instead, web communications could be used to support or draw attention to more favored traditional information formats.

There is an unexpected discrepancy in the responses to these two questions. Demonstrations on-farm and at ARECs were ranked as least likely ways to influence change in weed management strategy, but these same demonstrations were ranked as one of the most preferred methods of receiving information. It might be that while respondents like to see research results in person, those demonstrations should include hard numbers such as economic assessments, weed control data, and yield data to affect changes in weed management strategies.

Focus for Future Research

Questions between the crop and forage surveys varied because the surveys were tailored to an audience. Responses to the crop survey between farmers and farmer advisors could be pooled, but they could not be pooled for the forage survey. Crop producers said that Virginia Cooperative Extension personnel should focus on managing herbicide-resistant weeds, evaluating new herbicides, evaluating new genetic technologies, and effectively diversifying modes of action (Figure 5). Although many of the topics received statistically similar responses, crop producers indicated that they valued learning about new herbicides more than learning about alternative weed control techniques or using tillage/cultivation. Forge survey farmers ranked many options similarly were asked what they would like Virginia Cooperative Extension to focus on (Figure 6). Numerically, weed control recommendations were preferred over assessing weed escapes. When farmer advisors were asked to rank what they would like Virginia Cooperative Extension to focus on, they ranked evaluating new herbicides, weed control recommendations, weed identification, and the development of a pest management guide app as most important (Figure 7). Effectively diversifying herbicide modes of action, understanding weed toxicity/palatability to livestock, assessing weed escapes, and evaluating alternative weed control techniques received fewer responses and were therefore considered less important.

Although the questions in each survey were different, five choices in this section overlapped between the two groups. In general, both groups of survey respondents ranked evaluating new herbicides for weed control and crop safety as one of the most important topics for future research. Understanding how to effectively diversify herbicide modes of action, assessing weed escapes for herbicide resistance, and evaluating alternative weed control techniques were ranked lower. Forage farmer advisors indicated that having a pest management guide available via a smartphone or web app was important and ranked it higher than crop producers or forage farmers did.

Herbicide resistance is a problem in both crop and forage production systems. Currently there are 512 unique cases of herbicide resistance worldwide and that number will continue to grow (Heap 2022). Using IWM practices in combination with rotating or tank mixing herbicides with multiple effective modes of action has been shown to slow the development of herbicide resistance (Moss et al. 2019). Despite the data pointing to the need for research on nonchemical methods of weed control, crop and forage producers/supporters ranked evaluating alternative weed control techniques as least important areas for future research. This reveals that while farmers might understand the necessity of a proper IWM approach, they still prefer to use herbicides, likely due to the ease of application, and think that future research should focus on providing other herbicide options to help counteract herbicide resistance (Schroeder et al. 2018). Therefore, extension is likely to be more successful by including herbicides in IWM rather than relying solely on nonchemical approaches.

Practical Implications

Understanding what information, how it is best delivered, and from whom can help researchers and extension personnel best reach their audience. Our data indicate that the primary source of weed management information for survey respondents is agribusiness

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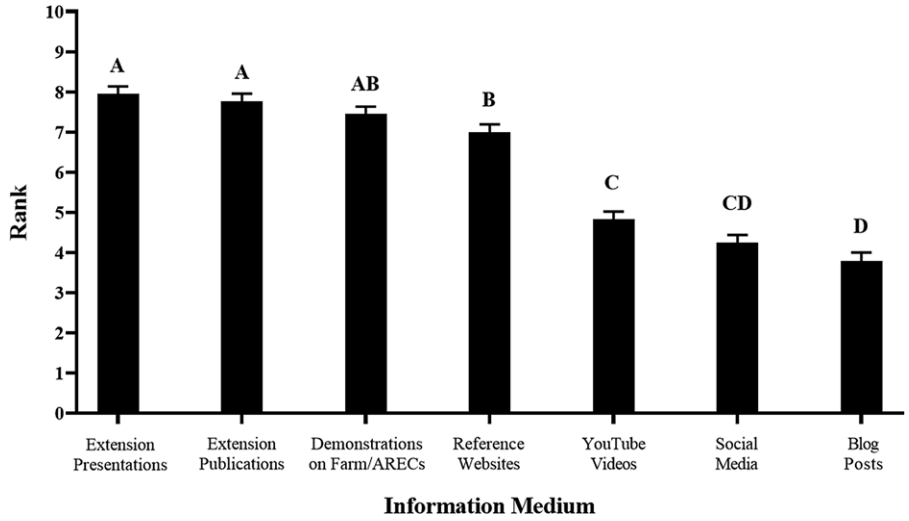

Figure 4. Information medium ranked on a scale of 1 (worst) to 10 (best) when asked what the best way is to present information, pooled across crop and forage surveys (n = 204). Abbreviation: ARECs, agricultural research and extension centers.

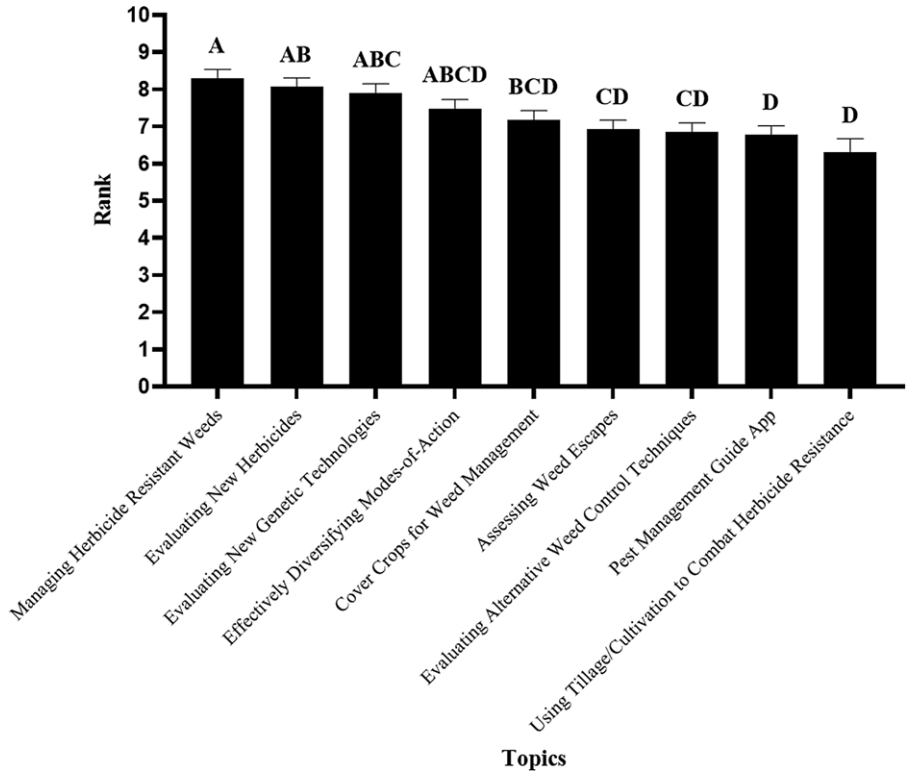

Figure 5. Topics ranked on a scale of 1 (least important) to 10 (most important) when crop producers/supporters were asked what research or educational topics Virginia Cooperative Extension efforts should focus on (n = 96). See Appendix 1 for full answer choices.

personnel followed by extension efforts. Respondents prefer to receive information through extension in the form of presentations, publications, or on-farm demonstrations and preferred to receive up-to-date information on herbicides and closely related topics over information on novel or antiquated weed management practices. Reaching farmers either directly or indirectly through agribusiness personnel with relevant information delivered appropriately can increase extension's impact and provide growers with a better understanding of various weed control methods. Feedback from growers is also essential and can lead to new areas of research and shed light on knowledge gaps that growers might have, thereby allowing researchers to focus on these areas for future extension meetings. With this two-way communication between growers and researchers, Virginia Cooperative Extension aims to provide a more thorough understanding of weed management to its growers.

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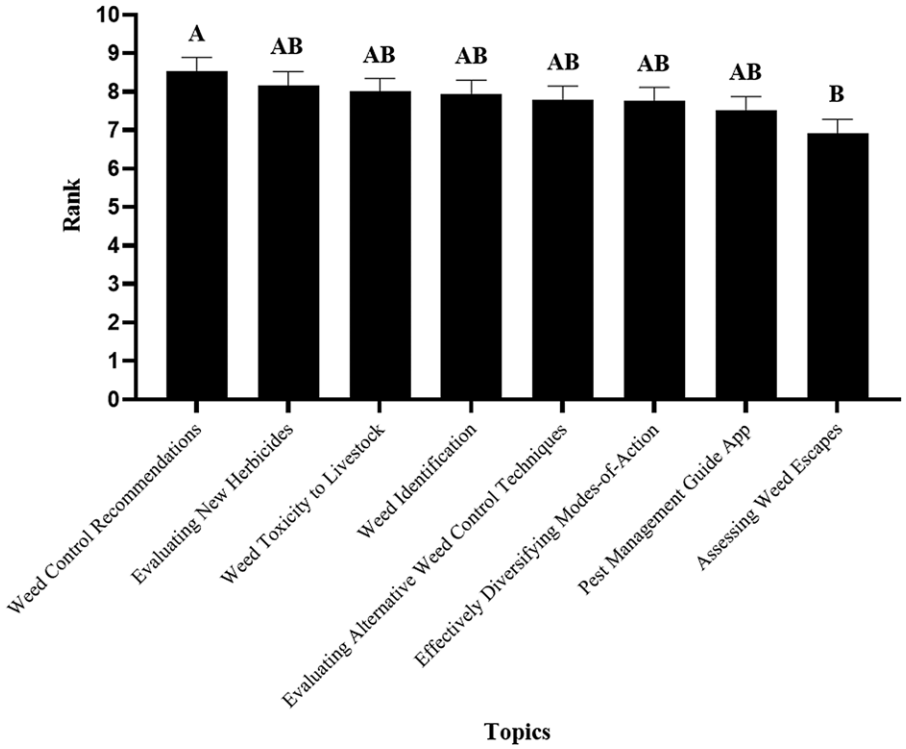

Figure 6. Topics ranked on a scale of 1 (least important) to 10 (most important) when forage farmers were asked what research or educational topics Virginia Cooperative Extension efforts should focus on (n = 41). See Appendix 1 for full answer choices.

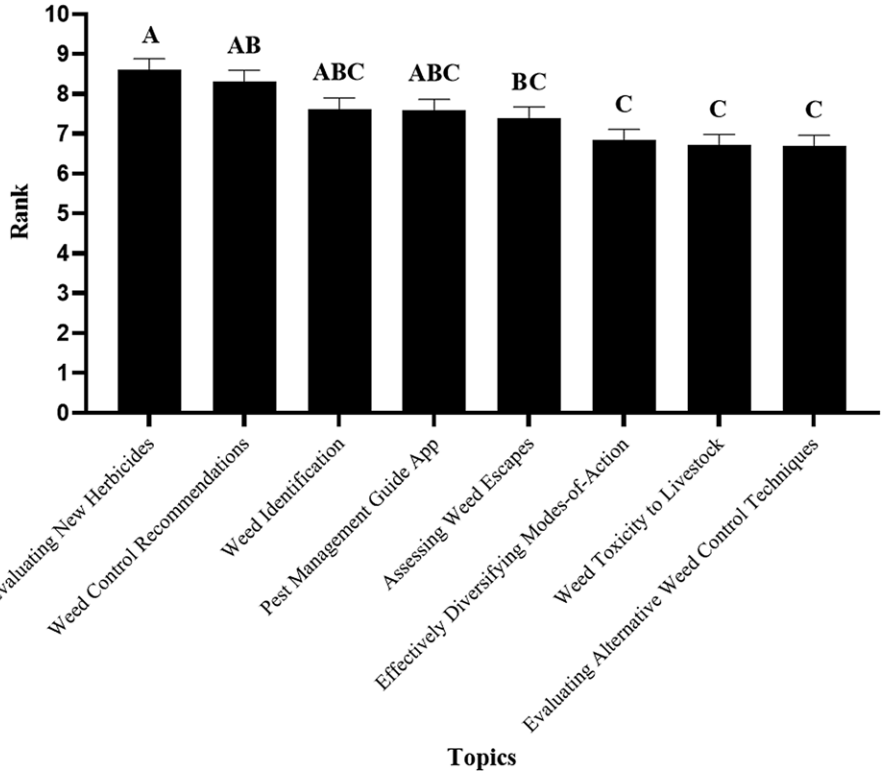

Figure 7. Topics ranked on a scale of 1 (least important) to 10 (most important) when forage farmer advisors were asked what research or educational topics Virginia Cooperative Extension efforts should focus on (n = 70). See Appendix 1 for full answer choices.

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Supplementary material. For supplementary material accompanying this paper visit https://doi.org/10.1017/wet.2023.43

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References

Arbuckle JG, Rosman H (2014) Iowa farmers' nitrogen management practices and perspectives. Extension Report PM3006. Ames: Iowa State University

Asmus A, Schroeder J (2016) Rethinking outreach: collaboration is key for herbicide-resistance management. Weed Sci 64:655–660

Bajwa AA, Mahajan G, Chauhan BS (2015) Nonconventional weed management strategies for modern agriculture. Weed Sci 63:723–747

Barrett M, Soteres J, Shaw D (2016) Carrots and sticks: incentives and regulations for herbicide resistance management and changing behavior. Weed Sci 64:627–640

Baumgart-Getz A, Prokopy LS, Floress K (2012) Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. J Environ Manage 96:17–25

Bish MD, Bradley KW (2017) Survey of Missouri pesticide applicator practices, knowledge, and perceptions. Weed Technol 31:165–177

Clement DM, Richardson JG, Mustian RD (1995) Level of use of extension by two diverse audiences and their preferred means for receiving extension information. Proceedings of the Southern Association of Agricultural Scientists Agricultural Communications Section. New Orleans, Louisiana, January 1995

Coble HD, Schroeder J (2016) Call to action on herbicide resistance management. Weed Sci 64:661–666

DeDecker JJ, Masiunas JB, Davis AS, Flint CG (2014) Weed management practice selection among Midwest US organic growers. Weed Sci 62:520–531

Dong F, Mitchell PD, Hurley TM, Frisvold GB (2016) Quantifying adoption intensity for weed-resistance management practices and its determinants among US soybean, corn, and cotton farmers. J Agr Resour Econ 1:42–61

Doohan D, Wilson R, Canales E, Parker J (2010) Investigating the human dimension of weed management: new tools of the trade. Weed Sci 58: 503–510

Eberle WM, Shroyer JP (2000) Are traditional extension methodologies extinct or just endangered? J Nat Resour Life Sci Educ 29:135–140

Franz NK, Townson L (2008) The nature of complex organizations: the case of cooperative extension. New Dir Eval 120:5–14

Frisvold GB, Hurley TM, Mitchell PD (2009) Adoption of best management practices to control weed resistance by corn, cotton, and soybean growers. AgBioForum 12:370–381

Givens W, Shaw DR, Neuman ME, Weller SC, Young BG, Wilson RG, Owen MD, Jordan DL (2011) Benchmark study on glyphosate-resistant cropping systems in the United States Part 3: grower awareness, information sources, experiences, and management practices regarding glyphosate resistant weeds. Pest Manag Sci 67:758–770

Givens WA, Shaw DR, Kruger GR, Johnson WG, Weller SC, Young BG, Wilson RG, Owen MD, Jordan D (2009) Survey of tillage trends following the adoption of glyphosate-resistant crops. Weed Technol 23:150–155

Godar AS, Stahlman PW (2015) Consultant's perspective on the evolution and management of glyphosate-resistant kochia (*Kochia scoparia*) in western Kansas. Weed Technol 29:318–328

Hammond C, Luschei E, Boerboom C, Nowak P (2006) Adoption of integrated pest management tactics by Wisconsin farmers. Weed Technol 20:756–767

Harker KN, O'Donovan JT (2013) Recent weed control, weed management, and integrated weed management. Weed Technol 27:1–11

Harvey WA (1954) Responsibilities of an extension weed specialist. Weeds 3:45–48.

Heap I (2022) The International Survey of Herbicide Resistant Weeds. http://www.weedscience.org. Accessed: March 15, 2022

Hurley TM, Frisvold G (2016) Economic barriers to herbicide-resistance management. Weed Sci 64:585–594

Johnson WG, Owen MD, Kruger GR, Young BG, Shaw DR, Wilson RG, Wilcut JW, Jordan DL, Weller SC (2009) U.S. farmer awareness of glyphosate-resistant weeds and resistance management strategies. Weed Technol 23:308–312

Knake EL (1987) Training weed scientists for Extension. Weed Technol 1:181–183

Kniss AR (2018) Genetically engineered herbicide-resistant crops and herbicide-resistant weed evolution in the United States. Weed Sci 66:260–273

Kruger GR, Johnson WG, Weller SC, Owen MD, Shaw DR, Wilcut JW, Jordan DL, Wilson RG, Bernards ML, Young BG (2009) US grower views on problematic weeds and changes in weed pressure in glyphosate-resistant corn, cotton, and soybean cropping systems. Weed Technol 23:162–166

Lineberger RD (1998) Integrating the world wide web into existing extension and educational technology. HortTechnology 8:313–319

Mortensen DA, Egan JF, Maxwell BD, Ryan MR, Smith RG (2012) Navigating a critical juncture for sustainable weed management. BioSciences 62:75–84

Moss S, Ulber L, den Hoed I (2019) A herbicide resistance risk matrix. Crop Prot 115:13–19

Norsworthy JK, Ward SM, Shaw DR, Llewellyn RS, Nichols RL, Webster TM, Bradley KW, Frisvold G, Powles SB, Burgos NR, Witt WW (2012) Reducing the risks of herbicide resistance: best management practices and recommendations. Weed Sci 60(SP1):31–62

Obahayujie J, Hillison J (1988) Now hear this! J Extension 26:21–22

Prince JM, Shaw DR, Givens WA, Owen MD, Weller SC, Young BG, Wilson RG, Jordan DL (2012) Benchmark Study: IV. Survey of grower practices for managing glyphosate-resistant weed populations. Weed Technol 26:543–548

Rankins A, Byrd JD, Mask DB, Barnett JW, Gerard PD (2005) Survey of soybean weeds in Mississippi. Weed Technol 19:492–498

Riar D, Norsworthy J, Steckel L, Stephenson D, Bond J (2013) Consultant perspectives on weed management needs in Midsouthern United States cotton: a follow-up survey. Weed Technol 27:778–787

Schroeder J, Barrett M, Shaw DR, Asmus AB, Coble H, Ervin D, Jussaume RA, Owen MD, Burke I, Creech CF, Culpepper AS (2018) Managing wicked herbicide-resistance: lessons from the field. Weed Technol 32:475–488

Schwartz-Lazaro LM, Norsworthy JK, Steckel LE, Stephenson DO, Bish MD, Bradley KW, Bond JA (2018) A midsouthern consultant's survey on weed management practices in soybean. Weed Technol 32:116–125

Scott BA, VanGessel MJ (2007) Delaware soybean grower survey on glyphosate-resistant horseweed (*Conyza canadensis*). Weed Technol 21:270–274

[USDA] U.S. Department of Agriculture–National Agricultural Statistics Service (2017) https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report. Accessed: March 15, 2022

Young SL, Pitla SK, Van Evert FK, Schueller JK, Pierce FJ (2017) Moving integrated weed management from low level to a truly integrated and highly specific weed management system using advanced technologies. Weed Res 57:1–5

Westwood JH, Charudattan R, Duke SO, Fennimore SA, Marrone P, Slaughter DC, Swanton C, Zollinger R (2018) Weed management in 2050: Perspectives on the future of weed science. Weed Sci 66:275–285