Renewable Agriculture and Food Systems

cambridge.org/raf

Research Paper

Cite this article: Bessette D, Zwickle S, Wilson R (2019). In the weeds: distinguishing organic farmers who want information about ecological weed management from those who need it. *Renewable Agriculture and Food Systems* **34**, 460–471. https://doi.org/10.1017/S1742170518000042

Received: 17 July 2017
Accepted: 29 December 2017
First published online: 31 January 2018

Key words:
Ecological weed management; organic farming; perceived risk; norms; behavior

Author for correspondence:
Doug Bessette, E-mail: bessett6@msu.edu

In the weeds: distinguishing organic farmers who want information about ecological weed management from those who need it

Doug Bessette[1], Sarah Zwickle[2] and Robyn Wilson[2]

[1]Department of Community Sustainability, College of Agriculture & Natural Resources, Michigan State University, 480 Wilson Road, East Lansing, MI 48826, USA and [2]School of Environment & Natural Resources, College of Food, Agriculture & Environmental Sciences, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210, USA

Abstract

The benefits of farming organically in the USA are increasingly known; however, organic farmers also encounter considerable risks, especially from weeds. Without herbicides, organic farmers can rely only on crop rotations, mechanical cultivation, manual weeding, beneficial insects and other cultural practices, termed ecological weed management (EWM), to control weeds. Despite promising results and the many ways in which EWM can be employed, it remains poorly adopted by the organic community. Organic farmers resist research and recommendations from University scientists and Extension, instead preferring to rely on local family and friends and their own experience to guide decisions. Here we investigate factors that may lead organic farmers to recognize that they need additional information about EWM and to seek that information out. Using a national survey of organic farmers ($n = 554$) and a risk-information seeking and processing model, we show that farmers' risk and benefit perceptions, worry, social norms encouraging seeking out information, and farmers' own perceived knowledge gaps, particularly with respect to their most problematic weed, influence information-seeking behavior. Identifying characteristics that may distinguish those organic farmers who need and want additional information, we provide recommendations to Extension and University scientists about how best to communicate, build trust and provide decision support to the organic community with respect to EWM.

Introduction

The economic, environmental and social benefits of farming organically in the USA are increasingly recognized. Over 2 million hectares of US land are currently farmed organically, with organic food sales making up 5% of total US food sales (Willer and Lernoud, 2016). Organic farmers report consistent double-digit annual growth in US sales (Willer and Lernoud, 2016); a continually shrinking gap exists between conventional and organic yields of US cash crops like corn and soybeans (De Ponti et al., 2012), and organic premiums operate well above break-even premiums (Reganold and Wachter, 2016). Organic farming methods, along with no-till methods, are also thought to be key in slowing unsustainable soil erosion (Montgomery, 2007), increasing soil biodiversity (Amundson et al., 2015) and may generate higher yields than conventional farms as drought conditions increase under climate change (Letter et al., 2003). A greater percentage of organic farms in an agriculture-dependent area has also been shown to encourage community economic development and increase social interactions between consumers and farmers (MacRae et al., 2007).

Organic farmers also face considerable risks—risks often thought to be greater than those faced by conventional farmers. These risks include input risks, like seed, labor and equipment shortages; external risks, like contamination by genetically modified organisms; economic risks such as a lack of access to, or rapidly changing, markets; and production risks, like crop infertility, pests and diseases (Hanson et al., 2004; Constance and Choi, 2010). Perhaps the greatest concern amongst organic farmers—and a major reason why conventional farmers report not transitioning to organic (Bastiaans et al., 2008)—remains weeds (Walz, 1999; Mohler and Johnson, 2009; Moynihan, 2011; Zwickle, 2011; DeDecker et al., 2014; Misiewicz et al., 2017). Weeds take a physical, psychological and economic toll on organic farmers (Zwickle et al., 2014). While conventional farmers can rely on a host of synthetic herbicides to mitigate the risk of weeds, organic farmers must be more creative, relying on crop rotations, mechanical cultivation, manual weeding, beneficial insects and other cultural practices (Hanson et al., 2004) to control weeds.

Such cultural practices are often termed ecological weed management, or EWM (Bastiaans et al., 2008). EWM has become a focus of the research community (Zwickle et al., 2014; Zwickle et al., 2016), and studies suggest EWM likely increases weed management effectiveness, reduces the time and labor required to manage weeds and possibly reduces weed

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

seedbanks over time (Jackson, 1997; Liebman et al., 2001; Hatcher and Melander, 2003; Gallandt and Molloy, 2008; Anderson, 2010). Despite the many ways in which EWM can be employed, weed scientists and Extension personnel argue that EWM has been poorly adopted by the organic community (Bastiaans et al., 2008), and organic farmers report both a lack of and desire for more research and recommendations regarding such options (Hanson et al., 2004; Tautges et al., 2016).

Previous work by the authors (Jabbour et al., 2014; Zwickle et al., 2016) and others (DeDecker et al., 2014) shows that organic farmers may resist such recommendations, particularly those coming from Extension. Organic farmers report relying primarily on their own past experience, e.g., what worked in the past, along with trusted sources like neighbors and successful farmers to determine which of the above management techniques to use—as well as how best to deploy them. Extension recommendations, the latest research and science, and National Organic Program standards are rarely mentioned as sources for information (Jabbour et al., 2014). This could very well be a result of Extension offices lacking the appropriate personnel, financial support and knowledge of organic farmers' needs to make relevant recommendations (Misiewicz et al., 2017). Indeed many organic farmers prefer local knowledge over expert recommendations (Norman et al., 2000); this despite the USDA's National Food and Agriculture Institute (NIFA, 2017) distributing upwards of 20 million dollars annually for research in organic agriculture.

Familiar sources may not always be reliable however as many organic farmers have demonstrated, at least relative to conventional farmers, an incomplete understanding of weed biology and the mechanisms by which weeds spread (Doohan et al., 2010). Additionally, many organic farmers have embraced 'soil balancing', or the base-cation saturation ratio (BCSR) theory of soil fertility, in managing weeds. Such theories have been empirically contradicted by some (Kopittke and Menzies, 2007) and termed by others to be merely 'pseudoscience' (De Decker et al., 2014; Jabbour et al., 2014). Despite evidence to the contrary, soil balancing is often heavily encouraged by consultants who not only offer the necessary amendments, but wield far more influence in local organic communities than do Extension and University personnel—at least in central Ohio. Regardless, organic farmers have been shown to rely on a 'limited suite' of mechanical weed control methods, ignoring more diverse 'information-intensive' and 'integrated' weed management strategies, strategies that may prove more successful in reducing weed pressures (Walz, 1999; De Decker et al., 2014: 529).

Due to the complicated tradeoffs that organic farmers face regarding risks and benefits (Zwickle et al., 2016), the longstanding disconnect between organic farmers and the research community, and what may be a misunderstanding of weed biology spread by some consultants and organic farmers, encouraging organic farmers to seek out the best available EWM information is crucial. At the same time determining the factors that lead some organic farmers to seek out such information and others to resist it is equally important. In the past, researchers (Lyson, 2012) and Extension personnel (Rogers, 2010) have relied heavily on the diffusion of innovation theories to describe and model how conventional farmers adopt different agricultural practices. Such theories have been less successful however in modeling how 'soft' technologies like knowledge—especially knowledge about EWM—diffuse through organic communities (Zwickle et al., 2016). As such, we test here an alternate model, an adaptation of Griffin et al.'s (1999) risk-information seeking and processing (RISP) model, to identify and examine the individual and social characteristics associated with organic farmers' EWM information-seeking (IS) behavior.

Literature review

RISP is an adaptation of Chaiken et al.'s (1989) Heuristic–Systematic model of processing and Azjen's (1991) Theory of Planned Behavior. Systematic processing is defined as comprehensive and analytical, a mode in which individuals seek to integrate all useful information into their judgments; heuristic processing, on the other hand, is less cognitively demanding and relies on simple decision rules and less information (Chaiken et al., 1989). The RISP model has been used to predict the extent to which individuals will seek out information about and then analyze a risk, e.g., organic farmers who rely more on systematic processing may be more likely to seek out information about EWM. RISP has been shown to successfully predict risk-information behavior across a variety of contexts, from health (Yang et al., 2014*a*) to river flooding (Griffin et al., 2008), the environment (Kahlor et al., 2006) and climate change (Kahlor, 2007; Yang et al., 2014*b*).

RISP incorporates up to seven principal factors to predict behavior. These include: (i) individual characteristics, including socio-economic and demographic factors, as well as an individual's relevant hazard experience, (ii) perceived hazard characteristics, such as the perceived risks and benefits of a hazard, (iii) individuals' affective response to risk, like the worry or dread associated with a risk, (iv) informational subjective norms, such as social pressure to know more about the risk, (v) information insufficiency, or the level of knowledge one believes is necessary to engage a risk, that individual's current knowledge and the gap between, (vi) an individual's perceived capacity to gather information and (vii) beliefs about the usefulness of information, as well as an individual's trust in risk management. While the original RISP included all seven factors, as little as two [e.g., current knowledge and informational subjective norms (Yang et al., 2014*a*)] have been shown to explain a significant portion of the variance in IS behavior.

In the current study, we use a modified RISP model to examine five factors that previous research (Jabbour et al., 2014) suggests may predict organic farmers' EWM IS behavior (see Fig. 1): (1) a *farmer's personal* (hazard) *experience* with the weed, or the amount of time a farmer has been managing a weed; (2) the hazard characteristics, or both the *risks* and *benefits farmers perceive* to be associated with the weed; (3) individuals' affective response, i.e., farmer's *worry*, regarding the weed; (4) *informational subjective norms*, or the extent to which neighbors and friends urge the individual to know about the weed; and (5) farmers' perceived knowledge gap, or the gap between what a farmer believes they should know (sufficiency threshold) and what they currently know (current knowledge) about managing the weed, also termed *information insufficiency*.

In this work, we did not expressly examine farmers' information *processing* behavior (e.g., whether they demonstrated heuristic or systematic processing of information); however, active, goal-directed seeking of information has been shown to lead to systematic processing (Kahlor et al., 2006).

Research questions and hypotheses

Based on previous RISP studies (Griffin et al., 1999; Kahlor, 2007), our own work examining the mental models of organic

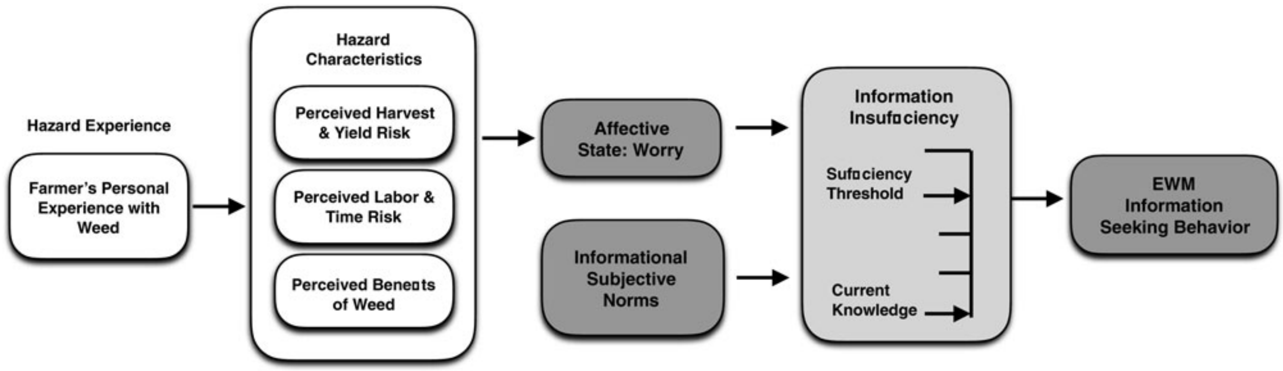

Fig. 1. EWM RISP model.

farmers (Jabbour et al., 2014; Zwickle et al., 2016), and our work with organic farmers in central Ohio, we hypothesized a number of relationships to exist with regard to our five factors. With regard to farmers' personal experience managing a weed, we expected that the more experience a farmer had managing a particular weed, the less risk they would perceive it to have. This is not to say that the risks of a weed would necessarily decline in reality, or that a farmer would become better able to mitigate those risks over time, only that the risk *perceptions* associated with it may decline based on the greater number of years the farmer demonstrated success managing or overcoming that risk. Put differently, we assume that a farmer must be successful in managing risk or else they would no longer be farming. As such:

H(1): The perceived risks of a weed will be negatively associated with the farmers' greater personal experience managing that weed.

The relationship between farmers' experience and the perceived benefits of a weed is not so clear. While some farmers may come to believe that a weed does help stem soil erosion or increase soil organic matter (SOM) over time, others may perceive the opposite. As such, we are only able to ask the following research question:

RQ(1): How does a farmer's greater personal experience managing a weed affect their perceived benefits of that weed?

With regard to an individual's affective state regarding a risk, Griffin et al. (2004) argue that one's worry is immediately influenced by their perceived characteristics of the hazard. Such characteristics, good or bad, pleasing or painful, generate 'risk as feelings', and these feelings precede and inform individuals' judgment and decision-making (Slovic et al., 2004). Indeed, one's dread regarding a hazard may be the key determiner of their risk perceptions and their avoidance or acceptance of a hazard (Slovic, 1987). High dread is often associated with risks that are new, difficult to see, and out of one's control, characteristics often associated with the weed seedbank.

As such, we would expect farmers to report greater worry if they perceive the risks of a weed to be high, for instance, if they expect the weed is likely to disrupt their harvest operations, decrease their yield or dramatically increase the time and labor they need to invest in managing the weed. Whereas, we would expect the farmers' worry to be negatively associated with the benefits they perceive the weed to have, such as its perceived ability to reduce soil erosion or increase SOM. We thus hypothesize:

H(2a): Farmers' affective state (worry) will be positively associated with the perceived risk of the weed.

H(2b): Farmers' affective state (worry) will be negatively associated with the perceived benefits of the weed.

Just as affect precedes and informs one's judgment, the RISP model proposes that individuals' affective state may also influence the degree to which they believe they have sufficient knowledge or information to manage a risk, i.e., whether or not they meet a knowledge sufficiency threshold (Griffin et al., 1999). Griffin et al. (1999) argue that the more a person is worried about a particular risk, the greater the confidence they will want to have in their knowledge of that risk. Additionally, the more a person is worried about a risk, the more likely it may be that they believe they lack sufficient knowledge necessary to manage that risk. As such we hypothesize that:

H(3a): Farmers' information insufficiency will be positively associated with the farmers' affective state (worry).

At the same time, we might expect that the more information a farmer believes they already have may lessen the degree to which they believe there is still information to acquire. As such:

H(3b): Farmers' information insufficiency will be negatively associated with the farmers' current knowledge.

Organic farmers have already been shown to rely extensively on networks of friends and neighbors for information about EWM (Jabbour et al., 2014). Accordingly, we would expect social norms, particularly expectations from other successful farmers that an individual seeks out information about how to manage weeds, to affect an individual's own perceived knowledge gap. Thus, we hypothesize that:

H(3c): Farmers' information insufficiency will be positively associated with informational subjective norms.

The ultimate goal of this work is to elucidate those factors that lead organic farmers to not only recognize they lack information about EWM but also to *seek* such information out. The RISP model predicts that both the greater an individual's information insufficiency regarding a risk and the informational subjective norms encouraging IS, the more likely they are to seek out information about managing that risk. As such, our final two hypotheses are:

H(4a): Farmers' IS behavior will be positively associated with information subjective norms.

H(4b): Farmers' IS behavior will be positively associated with information insufficiency.

One additional and important note about this study is that it purposely focused organic farmers' attention on their single most problematic weed. This is especially useful as previous interviews, surveys and focus groups (Zwickle, 2011) showed that most organic

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

farmers identify only one weed as representing the bulk of their weed pressure and concerns. Additionally, we expect that improved knowledge and management of the most problematic weeds would also lead to the mitigation of farmers' less worrisome weed species.

Methods

Sample

To test our five-factor framework, we collected data via an online survey delivered to a random sample of 3000 organic farmers, identified from the US National Organic Certification List. While relying solely on an online survey may introduce some self-selection bias into our sample, we believe it to be minimal as a 2017 (USDA, 2017a) report shows that 72% of farmers either own or lease a computer, nearly 40% of certified organic operators listed an email address in the Organic Integrity Database (USDA, 2017b), and the USDA National Agricultural Statistics Service now 'highly recommends' farmers respond to the online version of the 2017 Census of Agriculture (King and White, 2017).

A total of 574 respondents' surveys were returned for a response rate of 19.1%. Twenty respondents did not actively manage weeds on their farm and thus were removed from the analysis. Of the remaining 554 respondents, 361 reported their gender, with 284 reporting as male (78.7%) and 77 as female (21.3%). Additionally, of those respondents who reported their age, 150 out of 326 (46.0%) reported an age between 35 and 66 yr. One hundred and thirty-four (37.1%) participants reported having a bachelor's degree; 92 (25.5%) had a graduate or professional degree; and 134 had at least a high school diploma (37.1%). Of those who reported their farm's average gross sales ($n = 356$), 69.4% ($n = 247$) reported sales >$50,000; 60 (16.9%) reported between $50,000 and $100,000, 134 participants (37.6%) reported sales between $100,000 and $500,000, and 53 (14.9%) reported sales >$500,000.

Measures and factors

All of the survey questions used to test our RISP model were drawn from previous tests of the original RISP model (Griffin et al., 1999; Kahlor, 2007), but were refocused for examining farmers' weed perceptions and weed management behavior (see Table 1). As in the previous work, we used both unidimensional and multidimensional factors. Farmers' *Personal Experience*, *Current Knowledge* and *Worry* were measured using a single survey question, while farmers' *Perceived Risks* and *Perceived Benefits* of the weed, *Informational subjective norms*, *Information insufficiency* and *IS behavior* were measured using multiple survey questions. We used principal components analysis to group multiple questions into factors that would account for the most variance. All of the factors were represented as a single component except for *Perceived Risks*, which made up two components: *Harvest and Yield Risk*, and *Labor and Time Risk*. Questions pertaining to these four specific types of risks were informed by our previous work (Zwickle et al., 2016). Our measure of personal experience drew from the National Transition to Organic Survey (2017) and how the USDA classifies individuals as 'beginning farmers or ranchers', i.e., those with <10 yr experience farming or ranching. Our participants could select either <1 yr, up to 10 yr, or more than 10 yr experience managing their most problematic weed.

In addition to standard demographic questions, farmers were also asked to identify from a list of nine commonly reported sources of information (Zwickle et al., 2016) the three sources they used most often, as well as assess five statements about their beliefs regarding weed management and two statements about their weed pressure and weed seedbank.

Analysis

The Statistical Package for the Social Sciences (SPSS) and specifically hierarchical multiple regression were used to analyze the data. To examine the research question and hypotheses, we regressed farmers' IS behavior on the following blocks of variables in an order informed by Griffin et al. (2008) and the RISP model: (1) personal experience; (2) hazard characteristics; (3) worry and informational subjective norms; (4) current knowledge and (5) information sufficiency threshold. To avoid reliability issues and ceiling effects (Cohen et al., 2013), current knowledge was entered in the block previous to sufficiency threshold so that the latter variable represented the difference between the two. When insufficiency threshold was the dependent variable, we entered current knowledge in the first block so the remaining variables predicted the variance in the threshold not accounted for by current knowledge (Griffin et al., 2008).

To examine H(2), we regressed farmers' affective state on the blocks (1) personal experience and (2) hazard characteristics, and to examine RQ1 and H1, we conducted analysis of variance (ANOVA).

Paired sample *t*-tests were used to distinguish which risks and benefits farmers perceived to be greatest, and ANOVA was used to distinguish between the characteristics of farmers based on perceived knowledge gaps and IS behavior.

Results

Research questions and hypotheses

Only 26.1% ($n = 130$) of our respondents identified having <1 yr managing their most problematic weed, while 27.9% ($n = 139$) had between 1 and 9 yr, and 46.0% ($n = 230$) reported having at least 10 yr experience. The amount of personal experience a farmer reported managing a particular weed showed no significant negative (or positive) association with either their perceived harvest and yield risk ($F = 0.05$, df = 2, $p > 0.05$) or the risk of that weed to their labor and time ($F = 0.36$, df = 2, $p > 0.05$). Thus, H(1) was rejected. Regarding RQ1, farmers' personal experience with a weed was also not significantly associated with the perceived benefits of that weed ($F = 0.18$, df = 2, $p > 0.05$).

Based on paired-sample *t*-tests, respondents reported the greatest risk of their most problematic weed to be an increase in the time and labor they spent weeding ($t = 9.36$, df = 462, $p < 0.01$), followed by the likelihood that weed may reduce their crop yield and interfere with harvest operations ($t = 6.65$, df = 476, $p < 0.01$), respectively. No significant difference ($t = 1.16$, df = 454, $p > 0.05$) was found between farmers' perceptions of the benefits of that weed, i.e., between the likelihood of it stemming erosion or improving SOM.

Respondents reported moderate worry regarding their most problematic weed with 95% of farmers reporting worry between 3.20 and 8.20 on a ten-point scale (with 0 = no worry at all and 10 = a lot of worries). Amongst those problematic weeds mentioned by more than 15 farmers, the greatest worry was associated with bindweed (6.73), followed by foxtail (6.47) and giant ragweed (6.20) (see Table 2). Redroot pigweed (5.55) and grasses (5.63)

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

Table 1. RISP survey questions, descriptive statistics and principal components analysis (PCA) results

Concept variable label	Item wording	*M*	SD	PCA Contrb	PCA Var.
Personal experience (*n* = 489)					
Expr	How many years have you tried to manage (weed)? Response option was (1) <1 yr; (2) 1–9 yr; (3) 10 yr or more.	2.21	0.82		
Perceived risks (*n* = 457)					
Harvest	How likely or unlikely is it that (weed) will interfere with your harvest operations?	3.14	1.27	0.68	
Harvest%	How much will it interfere with harvest operations? Response option was (1) a little; (2) some; (3) a lot	2.19	0.58	0.75	
Yield	How likely or unlikely is it that (weed) will reduce your crop yields?	3.49	1.16	0.67	
Yield%	How much will it reduce your crop yields? Response option was (1) a little; (2) some; (3) a lot	2.06	0.61	0.66	44.47%
TimeLbr	How likely or unlikely is it that (weed) will increase the time and labor spent weeding?	4.14	1.12	0.72	
TimeLbr%	How much will it increase your time and labor spent weeding? Response option was (1) a little; (2) some; (3) a lot	2.50	0.56	0.67	22.56%
Perceived benefits (*n* = 448)					
SOM	How likely or unlikely is it that (weed) will improve your soil's organic matter?	2.55	1.15	0.85	
SOM%	How much will it improve your soil's organic matter? Response option was (1) a little; (2) some; (3) a lot	1.73	0.59	0.73	
Erosion	How likely or unlikely is it that [weed] will prevent soil erosion on your farm?	2.62	1.22	0.75	
Erosion%	How much will it prevent soil erosion on your farm? Response option was (1) a little; (2) some; (3) a lot	2.05	0.57	0.83	62.50%
Worry (*n* = 454)					
Worry	'When I think about the risks of (weed) to my farm, I feel ___.' Response option was (0) no worry at all to (10) a lot of worry	5.75	2.47		
Informational subjective norms (*n* = 443)					
Others	'Other successful organic farmers I know would seek out information about how to manage (weed).'	3.28	0.84	0.81	
Expect	'Other successful organic farmers I know would expect me to stay on top of information about how to manage (weed).'	3.14	0.90	0.80	
Convrs	'Knowing how to manage (weed)] will give me something to talk about with other organic farmers I know.'	3.27	0.92	0.81	65.43%
Current knowledge (*n* = 478)					
CurKnow	'How much knowledge I currently have about managing (weed).' Response option was a 100-point scale with scale endpoints defined by farmer	59.50	22.79		
Information insufficiency (*n* = 478)					
Thresh	'How much knowledge I need to successfully manage (weed).' Response option was a 100-point scale with scale endpoints defined by farmer	72.05	26.73		
Information-seeking behavior (*n* = 443)					
SeekBeh1	'I don't go out of my way to find information about how to manage (weed).' (Reversed)	3.35	1.14	0.79	
SeekBeh2	'When I saw (weed) for the first time, I tried to find out more about how to manage it before I did anything.'	3.14	1.00	0.79	63.12%

Response option was a five-point Likert scale from (1) very unlikely/strongly disagree to (5) very likely/strongly agree, unless otherwise noted.

inspired the least amount of worry. Regarding those hazard characteristics that may have led to such worry, multiple hierarchical regression demonstrated that farmers' worry was positively associated with a weed's perceived risk to harvest and yield (β = 0.53, t = 6.96, p < 0.01), but not with its risk of increasing the farmers' time and labor spent weeding (β = 0.10, t = 1.39, p = 0.17) (see Table 3). Thus, H(2a) was partially supported. H(2b) was supported as farmers' worry demonstrated a significant negative association with a weed's perceived benefits (β = −0.15, t = −2.03, p = 0.05). Grasses, which inspired relatively low worry compared with other weeds, were thought to be the most beneficial weed in both stemming erosion and improving SOM.

With regard to information insufficiency, 37 (7.7%) farmers reported having just enough knowledge to manage their most problematic weed. One hundred and twenty-two (25.5%) of the farmers reported having more than enough information and 320 (66.8%) reported needing more information. Multiple hierarchical regression showed farmers' current knowledge to have no negative association with information insufficiency (β = −0.06, t = −0.71, p = 0.48), thus H(3b) was rejected (see Table 4). Put differently,

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

Table 2. Farmer characteristics for each weed

Rank		Weed	Worry	Expr	Risk			Benefits		Norms[a]	Knowledge			Seek score
					Harvest	Yield	Time/Lbr	SOM	Erosion		Cur know	Thresh	Knowl gap	
Common weeds	1	Bindweed (*n* = 35)	**6.73**	2.27	10.05	9.24	**12.79**	7.33	7.56	3.36	56.42	73.24	16.82	**3.48**
	2	Foxtail (*n* = 44)	6.47	2.24	9.69	**9.29**	10.41	6.94	8.06	3.33	60.37	**79.23**	18.86	3.23
	3	Giant ragweed (*n* = 28)	6.20	2.11	**10.80**	8.95	*9.76*	6.86	8.00	**3.39**	*52.67*	75.78	**23.11**	3.18
	4	Canadian Thistle (*n* = 72)	5.77	**2.31**	*8.35*	*8.74*	11.31	7.13	8.45	3.34	57.25	76.94	19.69	3.38
	5	Grasses (*n* = 106)	5.63	2.13	9.80	9.17	12.00	**7.53**	**10.02**	*3.19*	**63.60**	68.33	*4.73*	*3.10*
	6	Redroot pigweed (*n* = 64)	*5.55*	*2.05*	9.56	9.00	12.24	*5.86*	*6.15*	*3.19*	55.73	*66.55*	10.82	3.12
Uncommon weeds	1	Nutsedge (*n* = 12)	5.96	2.25	7.14	9.71	9.88	–	–	3.25	52.33	67.25	14.92	3.46
	2	Hairy Galinsoga (*n* = 15)	5.79	2.20	8.93	8.67	13.87	5.00	8.00	3.20	59.07	87.07	28.00	3.03
	3	Purslane (*n* = 15)	5.71	1.93	9.50	7.20	12.90	–	–	3.17	58.71	75.43	16.72	2.96
	4	Velvet leaf (*n* = 7)	5.60	1.57	8.80	10.25	11.50	–	–	3.33	55.57	82.57	27.00	3.43
	5	Chickweed (*n* = 15)	5.41	2.27	9.00	8.75	9.78	5.33	7.00	3.20	58.69	68.69	10.00	3.25
	6	Lambsquarters (*n* = 11)	5.29	2.36	10.20	7.33	9.78	6.00	–	3.00	61.00	52.30	−8.70	3.15
		Other (*n* = 83)	4.89	2.36	9.36	8.66	11.86	8.81	10.70	3.09	61.27	70.23	8.96	3.28

Highest characteristic is in **bold**; lowest characteristic is in *italics*. Each Risk and Benefit is the product of its perceived probability and consequences (e.g., *Harvest* × *Harvest%*).
[a]Score is an average of the three *informational subjective norms* questions from Table 1.

Table 3. Multiple hierarchical regression of affective state: worry [standardized regression coefficients (β)]

	Affective state: worry		
Concept	β	*t*	Sig.
Constant	**2.54**	**3.06**	**0.00**
Personal experience	0.04	0.58	0.56
ΔR^2	0.00		
Perceived risks			
Harvest and yield	**0.53**	**6.96**	**0.00**
ΔR^2	0.00		
Time and labor	0.10	1.39	0.17
ΔR^2	0.05		
Perceived benefits	**(0.15)**	**(2.03)**	**0.05**
ΔR^2	0.00		
R^2	0.30		
Adjusted R^2	0.28		
ANOVA	***F* = 12.63**		**0.00**

the amount of information farmers reported having about a particular weed had no significant association with the amount of additional information they reported *needing* to manage that weed.

With regard to those weeds mentioned most often, farmers reported the least current knowledge about giant ragweed (52.67) and the greatest current knowledge about grasses (63.60) (see Table 2). The largest perceived gap between current knowledge and the knowledge necessary to manage a weed effectively also belonged to giant ragweed (23.11); the smallest gap belonged to grasses (4.73).

Multiple hierarchical regression showed that information insufficiency was positively associated with the farmers' affective state ($\beta = 0.23$, $t = 2.43$, $p = 0.02$) and informational subjective norms ($\beta = 0.20$, $t = 2.41$, $p = 0.02$). Thus, both H(3a) and H(3c) were supported; farmers' worry about a weed and strong social norms encouraging them to seek out information about that weed were both positively associated with needing additional information. Farmers reporting giant ragweed (3.39) as their most problematic weed reported the strongest norms; the weakest norms were associated with grasses (3.19) and pigweed (3.19).

As RISP predicted, H(4a) and (4b) were both supported with significant positive associations found between farmers reporting seeking information about weed management and both informational subjective norms ($\beta = 0.34$, $t = 4.17$, $p < 0.01$) and information insufficiency ($\beta = 0.31$, $t = 2.55$, $p = 0.01$). Put differently farmers reported seeking out more information about their most problematic weed when they reported stronger social norms encouraging that behavior and when they reported a lack of sufficient knowledge.

Overall the proposed models explaining information insufficiency and IS behavior explained approximately 20% of the variance in each model ($R^2_{\text{information insufficiency}} = 0.20$ and $R^2_{\text{IS behavior}} = 0.21$) (Table 4). Gender and education, the latter found in previous research to affect organic farmers' EWM behavior (Tautges et al., 2016), were both non-significant ($p > 0.05$) here and actually reduced the amount of variance explained in both models.

Sources of information

Regarding sources of information, organic farmers used most (see Table 5) often their own trial and error (58.3% of mentions; 3.24 on a four-point Likert scale where 1: useless and 4: very useful) and friends and neighbors who farm (44.4% of mentions; 2.62). The sources mentioned least by farmers were ACRES publications (7.9%) and websites they liked (4.2%), while local Extension agents were identified as the least useful source of information (1.56). Farmers reported using 19.0% (SD = 20.8) of their total time spent farming researching how to manage weeds (including reading and thinking about weeds, and attending workshops and field days); this proportion was unrelated ($p > 0.05$) to the weed identified, farmers' worry, perceived risks and benefits or social norms.

Beliefs about weed management and 'soil balancing'

Figure 2 displays the frequency of responses for five statements about farmers' beliefs regarding weed management. Over 23% of farmers (91 out of 391) reported using weeds to 'read' what nutrients needed to be added to the soil, and 38.5% (148 out of 384) agreed that weeds indicated what nutrients were missing in the soil and upon application of those nutrients weeds would stop growing. In total, 78.4% of farmers (301 out of 384) agreed that understanding weed biology made a difference in managing weeds effectively; only 10.2% (39 out of 384) disagreed.

Figure 3 displays the frequency of responses for farmers' perceived changes in weed pressure and the amount of weed seeds in the soil. Positively, 81.8% of farmers (302 out of 369) reported their weed pressure was either declining or staying the same, while 74.3% of farmers (274 out of 369) reported the number of weed seeds in their soil was either declining or staying the same.

Discussion

The principal goal of this study was to test a five-factor framework, informed by Griffin et al.'s (1999) RISP model, to identify those factors that may lead organic farmers to think they require additional information about EWM *and* to seek out such information to better manage their most problematic weed. The results support previous work testing the RISP model (e.g., Kahlor, 2007) and many of the relationships hypothesized to exist between such factors based on our own previous work (Jabbour et al., 2014; Zwickle et al., 2016). The perceived risks of farmers' most problematic weed were positively associated with their worry, while the weed's perceived benefits were negatively associated with farmers' worry. Both farmers' worry and informational subjective norms were positively associated with perceived information insufficiency; and information insufficiency and informational subjective norms were positively associated with the farmers' EWM-IS behavior.

The negative relationship hypothesized to exist between the amount of personal experience a farmer had managing a weed and their perceived risks of that weed was not supported. Nor did we find a positive relationship between a farmer's current knowledge and their perceived knowledge gap or IS behavior—indeed most farmers reported needing a similar amount of knowledge regardless of how much knowledge they reported already having.

Specific risk perceptions played different roles in inducing worry and promoting IS behavior, roles consistent with our

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

Table 4. Multiple hierarchical regression of information insufficiency and information-seeking behavior [standardized regression coefficients (β)]

	Information insufficiency			Information seeking		
Concept	β	*t*	Sig.	β	*t*	Sig.
Constant	**11.84**	**2.72**	**0.01**	**1.3**	**3.01**	**0.00**
Personal experience	(0.08)	(0.98)	0.33	(0.03)	(0.33)	0.75
ΔR^2	0.00			(0.01)		
Perceived risks						
Harvest and yield	(0.06)	(0.57)	0.57	0.08	0.78	0.44
ΔR^2	0.00			0.00		
Time and labor	**0.24**	**2.92**	**0.00**	(0.01)	(0.10)	0.92
ΔR^2	**0.05**			(0.01)		
Perceived benefits	0.04	0.45	0.65	(0.09)	(1.12)	0.27
ΔR^2	0.00			0.00		
Worry	**0.23**	**2.43**	**0.02**	(0.03)	(0.31)	0.76
ΔR^2	**0.03**			(0.01)		
Informational subjective norms	**0.20**	**2.41**	**0.02**	**0.34**	**4.17**	**0.00**
ΔR^2	**0.03**			**0.10**		
Knowledge	(0.06)	(0.71)	0.48	0.22	1.82	0.07
ΔR^2	0.00			0.01		
Information insufficiency				**0.31**	**2.55**	**0.01**
R^2	0.19			0.21		
Adjusted R^2	0.16			0.16		
ANOVA	**$F = 4.76$**		**0.00**	**$F = 4.53$**		**0.00**

previous research (Jabbour et al., 2014). Farmers who perceived a higher risk of weeds to their harvest and yield expressed more worry, but did not report a lack of knowledge or the need to gather more information as a solution. Conversely, those farmers who perceived weeds as increasing the time and labor they spent in the fields were more likely to report needing additional information to manage them. We expect this difference may be the result of farmers seeing their time and labor as manageable, a tractable problem that can be (at least somewhat) controlled by applying different tactics or strategies. Not only does previous work suggest that organic farmers are management-centered rather than ecology-centered (Jabbour et al., 2014), but one's ability to control a hazard is a key factor in reducing its dread—and thus its worry, as well as increasing its acceptance as a risk (Slovic, 1987). This is in opposition to the risk of weeds to a farmer's harvest and yield, which may be seen as more holistic, ecological problems, and less influenced by farmer's management strategies; organic farmers have previously reported that terms like yield—and profit—are not appropriate for their decisions (Mccann et al., 1997). Such a view may explain greater worry regarding these risks that are seemingly out of farmers' control (Slovic et al., 2004). Additionally, the risk of weeds and weed seeds damaging farmers' products as well as their reputation and relationships with buyers is certainly considerable, and yet also out of the farmers' control at the point of delivery or purchase.

Table 5. Sources of information mentioned most by farmers

Rank	Source of information	# (%) of farmers[a]	How useful[b], mean (SE)
1	Your own trial and error	323 (58.3%)	3.24 (0.04)
2	Friends and neighbors who farm	246 (44.4%)	2.62 (0.05)
3	Books on weed management	162 (29.2%)	2.19 (0.06)
4	Key word searches on Internet	121 (21.8%)	2.15 (0.06)
5	Regional farm conferences	118 (21.3%)	2.10 (0.06)
6	Local Extension agent	78 (14.1%)	1.56 (0.06)
7	Field days at local farm	70 (12.6%)	2.07 (0.06)
8	ACRES publications	44 (7.9%)	1.65 (0.06)
9	Website that I like	23 (4.2%)	1.76 (0.07)

[a]A total of 1205 mentions (72.5%) out of 1662 possible mentions ($n = 554 \times 3$ sources).
[b]Likert scale, 1 (useless) to 4 (very useful).

Another explanation for this difference in risk perceptions may be the time lag between when a management strategy is employed and when the consequences of weeds manifest. Farmers often begin making weed management decisions immediately previous to or at the outset of the planting season. At this point, and immediately following, high weed pressure can be managed via greater time and labor spent weeding. Thus, seeking—and finding—information about different EWM tactics can lead to direct, measurable benefits and a relatively clear, though not necessarily positive, cause–effect relationship. Farmers' harvest operations on the other hand and the resulting yields are both far more uncertain

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

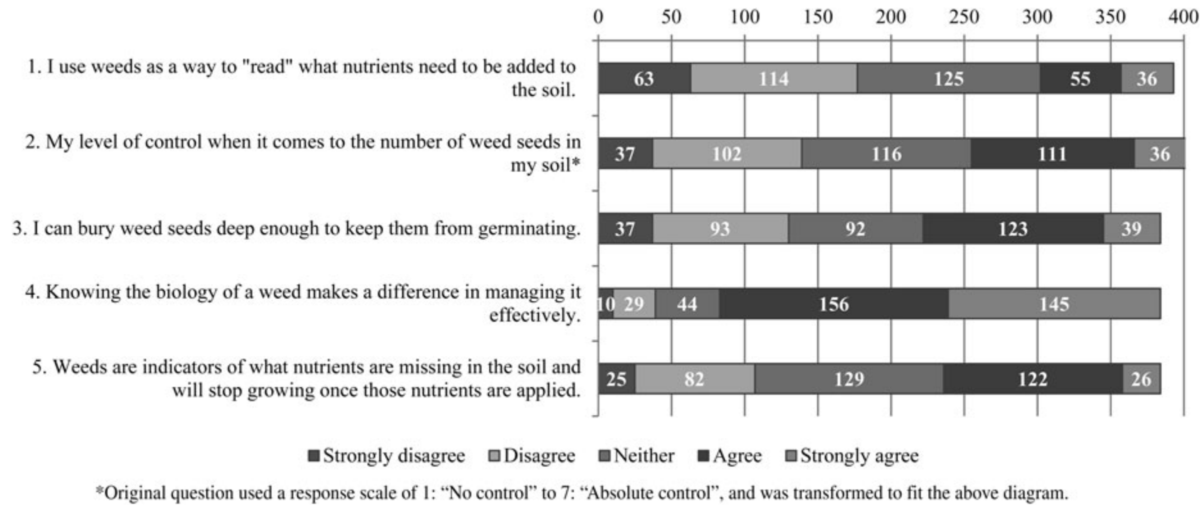

Fig. 2. Organic farmers' beliefs about weed management and control.

and occur at the end of the season, often long after farmers' weed management decisions have been made. Seeking out information at this point is, at least for the current season, futile. This separation of outcomes from decisions may reduce the perceived value of IS with regard to harvest and yield, at the same time increasing farmers' worry regarding both. Indeed, people are familiar with and have shown themselves to be adept at managing close cause–effect relationships; at the same time, we struggle with the decisions that are characterized by large time lags and low proximity (Gardner and Stern, 1996).

Farmers who perceived the benefits of weeds, on the other hand, were less worried and more likely to assume that they have the necessary knowledge to manage them effectively. This was especially apparent with regard to grasses. Farmers who reported grasses as their most problematic weed reported little worry, high knowledge and low social pressure with regard to acquiring knowledge about how to manage them, and perceived the greatest benefits with regard to that weed increasing SOM and stemming erosion. One exception to this pattern regarding grasses was foxtail, which inspired high worry and high social pressure, and was perceived to have low benefits. These findings suggest that researchers and Extension may not want to prioritize organic research on grasses with the exception of foxtail, instead focusing their research and communication efforts on ragweed, bindweed—and foxtail, far more worrisome and less (obviously) beneficial weeds.

That farmers perceived any benefit stemming from their most problematic weed may speak to philosophical differences between conventional and organic farmers (Sullivan et al., 1996; Stofferahn, 2009). Though recent studies comparing conventional and organic farmers' perceptions of weeds in the USA are sparse, organic farmers often report motivations for transitioning from conventional methods that suggest a more positive view of weeds and have already been shown to perceive the benefits of weeds to soil health (Jabbour et al., 2014). They may be unaware of additional weed benefits, however. For instance, Henckel et al. (2015) found that organic farms may generate a positive 'metacommunity effect' in providing habitats for less frequent weed species and enhancing weed diversity across landscapes. While these weeds may decrease yields, they also: (i) support critical ecological services like pollination (Henckel et al., 2015), (ii) improve biodiversity, not just of weeds, but also of insects, microbes and birds (Marshall et al., 2003; Gabriel et al., 2013) and perhaps most importantly, (iii) provide habitats for bees (Bretagnolle and Gaba, 2015). Supporting pollination and increasing bee habitat and health both readily come up in our own conversations with local organic farmers.

Ensuring that the information coming from University researchers and Extension makes these benefits more salient may be an effective way to overcome the worry of conventional farmers considering transitioning to organic and to reduce the worry of those already having transitioned, and reducing worry remains a critical goal of the agricultural community (Rosmann, 2005; Browning et al., 2008). Previous research has shown that most farmers battle high levels of stress, worry and depression (Browning et al., 2008; Stallones et al., 2013; Tiesman et al., 2015), levels linked to farmers'

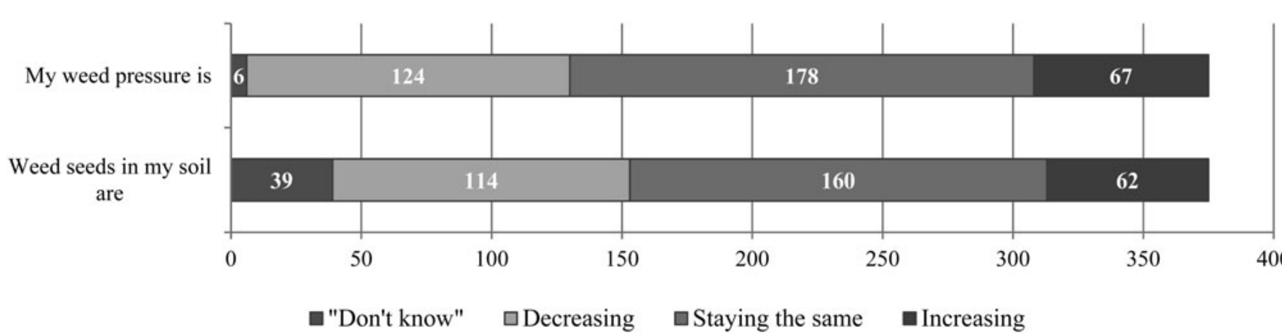

Fig. 3. Organic farmers' perceptions of weed pressure and weed seeds in soil.

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

long, demanding work hours, weather-contingent planning and harvest schedules, isolated working conditions and reduced access to affordable, high-quality healthcare services (Browning et al., 2008). Additional research is necessary, but framing weeds as a benefit instead of a risk, or simply helping farmers identify the thresholds at which weeds may begin to threaten their yield, may help to reduce farmers' worry, particularly in organic communities.

Our results demonstrate that organic farmers also rely extensively on their families, friends and other successful farmers to make EWM decisions; in fact, it is their top source of information outside their own experience. Additionally, social networks that encourage farmers to seek out information about weed management can lead farmers to both believe they lack the necessary information to manage weeds effectively and seek out more and better information. Indeed, these norms were the strongest positive indicators of farmers' IS behavior. Conversely, Extension, USDA personnel and University educators are rarely identified or included in these networks, and Extension was reported to be the least useful source of information here. While such exclusion may have once been the result of bias, criticism and scientific opposition to organics (Constance and Choi, 2010), its persistence today is more likely the result of insufficient personnel, their dwindling financial support and a 'lack of basic understanding of organic agricultural practices', organic farmers' needs and existing research (Misiewicz et al., 2017: 14). Misiewicz et al. (2017) add that even if the pertinent research is being completed, it may not be accessible to farmers, or because organic farming relies on processes that are intensely local, it may not translate from one area or crop to another.

This lack of understanding, support, personnel and relevant research does little to build trust between organic farmers and Extension personnel, and trust is key. It is commonly accepted that trust is critical in not only improving the public's understanding of science (Wynne, 1980) and effectively communicating about risk (Kasperson et al., 1992) but also in reducing (and increasing) the perceived risks (and benefits) of a hazard (Siegrist, 2000). Trust is a multidimensional theoretical concept—a composite of competence, care, fairness and openness (Poortinga and Pidgeon, 2003), but often involves the sharing of similar values and similar understandings of a situation, something called 'salient value similarity' (SVS) (Earle and Cvetkovich, 1995; Poortinga and Pidgeon, 2003). High SVS has been shown to increase trust and correspondingly increase (and reduce) the perceived benefits (and risks) of a hazard (Siegrist et al., 2000: 355). Extension personnel and research scientists may be inadvertently contributing to greater mistrust by misunderstanding the organic community, communicating disparate values and focusing on short-term research priorities as opposed to the long-term research projects organic farmers desire (Misiewicz et al., 2017). This lack of trust between the organic community and the traditional Extension and research community may then be leading to greater (and less) perceived risks (and benefits) of weeds, as well as discouraging organic farmers from seeking out information about EWM strategies that could be effective on their farm.

One particular area where different understandings exist between the two communities regards the ability of weeds to act as indicators of soil nutrients, or nutrients that are lacking. In this study, a considerable portion—nearly 40%—of farmers reported using weeds either to 'read' what nutrients the soil may be missing or to guide their nutrient management decisions. Furthermore, it was these farmers who reported relying on soil balancing who demonstrated the largest information insufficiency (see Table 6). This is especially important to recognize as the farmers most likely to need information are also those most likely to be turned off by research scientists and Extension personnel who ignore BCSR and soil balancing or worse yet admonish those farmers who practice them. The research community may be missing a key opportunity to build trust by constructively engaging those farmers and conducting local, accessible research that works to either support—or refute—such beliefs.

Table 6. Characteristics of organic farmers most needing and most wanting EWM information

Characteristics of farmers reporting largest knowledge gap:
• Have less years managing weeds***
• Rely less on own trial and error***
• Spend more money on weed management equipment and labor***
• Rely less on 'soil balancing', or using weeds to 'read' what nutrients are missing in soil*
• Report dramatically less control over both the number of weed seeds in the soil and the time and labor available for weeding*
• Report increasing weed pressure*** and number of weed seeds in soil**
• Report marginally greater IS behavior ($p = 0.076$)
Characteristics of farmers seeking information most:
• Report higher gross sales*
• Are newer to farming (did not transition from conventional)*
• Sell greater percentage of products wholesale, less percentage of products at farmers' markets*
• Spend more money on weed management equipment***
• Find books, ACRES publications, field days, the Internet and Extension agents to be more useful sources of information*
• Spend more farm time studying and doing research on weeds***

Characteristics of respondents ($n = 146$) reporting knowledge gap higher than the median (30)–not including those farmers who reported a negative gap, and those farmers reporting an IS behavior score higher than the median (3.5) ($n = 221$). Characteristics are significantly different from those reporting gaps and IS scores below the median at $*p < 0.05$, $**p \leq 0.01$ or $***p \leq 0.001$, unless otherwise noted.

Recommendations: organic specialists and active decision support

This study's results suggest that in order to increase organic farmers' IS behavior—and eventually their knowledge (both real and perceived) about EWM—we must increase the number of USDA, Extension and University personnel who share similar values, goals and common understandings with organic farmers. One means of doing so would be to create positions in the form of 'organic specialists', individuals who have:

(i) extensive personal experience farming organically and knowledge about organic farmers' day-to-day operations,
(ii) existing ties in established networks of organic farmers,
(iii) specific knowledge of farmers' most problematic weeds (for instance, bindweed, foxtail and giant ragweed),
(iv) exposure to and an appreciation for soil balancing and BCSR beliefs—as well as the ability to communicate with farmers about how their beliefs may or may not align with on-farm observations and
(v) access to, understanding of and the ability to communicate with farmers about government and University-funded research programs.

By engaging with the organic farming community, these specialists would build trust between themselves and the organic community, while also likely generating more relevant research

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press

priorities and results, and greater dissemination and understanding of research findings.

This study also provides some initial direction as to whom specifically these specialists might target in the organic community. Table 6 lists characteristics of those individuals who reported most needing information (largest knowledge gap) and those most seeking it out (high IS behavior). The former reported less experience managing their most problematic weed, but spend a comparatively larger amount on weed management equipment and labor, while feeling little control over weeds and weed seeds and perceiving increasing weed pressure and growing weed seedbanks. These characteristics describe a farmer navigating a possibly tenuous situation. Those farmers most seeking out information—it is important to remember that farmers seeking out information do not always report *needing* information—operate relatively larger farms, are newer to farming, sell more products wholesale relative to farmers' markets, and spend more money on equipment. These characteristics describe farmers who may have access to more financial resources and easier distribution networks. While certainly more research is needed, it may be that as organic farmers' weed pressures—and accordingly their worries—increase they move from a position of seeking out information to believing such information is either unavailable or inconsequential. The most effective risk communication efforts then may be those that engage farmers *before* they cross that threshold.

The above study also suggests that active decision-support frameworks may aid organic farmers in comparing different EWM strategies. Such frameworks, particularly those that rely on 'value-focused thinking'(Keeney, 1992), work to specifically identify farmers' values and allow for the evaluation of different strategies in terms of their performance with regard to farmers' most important values. These frameworks have demonstrated success in providing a means for balancing complicated tradeoffs (Bessette et al., 2014), and could allow farmers to engage the labor, harvest and yield risks discussed above as well as the benefits of different EWM practices and strategies. Clarity around the short and long-term performance of different EWM strategies may also be a key in assisting farmers to overcome or at least stay motivated in the face of short-term weed pressure and the worry that accompanies it. We hypothesize that such clarity may increase the adoption of EWM strategies that require greater up-front costs but perform better over the long run.

Acknowledgments. This work was supported by Organic Transitions Award No. 2015-51106-24193 from the USDA National Institute of Food and Agriculture. We also acknowledge and appreciate the help of Guang Han, Hugh Walpole, and two anonymous reviewers.

References

Ajzen I (1991) The theory of planned behavior. *Organizational Behavior and Human Decision Processes* **50**, 179–211.

Amundson R, Berhe AA, Hopmans JW, Olson C, Sztein AE and Sparks DL (2015) Soil and human security in the 21st century. *Science* **348**, 1261071.

Anderson RL (2010) A rotation design to reduce weed density in organic farming. *Renewable Agriculture and Food Systems* **25**, 189–195.

Bastiaans L, Paolini R and Baumann D (2008) Focus on ecological weed management: What is hindering adoption? *Weed Research* **48**, 481–491.

Bessette DL, Arvai J and Campbell-Arvai V (2014) Decision support framework for developing regional energy strategies. *Environmental Science & Technology* **48**, 1401–1408.

Bretagnolle V and Gaba S (2015) Weeds for bees? A review. *Agronomy for Sustainable Development* **35**, 891–909.

Browning SR, Westneat SC and Mcknight RH (2008) Suicides among farmers in three southeastern states, 1990–1998. *Journal of Agricultural Safety and Health* **14**, 461–472.

Chaiken S, Liberman A and Eagly AH (1989) Heuristic and systematic information processing within and beyond the persuasion context. In Uleman J and J Bargh's (eds). *Unintended Thought*. pp. 212–252.

Cohen J, Cohen P, West SG and Aiken LS (2013) *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. Lawrence Erlbaum Associates Inc.

Constance DH and Choi JY (2010) Overcoming the barriers to organic adoption in the United States: A look at pragmatic conventional producers in Texas. *Sustainability* **2**, 163–188.

Dedecker JJ, Masiunas JB, Davis AS and Flint CG (2014) Weed management practice selection among Midwest US organic growers. *Weed Science* **62**, 520–531.

De Ponti T, Rijk B and Van Ittersum MK (2012) The crop yield gap between organic and conventional agriculture. *Agricultural Systems* **108**, 1–9.

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

Earle TC and Cvetkovich G (1995) *Social Trust: Toward A Cosmopolitan Society*. London: Greenwood Publishing Group.

Gabriel D, Sait SM, Kunin WE and Benton TG (2013) Food production vs. biodiversity: Comparing organic and conventional agriculture. *Journal of Applied Ecology* **50**, 355–364.

Gallandt E and Molloy T (2008) Exploiting weed management benefits of cover crops requires pre-emption of seed rain. Poster at: Cultivating the Future Based on Science: 2nd Conference of the International Society of Organic Agriculture Research ISOFAR, Modena, Italy, June 18–20, 2008.

Gardner GT and Stern PC (1996). *Environmental Problems and Human Behavior*. Vancouver, BC: Allyn & Bacon.

Griffin RJ, Dunwoody S and Neuwirth K (1999) Proposed model of the relationship of risk information seeking and processing to the development of preventive behaviors. *Environmental Research* **80**, S230–S245.

Griffin RJ, Neuwirth K, Dunwoody S and Giese J (2004) Information sufficiency and risk communication. *Media Psychology* **6**, 23–61.

Griffin RJ, Yang Z, Ter Huurne E, Boerner F, Ortiz S and Dunwoody S (2008) After the flood: Anger, attribution, and the seeking of information. *Science Communication* **29**, 285–315.

Hanson J, Dismukes R, Chambers W, Greene C and Kremen A (2004) Risk and risk management in organic agriculture: Views of organic farmers. *Renewable Agriculture and Food Systems* **19**, 218–227.

Hatcher P and Melander B (2003) Combining physical, cultural and biological methods: Prospects for integrated non-chemical weed management strategies. *Weed Research* **43**, 303–322.

Henckel L, Börger L, Meiss H, Gaba S and Bretagnolle V (2015) Organic fields sustain weed metacommunity dynamics in farmland landscapes. *Proceedings of the Royal Society B: Biological Sciences* **282**, 20150002.

Jabbour R, Zwickle S, Gallandt ER, Mcphee KE, Wilson RS and Doohan D (2014) Mental models of organic weed management: Comparison of New England US farmer and expert models. *Renewable Agriculture and Food Systems* **29**, 319–333.

Jackson LE (1997). *Ecology in Agriculture*. San Diego: Academic Press.

Kahlor L, Dunwoody S, Griffin RJ and Neuwirth K (2006) Seeking and processing information about impersonal risk. *Science Communication* **28**, 163–194.

Kahlor LA (2007) An augmented risk information seeking model: The case of global warming. *Media Psychology* **10**, 414–435.

Kasperson RE, Golding D and Tuler S (1992) Social distrust as a factor in siting hazardous facilities and communicating risks. *Journal of Social Issues* **48**, 161–187.

Keeney RL (1992) *Value-focused Thinking. A Path to Creative Decision Making*. Cambridge, MA, Harvard University Press.

King S and White T (2017). *2017 Census of Agriculture Gets Underway*. Washington, DC: USDA.

Kopittke PM and Menzies NW (2007) A review of the use of the basic cation saturation ratio and the 'ideal' soil. *Soil Science Society of America Journal* **71**, 259–265.

Letter D, Seidel R and Liebhardt W (2003) The performance of organic and conventional cropping systems in an extreme climate year. *American Journal of Alternative Agriculture* **18**, 146–154.
Liebman M, Mohler CL and Staver CP (2001). *Ecological Management of Agricultural Weeds*. Cambridge, UK: Cambridge University Press.
Lyson TA (2012) *Civic Agriculture: Reconnecting Farm, Food, and Community*. Medford, MA, USA: UPNE.
Macrae RJ, Frick B and Martin RC (2007) Economic and social impacts of organic production systems. *Canadian Journal of Plant Science* **87**, 1037–1044.
Marshall E, Brown V, Boatman N, Lutman P, Squire G and Ward L (2003) The role of weeds in supporting biological diversity within crop fields. *Weed Research* **43**, 77–89.
Mccann E, Sullivan S, Erickson D and De Young R (1997) Environmental awareness, economic orientation, and farming practices: A comparison of organic and conventional farmers. *Environmental Management* **21**, 747–758.
Misiewicz T, Shade J, Crowder D, Delate K, Sciligo A and Silva E (2017). *Increasing Agricultural Sustainability Through Organic Farming: Outcomes From the 2016 Organic Confluences Summit*. The Organic Center.
Mohler CL and Johnson SE (2009). *Crop Rotation on Organic Farms: A Planning Manual*. Ithaca, NY: Natural Resource, Agriculture, and Engineering Service (NRAES) Cooperative Extension.
Montgomery DR (2007) Soil erosion and agricultural sustainability. *Proceedings of the National Academy of Sciences* **104**, 13268–13272.
Moynihan M (2011). *Status of Organic Agriculture in Minnesota: A Report to the Minnesota Legislature*. St Paul: Minnesota Department of Agriculture.
NIFA 2017. Organic Agriculture Program [Online]. https://nifa.usda.gov/program/organic-agriculture-program (Accessed).
Norman D, Bloomquist L, Janke R, Freyenberger S, Jost J, Schurle B and Kok H (2000) The meaning of sustainable agriculture: Reflections of some Kansas practitioners. *American Journal of Alternative Agriculture* **15**, 129–136.
Poortinga W and Pidgeon NF (2003) Exploring the dimensionality of trust in risk regulation. *Risk Analysis* **23**, 961–972.
Reganold JP and Wachter JM (2016) Organic agriculture in the twenty-first century. *Nature Plants* **2**, 15221.
Rogers EM (2010). *Diffusion of Innovations*. New York, NY: Simon and Schuster.
Rosmann M (2005) Sowing the seeds of hope: Providing regional behavioral health supports to the agricultural population. *Journal of Agricultural Safety and Health* **11**, 431–439.
Siegrist M (2000) The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis* **20**, 195–204.
Siegrist M, Cvetkovich G and Roth C (2000) Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis* **20**, 353–362.
Slovic P (1987) Perception of risk. *Science* **236**, 280–285.
Slovic P, Finucane ML, Peters E and Macgregor DG (2004) Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis* **24**, 311–322.
Stallones L, Doenges T, Dik BJ and Valley MA (2013) Occupation and suicide: Colorado, 2004–2006. *American Journal of Industrial Medicine* **56**, 1290–1295.
Stofferahn CW (2009) Personal, farm and value orientations in conversion to organic farming. *Journal of Sustainable Agriculture* **33**, 862–884.
Sullivan S, Mccann E, De Young R and Erickson D (1996) Farmers' attitudes about farming and the environment: A survey of conventional and organic farmers. *Journal of Agricultural and Environmental Ethics* **9**, 123–143.
Tautges NE, Goldberger JR and Burke IC (2016) A survey of weed management in organic small grains and forage systems in the Northwest US. *Weed Science* **64**, 513–522.
Tiesman HM, Konda S, Hartley D, Menéndez CC, Ridenour M and Hendricks S (2015) Suicide in US workplaces, 2003–2010: A comparison with non-workplace suicides. *American Journal of Preventive Medicine* **48**, 674–682.
USDA (2017a) Farm Computer Usage and Ownership [Online]. United States Department of Agriculture. Economics, Statistics and Market Information System. National Agricultural Statistics Service. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1062
USDA (2017b) Organic Integrity Database [Online]. United States Department of Agriculture. Agricultural Marketing Service. https://organic.ams.usda.gov/integrity/ (Accessed)
Walz E (1999) *Final Results of the Third Biennial National Organic Farmers' Survey: Sustaining Organic Farms in a Changing Organic Marketplace*. Santa Cruz, CA: Organic Farming Research Foundation.
Willer H and Lernoud J (2016) *The World of Organic Agriculture, Statistics and Emerging Trends 2016*. Bonn, Germany: FIBL, IFOAM First Edition Handbook. ISBN 978-3-03736-306-5.
Wynne B (1980) Technology, risk and participation: On the social treatment of uncertainty. *Society, Technology and Risk Assessment* **1980**, 173–208.
Yang ZJ, Aloe AM and Feeley TH (2014a) Risk information seeking and processing model: A meta-analysis. *Journal of Communication* **64**, 20–41.
Yang ZJ, Rickard LN, Harrison TM and Seo M (2014b) Applying the risk information seeking and processing model to examine support for climate change mitigation policy. *Science Communication* **36**, 296–324.
Zwickle S, Wilson R and Doohan D (2014) Identifying the challenges of promoting ecological weed management (EWM) in organic agroecosystems through the lens of behavioral decision making. *Agriculture and Human Values* **31**, 355–370.
Zwickle S, Wilson R, Bessette DL, Herms C and Doohan D (2016) Facilitating ecological weed management decisions by assessing risk-benefit tradeoffs. *Agroecology and Sustainable Food Systems* **40**, 635–659.
Zwickle SL (2011) *Weeds and Organic Weed Management: Investigating Farmer Decisions with A Mental Models Approach*. Columubs, OH, USA: The Ohio State University.

https://doi.org/10.1017/S1742170518000042 Published online by Cambridge University Press