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Farmers' perspectives on resistance in western corn rootworm to CRW-Bt corn in Midwest USA

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Resistance in western corn rootworm to transgenic corn hybrids was first confirmed in 2011 in Midwestern USA, and threatens their continued use. Farmers are often the first line of resistance detection, so their understanding and attitudes toward this issue are critical for improving resistance management. We conducted telephone focus groups during 2013 with farmers who had experienced rootworm resistance. There were four stages in dealing with unexpected rootworm injury: Awareness of a problem, diagnosis, confirmation, and recommendations. Most farmers discovered the problem themselves, but this usually happened too late in the growing season to limit yield loss. Once aware of a problem, farmers first sought help diagnosing the problem from their seed dealer, chemical rep, and/or crop consultant. They considered the problem to be a significant one, both because of its severity and suddenness, and were concerned about their difficulty in obtaining a correct diagnosis. They eventually used extension entomology specialists to confirm the diagnosis. Farmers gathered recommendations from independent consultants, input suppliers, and extension and indicated that they would aggressively deal with the problem, because they were not sure of what would work to protect their crop. They recommended that public extension put more emphasis on increasing awareness of the problem, assessing the extent of the problem and being an unbiased source of information. However, farmers were unlikely to report rootworm injury if the perceived barriers to reporting outweighed the perceived incentives. These barriers were emotional ones, including being unsure who to trust, fear that reporting will be time-consuming, and shame that they did something wrong. The incentive was access to credible advice. They did not automatically acknowledge the broader social benefits of reporting. Thus, extension probably needs to be explicit about these broader benefits to obtain information about the extent of the problem. With the conflicting demands and multiple information sources, it will be a challenge for extension to involve farmers to improve resistance monitoring and management.

Key words: Resistance management, focus group, qualitative analysis, *Diabrotica virgifera*, genetically modified organism, transgenic crop, extension.

INTRODUCTION

The development and use of transgenic crops has greatly changed crop production and pest management in the United States and worldwide (NRC, 2016). These crops have been developed with a variety of properties, including herbicide tolerance and insect resistance through the expression of insecticidal proteins produced by the bacterium, *Bacillus thuringiensis* (Bt). In the United States, transgenic corn, cotton and soybeans have been widely adopted (Wechsler and Fernandez-Cornejo, 2016).

Prior to the use of Bt corn in the USA, the lepidopteran, European corn borer, *Ostrinia nubilalis* (Hübner), and the corn rootworm (CRW) beetles, *Diabrotica virgifera virgifera* (LeConte) and *D. barberi* Smith and Lawrence, caused significant damage to corn. Crop losses from European corn borer were estimated at $1 billion/year (Mason et al., 1996). Losses and added production costs from corn rootworms were estimated at >$1 billion/year (Metcalf, 1986). Corn rootworm larval feeding causes losses by reducing root volume and function, and making plants more likely to lodge, reducing yield and increasing control and harvest costs (Gray and Steffey, 1998). Larvae hatch in the soil during the spring larvae emerge as adults in summer, and then adult females lay eggs in cornfields during the fall. Consequently, crop rotation has proven an effective means of managing this pest except in parts of the eastern US Corn Belt where the soybean variant rootworm is common (Levine and Oloumi-Sadeghi, 1996, Levine et al., 2002). CRW-Bt corn replaced soil insecticides and allowed farmers to plant corn after corn during periods of high corn prices.

Genes for several different Bt proteins have been inserted into corn hybrids for both above ground (European corn borer and other lepidopterous pests) and CRW protection (Cullen et al., 2013; DiFonzo, 2016). Protection against European corn borer with these Bt corn hybrids has been highly effective since the commercial release in 1996 (Huang et al., 2011; Tabashnik et al., 2013); however, the situation has been different with western corn rootworm. Bt corn hybrids active against CRW expressing the Cry3Bb1 protein were first commercialized in 2003. Farmers rapidly adopted this CRW-Bt technology throughout the Corn Belt (Wechsler and Fernandez-Cornejo, 2016). Unexpected CRW injury in Bt corn was first documented in 2009 (Ostlie, 2009; Hodgson and Gassmann, 2011), field resistance to Cry3Bb1 in Iowa was confirmed in 2011 (Gassmann et al., 2011), and unexpected injury was found throughout the upper Midwest during 2012. Subsequently, field resistance has been confirmed to one or more of the Bt proteins active against CRW in Iowa, Illinois, Minnesota and Nebraska (Gray, 2012; Gassmann et al., 2014; Wangila et al., 2015; Zukoff et al., 2016).

Because CRW larvae feed below ground, feeding injury is not easily detected by farmers until it is severe. Extension entomologists across the Corn Belt have been seeing increased incidence of Bt resistance, but still do not have good data on how extensive the problem is within the landscape. Confirming the presence of resistance to Bt toxins requires use of a labor-intensive bioassays (Gassmann et al., 2011) which limits the number of locations that can be tested. Farmers typically first report problems when detected, to their seed supplier, and the information often is not communicated to Extension personnel. As a result, Extension has an incomplete picture of the extent of the problem, which has limited their ability states to respond to this emerging problem.

As part of the USDA-NIFA (United States Department of Agriculture – National Institute of Food and Agriculture) Multistate Committees NC205 (Ecology and Management of European Corn Borer and Other Lepidopteran Pests of Corn) and NCCC 46 (Development, Optimization and Delivery of Management Strategies for Corn Rootworm and other Below-Ground Insect Pests of Maize), entomologists from the University of Illinois, Iowa State University, University of Minnesota, and University of Nebraska designed this study to get a better understanding of the problem from the farmers' perspective, as this is critical for improving the effectiveness of resistance management (Andow et al., 2015). Specifically, we investigated how farmers perceived the severity of the problem, their management options, reporting issues, information sources, and their experience with diagnosis and confirmation of the problem. A preliminary report of this project was published by Hodgson et al. (2015). The purpose of this study was to:

1. Better characterize farmers' perceptions of unexpected CRW injury in Bt corn;
2. Identify the kinds of information farmers need/want related to CRW in Bt corn;
3. Explore the role Extension could play in gathering and providing information on CRW in Bt corn.

MATERIALS AND METHODS

We conducted five telephone focus groups with farmers from Illinois, Iowa, Minnesota, and Nebraska who had unexpected CRW

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injury in their Bt corn in at least one field in at least one previous year. The farmers represented a diversity of farm operations, size of operation, and age of farmer. We conducted telephone focus groups because: (a) Telephone focus groups are preferred when potential participants are geographically dispersed; and (b) The focus groups were conducted in March, 2013, and telephone focus groups allowed us to avoid travel problems that can be caused by winter storms. We followed accepted focus group protocol throughout the study (Krueger and Casey, 2009).

All focus group participants had received information related to unexpected CRW injury in Bt corn from Extension, either directly from an extension entomologist, or indirectly through a crop consultant who had contacted a specialist. We do not know the extent to which this connection with Extension or consultants may have biased findings, but farmers seemed candid and outspoken. We used a multi-step recruiting process:

1. Characterized potential participants based on seven criteria: (a) farmed in one of the four participating states; (b) had experienced unexpected damage from CRW in Bt corn; (c) were the decision maker or were involved in decisions about corn production; (d) were not seed dealers; (e) seemed reflective and willing to talk; (f) were not domineering; and (g) represented the diversity in geography, farm size, and farm operation. In addition, only one participant from any one farm operation was allowed.
2. Identified the growers who best fit the selection criteria. Forwarded names and contact information of willing participants to a professional focus group facilitator.
3. Planned five telephone focus groups between March 13 and March 26, 2013; three in the evening and two in the afternoon to accommodate different participant schedules. All calls were hosted by the University of Minnesota call center.
4. Facilitator personally invited growers from the pool of names, by either phone or email, using predetermined talking points to assure consistency in the recruiting process. Facilitator explained how their name was obtained, reviewed the study, reviewed the Institutional Review Board protocol, explained the incentives, and asked which of the allotted times would work best for them. As incentives, participants were offered $50, a chance to hear how other farmers are thinking about CRW issues, and a summary of what was learned from the groups.
5. Scheduled up to five people in each focus group. Each focus group contained participants from at least two states.
6. Upon agreeing to participate, facilitator sent a confirmation letter through the US postal service, email, or both, depending on participant preference. The letter included the toll-free phone number to call and an access code.
7. Made a “reminder phone call” to each person the day before or the day of their scheduled focus group. Only one invited participant did not participate.

The structure of CRW telephone focus groups followed standard focus group methods (Krueger and Casey, 2009):

Address questions raised during the conversation includes:

1. Question 1. How did you become aware of the problem in your field?
2. Question 2. How big a concern is unexpected CRW damage to you in your operation? Probe: Do you see this as a problem in that field or as a bigger problem?
3. Question 3. When you knew you had damage: What did you decide to do in that field for the next year? What were the primary factors that nudged you toward that decision? Who or what influenced that decision?
4. Question 4. Was there a point when you would have welcomed input from or interaction with Extension? When was that?
5. Question 5. Let’s say extension developed a system where farmers could alert extension to instances of possible CRW resistance in their Bt corn, so extension could get a better understanding of the extent of the problem. What would it take for farmers to voluntarily report unexpected CRW in Bt corn to extension as soon as they are aware of it? What would keep farmers from reporting unexpected CRW damage in Bt corn to extension?

At least two members of the research team moderated each focus group, including the professional facilitator. Each call was digitally recorded. Each call started on time. The length of the calls ranged from one hour to 90 min, depending on the number of questions the growers had. Twenty farmers participated over the five groups (four from IL, five from IA, six from MN, and five from NE), including two farmer seed dealers.

After the completion of each of the first four conference calls, the organizers discussed whether any changes were needed before the next focus group. No changes were implemented. The taped conversations were transcribed before the next focus group, to allow review of the data and refinements in moderating subsequent focus groups. Transcripts were analyzed using the constant comparative method of analysis (Glaser and Strauss, 1967; Krueger and Casey, 2009). The constant comparative method is concerned with generating and suggesting properties and hypotheses about a general phenomenon (Glaser 1965), e.g., the causes, conditions, consequences, etc. of resistance to CRW-Bt corn. It does not attempt to prove the suggested causes or test the suggested hypotheses. The analysis uses three stages. The first is to compare all answers to each question to identify the kinds of answers. The second is to integrate the kinds of answers to each question with each other to create a holistic perspective on the issue. This both simplifies the many and highlights prominent characteristics of the answers. The third is to discover the underlying uniformities in the data and identifying the smaller set of concepts that illuminate these uniformities.

Because of the types of questions asked, the data were analyzed by participant. Individual identifiers (not names) were attached to comments in the focus group transcripts, which allowed creation of individual transcripts to follow one person’s description of their type of damage, how big an issue they saw this, what management decisions they made, what factors influenced those decisions, and who influenced those decisions. Quotes used in the report were edited to improve readability.

RESULTS

Question 1. How did you first become aware of the unexpected corn rootworm (CRW) problem in your field?

Farmers said they first noticed a problem when they observed standability issues, corn that did not look right, uneven, stunted, not healthy, reduced yields, or when a scout or crop consultant alerted them to a problem. The time of detection was usually too late in the year to do anything about it until the next crop season.

Lodged corn was, by far, the first indicator of a problem. Sometimes this problem was obvious: “You could see it out the window of my house, you could see the corn laying over.” Other times the problem was not easy to spot; farmers and/or crop consultants discovered small, hidden circles of lodged corn during scouting or harvest. Three farmers said that when they first realized

they had lodged corn, they went up in an airplane to see the extent of the problem. It is difficult to assess the extent of the problem by walking through fields. As one farmer said, you could be 20 rows away and not spot the problem. One farmer described this discovery:

Around July 20th, I walked in the fields with my [seed] dealer to check on a [CRW Bt] hybrid…. We chop about 1000 acres for corn silage for dairy. We walked in the field and, to our surprise, we found patches that were completely flat. That was our first sign of it. [You] couldn't see anything from the road. The corn was extremely tall. [We] have not had a problem like this in our history. But this [field] has been on corn probably 20 plus years…. When I found this problem, I got up in an airplane the next day. I contacted about eight farmers who had the same issues. They had no idea….

Several farmers said their first sign of a problem was that the corn plants just did not look right, noticing either extreme unevenness early in the season (while driving by the field), tasseling of corn plants that were too short, or that corn in an adjacent field looked much healthier.

I noticed my first rootworm problem last spring. It was alongside a…highway…. The corn was about a foot-and-a-half to two-feet tall and…the stand was perfect. Everything was doing well. But after it got about a foot-and-a-half tall, it stopped growing. As time went on it got to be real uneven and it even started to get smaller in some places…. I did not know if I put the wrong kind of herbicide on it or what I did wrong. It was a Bt corn. After a week or so, it got worse and worse. Finally, I had a crop specialist come in. He started digging up the roots and there were all kinds of rootworms working on the roots…. We had 150 bu yield difference from bean ground….

Some farmers noticed declining yields, but that did not necessarily alert them to a CRW problem. One farmer shared his story of being aware of declining yields for years, asking for input from agronomists, assuming he just needed to find a better hybrid, but not getting really concerned until his corn lodged:

I've had rootworm problems, I guess, for years and didn't know it. This particular field…has been in corn on corn from in the 60s…. We noticed 10 to 12 years ago that the yields were going down and having standability problems. I kept blaming it on the hybrids every year and trying to find a new hybrid, a better hybrid, different genes in it. Two years ago…August, the corn looked good. On a Sunday morning -- We had a 60-mile-an-hour wind during the night; the next morning I drove by and maybe 10% of the field was standing. The rest was flat. I got really concerned then. I had had agronomy people looking at this field for 4 or 5 years and nobody came up with an answer. So when this happened I got hold of the seed company. The agronomist came out and told me it was nematodes. I didn't believe it. So I called another company's agronomist and he kind of agreed. Nobody did any samples. It was just by eye. So I didn't believe him. So I got hold of a retired agronomist who had spent his whole life in the field. He was there about 5 min and he said, "You've got rootworm damage." He showed me that there is a difference between the damage from nematodes and the damage of rootworms.

In most cases, the farmer was the first to be aware that something was wrong. But in some cases, an agronomist alerted the farmer to the issue. For example, a number of farmers said their agronomist "caught it" by digging roots, spotting corn down in circles, or noticing high numbers of beetles.

Question 2. How big a concern is unexpected CRW damage to you in your operation?

Most farmers said unexpected CRW damage is big problem for them, whether it was in one field or across multiple farms. Farmers used terms like "train wreck" and "big mess." Farmers expressed several different concerns, including: (a) CRW increases costs and decreases yields, (b) CRW damage threatens their current farming system (corn monoculture, corn-livestock), (c) the CRW problem seems to be moving quickly and be under-detected, and (d) the solutions and treatments don't consistently work. Many farmers believed that the severity of the problem within fields is quickly escalating, some felt "blindsided;" that the geographic distribution of the problem is increasing rapidly, and that the extent of the problem may be hidden, as mild cases of CRW damage may be going undetected or farmers may be blaming low yields on other factors. Farmers were concerned that the Bt seed technology they relied on was not working the way they expected, that rotating to soybeans is not a foolproof solution anymore, and that there seemed to be "no good tools in the toolbox" to control the problem.

I consider it a huge problem. I think it is more of a problem than most of us realize. Even though we are getting 200-bushels an acre, we could probably be losing 10- or 15- or 20-bushels an acre and not even realizing it…

Several farmers also said this was not only a big issue for their operation, but that it is also a big issue for the corn industry and the US Corn Belt. A farmer who rotated crops said he agreed that it is a big issue for the corn industry, but that on his operation they were still able to manage CRW damage through rotation.

This is certainly an industry-wide problem. I would call it a

Table 1. Changes in management farmers said they would do in response to unexpected corn rootworm injury in their fields.

Change seed
Switch to a SmartStax hybrid
Switch to a Herculex Xtra hybrid
Stop using VT3 in that field or in their operation
Use different Bt traits on different fields
Switch to a hybrid with massive roots
Plant some non-Bt corn or stop using Bt corn
Buy “a few bags” of a different corn variety to evaluate it
Rotate crop schedule so not to have same traits too many years in a row
Use the same seed
Plant VT3 again, but with insecticide
In fields where there isn’t a problem, plant VT3 again
Rotate crops
Rotate to soybeans every third year
Considering rotating to soybean every other year
Rotate to alfalfa
Rotate to 1/3 soybean, 1/3 Herculex Xtra with insecticide, 1/3 VT3 plus insecticide
Apply insecticide
Use conventional insecticide against larvae (e.g., bifenthrin, chlorpyrifos, tefluthrin)
Apply insecticide to all corn, including CRW-Bt corn hybrids
Apply insecticide on continuous corn
Apply insecticide on half my fields of corn following soybean
Increase the rate of soil insecticide
Spray adult beetles to knock down the population in corn
If significant pressure at tasseling, spray even if under threshold
Use conventional insecticide (e.g., methyl parathion, or parathion[1]) with fungicide at tassel
Spray adult beetles to knock down the population in soybean and alfalfa
Rotate insecticides
Use different active ingredients in insecticides
Use different application methods
Other changes in practice
Scout for larvae and beetles
Spray twice to kill volunteer corn in soybeans with herbicide
Improve record keeping to aid in planning; track what was done in each field to support increased rotation of crops, traits, and insecticide treatments

[1]The registration for parathion (= ethyl parathion) has been cancelled.

major Corn Belt issue. We are paying high dollar for high-tech seed that is supposed to control these and they have obviously become resistant. It is the number one devastating pest in the United States for corn production for a reason and it is back.

Question 3. (a) When you knew you had damage, what did you decide to do in that field for the next year? (b) What were the primary factors that nudged you toward your management decision? (c) Who or what influenced your decisions?

In general, the farmers’ tone was that they were going to “be aggressive,” “hit it with everything,” or “throw the book at it.” Farmers considered changing seeds, using the same seeds, rotating crops, applying insecticides, rotating insecticides, other changes in practices, and combinations of several of these (Table 1).

These farmers experienced dramatic yield losses and/or the increased time and trouble of combining lodged corn. They don’t want these events to happen again, so they will do what they can to control the problem. Several farmers said they were “scared” by this issue, because, for example, it has the potential to be a long-term financial liability. The factors that influence the population dynamics of the insect, and whether it will cause substantial losses, are complicated. The

Table 2. Stages in how farmers deal with unexpected corn rootworm injury and who they typically involve.

Stage	Typically who is involved
Awareness of problem	Farmer Crop consultant (typically hired by farmer)
Diagnosis of problem	Farmer and some combination of: Crop consultant/agronomist hired by farmer Seed dealer/seed company Ag suppler/Chemical rep Local/county Extension (non-specialist in entomology)
Confirmation of diagnosis	Regional or state Extension specialist in entomology
Recommendations	Some combination of: Hired crop consultant/agronomist Seed dealer/Seed company Ag suppler/Chemical rep Regional or state Extension specialist in entomology

interactions of factors, including soil types, hybrid choices, previous crops, weather, insecticides, and insect biology, make the damage difficult to predict. Likewise, because many of these factors are out of their control, the pay-off for the pest management decisions that they must make is uncertain.

Farmers indicated that the severity/ extensiveness of their unexpected root injury suggested that they should manage the problem on a single field or encompassing their entire farm. They tended to see this as a field issue if: (a) injury seemed isolated to a field with a unique characteristic (e.g., flood prone), (b) there were no signs of problems in other fields, and (c) other farmers in the area did not seem to be having problems. They tended to see this as a farm issue if: (a) the injury was extensive, in and across fields, (b) the injury was easily attributed to the seed used (e.g., three kinds of CRW Bt corn were planted in adjacent fields on the same day, but only one had injury), or (c) they had seen injury on neighboring farms.

Farmers varied in their stated intention to use crop rotation as a way of managing unexpected root injury. Although most farmers recognized that crop rotation was an effective management tool, there were several reasons they cited for not rotating a field: (a) they have always been a continuous corn operation, (b) they need corn for livestock, (c) they do not want to haul corn silage too far, (d) the high price of corn, (e) they do not want to waste nitrogen from manure on rotation crops, (f) they have a rotation schedule where that field does not get rotated that year (e.g., 2/3 corn, 1/3 soybeans), (g) they want to plant only corn in their irrigated fields, (h) the soil pH is wrong for the rotation crops (e.g., noting iron chlorosis in soybean), (i) the soil type is wrong for the rotation crops, (j) the field is flood-prone and high risk for making soybeans hard to harvest, (k) a few farmers believed that rotation was no longer effective, and (l) the land owner only allows corn on the land. If the farmers planned to continue with corn, they focused on how to minimize the risk of CRW injury through proper variety selection, how to kill larval populations with insecticide to reduce injury to roots, and how to kill adult populations so they cannot lay eggs.

There appeared to be four stages in dealing with unexpected CRW injury where other people are involved: awareness of a problem, diagnosis, confirmation, and soliciting recommendations (Table 2). Many farmers discovered the problem themselves, and sometimes crop consultants alerted farmers to a problem. Once aware of a problem, farmers first sought help diagnosing the problem from their seed dealer, chemical rep, and/or crop consultant. In all these cases, farmers (or their consultants) tapped state or regional Extension entomology specialists to confirm the diagnosis and provide advice. Farmers gathered recommendations for how to proceed from independent consultants, input suppliers, and extension.

Crop consultant

Different farmers used different terms to refer to consultants, including crop consultants, scouts, and agronomists. They represented three different employment arrangements: (a) hired by the farmer and independent, (b) hired by the farmer and an input supplier, and (c) not hired by the farmer, employed by and representing an input supplier. Some farmers believe they get more unbiased information with an independent consultant who has nothing to sell but his service. The

Box 1. Example of the influence of seed companies.

One farmer shared his experience of working through the problem with his seed company. His story paints a picture of a seed company with a heavy hand.

I will be honest here. I had a trait failure. I had support from the seed company, to let's say, keep my seed sales with the company and to keep it hush, hush. I am not going to say the amount I got because that is all supposed to be confidential but I have gotten some kickback to keep me in-house. They have pretty much bought off everybody, and say, "Hey, we will give you a reduced price on seed and this and this and this and we will go another year." What they have done is bought themselves another year.

[Moderator: When they approach you with this, they ask you to keep it hush, hush?]

They are not asking me to keep it hush, hush. But they are asking me to keep the amount confidential. That is their game.

[Moderator: So that would keep people from reporting.]

Yes. What am I supposed to say? I have a half-million-dollar seed bill and they are going to take it down a certain amount. I know [the company] doesn't have anything too much better. I did go and buy some Herculex only product from a different company but I didn't have a lot of choice. They kind of locked me in. But I also know that I put them on the soybeans and I put them on the corn that I was going to keep, so they got two thirds of my acres. They instantly lost a third of mine by going to a different company and a different mode of action. And not a SmartStax pyramid because the way I have worked through it, I am already overkilling the situation by offering to put an insecticide on a trait package. When you buy a trait package, I feel that the trait package should control the bug. You should not need any other additional support. But I also know that our pressure is extreme. I am trying to work my way through the system as an operation so I can continue making money. It is a very, very high stakes, high profit game.

You need seed every year, so they have given a credit on your account. The only way you can get it is to go back through your original dealer. "This is what we are going to give you credits for." I know various options. "We are going to give you field spraying. We are going to give you seed. We are going to give you soybean seed…. But you have to do these three things to get it. You have to rotate the beans. You have to spray beetle bomb at tassel time. And you have to plant a SmartStax…" They have a system about it because they are not just going to hand out so many dollars an acre to someone who is at least not going to try to correct the problem. They have the checkbook.

use of independent consultants is more prevalent in Nebraska and Minnesota than in Iowa and Illinois (Wright et al., 1997). The crop consultants were well connected with extension, accessing extension on behalf of their clients, acting as conduits for information between extension and growers. These consultants provided triage, bringing Extension specialists in for the most severe or complicated cases.

Seed dealers/chemical representatives/agricultural input suppliers

After hired consultants, farmers called people who sold them their inputs for advice. They wanted them to diagnose and troubleshoot the problem, and expected them to help. Although farmers often gathered information from a variety of sources, they had certain sources they trusted more. They had confidence in people they had worked with a long time and were "sharp." While farmers often go to input suppliers for recommendations, some questioned the quality of the advice given "when there is a dime to be made (Box 1)."

I went to the seed company first because to me it appeared that they sold me something that, the technology had failed on. I guess that is where I start.

Our chemical representative is an agronomist. He comes out and recommends different varieties. This year he is recommending insecticide on everything, whether it is right or wrong, I don't know, but he wants you to use insecticide. He thinks it is…cheap insurance.

[Who influenced your decision?] My agronomist and my fertilizer guy here in town. He is sharp… I have all the faith in these guys, the crop specialists. I think they know more than the people in the [local] Extension office…. Just because of history…. He is very intelligent and he has been working with corn for 40 years himself. I have all the respect in the world for him. He will get to the bottom of a problem quicker than anyone that I know of.

Although farmers relied heavily on input suppliers, several farmers said their CRW problem went undiagnosed for years because these people could not identify the problem, or had misdiagnosed the problem. Several farmers said suppliers tend to blame problems on something other than their own product. For example, the seed dealer saying it is a chemical issue. Then the chemical representative saying it is a seed issue. One farmer said CRW was misdiagnosed as nematodes. Another said that suppliers tended to blame the problem on something the farmer did. Farmers were particularly frustrated with seed dealers and seed companies.

Last year we had a stand that just wasn't coming up…. The seed salesman blamed it on the herbicide we used. Then we had the herbicide people come out and they blamed it on the hybrid. So by having the university or Extension person out there, you get the unbiased party. Then maybe you can get a straight answer.

When I first saw this problem, I went to the seed technology company. … the [seed technology company] people said it was just overpressure in terms of the rootworm population. But when we got the results back

that were sent to Iowa State and then it was crosschecked through plots down in Champaign, IL, they were 90% resistant to the gene. I felt blindsided…. I want feedback. I want to know what is going on in the surrounding area.

Extension

Because of the way we recruited the focus group participants, all these farmers had received input from Extension, either directly or indirectly. The farmers (or their consultants) tended to bypass local (county) Extension, going directly to a regional or state entomology specialist for confirmation of the problem and advice on how to proceed.[1] Farmers and consultants went to entomologists when they needed a higher level of expertise. Farmers appreciated the independent, unbiased input and knowledge of regional- and state-level Extension entomologists.

We got [the regional entomologist] to come out. They set traps and confirmed we had resistance. We worked with the university. They were very helpful.

By the time we had the major breakdown, the University of Illinois people were in on it. I got their input and thoughts. That is how I arrived at the things that I did. They thought the insecticide was overkill, but they didn't argue with me doing it.

I worked with two or three scouts. One of the scouts is more prone to consult the University of Nebraska. So the University of Nebraska and a scout went out there, looked at the situation, and then did the recommendations from there.

A number of farmers said their local extension offices had been through budget cuts and that they no longer thought of local extension as a source of help. Several farmers said they view local extension agents as equivalent to crop consultants, and because they already have crop consultants, they do not need local extension.

I don't know how much help they [local Extension] can give you right out in the field. Most of the seed companies, they will send their agronomists out too when there is a problem. I don't know if that is the best opinion to have either. It would be nice if you had someone who was easy to contact. But I don't think our local Extension office is that active. Any time we have contacted them in the past it is usually several days before somebody responds.

I am sorry to say that in Illinois they gutted Extension. I can't even tell you who the guy is to deal with crops in my area.

Question 4. Was there a point when you would have welcomed input from or interaction with Extension?

All these farmers had input from Extension, either directly or indirectly through a consultant, to confirm the problem and to get recommendations. Farmers suggested that extension put more emphasis on: Increasing awareness of the problem and assessing the extent of the problem and being an unbiased source of information.

These farmers assumed they would not have CRW pest problems because they were using CRW-Bt corn. They were not looking for CRW problems because they were not aware that CRW injury could be an issue. They said farmers need to know that unexpected CRW injury does occur, that they are not alone and others also have this problem. Specifically, farmers need to know the symptoms of CRW root injury, how to diagnose CRW root injury, what can be done to prevent/ minimize it, and how to treat it.

It took them [seed companies] way too long to come back and say what the extent of the problem is…. So we are all sitting out here thinking it is just our problem. No one else is running into it…so we think that maybe it is localized.

When I did find that I had it, it was out of control. My scout is the seed dealer too, and, of course, he is reluctant to blame the seed company. We got the buck passed. But the Extension people could be more on top of it, being proactive and maybe put bulletins out… that you might be cautious of planting triple stack corn because it is not what it is supposed to be.

Some farmers said Extension's role should be to get their "arms around the issue," to conduct research, and to be an unbiased source of information. Farmers want an independent assessment of what is happening. They don't feel they can trust the information they get from seed companies. They feel they have little power and little recourse. Some farmers would like a third party to help hold seed companies accountable.

I don't know how a little pimple on an elephant's you know what out here can compete with big companies. Long term, we need to get…the university or somebody in extension to get their arms around this. Then we might have a little more clout than one-on-one…with the [big seed companies].

[I would like] an independent assessment of what is going on out there…. Commercial seed producers…are not apt to want information about their products or their traits distributed… saying that they are not working. That is going to impact their sales.

Farmers believed that extension does not have the resources needed to respond to individual cases of unexpected CRW injury. Regarding a reporting system, farmers seemed to assume that Extension would visit

[1] Extension in three of the four study states restructured during the 1990s and 2000s into a regional model, so that few local county extension offices retained entomology specialists.

each farm to confirm a CRW problem and provide advice.

But as far as Extension being out there, if they want to come look, I have no problem with it. But it really isn't their job to be out scouting people's fields on a per person individual basis unless there is something they want to see out there. They are spread too thin.

Question 5. What would it take for farmers to voluntarily report unexpected CRW injury in Bt corn to Extension as soon as they are aware of it?

Farmers said they would report unexpected injury if they received something valuable in return, such as personal confirmation of the diagnosis and advice, access to information about the extent of the problem and/or an ability to hold seed companies accountable.

Most farmers said if they reported unexpected CRW injury, they would expect a confirmatory diagnosis and personal advice. They believed that CRW issues can be difficult to diagnose and need to be confirmed. They questioned the accuracy of having farmers self-report.

I don't want to waste my time. If I don't think I am getting any feedback or something to do me good, I guess I have other things to do. That is kind of a mean way to say that.

Farmers were interested in learning how widespread the CRW problem is, locally and throughout the Corn Belt. They don't have this information and feel like they are "in the dark."

I would like to see a map of the Corn Belt; tell us where the problem is and how it is moving. And then be able to scan down in and see what is going on. But it is going to be hard to get that information.

One farmer suggested that everyone would report unexpected damage if reporting would get seed companies to guarantee their seed.

I was really disappointed with the seed companies as a whole. They charge you quite a bit of money for that trait. Then when it fails, they run and bail. They absolutely don't stand behind that, not one penny's worth. I just really think that was the saddest part of that whole experience. If we had reported it to Extension … if that would get them to honor their seed, we would all report it in a heartbeat. When I bought my seed, they looked across the table and said, "If our rootworm trait doesn't work, there are no payments from us on it." That is what they said. They don't warranty it, period. Not a bit.

Some farmers suggested that instead of relying on farmers to report damage, a reporting system should be designed based on input from agricultural professionals, such as crop consultants and retailers. The advantages of this system are: (a) Extension would get more accurate and timely information because these people know how to diagnose CRW damage; (b) It builds on existing relationships that many consultants already have with extension, (c) There would be no need to provide personalized responses to confirm diagnosis, and overwhelm Extension's resources. The disadvantage of this system is that some input suppliers may not be willing to allow reporting because they want to limit the flow of information.

All of the farmers said they would allow their consultants to report unexpected CRW injury to extension. However, they thought that other farmers might not report unexpected injury. They believed that many of their neighbors have a problem but do not know it. Several farmers thought one barrier to reporting is that the seed companies do not want the information to get out. They believe this because they were asked to keep quiet about the problem. Third, farmers are increasingly sensitive about data privacy and the ramification of information "falling into the wrong hands," especially government regulatory agencies that might audit them and anti-GMO organizations. Fourth, they suggested that other farmers might be ashamed to admit they had a CRW problem, particularly if they think they are the only one who has it, because it might hurt their image as a farmer. Several farmers said having CRW problems was "my fault," that they "blamed" themselves. Fifth, they said they probably would not report problems if they had not followed their refuge requirement in the technology agreement. Three farmers in our focus groups probably were not following the refuge requirements, and another said the requirements were so complicated, that even though he was trying to follow the rules he was out of compliance. Sixth, reporting unexpected injury would be inhibited by perception that reporting would lead to time-consuming paperwork or greater commitments, or that it would take too long to figure out who to call or contact. Finally, it is also possible that farmers believe that reporting would jeopardize potential reimbursement from seed companies for performance problems.

Most farmers don't even go in their fields. And if they do go in their fields, it is with their seed representative or their chemical company rep. Those guys are going to keep it pretty quiet within their companies and not share it. We all know the seed companies do not want the EPA knowing what is going on with rootworm damage…. The seed companies or coops don't want to say they are having a problem with the products we sold them…. They will keep it fairly quiet.

In my area, [two companies] …are trying to get all the yield monitor information from all the growers. And the growers are not wanting that because once those companies have that information they own it. As farmers, if you are using…the new Field View … that is a problem.

They [farmers] don't trust anybody…. [Seed companies] are offering to print yield maps for growers, but once the information is given to those companies, they own it.

DISCUSSION

The purpose of a focus group is to identify themes associated with the responses to questions of interest and not to gather quantitative information about what proportion of farmers have specific beliefs, attitudes, etc. (Krueger and Casey 2009). As more focus groups are conducted, the responses become repetitive of earlier groups, and as repetition increases, it becomes more likely that nearly all of the possible responses have been recorded. We began to hear considerable repetition by the fourth focus group, and the fifth focus group provided few new responses. As our participants were all farmers who had experienced unexpected CRW injury, we believe that our focus groups have captured nearly all possible responses. In the future, it would be possible to use these responses to develop a quantitative survey of farmer beliefs, attitudes, etc., to understand how Midwest US corn farmers think about the CRW resistance problem.

Recognition of and attitudes about CRW resistance

Farmers typically recognize that there was a resistance problem by crop symptoms, such as lodging, stunted growth, or yield losses. Although they often detected symptoms on their own, many relied on agricultural professionals to inform them. After becoming aware of the problem, farmers sought a diagnosis, often having difficulty obtaining a reliable one. Farmers then looked for sources to confirm the diagnosis, and only after obtaining confirmation, did they solicit recommendations for what to do. All of these processes take time, so that farmers typically did not have recommendations until it was too late to do anything about it during that year. Consequently, farmers felt alone, scared and blind-sided by the problem and wanted aggressively to manage it, typically using multiple tactics.

This suggests at least two challenges for public extension. Farmers need help with diagnosis and confirmation. Generally, however, extension does not have the resources to attend to all of these needs. So if extension could coordinate a system to ensure rapid and correct diagnosis and confirmation, farmers would benefit. This might involve training crop consultants to diagnose and/or confirm resistance. Second, farmers often did not know what to do to manage the resistance problem. For example, some wanted to do too much would change Bt varieties and use soil insecticides. Others were uncertain and thought that rotation would not work. Extension materials that address these concerns could help farmers determine their next steps.

The results also indicate challenges for agricultural industries. Farmers do not trust their input providers to give them unbiased diagnoses of root injury, and feel alienated from the biotech industry. The seed and agrochemical input industries may need to train their front line personnel to provide accurate evaluations of root injury, as some farmers do not believe they are credible. The biotech industry has a larger challenge. Farmers understand that the industry pursues its own interests and that these are not the same as theirs. It will take considerable efforts to change this understanding to the mutual benefit of both parties.

Scope of the problem

The focus groups revealed that obtaining information for public use about the extent of unexpected CRW injury and resistance to CRW-Bt corn would be challenging. According these farmers, the problem is often hidden because farmers do not look for injury and/or do not know how to look for, identify and confirm it. Information about the problem might nudge farmers to look more purposefully for this injury. However, farmers are unlikely to report CRW injury if the perceived barriers to reporting outweigh the perceived incentives. For these farmers, the barriers were emotional barriers, including being unsure who to trust, fear that reporting will be time-consuming, and embarrassment or shame that they have done something wrong. The stated incentive for reporting is that reporting the information gives them access to credible advice. Most did not automatically recognize the broader benefits of reporting injury (e.g., a means of holding seed companies accountable, stimulating independent third party research, and other societal goods). Extension probably needs to be more explicit about these broader benefits. In addition, based on the experiences of these farmers, it appears that the seed companies are inhibiting communication about the issue, e.g., farmers are asked to not talk about resistance and compensation packages are confidential.

However, identifying and diagnosing unexpected CRW injury can be difficult for untrained farmers. They need to know when and where to check roots, how many roots to check, how to score the injury, and how to interpret the scores. Thus, a reporting system based on input from agricultural professionals, such as crop consultants and input suppliers, may be more effective. Advantages are that extension could have more confidence in the accuracy of the data, it builds on existing relationships between extension and crop consultants, and it is less likely to overload extension entomologists. The disadvantages are that professionals associated with seed companies or other input providers may not be willing to participate, and crop consultants are not uniformly available across the U.S. Corn Belt.

If Extension decides to develop a public reporting system, it should be clear about who is gathering the information and why, how the information will be used and who has access to the information. It should be framed as an effort by regional- and state-level entomologists (using their names) rather than by an institution, extension or the land grant universities, because people are more willing to participate if personally invited by someone they trust (Putnam, 2001; Theiss-Morse and Hibbing, 2005; Snyder and Omoto, 2008). The incentives must be obvious and strategies to reduce the emotional barriers indicated above should be included.

An increasingly important contemporary issue in agricultural development is about control over scientific information available from farms (Thatcher, 2015). The focus groups revealed that Midwest US farmers are concerned about corporate control over information about resistance, which is a public agricultural problem. This control makes it difficult for independent researchers and land-grant scientists to conduct research and keep updated about this problem. More generally, farmers are concerned that the seed company requirements to report information about their yields and production practices gives the company greater control over their operations. Perhaps a public policy discussion about these concerns is needed to ensure that farmers retain sufficient control over data from their operations in the future.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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