Iowa Pest Resistance Management Plan

Version 1

Resistance management is the effort to slow the development of pest adaptation to chemical, genetic and agronomic control practices; foster methods of early, resistance detection; and mitigate resistance as it arises.

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Introduction

Pest resistance management (PRM) is the effort to slow the evolution of pest adaptation to chemical, genetic, and agronomic control practices. The PRM efforts gained momentum in Iowa following the January 2015 meeting entitled, "Resistance Management: Whose Problem and Whose Job," which was led by the Iowa Department of Agriculture and Land Stewardship (IDALS) and Iowa State University (ISU) College of Agriculture and Life Sciences (CALS). The January 2015 meeting resulted in a call for developing a statewide, voluntary, Iowa Pest Resistance Management Plan (IPRMP) in 2016, which would be coordinated by IDALS with broad participation from all sectors of Iowa agriculture. It was also agreed that ISU/CALS would help facilitate the effort. The meeting summary report can be accessed at http://www.ipm.iastate.edu/files/iprmp/resistance-meeting-summary-report.pdf.

IPRMP Conceptual Framework and Work Plan

At a subsequent June 2015 meeting with Iowa's Agricultural Strategic Thinkers Acting Together Effectively (AgState) team, a group of representatives from across Iowa's agricultural community, formed a taskforce to establish a Conceptual Framework for the IPRMP. The taskforce included representatives from the Agribusiness Association of Iowa (AAI), Agricultural Biotechnology Stewardship Technical Committee (ABSTC), Iowa Corn Growers Association (ICGA), the Iowa Chapter of the American Society of Farm Managers and Rural Appraisers (ASFMRA), Iowa Farm Bureau Federation (IFBF), Iowa Independent Crop Consultants Association, Iowa Institute for Cooperatives (IIC), Iowa Soybean Association (ISA), Pesticide Resistance Action Committees (RACs), Practical Farmers of Iowa (PFI), and the Soil and Water Conservation Society.

The framework (see http://www.ipm.iastate.edu/files/iprmp/resistance-management-conceptual-framework.pdf) was approved by AgState on December 19, 2015, with a request that a work plan be developed for preparing Version 1.0 of the IPRMP. Following the meeting, IDALS and ISU/CALS facilitated a cross-organizational team of 22 individuals to prepare the IPRMP work plan; the work plan was presented and approved at the March 28, 2016, AgState meeting. AgState established a goal of preparing a draft of Version 1.0 of the IPRMP for review by the end of September 2016. Subsequently, three committees comprised of approximately 39 individuals from Iowa organizations, including AAI, ABSTC, ICGA, IFBF, IIC, the Iowa Chapter of the ASFMRA, ISA, Pesticide RACs, IDALS and ISU/CALS were created to draft the governance, communication and outreach, and pilot projects chapters of the plan.

Features of the IPRMP

The IPRMP reflects the primary goal expressed in the Conceptual Framework: "to document and promote holistic and integrated management solutions that will effectively and sustainably control pests, and postpone or delay resistance development, foster methods of early detection, and then mitigate, to the extent possible, the spread of pest resistance." The plan also reflects the key components of the logic model presented in the framework. In the logic model, inputs from agricultural industries, farmers, farm managers, landowners and the public and will include funding, outreach, and in-kind contributions. Human behaviors will play an important role, including the identification of champions and communities to lead pilot project efforts. These inputs and human behaviors will lead to outputs, such as improved decision making, use of new technologies, and land rent leases with PRM plans, among others. Finally, all these efforts will contribute to outcomes that could include a minimum of new cases of resistance evolution, sustainable pest management, and reduced economic impact of pests on farming profits, among others. As noted in the logic model, changes in individual and community behaviors will be key to successful PRM. In this regard, economic factors will create challenges to changing opinions and behavior, and the Conceptual Framework recognizes likely increased short-term costs in PRM that must be justified with tangible benefits. The framework notes that incentives, financing and lease agreements can play a role in shaping the economic landscape for farmers. Incentives may include support to help landowners, especially absentee landowners, and farm operators, especially those on short-term leases, understand the rationale and importance of investing in short- and long-term PRM strategies. Economic benefits will help promote and incentive voluntary, long-term, sustainable pest management approaches for people and organizations, in addition to the benefit of preventing the need for potentially restrictive PRM regulations.

The Conceptual Framework also recognized that building and supporting connections within communities and identifying leaders within communities will be important factors in promoting and sustaining changes in PRM decision-making. This community-based approach needs to address farmers' willingness to coordinate PRM when considering options for addressing resistance issues for pests that can move into neighbor's fields. As explained in detail in the Conceptual Framework, a community approach will yield maximum benefits to members of the community in situations where farmers' pest management practices can lead to resistance spillover on neighboring farmer operations.

As initial PRM efforts are implemented, based on the best available scientific knowledge, implementation and results should be monitored and management efforts adapted as needed to increase and build on established successes. To help support individuals and communities, communication and outreach on the IPRMP's approaches and accomplishments will need to be timely, objective, consistent, and forward looking. Governance of the IPRMP by leaders that represent the diverse organizations in Iowa's agricultural community is essential to ensure efficient and effective statewide implementation of the effort and to ensure Iowa's efforts are recognized and reflected in related regional and national programs and initiatives.

Overview of the Plan

Consistent with the features of the logic model, the IPRMP includes chapters that address governance, the state of the science, pilot projects and communication and outreach.

An adaptive management approach to the IPRMP will be overseen and implemented by a program manager and three Operating Committees (Science, Pilot Projects, and Communication and Outreach), with support from an accountability coordinator. The program manager and committees will also receive input from an advisory council composed of representatives across organizations participating in the IPRMP. This governance approach will ensure advancement of the IPRMP is driven by those working across sectors in Iowa agriculture and provide a platform to support Iowa communities engaged in PRM practices.

The program manager will work with the Operating Committees to establish a process to identify key influencers and stakeholders. The Operating Committees will address plan metrics and stages of plan development with the program manager. The Operating Committees will also support the implementation, delivery and communication of early success from locally driven pilot projects. As acceptance of the message and adoption of PRM practices increase, stages of plan development will evolve based on recommendations from the Operating Committees and advisers to the program manager. The Pilot Projects Committee will have a key role in the assessment of PRM practices. The efforts of the Communication and Outreach Committee will help expand the scale of the IPRMP over time. A strong, consistent message that captures the goals and expected outcomes of the IPRMP is crucial to stages of community engagement and long-term adoption of PRM practices.

Growth and Support of Pest Resistance Management in Iowa Communities

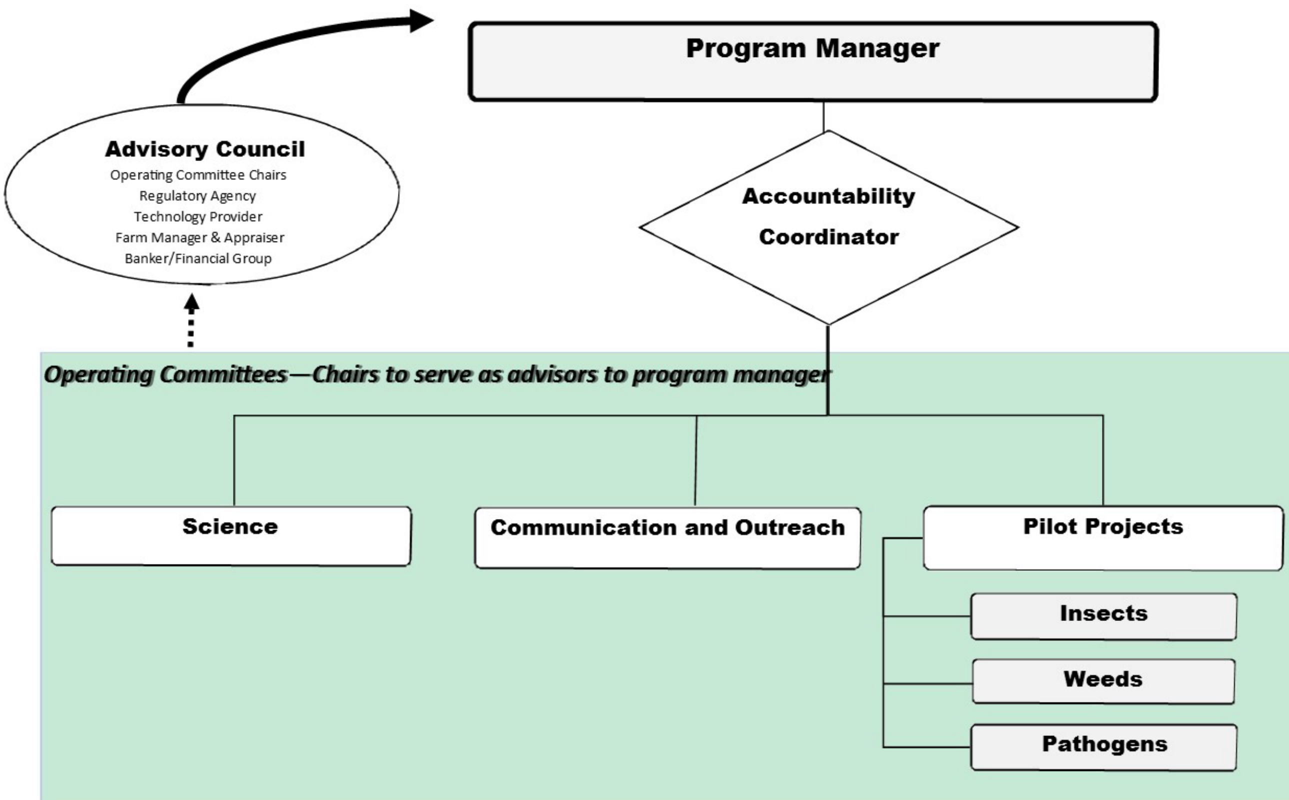
On-going growth and support of Iowa communities will be a focal issue for the program manager, advisers and the Operating Committees. With the goal from the Conceptual Framework, “to postpone or delay resistance, foster methods of early detection, and mitigate resistance as it arises,” some hesitation from individuals due to the complexity and scale of the problem is to be expected. As PRM communities emerge around the state, it will be critical to measure and communicate the results of these efforts to maintain and build momentum. This will be especially critical for those scenarios where the beneficial outcomes are greater than the sum of individual farmer benefits.

Governance

Governance describes the organization of the IPRMP and the foundation that will support all other components of the effort. This chapter describes the structure, membership and roles and responsibilities of the governing bodies of the IPRMP, including the roles of the program manager, accountability coordinator, advisers, and Operating Committees.

Structure and Membership

The proposed structure of the governing bodies of the IPRMP is depicted in this illustration and in the description below.



Program Manager

The program manager will be responsible for leading the IPRMP and will have day to day oversight over the entire effort so that critical, time-sensitive decisions can be made. This program manager will work with a groups of advisers and the Operating Committees to formulate approaches, review progress and make adjustments to plan implementation.

The program manager will be hired by ISU and will be accountable to a small oversight team of senior representatives from ISU, IDALS, and those organizations providing financial resources to the plan.

Accountability Coordinator

The accountability coordinator will provide support for the program manager, advisers, and Committees. The accountability coordinator will be an ISU employee.

Advisory Council to the Program Manager

An advisory council will meet with the program manager on a periodic basis to facilitate communication and feedback to and from the program manager, operating committees and to the advisers' organizations. The advisory council would include, but would not be limited to, representatives from

1. Chairs of the Operating Committees: Science, Communication and Outreach, and Pilot Projects
2. Champions of Pilot Projects
3. Iowa Farmer and Commodity Organizations
4. AAI
5. Technology Providers (e.g., ABSTC and RAC organizations)
6. Iowa Chapter of ASFMRA
7. Financial Community Organizations
8. ISU and IDALS
9. Federal Agencies (Environmental Protection Agency [EPA] and United States Department of Agriculture [USDA])

Operating Committees

1. Operating Committees will include Science, Pilot Projects, and Communication and Outreach.
2. Current chairs and members of Operating Committees (see attached appendix).

Roles and Responsibilities

Program Manager

Roles and responsibilities of the program manager will include setting strategic direction, approving tactical goals and objectives, and evaluating proposed work plans and workgroups from the Operating Committees (see below). The program manager will also review and approve budgets and annual progress reports. The program manager will help partner organizations in the IPRMP obtain support to implement the IPMRP and maintain coordination with regional and national organizations addressing PRM. The program manager will update AgState on progress once a year.

The program manager will work closely with the Science, Pilot Projects, and Communication and Outreach Committees. These committees will be responsible for executing (1) state of the science updates; (2) pilot projects for specific pests addressing issues including, but not limited to, data management, monitoring, farmer and landowner recruitment, adaptive management, and identification of knowledge gaps; and (3) communication and outreach of the IPRMP.

Specific responsibilities of the program manager include:

- Lead the IPRMP within Iowa
    - Establish objectives and set timelines for the Operating Committees to meet goals based on agreed metrics and available resources
    - Monitor size and scope of pilot projects to ensure the probability of success is high
    - Broaden, reduce or alter strategic goals as needed
    - Obtain public/private funds or resources to complete approved work plans
- Manage plan implementation
    - Provide feedback on tactical goals and objectives developed by the three Operating Committees' work plans
    - Consider recommendations to broaden, reduce or alter work plans based on progress and challenges
    - Remove barriers to implementation
    - With participating IPRMP organizations, identify and consider factors, such as timing of incentives, agricultural financing, lease agreements, availability of economic tools, and the influence of other economic factors

- Collaborate with regional and national counterparts and stakeholders to ensure continuity in related resistance management initiatives

Accountability Coordinator

The accountability coordinator will provide support for the program manager and committees and have the primary responsibility for integrating and tracking inputs, outputs, and outcomes consistent with the plan's logic model and work plans implemented by the three committees.

The coordinator will provide regular reports to the program manager. This person will provide full time, day to day support to IPRMP implementation.

Advisory Council to the Program Manager

The advisers to the program manager will provide input during strategic planning for implementation of the IPRMP. Advisers will serve as the communication conduit between the program manager and Operating Committees and other stakeholder organizations in Iowa.

Operating Committees

The Science, Pilot Projects, and Communication and Outreach Committees will be responsible for tactical implementation of the IPRMP, and through the committee chairs, ensure efforts are in concert with meeting the strategic goals and objectives.

The committees, through their respective chairs and the program manager, and with the support of the accountability coordinator, will be responsible for drafting committee mission statements and proposed membership. They will also develop yearly work plans, budgets, and annual reports, which will be based on the logic model outlined in the Conceptual Framework. The program manager will be responsible for approving work plans and reports.

State of the Science

Overview

Pest resistance management is the effort to slow the development of pest adaptation to chemical, genetic, and agronomic control practices. To facilitate the development of an IPRMP, it is essential to understand the science, technology, and management solutions that are available to combat pest resistance and the factors that influence the adoption of practices by farmers. The State of the Science Chapter summarizes the current PRM options and the perceived and actual costs, and short- and long-term benefits of PRM practices.

The State of the Science Chapter serves as a foundation for the IPRMP and the proposed Pilot Projects Chapter. The chapter draws upon previous documents, and references cited therein, that were prepared to support the initial statewide discussions on PRM (see http://www.ipm.iastate.edu/files/iprmp/resistance-meeting-background-materials.pdf and http://www.ipm.iastate.edu/files/iprmp/resistance-management-conceptual-framework.pdf).

There are similarities in resistance evolution and management between insects, weeds, and pathogens. In general, resistance builds over time when the same pest management techniques are used repetitively. When resistance is caught early, it is easier to remedy, and strategies for preventing resistance evolution include the use of a diverse combination of crop rotations; effective use of pesticides with different sites of action; seed with stacked native and biotechnology-derived traits that provide effective control of the target pest(s); and mechanical controls in the context of diligent use of integrated pest management (IPM). This IPM should include scouting to assess pest pressures and monitoring for early detection of poorly performing pest management technologies.

Despite these similarities, optimal strategies for prevention and management of resistance vary depending on the type of insect, weed, or pathogen. Generally, PRM can be relatively straightforward in situations where resistant pests are somewhat sedentary and less likely to infest neighboring farm fields. In cases where a resistant pest is more mobile and can infest neighboring fields, farmers must cooperate with each other and other members of the community, including absentee landowners and financial institutions, to ensure longer-term productivity and profitability associated with the delayed evolution of pesticide resistance.

While employing PRM practices is likely to increase input costs, time commitments and production complexity in the near term, long-term productivity and profitability will also likely be higher due to the reduced rate of pest resistance evolution and more effective pest management. Thus the socioeconomic considerations of PRM will also be reviewed in this chapter.

Insect Resistance

Insect pests have repeatedly demonstrated an ability to evolve resistance to insecticides, including insecticidal proteins derived from the bacterium *Bacillus thuringiensis* (Bt) that are used in genetically modified crops.

Western corn rootworm (WCR, *Diabrotica virgifera virgifera*) is among the most serious pests of corn in North America, and Bt corn is currently used to manage this pest.[1] Beginning in 2009, severe feeding injury to single-trait Cry3Bb1 corn was observed in Iowa and was attributed to Bt resistance.[2] On average, the feeding injury translated to an average corn yield loss of 17%.[3] Since then, resistance to mCry3A was reported as well as cross resistance between Cry3Bb1 and mCry3A toxins. Once Bt resistance develops in fields where the same management practices have been used repeatedly[2], movement of Bt-resistant rootworm adults can lead to the presence of resistant WCR in fields without a history of continuous use of the same Bt trait.[4] Thus, there is the potential for resistance problems to affect farmers in the broader landscape if appropriate actions are not taken.

Pests of soybean production in Iowa include the soybean aphid (*Aphis glycines*), two-spotted spider mite (*Tetranychus urticae*) and bean leaf beetle (*Cerotoma trifurcata*). Resistance to conventional insecticides by soybean aphid has yet to be documented in Iowa. However, extensive reliance on conventional methods to manage this pest, including neonicotinoid seed treatments and several classes of foliar insecticides, are placing intense selective pressure that could result in resistance.[5] Recent failures of foliar insecticide treatments in southwestern Minnesota may be a harbinger of resistance development. The two-spotted spider mite is a pest that has repeatedly demonstrated an ability to evolve resistance, with documented resistance to more active ingredients than any other arthropod.[6] Insecticide resistance in bean leaf beetle has not been documented in Iowa, although reduced susceptibility to pyrethroids has been found in some regions of the southern United States.[7]

The cases of WCR resistance to Bt corn and resistance to conventional insecticides by many pest species illustrate the potential for insects to adapt to management practices. By applying a diversity of management tactics, selection pressure for resistance to any single tactic will be reduced and the evolution of resistance delayed. For example, to delay the evolution of Bt resistance by WCR, farmers should plant non-Bt refuges and apply IPM by rotating among a variety of tactics, including crops; different Bt traits, including pyramided traits; and soil-applied insecticides.

Weed Resistance

Scientific literature about herbicide resistance in weeds is extensive. Several Iowa weeds have evolved resistance, including waterhemp (*Amaranthus tuberculatus* syn. *rudis*), horseweed (*Conyza canadensis* also referred to as marestail), and giant ragweed *(Ambrosia trifida*). All of the weeds in Iowa with evolved resistance to herbicides are annuals and are well adapted to current production agriculture systems. Once established in a weed population, the resistance remains.

A project sponsored by the ISA[8] provided a clear picture of the prevalence of herbicide resistance of waterhemp in Iowa. A high percentage of Iowa fields have herbicide-resistant waterhemp, with a majority of the populations demonstrating multiple resistances. The most common multiple resistances in waterhemp is to acetolactate synthase (ALS) inhibitor, photosystem II (PSII) inhibitor, and 5-enolpyruvyl-shikimate synthase (EPSPS) inhibitor herbicides. A small percentage of waterhemp populations have resistance to five herbicide groups. Evolved resistance in waterhemp to protoporphyrinogen oxidase (PPO) inhibitor and 4-hydroxyphenylpyrubate dioxygenase (HPPD) inhibitor herbicides is increasing rapidly. Recently, resistance to auxin herbicides has been reported in Illinois and Missouri waterhemp populations. Evolved resistance to glyphosate and ALS inhibitor herbicides is widespread in Iowa, and evolved resistance to auxin, PPO inhibitor, and HPPD inhibitor herbicides represents a serious future problem to Iowa agriculture.

A significant economic impact is expected due to yield reductions, but is difficult to estimate, as are economic and social impacts in cases where herbicide resistant weeds are mobile and can infest neighboring farmers' fields.

In a general sense, weed management focusing primarily on herbicides has not changed greatly over the last six decades. However significant changes in tillage practices, both in primary tillage and secondary tillage (i.e., inter-row cultivation) has dramatically impacted weed communities and thus weed management. Current strategies include chemical-based approaches (often used due to lower input costs and convenience), cultural, mechanical and, to a lesser degree, biological approaches. The emphasis has been on chemical strategies, and given the unprecedented adoption of genetically engineered crops with tolerance to glyphosate, biotechnology traits, and chemistry combinations, almost to the exclusion of mechanical and cultural strategies. While the options for avoiding herbicide resistance are understood, more effort is needed to ensure implementation of diverse weed management practices by Iowa farmers.

Pathogen Resistance

Like insects and weeds, plant pathogen populations can evolve due to selection pressure from continuous use of specific fungicides or crop varieties. There are numerous examples in the literature of pathogens evolving resistance to fungicides within a couple of growing seasons. When pathogen resistance develops, it is usually not as obvious as with Bt-resistance, where lodged corn is evident; or herbicide resistance, where weeds are easily visible growing over the intended crops. Damage from many pathogens is generally subtle and sporadic. Crops may be less vigorous, stunted or deformed, discolored, senesce earlier, or just have lower yields.

One example of fungicide resistance is frogeye leaf spot, which has developed resistance in soybeans during only a couple of growing seasons. The pathogen that causes frogeye leaf spot is genetically diverse, and strains have been found in other Midwestern states that are insensitive to strobilurin fungicides.

There are very few choices of fungicides available to farmers. The most common foliar and seed treatment fungicides currently registered for use in Iowa include a limited number of modes of action (e.g., strobilurin; triazoles; succinate dehydrogenases inhibitors [SDHI]; phenylamides; thiazole; carboxamide; phenylpyrrols; and methyl benzimidazole carbamates). Many commercial products combine two or more fungicide mode of action classes.

Similarly, there are a limited number of sources of host plant resistance for fungal pathogens and soybean cyst nematode (SCN). The sources of host resistance for SCN include: PI 88788, Peking and PI 437654.[9] It is important to note that 97% of commercially available soybean varieties use

PI 88788. Repeated use of soybean varieties with the same source of resistance can result in SCN populations developing increased levels of reproduction on that source of resistance. There is evidence of this happening with the PI 88788 variety in Iowa.

To reduce selection for fungicide resistance or SCN resistance to soybeans with PI 88788, farmers should use fungicides belonging to different mode of action groups or different soybean varieties, respectively. An integrated or rotating use of fungicides, in combination with other disease management practices, such as disease resistant varieties, crop rotation and other cultural practices, such as varied tillage, planting dates, plant populations and row spacing should also be employed. A fungicide should be applied only when needed, early in disease development, and at full label recommended rates. While some fungicide-use advisers have emphasized that broad prophylactic application of fungicides can promote overall plant vigor and increased yields, this practice may contribute to more rapid fungicide resistance development. Monitoring for pathogens or specifically for certain strains of pathogens that are insensitive to the targeted management (plant variety or fungicide) is often time consuming and requires trained personnel. However, farmers and agronomists can monitor and address selection for pest resistance by scouting for disease after a fungicide application is made. If the disease does not appear to be controlled by the fungicide, it should be investigated.

Economic Considerations

All pest management and PRM decisions may have socio-economic implications that need to be better understood across the agricultural sector. Socio-economic implications include the movement of resistant pests into neighboring crop fields, which may impose a social cost on neighboring farmers and landowners.

Only with judicious use of PRM practices can the efficacy (or economic value) of pest control practices be sustained over the long-term. Once resistance evolves and pest susceptibility to a pesticide or trait is lost, the only pest management solution is to use alternative and still efficacious products, develop a new product or trait, or to use a combination of PRM practices to achieve a degree of pest control, albeit at a higher cost and complexity.

While failure to implement PRM practices in the short term will likely lead to greater costs in the long term,[10] most decisions are made on an annual or short-term basis. Consequently, the economics of pest management need to be addressed as a long-term decision-making process (i.e., PRM practices have to be built on goals of maximizing long-term net benefits to the farmer, neighboring farmers/landowners and the broader community, which includes technology providers, crop advisers, and financial institutions).[11] While initial adoption of PRM practices may reduce short-term net benefits, these practices will improve long-term net benefits. Not only individual farmers, but neighboring farmers and landowners and the community as a whole may be better off in the long term. Even though longer-term net benefits are likely to be improved with PRM practices, it does not mean that all farmers will adopt these practices, especially if there are no perceived benefits. Some may even sacrifice short-term benefits for simplicity, time-savings, convenience, and other behavioral factors. Implementation of PRM approaches need to recognize these challenges as well as the willingness of farmers, landowners, farm managers, crop advisers, technology providers and financial institutions to cooperate as a community to manage pests.[12]

Sociological Considerations

It is increasingly understood that evolution of resistant pests is both a biological and social problem. Dealing with resistance will require substantial changes in management strategies, and research demonstrates that people change their behaviors only if they believe that (1) a problem exists and (2) that it represents a threat.[13]

Accordingly, a first step toward addressing the problem of resistant pests is the development of an understanding of beliefs and perceived risks by farmers and stakeholders. Survey research in Iowa in 2012 and 2013 documented that 82% of farmers agreed that they were concerned about herbicide-resistant weeds becoming a problem, and 62% were concerned about Bt-resistant insects becoming a problem in the areas where they farm.[14] Importantly, very few farmers were confident that new technologies would be developed to help manage resistant pest populations. Further, farmers surveyed also understood that the ways pest-management technologies are used have a major impact on the rate of resistance evolution, and they viewed PRM as a community problem involving multiple stakeholders (e.g., farmers, landowners, and a variety of organizations in the private and public sectors).

Similarly, non-random surveys of representatives from three Iowa stakeholder groups—agricultural retailers and advisers, farmer and commodity associations, and pesticide/biotechnology companies—indicated that these stakeholders are very concerned about pest resistance. Most of these stakeholders also believe that farmers' actions play a major role in the evolution of resistance; realize that farmers look first to agricultural retailers for information to help them make pest management decisions; and believe that multiple stakeholders, including farmers, private firms, university scientists, and government agencies bear responsibility for PRM.

Taken as a whole, the farmer and stakeholder survey results suggest there is much collaborative potential on which to build coordinated approaches to PRM.

Communication and Outreach

Effective and relevant communication efforts are critical to achieving the goals of the IPRMP. A strong, clear, and consistent message that captures the goals and expected outcomes of the plan is crucial to promoting community engagement and the long-term adoption of PRM practices. Primary audiences for the IPRMP include farmers and agricultural professionals. Secondary audiences are also significant and include government, media, and the public. Tactics and communication tools will be identified, and partnering organizations will cooperate to achieve communication goals.

Communication and Outreach Goals

Partnering organizations will reach out directly to farmers and landowners regarding opportunities to learn about and adopt PRM practices on their farms. Certified Crop Advisers (CCAs), Independent Crop Consultants (ICCs), agriculture retailers and other agronomic and farm advisers will be key partners. It will be important to build relationships with these experts and incorporate their feedback into communications efforts.

The communication and outreach plan will help identify the importance of PRM and consequences of inaction, including potential loss of management tools/technologies and loss of productivity/income. Communications will also highlight advances made by pilot projects and utilize success stories to further engage partnering organizations and promote stewardship practices within Iowa agriculture.

The IPRMP partnering organizations will have important roles in communicating with farmers and other stakeholders about the plan.

- ISU Extension and Outreach representatives will share recommendations and help troubleshoot problems that arise
- ISU will host webpages and provide a web presence for others to reference
- IDALS will help coordinate messages and provide leadership in development and dissemination of those key messages
- AAI, ABSTC, ICGA, IFBF, IIC, Iowa Chapter of the ASFMRA, ISA, PFI, RACS, IDALS, and ISU will distribute news via their communication mediums
- ICCs, CCAs, retailers, and other agronomic and farm advisers will meet with farmers and share recommendations
- Farmers and farm managers adopting resistance management tools will share resistance management experiences with others

In addition, it is a goal of all IPRMP partnering organizations to identify and utilize existing partnerships and communities to share the importance of PRM programs as well as identify and develop additional partnerships to further share key messages.

To help share information about the plan, the Communication and Outreach Committee will develop and deliver tools for hands-on/real life views of continuous improvement practices. This includes a website that will house communications and serve as a hub to share timely information. Other potential tools include decision trees, infographics, videos/animations, and informational articles/text.

Finally, the communications group will work with IPRMP leadership to help develop, deliver, and continuously update meaningful and realistic metrics for progress. Important metrics to identify and measure include cooperation by agronomic and farm advisers; knowledge about resistance on farms; knowledge among farmers about the potential impacts of resistance and benefits of proactive management; strategic selection and implementation of management practices in Iowa crop production; and farmers becoming leaders and encouraging each other to participate.

Audiences

To achieve these goals, it is important to recognize there are a wide variety of stakeholders that play an important role in PRM. The communication and outreach efforts will reflect the goals of the IPRMP, which strikes a balance between implementing physical and biological controls, including conventional pesticides, biotechnology products, and native trait control. This multi-disciplinary approach to develop PRM practices is continually changing and evolving and must be tailored for local pest pressures so creating a sense of community around the plan is essential.

Farmers *(including landowners and land managers)*

Iowa's 90,000 farmers will play a leading role in PRM through their stewardship of pesticide management technologies and biotechnology traits and tools. Farmers make management decisions each year on more than 23 million row-crop acres. As summarized the State of the Science Chapter, ISU/CALS surveys show farmers are becoming more aware of emerging insect- and weed-resistance challenges, and they view PRM as a community problem involving multiple stakeholders (e.g., farmers, landowners, and a variety of organizations in the private and public sectors). Proactively adopting practices to delay the development of insect and herbicide resistance, protect crop traits, and manage existing cases of resistance will help farmers remain competitive in the global market by maintaining the long-term productivity of Iowa agriculture while reducing pest-associated yield losses.

Ag professionals

Reaching agricultural professionals, such CCAs, ICCs, seed and pesticide retailers, and agronomic and farm advisers will be critical to the success of the strategy. According to the Ag and Rural Life Poll from ISU/CALS, the most trusted advisers are farmers' agricultural retailers and crop consultants. Also, looking over the results from past years shows the progression of information to the farmer correlates directly to the awareness of crop advice professionals. Crop consultants who can provide multi-year plans that include long-range PRM tactics will provide additional value to their services.

Government (regulators/legislators)

Keeping pesticide regulators and legislators aware of IPRMP goals and PRM approaches will re-enforce the importance of providing flexibility and incentives to farmers and their advisers. Each pest management situation is unique, and with appropriate flexibility, farmers and agriculture professionals can use the best available science to prescribe safe PRM options for different scenarios. Experience gained through the pilot projects can provide legislators insights on how incentives for PRM practices can encourage and support collaboration among communities to employ best PRM practices.

Public

The public face of PRM will focus on the proactive, collaborative nature of the plan, with farmers, agribusiness, research, crop professionals, regulatory agencies, etc., working together to sustainably produce row crops and livestock.

Key Messages

They key messages that will drive outreach efforts to each of the identified audiences include the following:

- Pest resistance management is a holistic approach to proactively manage the challenges facing agricultural productivity, including weeds, insects, and diseases.
- The IPRMP is being developed with a broad cross-section of Iowa agriculture partners and is flexible to incorporate new information.
- The time to learn more and take action on pesticide resistance is now.
    - Don't wait until you have a problem to act.
- Proactive PRM will focus on helping farmers keep technology and tools--including pesticides for managing weeds, insects and disease; seed treatments; and biotechnology products and native traits—available and effective.
- This proactive approach may require a change in traditional methods of dealing with a pest, even when a practice may still appear to be working and have a history of success.
- Pests do not recognize field borders, so it is important farmers work collaboratively with neighbors when dealing with pest resistance.
- Farmers are not alone in their effort to address resistance; experts and resources are available to help.
- Pest resistance management makes good business sense – helping farmers to produce more on every acre improves sustainability and ultimately improves financial return.
- Practices and recommendations will be modified as needed based on continuing research and results coming out of the pilot projects.

Tagline/Campaign Theme

The PRM Communications and Outreach Committee will develop a short campaign theme or tagline to house overall messaging and build engagement.

Communications Tools

Website

While communications about IPRMP updates will come from a variety of sources, a website will be utilized to store progress and news in one central location. A new series of pages will be added to ISU's IPM website to accommodate information that is being generated by the IPRMP efforts. A short url redirect will lead users to these pages, along with direct links from partnering organizations. Specific tag words will be used on all IPRMP web pages and publications to make searches more efficient. The advantages of building onto the current ISU IPM website include an immediate presence with search-engine optimization (SEO), a quick start to website creation, and credibility that extends from the ISU brand. Long-term benefits of building current efforts onto the ISU IPM site include reduced maintenance effort costs, excellent search ability of the site, ongoing SEO and security protocol updates, content that meets legal standards (e.g., accessibility guidelines), and high quality IT support and maintenance.

Additional tools

Providing useful tools to help farmers and the agricultural professionals that advise them access to current information on PRM is critically important. The Communication and Outreach Committee will work with partnering organizations to identify and develop these tools. Potential tools include decision trees, infographics, videos/animations, and informational articles/text.

Partners Outreach

Partners including AAI, ABSTC, ICGA, IA Chapter of the ASFMRA, IFBF, IIC, ISA, RACS, IDALS, and ISU will distribute news via their communication mediums. Examples may include blog posts, newsletters, email communications, short message service (SMS) text alerts, social media posts, news outlets, event print collateral, online agronomy resources, etc.

Pilot Projects

To encourage adoption of science-based resistance management efforts and to develop adaptive management approaches, it is essential to establish pilot projects of active PRM. In addition to utilizing the latest PRM tools, these pilots will also seek to examine approaches to encourage successful, voluntary PRM adoption. The pilot projects will identify key stakeholders within a defined "community" and will be inclusive, bringing all potential players to the table. The pilot projects will work to establish incentives and novel approaches to encourage the community to work together to address the identified pest-resistant problems (i.e., weeds, insects, and pathogens). Criteria that should be considered for pilot projects are summarized below. Effective PRM is the major goal for these pilot projects. These projects are intended to deal with resistance issues that are imminent or already present with the objective of minimizing the potential of further resistance development.

Potential pilot projects initially identified have a focus on weed and insect pests. More specifically, suggested pilot pests include WCR, soybean aphid, waterhemp, and Palmer amaranth. Following hire of the IPRMP program manager, the Pilot Project Committee will provide more detailed descriptions of the potential projects. The Pilot Project Committee notes the program manager may request additional project options be considered. For example, resistant pathogens, especially SCN, were considered by the Pilot Project Committee for a potential pilot and remain a topic of discussion. There are current and growing SCN issues and concerns about overuse of PI 88788 resistance sources. A pilot project could illustrate how integrated cropping systems and PRM approaches (agronomic practices, genetics, chemistries, biologicals) can work together for sustained management of SCN.

Criteria for Selection of Pilot Projects

- Potential local community champion and/or leadership groups (e.g., community and agricultural leaders, cooperatives, watershed organizations, agronomists) willing to deliver on a long-term commitment to PRM.
- Demonstrated need or demand for options to manage or mitigate resistance. For the project to be successful, the benefits of community-based intervention need to outweigh the external costs of pest spillovers onto neighboring farms and into the community.
- Ability to demonstrate that PRM methods preserve viability of pest management technologies and farm profitability for the long term.

Information needed for Potential Pilot Projects

There are several critical pieces of information needed to assess how well a project might serve as a potential pilot. Together the projects should seek to address these areas of concern:

- What are the critical features of the pest pressure, and what are their impacts on farm productivity?

    - Describe how the pest was established, the area or community covered, whether resistance currently exists or not, and the potential for community impact (ability to impose significant costs onto farms if not managed).
- How is the pest currently managed?
    - Have resistance management efforts been implemented?
    - To what degree are resistance management practices being utilized?
- Is a community-based resistance management system/team already in existence?
    - Who are the community members? Who do they represent? Will additional members be needed?
    - Is there a defined leader of this group? Is the leader willing to serve?
- Who should comprise the community members?
    - Members could include: farmers, landowners, cooperatives, farm management firms, financial institutions (lenders), ag retailers, ISU Extension and Outreach, crop consultants, equipment companies, seed companies, and others.
- Are there currently any incentives (tangible or intangible) available to encourage community participation?
    - Example: CCAs now have an option of pursuing a Resistance Management Specialty Certification, which increases their credibility. Other consultants could offer similar opportunities.

The above questions help shape approaches for potential pilot projects and their short-term, intermediate, and long-term objectives and goals.

Pilot Project Monitoring and Evaluation

Monitoring and evaluation are essential components of the pilot projects. To evaluate progress towards successful resistance management, the pilot projects will require annual monitoring and evaluation. The pilot projects will need to initially establish annual inputs, changes in human and community behavior, changes in pest management practices, and ultimately changes in resistance development rates or reduced spread of resistant pests, consistent with the Conceptual Framework's logic model. Inputs, behavior changes and adoption of PRM practices will be the initial focus of project evaluation. Actual measurement of resistance is costly and slow; however, the projects will explore cost-effective techniques to track cases of pest management failures (e.g., weedy fields or high insect abundance). In these cases, resistance bioassays at a tertiary level could be undertaken after behavior of farmers and implementation of different PRM approaches have been established. By monitoring outcomes and accomplishments, and evaluating successes and challenges, we can measure progress in adoption of PRM practices. The IPRMP will use research-based methods and results from on-farm, practical methods to continually improve management practices.

It is anticipated that pilot projects will report the results on their monitoring and evaluation to the Pilot Projects Committee by November 15 each year to be reported by December 1 to AgState and the Communication and Outreach Committee. Details of pilot project evaluation and monitoring approaches will be addressed in IPRMP Version 2.

Potential Pilot Projects

Suggested pilot projects include WCR, soybean aphid, waterhemp, and Palmer amaranth. These potential pilot projects were selected because resistant pest populations have been observed in Iowa, and improved resistance management practices will have significant financial payoffs to farmers and communities.

Pilot Resistance Insect Pest Project

Western Corn Rootworm in Northeast Iowa

This pilot project will focus on managing Bt resistance by WCR in northeastern Iowa. WCR is a well-established pest of corn throughout much of the Corn Belt. Adult WCR disperse among fields, and management practices of one farmer can spill over and influence the actions of neighboring farmers. Currently, WCR resistance to Cry3 Bt traits (Cry3Bb1, mCry3A and eCry3.1Ab) has been confirmed in much of Iowa, including northeastern Iowa. Continuous corn production is common in northeastern Iowa, creating a favorable environment for large WCR populations and an increased risk of resistance development. This pilot project would determine the success of a voluntary, community-based approach that encourages farmers to adopt PRM practices for WCR. Resistance management strategies are evolving; however, farmers still struggle with the lack of an integrated management strategy. This often leads to the evolution of resistance and the development of large WCR populations, which causes significant economic loss. Improving adoption of key PRM practices should help reduce WCR populations and prevent overuse of available WCR management tools, delaying the onset and spread of resistance. Key stakeholders for this project could include, but would not be limited to, farmers, ICGA, crop advisers, local agricultural businesses, cooperatives, ISU faculty and staff, and ISU Extension and Outreach.

Soybean Aphid in Northwest Iowa

Growing evidence from southern Minnesota and northwest Iowa indicates that soybean aphid populations are developing resistance to pyrethroid insecticides. Pyrethroids are a popular insecticide mode of action to apply both preventatively (without scouting) and when soybean aphid outbreaks occur. When pyrethroid-resistant aphids are present, farmers are more likely to suffer yield loss, especially if they are unaware that such resistance could occur in their fields. In the time it takes a farmer to identify the resistance problem and apply another insecticide, the remaining aphids could reduce yield by 25% to 40%. A likely confounding issue for this problem is the potential restriction on chlorpyrifos, an organophosphate insecticide that is effective against soybean aphids. A pilot project addressing soybean aphids could take two forms: (1) educating farmers about the risk of pyrethroid resistant populations in their fields, and (2) adopting practices that limit the spread of insecticide resistance in soybean aphids. Key stakeholders for this project could include, but would not be limited to, farmers, ISA, crop advisers, local agricultural businesses, cooperatives, and ISU faculty and staff, and ISU Extension and Outreach.

Pilot Weed Resistance Projects

Weeds are the most important and ubiquitous pest complex that negatively impacts Iowa agriculture. Unfortunately, weeds are also the most frequent pest complexes to demonstrate resistance to the control measures. In Iowa, ten different weed species are reported to have populations with evolved resistance(s) to herbicides: shattercane (*Sorghum bicolor*), giant ragweed, giant foxtail *(Setariafaberi*), Pennsylvania smartweed *(Polygonum pensylvanicum*), common lambsquarters *(Chenopodium album*), Kochia *(Kochia scoparia*), waterhemp, common cocklebur *(Xanthium strumarium*), common sunflower *(Helianthus annuus*) and horseweed (marestail). Three weeds, waterhemp, horseweed (marestail) and giant ragweed are widely distributed throughout Iowa, but waterhemp represents the greater threat to Iowa agriculture. Surveys supported by the ISA indicate that herbicide-resistant waterhemp is widespread with some populations having resistances to up to five herbicide groups, with multiple herbicide resistance in a high percentage of the populations. Fortunately, if effective management practices are employed, the problem may be contained.

Recently, populations of Palmer amaranth *(Amaranthus palmeri*) with resistance to specific herbicides have been discovered in Iowa. Palmer amaranth is a recent invader in Iowa and represents a significant future threat to Iowa agriculture based on its ability to adapt to new environments and its aggressive growth habit. Most of the fields with Palmer amaranth have scattered plants and are not yet major problem fields, and management of the pending problem is possible.

Over the last decade, many useful weed management tools have become ineffective due to overuse. For example, with the advent of soybeans genetically engineered to be tolerant to glyphosate, efficiency and ease of weed management increased dramatically. The technology was so effective it was subsequently used to establish corn traits tolerant to glyphosate. As a result, rotating between these two tolerant crops increased the rate of glyphosate resistance since fields were treated with the same herbicide each year, regardless of the cropping pattern. There is potential for similar scenarios to develop with newly introduced weed management tools, e.g., 2,4-D/glyphosate or dicamba/glyphosate tolerant crops. Weed pilot projects involving Palmer amaranth and waterhemp will be established in a manner to evaluate approaches for maintaining the long-term viability of existing and emerging technologies.

Palmer amaranth in Harrison County

This project would address Palmer amaranth and three other weeds in Harrison County. The fields where Palmer amaranth was discovered in 2013 had been used for several years to dispose of a by-product from corn processing in Blair, Nebraska. The project would focus primarily on Palmer amaranth but could also address three other weeds that are increasingly demonstrating herbicide resistance: waterhemp, horseweed (marestail), and giant ragweed. The pilot project objectives would focus on (1) continuing to achieve landowner and farmer awareness of current weed resistance issues and how to decrease their impacts, (2) gaining landowner and farmer support in efforts to prevent further development of weed resistance issues, and (3) increasing landowner and farmer awareness that weed resistance issues should be a factor in annual seed and herbicide selections. A current local community champion exists via a farmer who provided leadership in the 2016 educational forum and the noxious weed effort. Other stakeholders that are either interested or have already engaged include local farm supply agronomists, bankers, and ISU faculty and staff, and ISU Extension and Outreach personnel.

Palmer amaranth in Conservation Reserve Program Habitat

This project would also address Palmer amaranth but in a broader community. Conservation Reserve Program (CRP) and related efforts to establish pollinator and monarch habitat have expanded dramatically across the Iowa landscape. Widely dispersed Palmer amaranth plants have been discovered in a number of habitat sites established in 2016. The source of these infestations is thought to be contaminated seed mix. The pilot project objectives would be to assess fields with Palmer amaranth and work with communities to contain and, if possible, eradicate the weed. Given that CRP and related plantings are statewide, it is likely that there will be challenges associated with identifying champions; however, affected landowners and farmers may wish to lead community-based efforts. The USDA Natural Resources Conservation Service (NRCS) and other state organizations, such as ICGA, ISA, IFBF, as well as ISU faculty and staff, and ISU Extension and Outreach have a significant stake in the success of these conservation programs.

Palmer amaranth and Cattle and Dairy Production

This project would address Palmer amaranth management in a different land use “community.” Specifically, cattle feeders and dairyman often supplement feed rations with “gin trash” obtained from cotton gins in the southern United States. The “gin trash” may contain viable Palmer amaranth seeds, collected during cotton harvesting, which are spread into fields with the manure. This has been identified as the source of the Palmer amaranth infestations in Wisconsin, Michigan and Indiana. A field in Iowa with Palmer amaranth from a feed ration was recently identified. For this pilot project, the “community” would include the cattle feeders and dairies of Iowa. The pilot project will determine the source of contaminated rations, identify the fields with Palmer amaranth infestations and develop a suite of resistance management practices to control the problem. It will be critically important that the appropriate livestock and commodity associations (i.e., Iowa State Dairy Association, Iowa Cattlemen’s Association, ICGA and ISA) serve as leaders in this pilot program, with support from ISU faculty and staff and ISU Extension and Outreach.

Waterhemp in Story County

This pilot project addresses waterhemp, a widespread herbicide-resistant weed in Iowa. Waterhemp has evolved resistance to numerous herbicides statewide. Thus, it is suggested that an initial “community” be designated at the county level. Story County is located in the center of Iowa and has fields with herbicide-resistant waterhemp. Story County also has many of the major seed companies that through their production of corn seed have, along with corn and soybean producers, contributed to waterhemp resistance problems. Iowa State University also has a major presence in Story County, and farm management companies and cooperatives are active in the county as well. Champions could include seed companies and local farmers with support from ICGA, ISA, crop advisers, local agricultural businesses, cooperatives, and ISU faculty and staff, and ISU Extension and Outreach.

IPRMP: Near Term Objectives and Milestones

With approval, implementation of proposed IPRMP actions will begin. A proposed timeline and list of milestones is outlined below to provide an overview of anticipated future progress.

1. AgState Review of Version 1.0 IPRMP initiated October 5, 2016
2. Approval of Version 1.0 IPRMP – December 12, 2016
3. Establishment of Operating Committees – January, 2017
4. IPRMP communication rollout – January, 2017
5. Review of potential pilot projects – March, 2017
6. Selected pilot projects' year 1 work plans prepared and approved – May 1, 2017

Appendix A: Operating Committees

Communications and Outreach

Dustin Vande Hoef (Chair)	**IDALS**
Allison Arp	Iowa Soybean Association
Tom Block	Iowa Farm Bureau Federation
Ben Gleason	Iowa Corn Growers Association
Jacque Pohl	Iowa State University
Dawn Refsell	RACs
Sharyl Sauer	ABSTC
Caydee Savinelli	RACs
Kristine Schaefer	Iowa State University
Tyler Teske	Agribusiness Association of Iowa
Morgan Troendle	IA Chapter of the American Society of Farm Managers and Rural Appraisers
Alexa Wahl	IDALS

Pilots

John Miranowski (Chair)	**Iowa State University**
J. Arbuckle	Iowa State University
Amy Asmus	Agribusiness Association of Iowa
Larry Buss	Iowa Corn Growers Association
David Ertl	Iowa Corn Growers Association
Ron Flannagan	ABSTC
Aaron Gassmann	Iowa State University
Bob Hartzler	Iowa State University
Erin Hodgson	Iowa State University
Daren Mueller	Iowa State University
Matt O'Neal	Iowa State University
Mike Owen	Iowa State University
Clint Pilcher	ABSTC
Jacque Pohl	Iowa State University
Larry Pohlman	IA Chapter of the American Society of Farm Managers and Rural Appraisers
Alison Robertson	Iowa State University
Jim Steffel	RACs
Stacey Webster	Iowa Institute Coop

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