Report from the Resistance Management Work Group
Pesticide Program Dialogue Committee

Executive Summary

Pest resistance is a classic example of a "wicked" problem: the causes arise from a myriad of biological and technological factors, and are affected by a host of other, non-pest management decisions, including economic, social, environmental and pest control actions.

EPA already plays a critical role in pest resistance management, but has the opportunity to have an even greater impact. The Pesticide Program Dialogue Committee (PPDC) recognized this opportunity and has created a resistance management work group to develop recommendations for how EPA can play a stronger role in addressing resistance. The Agency needs to evaluate how to take a more inclusive role if valuable pest management options are to be preserved and enhanced.

Recognizing the complex nature of resistance management, the following recommendations were developed for consideration and action by EPA (with equal ranking of importance):

Recommendations:

1. **EPA should explore changes in pesticide labels to make them more uniform across manufacturers. Labels need to contain clear and concise language so all needed information to implement resistance management is easily found and understood by end users such as crop consultants, pesticide decision makers, and commercial and private pesticide applicators.**

2. **EPA should conduct a thorough review of EPA policies and regulations that impact resistance management, and remove contradictions and situations that hinder effective resistance management to the maximum extent possible.**

3. **EPA should expand collaboration and outreach efforts with other federal agencies and convene panels of relevant stakeholders to address specific priority issues and questions associated with resistance and resistance management.**

4. **EPA should explore how it can encourage proactive pesticide resistance management and prevention programs in cooperation with industries and universities through cooperative agreements, updated training materials, and grant programs.**

5. **EPA should explore the creation of incentive programs for assistance in overcoming the hurdles associated with resistance management, in particular incentives to researchers, users and suppliers for accurate early detection and timely adoption of regionally specific resistance management actions.**

A wicked problem such as resistance management cannot be solved by overly simplistic recommendations and solutions. Given the uncertainty and complexity of the causes of resistance

development, making progress in proactively and reactively managing resistance development will require new learning and adaptive management through time. EPA can be a leading catalyst in bringing stakeholders together to address pesticide resistance issues as well as how pesticides are used in integrated pest management through the adoption of these recommended actions.

Introduction

Escalating pest resistance to common control treatments risks significant economic, environmental, and social damages. In all likelihood, the damages will multiply over time and space. A "wicked problem" is a term used to describe an issue without clear singular causes or solutions, and thus difficult or impossible to solve. The EPA's Pesticide Program Dialogue Committee (PPDC) recognized the challenges that resistance creates and established a working group with the charge to ***"Develop recommendations to EPA on how the agency can assist stakeholders in addressing the challenges of conventional pesticide resistance."***

The PPDC defined four primary questions that required investigation, and provided these to a Resistance Management Working Group in order to spur discussions in developing recommendations to better address issues effecting resistance management. The questions were:

1. *Are there current EPA policies that positively or negatively affect conventional pesticide resistance management? What policies could be re-worked to more positively address resistance management?*

2. *Are there current industry programs that positively or negatively affect conventional pesticide resistance management? Would EPA have a role in those programs, and what might that be to positively influence industry?*

3. *Are there incentives (for registrants or pesticide users) that could be considered related to conventional pesticide regulation that might positively affect resistance management? Are there other ways in which the agency can work with stakeholders (e.g., growers, commodity groups, academics) to cooperatively address resistance management?*

4. *Are there elements from EPA's Bt PIP resistance management program that could be used in conventional pesticide resistance management?*

See Appendices 1 through 4 for further information. Each appendix corresponds to the respective charge question and lists the charge question, work group members assigned to address the question, and a summary of the work group discussions. The charge questions inspired many brainstormed ideas and options; however, not all thoughts were judged desirable or implementable at this point and did not make the final recommendations. They are however worthy of inclusion to help those who evaluate our report understand what considerations were explored at the beginning of this process.

Appendix 5 presents a summary of the results of an initial survey administered to work group members by Katie Dentzman and Matt Houser. The survey was designed to assess the perspectives of the diverse members of the workgroup as we started our work on this project.

Following are more detailed descriptions of the rationale for the final workgroup recommendations, proposed implementation processes, expected benefits and challenges, and potential impacts if the recommendations are enacted. An overarching consideration for all five recommendations is the need to identify and address the agency and stakeholder resources needed to accomplish these recommendations. These recommendations primarily address pesticides registered for use by the agricultural and public health communities; however, resistance management label language and education for homeowners and professionals who use pesticides in urban settings should be addressed separately by EPA.

These recommendations represent the consensus of the working group. As can be noted in the notes section in Appendices 2-5, a wide variety of ideas and many differences of opinion existed within the working group.

Recommendation 1

EPA should explore changes in pesticide labels to make them more uniform across manufacturers. Labels need to contain clear and concise language so all needed information to implement resistance management is easily found and understood by end users such as crop consultants, pesticide decision makers, and commercial and private pesticide applicators.

Rationale:

The EPA published two Pesticide Registration Notices (PRN 2017-1 and PRN 2017-2) to encourage registrants to provide needed information on resistance identification and management to end users on pesticide labels. We compliment the Agency on taking this step to engage in the discussion regarding the evolution and management of resistance in the U.S. However, information on current pesticide labels that is needed for effective use and resistance management is often difficult to find due to varying formats used by registrants. Considerations need to be made to not only improve resistance management label language but also provide best management practices for resistance management.

Those stakeholders who work with applicators and end users of labeled pesticides often hear of difficulties finding and interpreting label information and leads to frustration on the part of pesticide retailers, consultants, and applicators. This is true in general but is especially frustrating for resistance management which relies on all the label information to implement proper best management practices (BMP's) outlined in the PRN language. Clear instructions for users are critical for improving effective resistance management due to the complexity and specificity of necessary practices. For instance, basic tenets of resistance management include understanding and using pesticides with diverse modes of action (MOA); using the correct adjuvants when needed; applying pesticides at the appropriate rate, coverage, and timing; and reporting situations where control of the target pest has failed. The resistance information many labels currently use

is the language outlined in PRN 2017-1 and PRN 2017-2 which is excellent general information; however, this language does not always appear in the same location on labels which reduces its impact and does not offer specific and relevant integrated pest management (IPM) recommendations to the end user. Because the labels are federal documents and are already lengthy and complex, the labels cannot include IPM recommendations that have been developed specifically for local cropping systems, specific pests, etc. that are needed for users to be successful in controlling pests and reducing impact of resistant pests.

Label information is currently accessible through paper labels attached to products, label lookup resources like Agrian, CDMS (Crop Data Management Systems), registrant websites and soon through a searchable database connected with the Office of Pesticide Program Electronic Label (OPPEL) pilot delivery system (formerly known as SmartLabel). These options should be streamlined and accessible, with broad promotion and awareness. Therefore, we recommend that EPA initiate rule making that would mandate a uniform, standardized label format to make relevant resistance management information easier to locate on paper labels and to continue to explore the use of electronic labeling that would make it easier to search by end users.

Implementation Process:

EPA should evaluate, create, and implement a standard label template which would require manufacturers to organize label information in a uniform, clear and concise format.

EPA should develop a required format outlining the organization of labels which would increase the usability and improve user understanding of labels for all purposes. Specifically, regarding resistance management, EPA should mandate clarity of language around resistance management, and all other label information such as full rates and controlled pests, that is necessary to correctly address resistance management and be most beneficial to label users.

EPA should also develop stronger partnerships between stakeholders who interpret labels, including federal and state government agencies, research and extension scientists, pesticide safety educators, crop advisors, industry, end users, and other stakeholders. Some of these stakeholders may include: AAPCO label review taskforce; EPA OPPEL taskforce; EPA Label Consistency Committee; pesticide handlers/operators and those who use or supervise the interpretation and use of labels; manufacturers who would need to change their companies label format to be consistent with all other labels; and someone who could evaluate formats used in other countries where a standardized format is adopted. While some of the stakeholders are the same as identified to assist with other workgroup recommendations, this group would have the specific task of creating and educating on the new label format.

- This stakeholder group needs to define and differentiate between mandatory language and advisory language on the label regarding resistance management through a thorough evaluation of regulatory and practical feasibility of such statements.
- While it is not feasible or practical to include local information on the label itself, it is important to make pesticide users aware of how to access locally relevant, current information that is important to best manage the target pest. This stakeholder group

needs to consider options for accessing local information and recommendations on integrated practices for resistance management as well as lack of control issues updates (e.g., watch lists of pests of concern, area bulletins).

EPA should explore the use of the OPPEL pilot delivery system focused on resistance management to provide access to searchable local resistance language as well as verified and documented resistance and potential resistant pest watch lists.

EPA is already developing an OPPEL program and instructions for effective pesticide use as part of an integrated pest management tool. Resistance management would be ideally suited as an extended model effort. The electronic labels are searchable to ease information delivery that is specific to the pest situation and use site. Because the program is still under development, there is an opportunity to bring key information needed for effective resistance management into the program as an exploratory effort to maximize the benefits of this delivery system for label information.

EPA should bring together the stakeholders identified earlier to determine additional information that is needed for resistance management both at the federal and local levels. Bringing this group of federal and local label stakeholders together to advise the agency would result in a label with clear directions for the target pest situation as well as electronic access to readily available and specific integrated pest management (IPM) information based on geography, cropping system or use site, time of year, and other factors that could be used to provide highly accurate and specific information.

The OPPEL Pilot is an important step forward in addressing label uniformity and clarity. But it is important to remember OPPEL is only electronic delivery; therefore, paper delivery must also be addressed by this effort, along with education in IPM through extension and outreach and other stakeholder instruction.

Benefits and Challenges:

Challenges that must be addressed include an evaluation of company or legal barriers that may affect the requirement to adhere to a uniform label. The EPA likely will need to initiate rulemaking to establish regulations for uniform labeling and the timeline for registrants to adhere to the new rules (an example would be the FDA process to implement uniform nutrition labels). The EPA would also need to assess current EPA/FIFRA exceptions to determine if a change like this can be made without triggering a reregistration or registration action for the label. The registration review process might serve to change label formatting as recommended herein. However, a concern with using the reregistration process for implementation is that it would take 15 years after rulemaking is finalized to complete the change to uniform labels and would not address the urgent need for uniform, clear and concise labeling. Additionally, for effective implementation of the OPPEL, responsibility for data quality and timely updates and maintenance of the system must be addressed. EPA also needs to consider that while uniform product labeling is important, proper use of pesticides must be part of an IPM program that includes non-pesticide management approaches to successfully address resistance. If this

recommendation is fully implemented, the EPA, through registrants, will provide the user with access to other locally relevant information to manage resistance.

Benefits of the recommended label improvements described herein would be to sharpen the engagement and understanding of all relevant stakeholders, improve the understanding of label language and information by users/applicators, and create a format that includes the importance of not only federal language, but also local socio-ecological conditions and their importance on efficacy of pesticides and the development of resistance.

- Principles of resistance management can reach every user of pesticides because they are located on the product label and can be easily accessed, read, and implemented by the purchaser and applicator.
- If general resistance language is required on all labels, it would bring all labels up to the same set of standards where all product labels contain basic resistance language. This recommendation would not preclude the inclusion of additional resistance management language on the label but would ensure that all labels include, at a minimum, the language outlined in PRN 2017-1 and PRN 2017-2.
- Implementation of this recommendation could streamline and improve label reviews and label updates could be reviewed more efficiently by registration and reregistration division staff.
- If product use parameters need to be adjusted to maintain resistance management in certain situations, use directions on the product label can be inserted (subsection or supplemental) to instruct user how to apply, i.e., tank mixing with multiple MOAs and adjuvants that help the active ingredients perform effectively.
- Implementation of this recommendation would provide users with information on how to access local IPM recommendations and information to supplement the general resistance management guidance.

Potential Impact*:*

The consensus of our workgroup was that we support the requirement to include general resistance management language on the pesticide label as a basis for developing a resistance management program that includes effective use of pesticides. However, we felt that a federal mandate for a uniform set of specific IPM practices if resistance is suspected as part of the registration process (the Bt PIP program is an example) would have limited benefit for addressing resistance management. Uniform, clear, and concise label language is crucial to ensure that users have the information needed to make safe and effective pesticide applications that complement their locally developed resistance management programs. If this recommendation is not implemented, the industry and pesticide users risk continued and accelerating resistance and likely loss of important tools for pest management due to resistance. Clear and uniform labels that include easy options for accessing local resistance information will impact all who purchase, apply, and use pesticides (including homeowner uses). This resource will provide users with the tools to understand and apply practices that will reduce the incidence of resistance, as well as the impacts of resistance on overall pest control.

Recommendation 2

EPA should conduct a thorough review of EPA policies and regulations that impact resistance management, and remove contradictions and situations that hinder effective resistance management to the maximum extent possible.

Rationale:

EPA is charged with implementing many regulatory recommendations and requirements. A number of these were drafted with other regulatory objectives in mind beyond resistance management, such as health and environmental safety. Consequently, their implications for advancing or hindering pesticide resistance management often were not considered. As currently written or implemented, some requirements may inadvertently discourage resistance management. Further, there may be a lack of formal mechanisms in place to explicitly consider implications of these other recommendations on resistance management. Pesticide resistance itself can have negative environmental and economic consequences. Lower risk pesticides may become ineffective or uneconomical, inducing a shift to less benign pesticides. Resistance to pesticides, and most specifically herbicide resistance, may also discourage use of conservation tillage. This in turn may lead to greater environmental problems such as effects of soil erosion on air and water quality, or greater carbon emissions from more mechanized tillage passes. Under various environmental laws (e.g., FIFRA), EPA is charged with considering both risks and benefits of pesticide use. Because pest resistance can affect these risks and benefits, failure to account for resistance will not provide a full accounting of these risks and benefits. There has been increases in cost of discovery and development of new pesticides. Regulatory processes that delay the approval of pesticides with new modes of action results in less access to a diverse suite of pest control options and increase reliance on compounds for which resistance has been developing. If EPA rules and regulations were reviewed for their implications for managing resistance, then unintended negative consequences for resistance management could be avoided.

Implementation Process:

Preserve the efficacy of current pesticides: Develop or revise policies o preserve or extend the durability of pesticide efficacies in the market in order to delay the development of resistance.

- EPA should review label requirements that make it difficult to include instructions for tank-mixing products. In some instances and when appropriately applied, tank mixtures can be a means of applying multiple MOAs simultaneously.
- EPA should reduce barriers and delays to registration of pesticide premixes in cases where individual active ingredients in the premixes have already been approved for use in tank mixtures. Concerns over synergistic effects when pesticides are used in combination in the premix have already been addressed in decisions to allow tank mixtures. In terms of environmental safety, it is not clear that having the same combinations mixed by the registrants is effectively different than having them mixed on a farm site. From a worker safety perspective, there is an argument that premixing under controlled conditions in a replicated fashion would be superior and safer to applicators than doing the tank mixing

themselves onsite. In addition, resistance management benefits of using individual pesticides or tank mix partners in sequence or in rotations will remain available to users.

- EPA should explore methods to leverage EPA's "Reduced Risk Program" for certain pesticide formulations that address key resistance management, for expedited registration. Pest resistance potential is already included as one of the review components on the list that EPA is allowed to use for facilitating reduced risk status which will allow for faster review of label submissions with reduced fees. However, historically, the EPA has not used resistance management as a primary benefit under the review, and it is recommended to leverage and strengthen moving forward to provide options for growers in resistance management.
- EPA should evaluate assessment of the Endangered Species Act (ESA) for pesticide premix registration by accounting for their importance in resistance management of target insects/ weeds/disease. The ESA assessments take substantial time and are currently only being done for individual active ingredients. This is a further restriction on registering new combinations of active ingredients in premixes that would have a positive impact on reducing selection pressure for resistance. In addition, subjecting pesticide premixes registration similar to single active ingredients under ESA, would impact its registrability and subsequent timely access of pesticide premixes to end users. If EPA conducted parallel regulatory reviews of single active ingredients and their component premixes, this would allow prescriptive blends through precision equipment to be mixed at the retailer level to address specific pest issues. These blends could be provided to the grower, limiting their tank mix exposure without requiring sequential review, this may encourage growers to ultimately use pesticides with more diverse modes of action at the most efficacious rates for their local situation.

Proactively review and adjust rules to account for opportunities presented by new technologies and that account for the diversity of US cropping systems and pesticide uses.

- Emerging technologies such as digitally enabled spot sprays or drone-based aerial application may ease some environmental concerns regarding pesticide use (such as low pesticide footprint in the environment, crop safety, etc.). EPA should proactively consider policies to ease registration (where applicable) to promote use of these emerging technologies through defining risk assessment such as zero tolerance, higher spot rates, flexible application timing, no buffer management, digitally capable labels (such as OPPEL), etc.
- EPA's policies on Exclusive Data Use Protection for Minor use of pesticides can be expanded to include resistance management. Like patents, under § 3(c)(1)(F)(i) of FIFRA, US-EPA authorizes exclusive use of the supporting registration data for a specific period by the registrant. Minor uses of pesticides are those for which the total production for a crop is fewer than 300,000 acres in the US. Currently, minor uses include some fruits and vegetables, and control of disease vectors, such as mosquitoes, ticks, cockroaches, rodents, and disease-causing organisms. Minor use also applies to pesticide uses that do not provide sufficient economic incentive for a registrant to support initial or continuing registrations. EPA should consider leveraging this policy to extend minor use definitions to support certain use patterns of pesticides/ pesticide mixtures that aid in delaying resistance development and/or managing localized, troublesome insects/weeds/disease pressure.
- EPA should incentivize registration of pesticides that offer diversity in resistance management in the Risk/Benefit analyses. It is not clear from review of FIFRA Risk/Benefit guidelines whether resistance management is explicitly considered in benefit estimation.

Resistance management would be enhanced if registration and cancellation decisions considered implications for the diversity of chemicals available for use and the implications for resistance management.

Elevate resistance management as a major benefit: Develop/revise policies that achieve balance in various pesticide application requirements without compromising best resistance management practices to support long term availability of pest control options.

- EPA should approve application of pesticide rate and coverage for effective resistance management. EPA's restrictions on specific application requirements to limit off-target pesticide movement would, in most cases, impact pesticide rate and coverage on the target pest/s, thereby potentially compromising resistance management. While minimizing pesticide off-target movement is necessary, EPA should elevate resistance management as a major benefit through promoting application of correct pesticide rate and coverage. Similarly, use of certain pesticides are banned or restricted due to concerns of their potential effect on pollinators; resistance management is not a consideration in the decision to ban or restrict these pesticide uses.
- Buffer requirements can have an impact on resistance management indirectly. New products are restricted from being used in buffer areas which may result in end users relying on less efficacious products in the very areas where mobile pests are often first introduced into a field. The practice may result in build-up of already resistant insect, disease, or weed populations. In case of weed management where most reported resistance cases are controlled by dominant gene/s, this practice creates a refuge for uncontrolled weeds that can result in intra- and inter-field spread of resistance.
- EPA should evaluate pesticide label use patterns and restrictions to encourage adoption of integrated pest management strategies, including use of non-chemical methods for pest control. In addition, EPA should conduct a thorough review of the impact of cover crops on all pests. A great deal of conflicting information exists, and decisions regarding one pest can run counter to effective management of other pests.

Improve efficiency in approval of pesticides that growers need to manage pests and fight the selection of resistant pest populations.

- EPA should consider a thorough review of ways to continue to improve its efficiency and effectiveness that enhances grower access to tools and uses that provide more options to minimize selection pressure for products that are currently on the market for several decades. EPA should work with land grant university scientists to develop widely accepted efficacy rating systems that include multiple variables as to what makes products acceptable alternatives to growers in varying crop systems, including resistance management. EPA should also consider expanding its administration mechanism directly at the growers' level via incentivizing growers' compliance in following resistance management best practices in addition to its administration via product registrants. EPA should consider their continued efficiency improvement via PRIA (for example, Pesticide Registration Improvement Extension Action of 2018) through proper resourcing and overall continuous improvements in the registration process.

- EPA should conduct detailed review of actual FIFRA mandates vs. its suggested guidelines/ recommendations such as Pesticide Registration Notices or PRNs that are not legally binding requirements. Overtime, PRN recommendations tend to get perceived as mandates causing delays/ confusions and eventual impact on product use.
- EPA should drive towards minimizing variabilities in state registration mechanisms. There is strong need to streamline and make these processes more uniform. EPA should also clarify and enforce proper use of 24(c) labels by states, as this mechanism aids in efficient label implementation.
- EPA should engage generic manufacturers, retailers, and supplemental distributors involved in pesticide production and distribution to promote resistance management. Engaging these stakeholders is an important gap to fill in resistance management participation.

Benefits and Challenges:

The proposed policy reviews and revisions will ensure long term availability of pesticides to growers for effective insect/weed/disease control as well as avoiding delays through registration for new products

Potential Impact:

The proposed changes and enhancements to the policies proposed will enhance our leadership in agricultural food production by promoting longevity of pesticides efficacies, promote innovation and rapid adoption of emerging technologies. Pesticide resistance in insects/weeds/pathogens has forced growers to become more innovative in the last 20 years thus changing pest control practices to remain competitive and sustainable. Efficiency in pesticide regulation and registrations will be critical moving forward in to protect yield from losses due to insects/weeds/diseases to ensure global food security rise.

Recommendation 3

EPA should expand collaboration and outreach efforts with other federal agencies and convene panels of relevant stakeholders to address specific priority issues and questions associated with resistance and resistance management.

Rationale:

Innovating sustainable resistance management is a complex challenge that defies simple applications of technological or regulatory tools, in part because the evolution of resistance amongst many pests is a dynamic and stochastic process. Furthermore, pesticide resistance undermines integrated pest management (IPM), which is a fundamental management objective for systems that support our modern, interconnected society including agriculture and the maintenance of public health.

Regular and open dialogue between all involved stakeholders, from government agencies involved in regulatory decision making to end users of pesticides, is instrumental to any

sustainable resistance management effort. The importance and value of discussions and collaborations between varied and diverse resistance management stakeholders assures credible, relevant, and legitimate knowledge production and distribution. Engagement with stakeholders should not only focus on technologies to monitor for and manage resistance in pests, but importantly must also involve the simultaneous promotion and advancement of IPM more effectively.

There is a particular need for coordination and regular, transparent communication between US government departments and agencies that play varying roles in the regulation or implementation of IPM practices. These would include, but not limited to: Centers for Disease Control (CDC); Department of Agriculture (USDA); Department of Defense (DOD); Department of the Interior (DOI); Environmental Protection Agency (EPA), Food and Drug Administration (FDA); Housing and Urban Development (HUD); and the Office of Science Technology and Policy (OSTP). For instance, while EPA has sole regulatory authority over pesticides and other chemicals, other agencies, including those at USDA, have statutory obligations to practice and promote non-chemical pest control practices such as cover crops and conservation plantings. Moreover, CDC, FDA and HUD have important influence in non-agricultural settings in which resistance management is just as paramount of a challenge as it is in field crop production.

Implementation Process:

An initial task is to identify stakeholder groups who have legitimate interests in resistance management, and to consider applicable federal statutes that might constrain these discussions. It's critical to ensure that these discussions involve representative stakeholders from across affected sectors, including agriculture, but also including those involved in structural and public health pest control, as well as representatives from medical and veterinary sectors. It's also important that stakeholders from all regions of the US are included in these discussions to help identify key ecosystem attributes, effects and benefits that matter, and why they matter. Engaging all parties will require consideration of their abilities to represent interests, cost to administer, and time requirements. Possible stakeholders include:

- Individual pesticide users, e.g., individuals involved in production, application, planning, and decision making
- Independent pest/crop consultants and retailers who provide pest management products, services, and advice
- University scientists, including researchers and extension experts who research and provide pest management information to stakeholders
- Non-governmental organizations involved in advocacy related to IPM, food, natural resource management, including alliances of supply chain stakeholders such as Field to Market: The Alliance for Sustainable Agriculture
- Pesticide registrants
- Federal and state government agencies that have regulatory oversight, authority to aid with pest management technologies, or are engaged in pest management on federal lands, e.g., CDC, DOD, DOI, EPA, State Departments of Agriculture, and USDA
- Consumer groups, consumer packaged good companies, and retailers

Federal statutes such as the Federal Advisory Committee Act (FACA) and the Paperwork Reduction Act (PRA) place constraints on how and the degree to which federal agencies, particularly those such EPA that are actively involved in decision making, can actively solicit and engage in discussions with those outside the US government. This is especially the case when these discussions are meant to determine consensus opinions from diverse stakeholders intended to inform policies and regulations.

As such, and to initiate these outreach efforts most rapidly, we suggest four separate initiatives to implement this overarching recommendation:

Scientific Advisory Panels (SAPs) should be established by EPA, initially focusing on:

- The current state of the science regarding the confirmation of pesticide resistance in relevant pests, e.g., weeds, insects, fungi, pathogens, etc. Related questions that this SAP could discuss include barriers or issues (scientific and otherwise, e.g., social aspects driving a reluctance to report suspected resistance), types of resistance (i.e., single vs multiple-pesticide resistance, metabolic vs target-site mechanisms of resistance)
- Development of a rigorous system or tool for monitoring for and reporting cases of pesticide resistance to USEPA, or if applicable, other appropriate federal authorities (e.g., CDC, FDA, USDA). For the purposes of USEPA, an ideal reporting tool would at least meet existing Agency data quality standards, ensure the confidentiality (and potentially anonymity) of respondents, and feed data into USEPA's Incident Database System (IDS).

The SAP/s should not only involve relevant scientific and applied experts but include participants from all relevant federal agencies to ensure that the regulatory and policy implications of pesticide resistance confirmation appropriately account for the diversity of organisms that can develop resistance to pesticides. Two key topics that were identified by the workgroup are listed here; however, EPA should consider convening panels as needed to address issues identified in all the recommendations.

The formation of a Federal Working Group on Resistance Management (FWGRM), to be comprised of US government employees representing relevant departments and agencies.

We encourage staff from EPA's Office of Pesticide Programs (OPP) to work closely with USDA's Office of Pest Management Policy (OPMP) to operationalize this federal working group. Participants in this working group should ideally include representatives from all federal departments/agencies that affect, or that are affected by, the issue of pesticide resistance, including (but not limited to): CDC; USDA (including all relevant agencies within USDA); DOD; DOI; EPA, FDA; HUD; and OSTP. We would also suggest that representatives from groups speaking for state regulatory authorities be included, such as the Association of American Pest Control Officials (AAPCO), the Association of Structural Pest Control Regulatory Officials (ASPCRO) and the National Association of State Departments of Agriculture (NASDA).

The Pesticide Program Dialogue Committee (PPDC) is chartered as an official standing committee within EPA, and as such already functions to formally support dialogue between

pesticide regulators and affected stakeholders. We would suggest that – contrary to typical practice in which PPDC workgroups operate for temporary periods of time – the Resistance Management Workgroup be allowed to continue to exist for the purpose of organizing and facilitating an annual meeting with non-federal stakeholders on resistance management.

> This annual meeting would take place prior to the Spring PPDC meeting and would serve as a forum for dialogue on resistance management issues between representatives of the FWGRM and non-federal stakeholders.

This workgroup was charged with developing recommendations for PPDC and EPA on advancing resistance management concerns in the US, and as such our recommendations related to furthering dialogue and outreach with stakeholders is limited to opportunities related to EPA and PPDC.

> However, we fully acknowledge the need for dialogue and discourse between non-federal stakeholders outside of the context of PPDC, and encourage existing groups such as the regional IPM Centers, the Resistance Action Committees (RACs) for fungicides, herbicides and insecticides, scientific societies e.g., the American Phytopathological Society, the Entomological Society of America, and the Weed Science Society of America, as well as other groups (e.g., Pesticide Education Resource Collaborative) to establish parallel outreach efforts that could better acquire locally-specific feedback from growers and pest management professionals on resistance management concerns.

Benefits and Challenges:

There are many communication challenges related to the advancement of IPM and resistance management. We anticipate that the efforts of this workgroup will facilitate integrating solutions focused on identifying priority resistance management challenges, collaboration to support proactive resistance management and prevention using IPM principles and produce innovative and sustainable solutions. Obstacles to these efforts include not only federal statutes that dictate how US government employees and others can reach consensus on matters related to rulemaking, but also the sheer scope of the issue, and divergent interests and priorities amongst affected stakeholders. We have proposed relatively limited recommendations here that we feel are most realistic and can most quickly get off the ground, because there is a clear and urgent need for increased dialogue on resistance management.

We cannot discuss resistance management without clearly recognizing that affected stakeholders have varying, and sometimes opposing, interests. It is widely acknowledged that pesticide resistance is a wicked problem, and one that affects vital services and industries in the US and across the globe. If we cannot develop innovative and sustainable solutions to pesticide resistance issues pervasive within our food production systems, public health sectors, and elsewhere, and distribute the costs of management equitably, then we must appreciate that the collateral costs will be substantial and widespread.

The benefits of expanded outreach, both narrowly within the context of US government agencies' decision making and policy (which is where this recommendation necessarily lies), and

more broadly across stakeholder groups, are numerous and widely beneficial. Not only is open dialogue necessary to clearly identify where problems lie, but discussions are necessary to determine viable and impactful solutions that can be implemented and embraced by affected communities. Collaboration and honest outreach amongst all affected stakeholders are instrumental to any hope that lasting and effective strategies and technologies can be developed to manage resistance.

Potential Impacts:

Implementation of the proposed recommendations, and in particular convening SAP(s) focusing on technical issues related to pesticide resistance monitoring and management, and the formation of a federal inter-agency working group on the topic, will serve to dramatically accelerate coordination within the US federal government on pesticide resistant issues and promote holistic human and technological innovation. At its core pesticide resistance is a community problem, and only by openly and routinely communicating about resistance, and discussing bold new solutions, can pesticide resistance in diverse systems be sustainably controlled. Key to achieving these advances is integrating experimental knowledge of practitioners in the field with frontier science to assure the solution paths have maximum impact. This integration is a prime impact of inclusive stakeholder engagement in the search for actionable and sustainable approaches to this wicked challenge.

Recommendation 4

EPA should explore how it can encourage proactive pesticide resistance management and prevention programs in cooperation with industries and universities through cooperative agreements, updated training materials, and grant programs.

Rationale:

As with any product stewardship practice, resistance management training and information must be timely, broad in scope, and reach a large and diverse audience to be effective and have an impact. At the same time, it needs to be context-sensitive and locally relevant. With such a large and diverse audience of pest control advisors, applicators, retailers, and end users, it will be important for EPA to collaborate and coordinate activities with universities, industries, and other stakeholders, in agriculture and non-agricultural settings, who provide resistance management training and information. This is especially necessary as resistance is not a static problem – it spreads between fields, farms, and landscapes. While individual farmers and other pesticide users are often on the front lines of resistance management, they need support and buy-in from all relevant groups in their communities to effectively manage resistance spread.

Resistance management depends upon cooperation among a community of geographically interconnected stakeholders who represent a range of expertise and interests. Many of the key factors which will determine the success of these cooperative management communities will be geographically variable and specific to their resistant pest of primary concern, including who are

the relevant stakeholders, what scientific knowledge is in need, the local policy levers that can be pulled (or created), among others.

We recommend that EPA explore several different mechanisms for resistance management programs and training materials through cooperative agreements and grant programs for resistance management programs. The core of this recommendation is collaboration to enhance information sharing, collective management strategies, and landscape-level coordination. We suggest implementation through assessing existing programs and training materials, conducting a workshop, and planning future grant programs and proposals.

Resistance management depends upon cooperation among a large group of geographically interconnected stakeholders who represent a range of expertise and interests. Many of the key factors which will determine the success of these cooperative management communities will be geographically variable and specific to their resistant pest of primary concern. In short, a top-down, one-size-fits-all approach to resistance management is unlikely to be successful at encouraging voluntary participation among natural resource managers, nor could it efficiently address a myriad of specific circumstances in which resistance occurs. At the same time, local, voluntary efforts are unlikely to form unless there is sufficient social and financial capital to spur their formation and foster long-term commitment to group aims across stakeholders. We must reduce barriers to cooperative resistance management for all relevant stakeholders, while also encouraging the formation of collaborative teams.

Specifically, we recommend EPA should explore the creation of a grants program for collaborative resistance management efforts.

> Funding opportunities may be able to enable new collaborative efforts by alleviating barriers to participation, while also encouraging the development of new scientific and private investment in resistance management knowledge and outreach.
>
> We recommend that the community-based resistance management grant program require projects to include several components that we believe will increase the likelihood that practical impacts will be achieved. These components include:
>
> - Project teams are transdisciplinary, including a range of all relevant stakeholders such as (but not limited to): resource managers, public and private sector scientists (including social scientists and economists), university affiliated extension educators, and consultants from local chemical companies. Notably, we strongly encourage that a resource manager be an official partner (i.e., co-PI/PI) on the grant proposal and, moreover, that there be a specific component of projects related to facilitating cooperative engagement/understanding among relevant resource managers.
> - Projects address a resistance management issue in a clearly defined geographical area, the size of which is appropriate to foster effective communication and continued participation among local stakeholders.
> - Clearly defined outcome goals, which should include novel scientific understanding of resistance management and clearly defined practical outcomes which will work toward mitigating resistance in the project area.

USDA-NIFA's Sustainable Agricultural Research and Education (SARE) program is a suitable grant model that the EPA could base the design of this program upon. Among its many qualities, we feel that the regional-level administration of the SARE program is particularly important to consider in the design of this program. The EPA could also consider forming a partnership with USDA-NIFA to encourage a specific call for resistance management projects in the SARE program.

A growing body of research consistently indicates that several factors limit resource managers (e.g., farmers) use of resistance management techniques. These include social and economic risks (e.g., cost of alternative methods; concern that others won't also practice resistance management), insufficient knowledge of best practices, and expectations that new, better chemicals will be developed that eliminate resistance issues. Through cooperative engagement with other managers, funding opportunities for practice-trial, and collaborative teams that include expert and technical service providers from the public and private sector, we believe these grants programs could address key barriers to the development of resistance management. Most importantly, they do so at the local level and place-specific expertise will inform the exact project structure to better address place-specific challenges. There is even some evidence that once formed, cooperative resource management can function relatively autonomously, and thus initial "seed" funding could precipitate enduring benefits in terms of resistance management.

The immediate impacts of such a program will be to increase scientific interest in resistance management and encourage a myriad of collaborative teams to form across the United States as they develop their project proposal. The longer-term impact will be the formation of cooperative management efforts that can fostering cross-communication and new knowledge about the problem of resistance, barriers to resistance management adoption, and potential solutions to place-specific problems.

Implementation Process:

A first step in the implementation process of EPA encouragement of proactive resistance management programs is to conduct an analysis of current resistance management programs as well as training information available. The EPA should also conduct an analysis of the target audience for the programs as well as the success rate or outcomes. Examples include the Centers for Disease Control and Prevention (https://www.cdc.gov/mosquitoes/mosquito-control/professionals/index.html), Herbicide Resistance Action Committee (https://www.hracglobal.com/), Fungicide Resistance Action Committee (https://www.frac.info/), Insecticide Resistance Action Committee (https://irac-online.org/), and Take Action (https://iwilltakeaction.com). Additionally, CropLife Canada's resistance management website (https://manageresistancenow.ca/) may serve as a useful example of a well-organized informational website.

The EPA should also conduct a survey of resistance management programs that are being promoted by land grant universities. An example is the Iowa Pest Resistance Management Program run out of Iowa State University (https://www.ipm.iastate.edu/about-the-iprmp). Additionally, organizations that may play an important role in wide scale program delivery

should be identified and assessed; for example, the IPM centers and the Pesticide Safety Education Program.

After the EPA has assessed the current resistance management programs and training materials, a gap analysis should be conducted to see if there are areas of resistance management that need to be improved. After the gap analysis, EPA should reach out to the stakeholders who have resistance management programs and materials and have a workshop to review the current state of the programs and training materials. One of the outcomes of the stakeholder workshop would be to discuss possible grant programs and proposals.

For the grants program, EPA should consider by what means they can secure a sufficient fund to support the awarding of multiple, large grants across numerous years. We feel that empirical scientific research is needed to identify:

- Barriers or roadblocks within the confirmation testing process.
- Solutions to these issues, including those related to addressing social or behavioral challenges, developing technology, and funding infrastructural development to support implementation.
- The most effective strategy to ensure the widespread implementation of a new testing procedure.

The EPA could be the direct administrator of these grants, though there may be advantages to a cooperative or indirect approach where the EPA works to encourage or support other federal agencies such as the USDA/NIFA in developing a proposal call focused on accelerating resistance confirmation timelines.

Like resistance itself, these topics are tied up in a set of complex human-environment interactions. We, consequently, recommend that project teams be transdisciplinary, including social and natural scientists, along with all other relevant expertise (e.g., engineers, programmers) from the public and/or public sector, stakeholder outreach, and advisor experts (e.g., crop consultants, extension educators), and relevant natural resource managers. We also feel that it may be necessary or beneficial to support, via these grants, a full-time dedicated professional position at various key institutions throughout the United States. The *National Oceanic and Atmospheric Administration's* (NOAA) Sea Grant program, which often includes funding to support extension faculty and staff in universities across the country, is a good model for this recommended grant.

Benefits and Challenges:

This recommendation is intended to support proactive, system-wide management. Collectively planning for resistance *before* it becomes unmanageable preserves current pest management technologies, protects yield, safeguards consumers, and results in the best financial, environmental, and societal outcomes for a wide variety of agricultural stakeholders and society at large. For instance, effective resistance management may prevent tillage of highly erodible land as a last resort to deal with problematic weeds, preserving water and soil quality. Additionally, by taking a cooperative approach, this recommendation brings together the

strengths and resources of industry, universities, farmers, and other pesticide users to address a pernicious problem in ways that could not be achieved otherwise. Assuring consistency of messaging and approaches, as well as supporting farmers or other pesticide users who may otherwise be too overburdened to deal with landscape-level resistance issues, will be fundamental. System-wide management approaches have shown great promise in Arizona, Arkansas, Georgia, Idaho, Iowa, Washington, and Oregon, as well as across Australia. Further study of what drove the successes, and struggles, of these groups can be combined with education, grant opportunities, and cooperative agreements to create a comprehensive community management toolkit that is broad in scope and simultaneously highly locally adaptable.

Potential Impacts:

Perhaps the most significant impact from implementation of this recommendation would be the creation of an integrated framework that allows for better coordination across the breadth of stakeholders of programs that foster awareness and implementation of programs to manage resistance proactively instead of reactively. Consistent messaging around resistance management between EPA, universities, industry (manufacturers and distributors), and advisors will lead to more effective communication to growers and other end-users of resistance-prone crop protection and vector control agents. More effective communication will improve our ability to educate around not only the importance of proactive resistance management, but also how this benefits the individual and the community at large. The impact of this recommendation to individual users would be preservation of valuable pesticide tools to manage weeds, insect pests, and diseases that are needed to maintain public and animal health and high levels of crop and animal productivity and economic return. Positive environmental impacts would follow from targeted, rational use of products combined with cultural practices which would introduce only what is required, when it is required into the environment. Extending the useful life of important active ingredients through proactive resistance management would protect manufacturers' outlay of resources required to develop pesticides and allow for investment in the next generation of safe and effective products.

Recommendation 5

EPA should explore the creation of incentive programs for assistance in overcoming the hurdles associated with resistance management, in particular incentives to researchers, users and suppliers for accurate early detection and timely adoption of regionally specific resistance management actions.

Rationale:

Despite an accelerating focus on resistance management education and technical information solutions, the adoption of key resistance management best practices remains uniformly low among key stakeholder groups (e.g., farmers) and resistant pests are developing and spreading at an alarming rate in the United States.

The public and private sectors have developed a range of effective strategies to mitigate the potential for resistance. Currently, the likelihood that these efforts will be widely implemented and adopted within agriculture is limited given existing disincentives to their adoption.
Many pests are mobile. When they develop resistance to a particular form of a pesticide, there is potential for mobility to neighboring sites—for instance, in the case of agriculture, other farmers' fields. Effective resistance management therefore depends on a cooperative, regional-scale response where each stakeholder adopts strategies which effectively limit the potential for resistance development. Should one stakeholder fail to change their management, the efforts of *all* the stakeholders in that region will have been for not. And, when insufficient incentives for behavioral change/cooperation exist, individuals often fail to change their management.

Given this scenario, it is critical to develop effective incentive programs to address this dilemma. Notably, our definition of "incentive" is encompassing, including interventions that either actively motivate new behavior that would not occur without said prompt and/or those that remove barriers to the emergence of voluntary behavior.

We specifically recommend the following strategies:

EPA should explore the creation of incentive programs for researchers, users, and suppliers for accurate and faster confirmation of resistance and early implementation of resistance management tactics following reports of potential resistance.

> Participants of our working group consistently noted an enduring challenge: the timeline of resistance confirmation testing. The timeline for confirmation testing varies considerably depending on circumstances or context (there is, to our knowledge, limited empirical research documenting average testing timelines), but even the best of circumstances, a timeline of 18 months of more can be expected (and, in less-than-ideal circumstances, the timeline can easily exceed 5 years). During this prolonged period, isolated resistance issues can spread geographically, as reactive management responses are rarely undertaken. The timeline between suspected resistance and confirmation needs to be shorted and that time, regardless of how long it is, needs to be an active period of implementation of resistance management strategies.
>
> Examples worth further evaluation are the European and Mediterranean Plant Protection Organization database, which can be found at https://resistance.eppo.int/index, and the CDC Bottle Bioassay (https://www.cdc.gov/mosquitoes/mosquito-control/professionals/cdc-bottle-bioassay.html).

Consequently, we recommend the EPA consider strategies that can shorten the timeline between suspected resistance and confirmation (or not) of that resistance. We include two specific recommendations toward this end.

> *First, we recommend that the EPA consider a establishing a nationwide research-focused grant program that would encourage and support efforts to accelerate the rate at which resistance confirmation testing occurs.* Ultimately, empirical confirmation of suspected resistance is necessary to ensure the appropriate response. Yet, there are currently few

incentives or resources that would encourage or enable autonomous efforts to evaluate, develop, and implement more effective testing procedures. We feel that a grant program could be a particularly effective incentive strategy given the breadth of research needed at this time.

Second, we recommend the EPA explore programs that would provide decision makers like growers, consultants, farm managers, and applicators the tools necessary to implement resistance management tactics between the period of suspected resistance and confirmation.

Given the consequences of the lengthy confirmation testing process, the resistance management working group members recognized the need to better enable proactive management responses to issues of suspected resistance. Despite the recognition of this issue, the scope of our charge combined with the limited timeline prevented us from being able to develop a firm and widely supported recommended approach. Consequently, we recommend that the EPA continue to consider this topic by convening a working group specifically to consider the issue of how best to enable more effective management responses in the context of suspected resistance. As with the original working group, the membership of this more specifically focused group must represent a diverse range of stakeholders.

Implementation Process:

For the programs to proactively respond to cases of suspected resistance, we recommend that the EPA consider convening a group of decision-making stakeholders along with social scientists (possibly taking advantage of the stakeholder group formed in recommendation 3) to ask and address questions of why more resistance management is not implemented between cases of suspected resistance and confirmation. Whether it is a lack of information, an ineffective delivery system, or a lack of motivation or reward to implementation. It is important to identify barriers so effective solutions can be developed.

Benefits and Challenges:

Both recommendations are intended to accelerate the timeline to proactive resistance management.

The confirmation testing grants program does this through a monetary incentive that, we expect, will directly encourage experts nationwide to participate in developing strategies to accelerate confirmation testing process. We realize that this strategy will have significant costs associated with its implementation, with no guarantee of successful outcomes. These risks must be acknowledged. Yet should strategies be developed that could shorten the timeline between suspected and confirmed resistance, the benefits would be significant.

The development of programs that will encourage proactive resistance strategies as soon as a user experiences a case of suspected resistance will reduce the risk of rapid spread of potential resistance.

Potential Impacts:

For the recommendations related to accelerating confirmation testing via a grant, we expect impacts from this will be felt in the long-term or over the next 10-20 years. For implementation of the program to encourage proactive use of resistance management strategies we expect the impacts could be felt more in the medium-term, likely over the next 5 years if barrier can be identified and program built to overcome them.

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The working group gratefully acknowledges the invaluable assistance, insights, and support from EPA staff, particularly including William Chism, Alan Reynolds, and Shannon Jewell.

Appendix 1

Charge Question 1: *Are there current EPA policies that positively or negatively affect conventional pesticide resistance management? What policies could be re-worked to more positively address resistance management?*

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The information presented here is an overview of the discussion in charge question group 1 that lead up to the overall recommendations made by the full workgroup. Not all the recommendations found in this summary are part of the full workgroup recommendations but are presented as a record of the group 1 discussion.

Major Topics

- Recommendation that EPA work to establish a federal interagency workgroup on resistance management.
- Recommendation that stakeholders, both public and private, have a yearly meeting to coordinate and discuss resistance management plans across disciplines (insects, plant pathogens, and weeds).
- Could the EPA develop incentives for users and suppliers to reward people who report suspected resistance or reveal of lack of performance patterns early?
    - Develop tools and centers for rapid identification of resistance.
- Updated training modules from OPP on resistance provided to states for applicator training.
    - Resistance management training.
    - Mode of action training.
    - OPP should have a training requirement for resistance management as part of pesticide licensing.
    - Other key topics.
- NRCS Enhanced Conservation with resistance management practices. Help develop.
    - Resistance management training for NRCS staff (see training above).
- EPA policies that impact resistance management (see March 11 list)

April 8, 2021

- Working with other federal agencies.
- Recommendation that EPA work to establish a federal interagency workgroup on resistance management.
- Recommendation that stakeholders have a yearly meeting to coordinate and discuss resistance management plans across disciplines (insects, plant pathogens, and weeds).
- NRCS – considering conservation enhancement for resistance management.
- Crop Insurance

March 25, 2021

Incentives for users.

- Risks for pesticide resistance are at the local level. Benefits from controlling resistant pests is to the neighbor or region. Individual farmer may not get rewarded.
- Could the EPA develop incentives for users and suppliers to reward people who report suspected resistance or reveal of lack of performance patterns early?
- Incentives for disease or resistance reporting. Overcome tight lipped farmers who don't want to admit they have a problem. Reward people for telling the truth. For companies they don't want competitors knowing their product(s) may have problems.
    - Section 18 incentive for grower reports on likely resistance improved chance of getting a Section 18 to control a resistant pest.
- Incentive – continuing education credits if participate in resistance management study. Or submit samples to diagnostic labs for testing. First responder course – how to collect field history and samples for resistance. Get credit for course.
- Updated training modules on resistance provided to states for applicator training. Less than 50% of farmers understand MOA and rotating effective MOAs. Not all growers have applicator licenses. Could we get to non-licensed farms through Good Agricultural Program (GAP) training which is designed around food safety not pesticides, mostly fruit and vegetable growers.
    - Better information on multiple resistance. Farmers that think they have multiple resistance could be a powerful lever for other farmers.

Incentives for users and companies

- Develop standard methods to estimating the costs and benefits of resistant pests. CDFA is looking into this. Users and companies would know what information is helpful to provide for these assessments. Check with BEAD to see if methodology exists or could be modified (EPA question)?
- Genomic tools to confirm resistance. Report resistance get test kit shipped overnight. Would work when target site resistance is the problem. May not be helpful if resistance mechanism is not yet known.
- Diagnostic Clinics – network of diagnostic clinics to test resistance. Growers would get testing and companies would get seeds and data. Some growers do not want to give permission for companies to collect resistant weed seeds. Can additional funding be made available for this type of network?

- Premixes – faster approval. Does EFED or HED have any policies on premixes (EPA question)?
- Tank mixes – make easier to use.
- Reduced Risk – clarify to companies how to better clarify their case for resistance management. Would an easier path for reduced risk increase or decrease OPP workload?

USDA Incentives

- Cover crops are currently grown for soil conservation concerns. Could USDA or states use cover crops to drive resistance management programs?
    - List of states with existing programs check with AAPCO or SFIREG?
- Incentive to use seed destructor.
- USDA Germplasm Repository. Starting to collect reference samples for susceptible and resistant pests.
- Climate Change or Crop Insurance– could these programs also address pesticide resistance.

Other Groups

- Bank Loans – could they also have incentives for resistance management?

March 11, 2021

- Overall, industry would like EPA to focus on the areas it is mandated to and best equipped to focus on, namely reviewing and approving label submissions. Focus in other areas creates onerous requirements for registrants (especially the larger registrants) and delays review and approval of new tools that growers need to manage pests and fight the selection of resistant pest populations. Today, EPA is not always meeting review timelines, and this effectively limits grower access to tools & uses that could affect overall product longevity in the market.
- EPA Policies Considerations:
    - EPA's policies on extension of minor uses can include resistance management (RM).
    - Risk/Benefit analyses can include RM.
    - Re-registration can include RM.
    - Labeling itself includes RM.
    - Buffer requirements can have an impact on RM indirectly.
    - Conflicting impact of current policies: Other EPA policies may also have indirect effects on RM, including Endangered Species Act, Monarch butterflies, and spray drift.
    - Less than optimal policies conflicting between off-target management (OTM) and weed resistance management. There is confusion at the grower level on how to best set up their equipment to manage OTM and get good weed control. The EPA could consider balancing the pendulum in this space. Right now, OTM guidelines

have negative effects on weed management and, therefore, likely increasing selection pressure on weed populations.
    - Leverage Reduced Risk Status for certain herbicides for faster registration. There is a resistance management component on the list that EPA is allowed to use for facilitating reduced risk status and faster review of label submissions. To our knowledge, the EPA has not used this component and should do so.
    - Do not make it difficult to use tank-mixes. Can EPA policies be developed that incentivize tank mixes as a RM tactic; e.g. quicker approval. There is good science regarding the importance of tank mixing to reduce the selection pressure on any one active ingredient. Label requirements that make it difficult to include instructions for tank mixing products is detrimental to delaying selection for resistant pest populations. First, removing rate guidance, and then removing brand names unless registration numbers for each brand name product is provided reduces clarity of recommendations to growers.
    - High variabilities in state registrations mechanisms. Opportunity to streamline and make it uniform. Clarify and enforce proper use of 24C labels by states.
- Label simplification:
    - Label is too complex and simplification needed. Growers need clear, concise use instructions for products that they can pull out from all the boiler plate information on labels. Smart digital labels that has RM information specific to a region/ state/ county level for effective Resistance Management; or take RM language outside of the label.
    - RM can be included under reduced risk, but it is not currently used by EPA.
    - Consistent, clear and transparent labeling is needed. Effectiveness of RM labeling must be improved.
    - Overall labeling must be addressed to make RM more prominent and clear, as it is often lost in the fine print.
    - E-labeling is being explored by EPA. Could we use RM as a pilot project with e-labeling? Make it attuned to geographic location, crop, etc. so that the user has clear information applicable to their specific situation.
- It is the registrants responsibility to steward their products for maximum longevity. This includes communicating product use rates to growers, academics, retailers, crop consultants and other influencers of growers. It is also the responsibility of registrants to manage grower claims in a responsible way and not reward growers for applying lower than label use rates (which is one of the cause for resistance development). Registrants, academics and other grower influencers should primarily drive it with the support from EPA.
- EPA requires registrants to report pest resistance. However, this is difficult for registrants, as research must be conducted to sort out other factors from true resistance.
- Researchers other than registrants are also incentivized to report in the literature cases of resistance before registrants do.
- In weeds, there is a very good reporting website, weedscience.org. There is not a corollary website for fungicides or insecticides. This would be highly desirable by EPA.
- EPA fully recognizes that remediation is much more important than reporting.
- Off-target management is another EPA policy that can indirectly affect RM.

- Engage generic companies/ retailers/ distributors; currently big Ag Companies were asked to enforce RM by EPA but no such push for generic companies. There should be a level playing field. Engaging the small companies and generics is an important aspect of RM, as their certification and labeling often is not as thorough in regard to RM.
- Additional training requirements on RM are needed as an EPA policy.
- Communication:
    - Certification programs for the applicators to emphasize the RM programs.
- Incentivizing registrants:
    - Faster registration for tank mixes
    - Meeting timely approvals
    - EPA consider ways that EPA can incentivize certain products, labels, registrant behavior similar to the USDA's IR-4 program.
    - Incentivize registrants for premix herbicide or new MOAs registrations and tank mix enablement – faster registration Again, the reduced risk ststuas could be used here or an IR-4 like program.
- Plant incorporated pesticide (PIP) policies to conventional pesticides.
    - Insect res mgt (IRM) policies for Bt products are not relevant to conventional pesticides and should not be considered. Very concerning. It hurts more than helps in RM for conventional pesticides.

Appendix 2

Charge Question 2: *Are there current industry programs that positively or negatively affect conventional pesticide resistance management? Would EPA have a role in those programs, and what might that be to positively influence industry?*

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George Frisvold, University of Arizona
Tim Lust, National Sorghum Producers
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The information presented here is an overview of the discussion in charge question group 2 that lead up to the overall recommendations made by the full workgroup. Not all the recommendations found in this summary are part of the full workgroup recommendations but are presented as a record of the group 2 discussion.

Industry Type	Industry Name Program	Website	Pest Target	Target Audience	Program Summary	Positively or Negatively Affect Conventional RM	EPA Role in Programs	EPA Positive Influences
Commodity Group	**American Mosquito Control Association**	www.mosquito.org	Disease vectors predominately mosquitoes but also ticks, flies etc	Product users	Provides best management practies and has chemical control subcommittee that includes discussion/work on IR	Provides alternative practices but once an adulticide is needed there is little advice other than rotation	None	
Commodity Group	**United Soybean Board** Take Action Pesticide Resistance Management	https://iwilltakeaction.com/	Diseases Insects Weeds	Product users	National and state-specific weed, disease, and insect management resources from university extension scientists and researchers.	Positively - offers different solutions depending on the situation.	EPA program promotion	Supports local initiatives
Community Based	Pink Bollworm Eradication USDA / University /Farmer	https://www.usda.gov/media/press-releases/2018/10/19/usda-announces-pink-bollworm-eradication-significantly-saving	Pink Bollworm	Various		Positively	None - Typically, government intervention is a top-down, one size-fits-all approach that does not recognize unique features of the local community, production environment, local farming systems, or characteristics of local farmers and agriculture. A voluntary, community-based approach can be tailored to address local conditions, farming systems, people and community.	
Government	**CDC Division of Vector Borne Diseases**	CDC Bottle Bioassay | Mosquitoes | CDC	Mosquitoes	Product users	Free test kits and training on IR testing in mosquitoes	Positively- offers testing to document presence and extent of IR in a jurisdiction	none now but could maybe help sponsor training resources	
Government	**NRCS** Conservation Choices: Pest Management	https://www.nrcs.usda.gov/wps/portal/nrcs/detail//?cid=nrcseprd415417	Crops and Pests	Product Users Land Owners	Pest Management Tools that are also part of conservation	Positively - offers different solutions depending on the situation.	Promote pest management practices	MOA with NRCS and other federal agencies
Government	**USDA** A National Roadmap for Integrated Pest Management	https://www.ars.usda.gov/ARSUserFiles/opmp/ipm%20road%20map%20final.pdf	Production Ag Natural Resources Residential, Structural, Public Areas	Government University	The goal of the IPM Road Map is to increase adoption, implementation and efficiency of effective, economical and safe pest management practices, and to develop new practices where needed.	Positively	Work with other federal agencies - existing risk-management programs, including federal crop insurance, and incentive programs such as the Natural Resources Conservation Service's Environmental Quality Incentives Program (EQIP) and other farm conservation programs to fully incorporate IPM tactics as rewarded practices.	MOA with NRCS and other federal agencies
NGO	**FRAC** **Fungicide Resistance Action Committee**	https://www.frac.info/	Fungi	Product Users Academics EPA	FRAC works to prolong the effectiveness of fungicides liable to encounter resistance problems and to limit crop losses should resistance occur	Positively	Help facilitate educational opportunities	Engage with FRAC for outreach and education materials
NGO	**HRAC** Herbicide Resistance Action Committee	https://www.hracglobal.com/	Weeds	Product Users Academics EPA	Herbicide Resistance Action Committee (HRAC) is an international body founded by the agrochemical industry, helps to protect crop yields and quality worldwide by supporting efforts in the fight against herbicide-resistant weeds.	Positively	Help facilitate educational opportunities	Engage with HRAC for outreach and education materials
NGO	**IRAC** Insecticide Resistance Action Committee	https://irac-online.org/	Insects Mites	Product Users Academics EPA	IRAC is prolonging the effectiveness of insecticides, acaricides and traits by implementing insecticide resistance management strategies, countering the development of resistance in the three core sectors of traditional Crop Protection, Plant Biotechnology and Public Health.	Positively	Help facilitate educational opportunities	Engage with IRAC for outreach and education materials
NGO	**The Sustainability Consortium** (TSC)	https://www.sustainabilityconsortium.org/	Crops	Commodity buyers and suppliers	Key Performance Indicators (KPIs) for many uses including pesticides	Positively - offers different solutions depending on the situation.	Membership (potential) in TSC	
Professional Society	**American Mosquito Control Association**	PESP Program - American Mosquito Control Association	Mosquitoes	Product users	PESP membership umbrella and Best Management Practices	positively	EPA runs the PESP program that AMCA participates in. AMCA also hast training on BMP that EPA could support.	
Professional Society	**NAICC** Crop Consultants	https://naicc.org/	All - Insects, Diseases, Weeds	Product Users	Utilize various tools to give pest management guidelines	Positively Participate in RACs	Help facilitate educational opportunities	Expedite registration process for new chemistry and modes of action
Professional Society	**NPMA** Field Guide Pro	https://npmapestworld.org/resourcecenter/npma-field-guide-pro/	Structural Pests	Product users	Provides up to date information on pest identification, biology and control tactics	Positively - Proper identification and control practices	EPA program promotion	Educational resources
Retail	**ADAPCO**	www.myadapco.com	mosquitoes	product users	Provides help conducting field and lab assays upon request	positively	regulates products used in field tests	

Appendix 3

Charge Question 3*: Are there incentives (for registrants or pesticide users) that could be considered related to conventional pesticide regulation that might positively affect resistance management? Are there other ways in which the agency can work with stakeholders (e.g., growers, commodity groups, academics) to cooperatively address resistance management?*

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The information presented here is an overview of the discussion in charge question group 3 that lead up to the overall recommendations made by the full workgroup. Not all the recommendations found in this summary are part of the full workgroup recommendations but are presented as a record of the group 3 discussion.

PPDC Charged Question	Hurdle to RM adoption	How lead to resistance	Incentives to overcome	EPA Role in Incentive
3. Are there incentives (for registrants or pesticide users) that could be considered related to conventional pesticide regulation that might positively affect resistance management? To properly suggest	1. Grower does not implement BMP's until in their area or field. a. Mobility of resistant pests b. Environment/ability to overwinter or survive until host crop emerges again 2. Not able to recognize resistance in first years of establishment. Especially in emerging resistant pests. 3. Economic Thresholds - Cost of RM BMP's incorporated into programs like multiple MOA and layered residuals	1. Allows resistance to get a stronger foothold in field before addressing problem 2. Allows resistance to get stronger in field before addressing problem 3. Economics leads to	1. Available suspected and known resistance maps 2. Available suspected and known resistance maps	1. EPA facilitate and/or work with stakeholders to host the webpage. 2. EPA facilitate and/or work with stakeholders to host the webpage.

effective incentives, we must identify hurdles.	4. Environmental difficulties ie spring too wet/windy to apply timely control measures. 5. Product Performance/ application error – differentiate failure vs resistance. 6. Conflicting Messages from trusted advisers a. Priorities of Partners b. Science vs Sales c. Maximizing vs Optimizing 7. Grower follow through of planned practices 8. Educational resources available – Evaluate, Educate and Encourage 9. Social factors – what is acceptable – ie: tillage in a no til field, Pesticides by public buildings 10. Sole use of label language may/does not incorporate IPM / non chemical practices of RM	decision making possibly not with BMP's 4. Allows resistance to get stronger in field before addressing problem 5. Does not believe resistance, just a non performance claim. $$$ 6. Delays effective resistance management. 7. See 4, 5 & 6 8. Growers can't implement BMP if don't know them 9. Some programs conflict and growers have to chose 10. Resistance management not all chemical based	3. Everyone wants money… 4. Mother nature… work with agronomist on alternatives 5. Available suspected and known resistance maps, faster testing. 6. Business have right to do business/ market… pick good trusted advisers? 7. See 4, 5 & 6 8. Available science based resources for applicators - training 9. ???	3. Grants and partnerships to provide incentives. 4. Probably not in EPA scope 5. EPA facilitate and/or work with stakeholders to host the webpage. 6. Probably not in EPA scope 7. Probably not in EPA scope 8. Already information on Label. Make Labels consistent, clear and readable 9. Look at conflicting grower programs that overlap resistance practices.

			10. Programs to promote IPM practices	10. EPA facilitate and/or work with stakeholders to promote IPM

PPDC's Charged Question	Benefits	Concerns
3. Are there <u>incentives</u> (for registrants or pesticide users) that could be considered related to conventional pesticide regulation that might positively affect resistance management? **What are the Benefits or Concerns for instituting Resistance Management (RM) on pesticide product labeling??**	Principles of RM can reach every user of pesticides because they are located on the product label and can be easily accessed and read by the applicator. RM on all product labels, including both basic and generic registrations (i.e., bring generic labels up to the standards of the basic). Simplifying RM to a few essential principles can efficiently be portrayed on product labels, (this assumes EPA can administer RM fairly and effectively across all product labels) If product use parameters need to be adjusted to maintain RM in certain situations, use directions on the product label can be inserted (sub-section or supplemental) to instruct user how to apply. (i.e., tank mixing with multiple MOAs).	Product labels becoming too much like academic textbooks … too long, too much information, too complicated for pesticide users to find the most critical information. Inserting RM into a long-winded "EPA mandated section of label" will likely be passed over by the reader eager to find "directions for use" of the product. For RM to be effective, it needs to be simplified and practical. Maybe product label is not best place to do this Is RM more effectively communicated to the grower by the product label (i.e., EPA regulation) or by advice and/or recommendations from university extension, crop consultants, industry (basic and retailers)? It is likely the latter group(s) would have more impact than EPA-mandated label text. RM is currently advisory information. To make RM mandatory and enforceable would be EPA overreach. The pesticide is regulated, but the way a grower manages their operation and the degree of crop protection they chose to implement is not regulated. Requiring RM to be part of pesticide use may/will be viewed as a EPA step too far. Requiring RM be practiced via the use of a pesticide product could place further economic burden on the grower.

And a thought provoking question …. What are the most effective ways to get RM to be implemented by growers, should EPA offer a carrot or use a stick ??

Response: a pesticide product and it's use is regulated, i.e., the label is the law. If RM became an enforceable part of the label, it would then require the user to abide not only be the "directions for use"

of the pesticide but also apply the required RM steps. The RM steps would have to be clearly defined (with their own restrictions). Would it be a compliance issue if the grower did the first part but not the second ?? Could the "stick" then get too big and powerful ?? A tasty carrot might be more palatable.
If we use the label as a means to educate about RM are we not tying it with IPM? Can we use Dicamba webpage as a model to point to more information? Who would host and maintain that? Would applicators go there?
On Label the intent of RM PR's is to make RM information advisory to end user, but not for registrant, and not mandatory. Viewed by Craig as good idea, but some of the BMP's may be overreaching.

PPDC's Charged Question	Carrots/Sticks/Carrot Sticks
3. Are there incentives (for registrants or pesticide users) that could be considered related to conventional pesticide regulation that might positively affect resistance management? Note incentives are not always monetary payments or economic. Let's be creative with what we consider as an incentive. Stick = enforceable regulation, a push method. Carrot = incentives of all kinds, a pull method. Carrot Sticks = blending of enforceable regulation and incentives	**Carrots** 1. **Education** – how do we get to the right people. a. Identify already gathering stakeholder groups ie: potato expo 2. Grower Forums 3. Points program for participation in RM practices and point redeemable for various things a. Reduced cost education b. Resistance Fighter (already Syngenta) status. 4. Incentivize Stakeholder Community involvement a. Within stakeholder communities maybe impose peer incentives/penalties 5. Role of Industry Marketing Programs in incentivizing RM practices (Charge Q2) 6. **Education around long term economics** of a practice to optimize ROI over several years vs maximizing ROI each year. And dealing with it when it gets to a critical level. **Sticks** 1. Make mandatory enforceable part of the label. 2. Pest commissioners to move in and control uncontrolled pests a. Landowner expense b. Focus to control pest first and maintaining crop 2nd 3. Consider "good grower vs Bad Grower scenarios. Segment audience – one hammer does not drive all fasteners. **Carrot Sticks** **1. Private/commercial applicator training include soft "mandatory" RM education** **2. Mandatory reporting and mapping of target resistance issues** a. Suspected resistance vs proven resistance b. Access to tracking not only to manufacturers and agency, but also retail, advisers and growers

Appendix 4

Charge Question 4: *Are there elements from EPA's Bt PIP resistance management program that could be used in conventional pesticide resistance management?*

Group Members:
Jill Schroeder (Organizer), New Mexico State University
Larry Dallas, Independent Grower
Katie Dentzman, Iowa State University
Steve Eskelsen, ADAMA
Patti Prasifka, Corteva
Gary Prescher, National Corn Growers Association
Alan Reynolds (EPA liaison)
PPDC Program Support: Shannon Jewell, Carla Theriault

The information presented here is an overview of the discussion in charge question group 4 that lead up to the overall recommendations made by the full workgroup. Not all the recommendations found in this summary are part of the full workgroup recommendations but are presented as a record of the group 4 discussion. The discussion was structured around the four mandatory Integrated Resistance Management (IRM) elements described in the document "Aspects of EPA's IRM Plans for Bt PiPs".

1. Mitigation: Four Bt PiP requirements include: refuges, integrated pest management (IPM) stewardship measures, acreage limitations, and crop residue destruction requirements. Only the requirement to adopt IPM stewardship measures was broadly applicable to conventional pesticides.

Benefits: IPM stewardship which includes practices to complement appropriate pesticide use is key to successful resistance management.
Challenges:

- Who would have responsibility for ensuring that growers apply IPM stewardship because the pesticide distribution network is highly complex? How would/could EPA and state regulators enforce the implementation of stewardship Best Management Practice (BMP) measures?
- EPA would need to consider local situational management needs in mandating IPM practices which would increase complexity of the regulation and enforcement.

Actions to consider: EPA could consider an approach similar to the EPA Energy Star program to develop a program to recognize IPM stewardship instead of a mandatory set of IPM practices which may not be appropriate for all use situations.

2. Resistance monitoring/scouting: Two Bt PiP requirements include: Investigations of unexpected crop damage and sampling and bioassays of pest populations in high adoption areas.

Benefits: The goal of this requirement would be to preserve the pesticide tools and to manage resistance through information exchange.

Challenges:

- The Bt PiP program requires monitoring. This requirement is satisfied by registrants (a limited number of registrants currently have registered PiPs) pooling resources to provide a single monitoring effort for all registered traits. In the case of conventional pesticides, the number of registrants and products, including mixtures of active ingredients, would make a comprehensive monitoring and information exchange effort challenging for both EPA and registrants in terms of time, bioassay space and supplies, personnel, and cost.
- The industry faces challenges in determining whether a nonperformance situation is suspected resistance versus other causes of nonperformance. If resistance is suspected, confirmation of resistance takes considerable time and resources which could delay timely action to address resistance.

Actions to consider: EPA could consider serving as a resource for companies by bringing industry representatives and other stakeholders together to discuss how to improve or perhaps standardize field investigations of nonperformance. Any such discussion must include survey methodology specialists to help frame the discussion. An outcome might be a tool kit or guidance to assist companies with their investigation process to increase the potential to identify suspected resistance cases in the field.

3. Remedial action if resistance detected: Five Bt PiP requirements include: use of alternate control measures; communication with stakeholders; additional monitoring; restrictions on use of affected PiP (would be pesticide for the conventional system); Notification to EPA.

Benefits: Confirmation of resistance in a pest population would trigger communication among the user community and the use of alternate control measures which would serve to preserve pesticide tools and manage resistance to conventional pesticides.

Challenges:

- Pest resistance is not clearly defined by the scientific community for field populations. Identification of underperformance or suspected resistance is very challenging and not well defined. Confirmation of resistance can take years making it difficult to mandate timely remedial action.
- Coordination across the distribution chain would be needed to address mandated remedial action -- how would this be enforced, by whom, and what would be the cost to EPA, state regulators, registrants, and growers?
- Uniform, federally driven mandatory language for a uniform set of remedial practices would preclude locales from adapting resistance management recommendations to local pest issues and conditions.
- The lack of direct connection from the registrant to the grower, competitive issues (competitive disadvantage to reporting for both the registrant and user), and the many generic registrants (companies with differing resources being expected to sample/mitigate equally) all complicate the ability to mandate remedial action if resistance is suspected in the field.
- Nonperformance concerns after the use of mixture products or tank mixes complicates the ability to evaluate which component is responsible for lack of performance and how to handle sampling/bioassays to confirm.

Actions to consider: EPA needs to consider how the information network can be improved so that timely information is accessible to all, and effective and timely management adjustments can be made to manage resistance (get the right information to the right people at the right time). Is there a role for EPA in information management/networking beyond the FIFRA 6.a.2 process which has limited utility for providing timely information to the grower community?

4. Grower education: Requirements include: "Grower guides" with IRM information required; use of multiple media required: mailers, ads, websites, face-to-face meetings, webinars; engagement with grower groups (e.g., NCGA, NCC).

Benefits: User education and information exchange is extremely important for successful resistance management and must be encouraged.
Challenges:

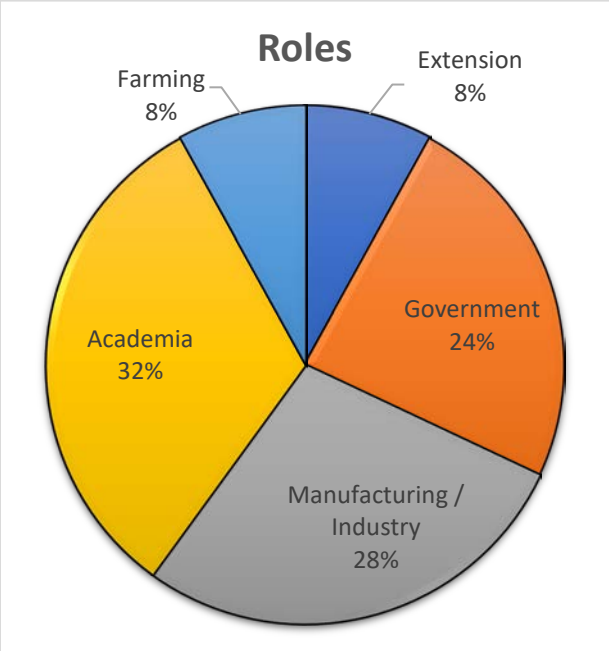
- How can education be made more effective?
- Consistency in messaging is key but is not always accomplished.

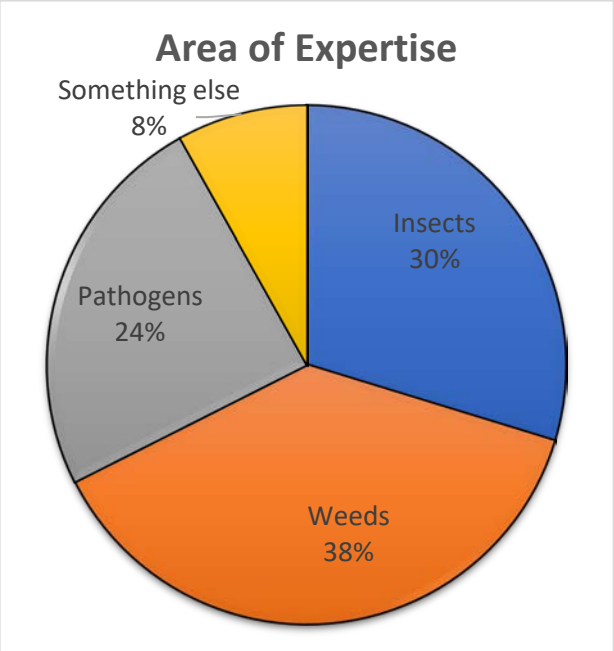
Actions to consider: Consistency in labelling to make it easier to find key information on the label is essential to improving appropriate use of pesticides within an IPM program and for successful resistance management.

Appendix 5

Survey information collected and summarized by Katie Dentzman and Matt Houser

The stakeholder roles represented in our working group included academia, manufacturing/industry, government, farming, and extension. Areas of expertise included weeds, insects, pathogens, and other areas such as human behavior and nematodes. When asked why they became involved in this group, top responses included public service, contributing their own expertise or knowledge, preserving current pest management options, and shaping regulatory and voluntary policies.





Our members cited the major causes of pesticide resistance as 1) over reliance/over application of pesticides, 2) other improper use of pesticides, 3) lack of chemical control options, 4) costliness of alternatives, and 5) pesticide users' beliefs and resistance to change. Major negative impacts included 1) economic drains, 2) environmental impacts, 3) decreasing product effectiveness/pest advantages, and 4) viability of agricultural systems.

Group members had engaged in a variety of management efforts; primarily related to education, label development, on-farm application of Best Management Practices (BMPs), and academic research.

Desired pesticide resistance management goals included encouraging the use of BMPs, slowing the development of resistance and preserving current tools, and conducting more effective education and outreach.

Identified barriers to managing pesticide resistance were ranked as follows: 1) lack of alternative control methods, 2) cost of current control methods, 3) end user reticence/lack of knowledge, 4) social barriers and a stagnant agricultural system, and 5) the inherent complexity of pest management.