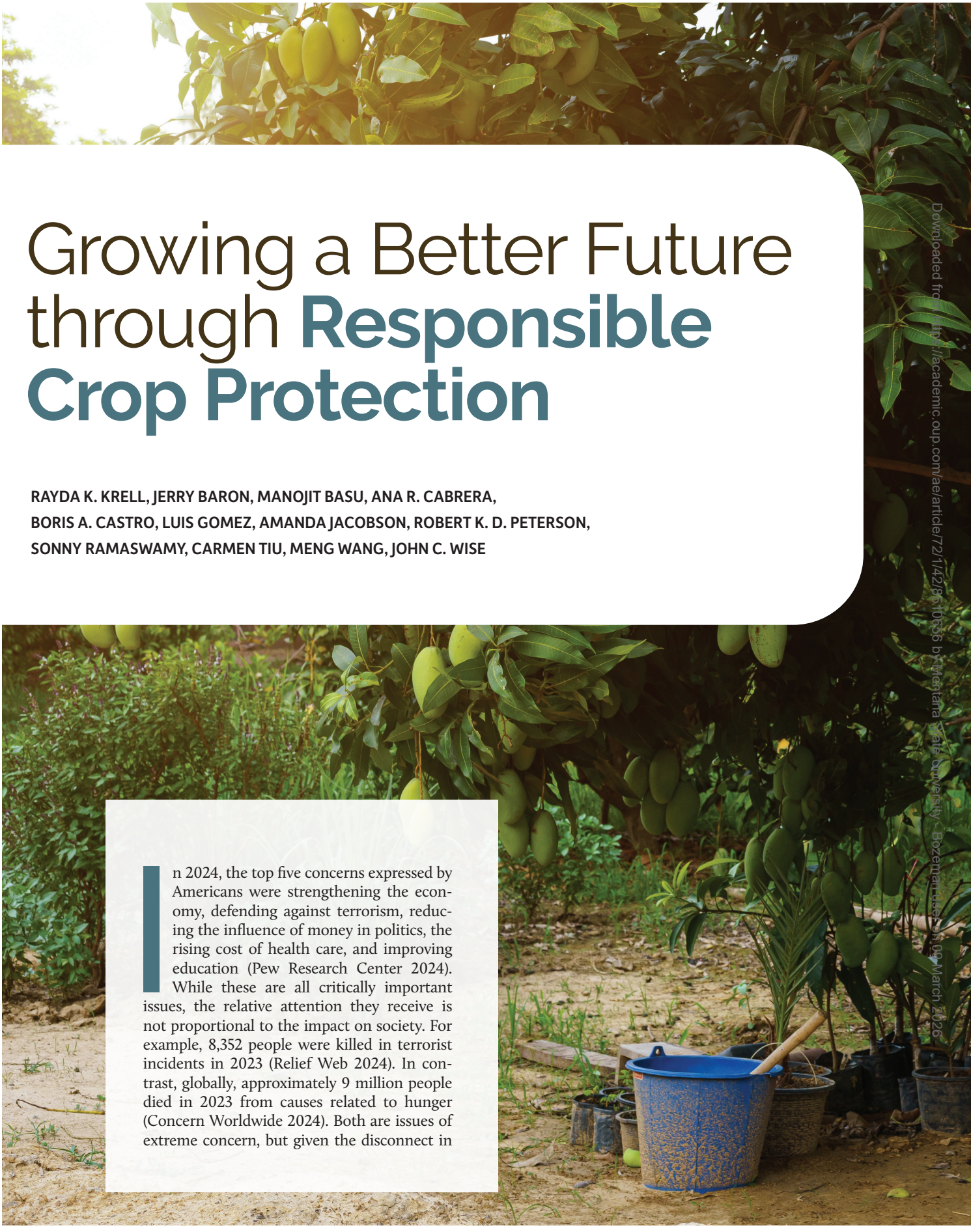
Growing a Better Future through **Responsible Crop Protection**

RAYDA K. KRELL, JERRY BARON, MANOJIT BASU, ANA R. CABRERA, BORIS A. CASTRO, LUIS GOMEZ, AMANDA JACOBSON, ROBERT K. D. PETERSON, SONNY RAMASWAMY, CARMEN TIU, MENG WANG, JOHN C. WISE



In 2024, the top five concerns expressed by Americans were strengthening the economy, defending against terrorism, reducing the influence of money in politics, the rising cost of health care, and improving education (Pew Research Center 2024). While these are all critically important issues, the relative attention they receive is not proportional to the impact on society. For example, 8,352 people were killed in terrorist incidents in 2023 (Relief Web 2024). In contrast, globally, approximately 9 million people died in 2023 from causes related to hunger (Concern Worldwide 2024). Both are issues of extreme concern, but given the disconnect in

THINAPOB/ADOBESTOCK; SULIT.PHOTOS/ADOBESTOCK

Fig. 1. Kenyan mango farmer Veronica Kioko (far right) with her children. Author Carmen Tiu was the study monitor and sponsor representative for the research to support regulatory approval for sulfoxaflor use on mango. (Photo: Minor Use Foundation)

attention compared to impact, how do we promote interest in policy issues that can directly improve the most lives globally?

In the U.S. alone, almost 13.5% of American households (18 million) were food insecure in 2023 (USDA-ERS 2025), even though the availability of food has increased over the past 50 years (Kearney 2010). Many of us in the U.S. may take for granted the diversity, nutritional variety, and taste of unique ingredients when we live just a short distance away from the grocery store. But it is difficult to grasp what it takes to bring this quantity, quality, and diversity to our tables.

Consider mangoes, an important source of nutrition and income for medium and smallholder farmers and a staple crop in tropical regions. More than 7,000 miles away from the U.S., there is a mango farmer named Veronica Kioko in Kenya (Fig. 1). Farming is Veronica's livelihood, but every year, she faces a risk of losing 20–100% of her crop to pests (Muriithi et al. 2024). In the scope of global agriculture, mangoes are considered a minor crop, but to a farmer such as Veronica relying on them for income, every mango is important. Fruit flies, mealybugs, aphids, and whiteflies are all insect pests that can affect the quantity and quality of her crop. The availability of crop protection solutions to manage these pests has a direct impact on food abundance, economic well-being, and quality of life for farmers and consumers. In Kenya, a coalition of stakeholders worked to bring a new, approved pest management option, Isoclast™ Active (sulfoxaflor) insecticide, to mango farmers. The relatively simple step of making a new crop protection option, sulfoxaflor, available to smallholder farmers in Kenya positively affected production and human lives by increasing the annual mango yield and quality. Veronica articulated this value: "The extra income, in fact, is helping us to educate our children … it has helped in paying school fees" (Minor Use Foundation 2024). Veronica's story is just one out of millions that illustrates the significant biological and social impacts of crop protection solutions.

Conventional modern agriculture supplies over 98% of the world's food (Tal 2018). Thus, policies and regulatory frameworks that enable access to crop protection solutions and allow for the use of diverse practices are critical and have an impact on global nutrition and food security. Crop protection solutions are among our most valuable tools for

Table 1. Presentations as part of the Larry Larson Symposium "Advocating Responsible Crop Protection to Influence Policy and Gain Public Engagement" on 5 November 2023 at the Annual Meeting of the Entomological Society of America in National Harbor, Maryland.

Presentation title	Authors	Affiliation
Introductory remarks by symposium organizers	Boris A. Castro, Luis Gomez, Amanda Jacobson	Corteva Agriscience
It's the Message, Stupid: Communication in the Policy Realm	Sonny Ramaswamy	Northwest Commission on Colleges and Universities
Influence 101: The Academic and ESA Perspective on Engaging Policymakers and the Public About Crop Protection	Robert K. D. Peterson	Montana State University
Communicating to Update Pesticide Mindsets	Rayda K. Krell	Corteva Agriscience
Bayer's Commitments to Transparency: Opening Our Science to Build Public Trust	Meng Wang	Bayer CropScience
The IR-4 Project: Sixty Years of Supporting Food Safety and Food Security	John C. Wise[1] and Jerry Baron[2]	[1]Michigan State University, [2]IR-4 Project, Raleigh North Carolina
Pesticide Recommended Use Patterns and Impact on Food Trade Standards and Their Global Harmonization	Manojit Basu[3] and Carmen Tiu[4]	[3]CropLife America, [4]Corteva Agriscience—retired
Beyond the Requirements: A Multi-Disciplinary Approach to Advancing Pesticide Risk Assessment for Pollinators	Ana R. Cabrera	Bayer CropScience
Policy Opportunities in Environmental Compliance	Robyn Rose	United States Department of Agriculture
Role of Pesticides in Addressing Food Insecurity	Manojit Basu	CropLife America

Fig. 2. Meng Wang presenting during the 2023 Entomological Society of America Annual Meeting symposium, "Advocating Responsible Crop Protection to Influence Policy and Gain Public Engagement."

Fig. 3. Three criteria for Responsible Crop Protection.

protecting and optimizing food production. These tools include plant breeding (traditional and genetic engineering), fertilizers/biostimulants, pesticides (biological and synthetic), biological control, cultural practices, behavior-modifying chemicals such as pheromones, mass trapping, and other emerging technologies. The benefits these tools offer are directly connected to the quality of life for the ≈25% of the global population who work in agriculture (Roser 2023) and to our collective food security.

In response to the lack of public understanding (and in some instances hostility) about the role of crop protection to promote a peaceful and food-secure world, the authors of this article organized a symposium at the 2023 Annual Meeting of the Entomological Society of America titled "Advocating Responsible Crop Protection to Influence Policy and Gain Public Engagement" (Fig. 2). It highlighted the importance of promoting public understanding and trust in science-informed crop protection. It brought together a diverse group of speakers from academia, government, non-governmental organizations (NGOs), and industry (Table 1).

Collectively, the authors of this article promote the use of science-informed decision making to protect diverse options for global food security and to improve people's lives. To provide a framework for advocacy on this topic, we formalize a new concept to encompass biological and socioeconomic outcomes. In this article, we define the term from the symposium title: *Responsible Crop Protection*.

Defining Responsible Crop Protection

Responsible Crop Protection (RCP) is a science-informed, socially responsive, and collaborative approach to managing pests. It ensures that solutions are societally informed, economically viable, guided by stewardship, and empowered by community engagement and education. Responsible Crop Protection relies on collaborative decision-making among agricultural stakeholders, including private industry, academia, government, non-governmental organizations (NGOs), farmers, and consumers. RCP builds upon the principles of integrated pest management (IPM) to protect crops that support global food, fuel, and fiber needs in a socially responsive manner (Dara 2019). RCP is a proactive response to modernize and build upon the iconic IPM concept. RCP must meet three criteria, and we identify five tenets to achieve that end. To meet the three criteria, RCP must 1) be effective for pest, vector, and pathogen management, 2) not cause unreasonable adverse effects on humans and the environment, and 3) be economical for farmers and consumers (Fig. 3). RCP provides a framework for evaluating crop protection innovations to ensure they respond to and benefit social needs. RCP that meets these criteria involves these five tenets: integrated pest management; technological innovation; regulatory compliance; environmental stewardship, human health, and wellbeing; economic viability; and community engagement and education (Fig. 4).

RCP provides a framework that we believe facilitates more constructive action and conversation around contemporary crop protection needs. The following sections provide details regarding each tenet and how to put them into action.

Integrated Pest Management (IPM) as the Foundation for Responsible Crop Protection (RCP)

IPM is "a comprehensive approach to managing host stress that is economically and ecologically sustainable" (Peterson et al. 2018). IPM uses a range of tactics, including behavioral, biological, cultural, physical, and chemical, along with resistant crops that may have been developed through traditional breeding, precision breeding, or genetic engineering. RCP is not a replacement for IPM; rather, IPM is at the core of RCP. Embedding IPM in RCP builds on the legacy of integrating science-informed tactics for pest management, while heightening the social responsibility around the choice of tactics (Kogan

1998; Wise and Whalon 2009; Pedigo et al. 2021; Zhou et al. 2024).

From its origin as "integrated control" (Stern et al. 1959) and "an ecological approach to pest control" (Geier and Clark 1960), the concept of IPM was based on concerns of overreliance on chemical pest control and the need for an approach based on understanding pest populations and using diverse tactics. As Stern et al. (1959) highlighted, "Biological and chemical control are not necessarily alternative methods; in many cases they may be complementary, and, with adequate understanding can be made to augment one another." At the time, the authors recognized the need to replace highly toxic pesticides common at the time, which were used at high use rates, lacked selectivity, and had high environmental persistence. The thoughtful integration that was called for over 60 years ago is more accessible than ever with the expansion of low-use rate, highly selective pesticides, with low environmental persistence.

As we apply IPM in the context of RCP, we reinvigorate deliberate programs to diversify tactics, minimize the environmental impact of the various tactics, enhance stakeholder engagement, and ensure economic returns to producers. Because contemporary pesticides are developed with an emphasis on sustainability goals and are applied with precision technologies, significantly lower quantities are used (Fig. 5; Corteva Agriscience 2025a).

With IPM at the core, RCP incorporates minimizing environmental impacts broadly. For example, in the past, tillage was part of effective weed control (Walsh et al. 2020), but responsible application of crop protection tactics emphasizes practices that limit soil disturbance and reduce greenhouse gas emissions. IPM at the core of RCP highlights that the concept remains a gold standard for pest management, but there are new tools and tactics available that can meet the benchmark for "responsible."

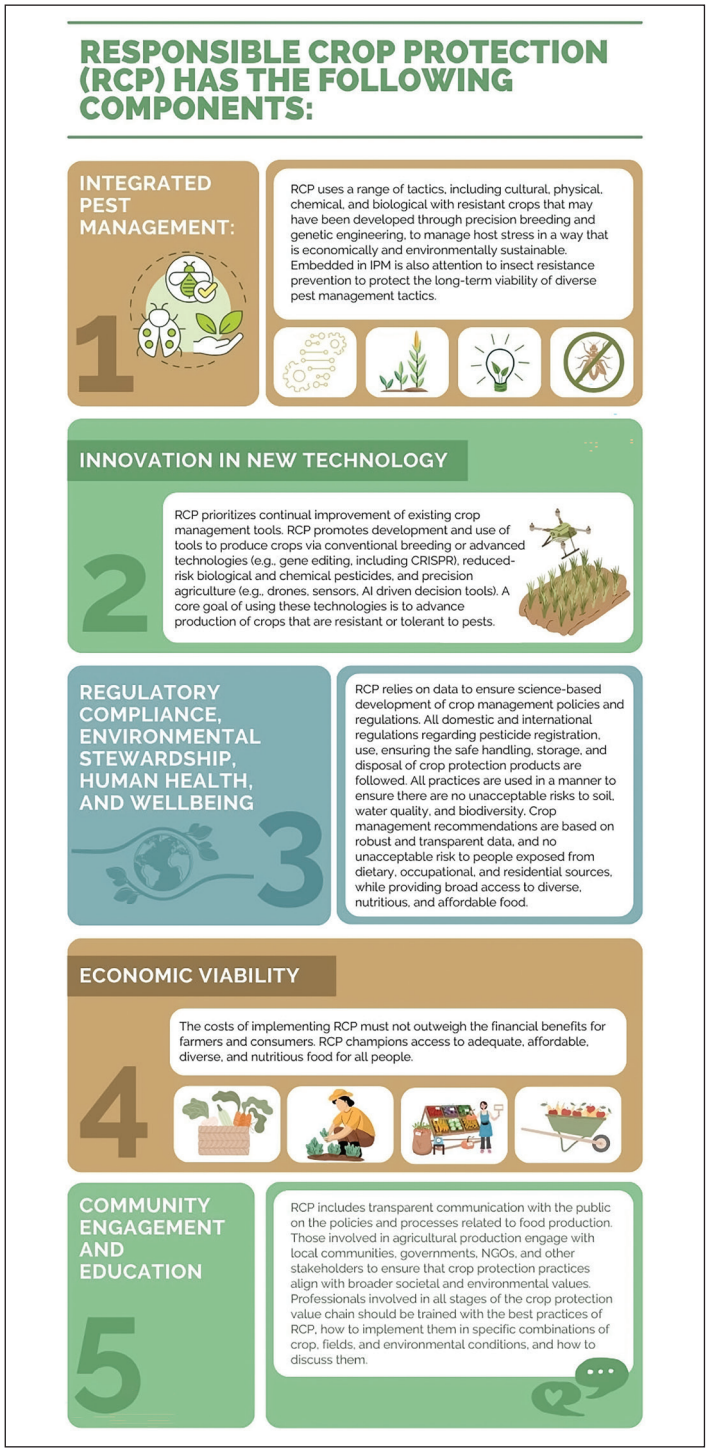


Fig. 4. The five tenets of Responsible Crop Protection.

The Role of Technology Innovation in RCP

Modern agriculture stands as the only solution for achieving safe and sustainable global food security. This requires scientific innovation and societal acceptance of new crop protection technologies. Innovation is an area in which the collaboration of all sectors involved in agricultural production will be especially important to ensure that these technologies are developed and deployed in a way that benefits farmers and is understood by the public. The development of next-generation crop protection approaches must continue to advance favorable characteristics and enable the adoption of precision agriculture practices. Increasing development and deployment of scale-neutral technologies including artificial intelligence (AI) to manage, integrate, and interpret more data, along with the use of sensors, rapid diagnostics based on big data and machine language, more accurate sampling, and improved application technology via drones and robotics, creates

options that did not even exist in the recent past for crop protection.

The current and future demands to feed the world are driving the crop protection industry to move from the traditional "trial-and-error" discovery approach to predictive modelling and design approaches that enable development of effective, affordable, and more selective molecules with pesticidal activity. These molecules undergo a selection process that is aligned with sustainability goals and meet or exceed regulatory safety standards for human health and the environment. An example of this new approach is the CropKey initiative that Bayer CropScience put in place in 2024 (Bayer 2024). Additionally, Bayer is developing new tools and assays to generate relevant safety data earlier in the process, enabling fast characterization of candidate molecules in a high-throughput manner (Haas and Nauen 2021). This fast, early safety characterization then guides chemistry selection (e.g., by promoting molecules with more favorable profiles for bees and other taxa). Corteva Agriscience uses a similar approach to evaluate molecules in its Predictive Safety Center (Rasoulpour et al. 2025) and requires all potential products to meet sustainability requirements to advance in the development pipeline (Corteva Agriscience 2025b). At an early stage of pesticide development, the goal is to identify properties related to potential human, animal, pollinator, or other environmental concerns and discard candidate chemistry that would pose unreasonable risk before it ever advances.

RCP embraces continuous improvement of existing crop management tools. It promotes development and use of tools to produce crops via conventional breeding or advanced technologies (e.g., gene editing, including CRISPR), reduced-risk biological and chemical pesticides, and precision agriculture (e.g., drones, sensors, smart systems, and AI-driven decision tools). Embracing innovative technology can exist in RCP because it is done in the context of support for a regulatory environment that prioritizes health.

The Importance of Regulatory Policies That Protect Human and Environmental Health

The widely accepted precept that "whatever gets measured, can be managed" (FAO 2021) is a critical pillar for regulatory policies governing the development of crop protection products. Many consumers hold the view that food safety is dichotomous, and crop protection is either "safe" or "not safe" according to whether it is "natural" or "unnatural." However, the revolutionary scientist Paracelsus (1493–1541) discovered long ago that "All substances are poisons; there is none which is not a poison; it is the dose that differentiates a poison from a remedy" (ChemicalSafetyFacts.org 2022). Thus, a science-informed approach to crop protection regulation relies on robust measurements as a basis for human and environmental health exposure and risk.

Because contemporary pesticides are developed with an emphasis on sustainability goals and are applied with precision technologies, significantly lower quantities are used.

RCP can only succeed when the science-informed regulatory frameworks and compliance policies are properly communicated, understood, and supported by the public and other stakeholders. Consistent global regulations of crop protection technologies are necessary to ensure a predictable environment for regulators and the regulated communities who drive crop protection development, registration, and use.

Predictability does not mean stagnation; in fact, regulatory entities such as the U.S. Environmental Protection Agency (EPA) integrate novel scientific advances in their work (e.g., Sequence Alignment to Predict Across Species Susceptibility (SeqAPASS), U.S. EPA 2024), develop taxa-specific frameworks (e.g., Pollinator Risk Assessment, U.S. EPA et al. 2014), create strategies to streamline complex processes (e.g., Strategy to protect Endangered Species from Insecticides, U.S. EPA. 2025), and pursue policies to modernize their approaches (e.g., U.S. EPA's New Approach Methods Work Plan, U.S. EPA 2021b).

Crop protection products must comply with the regulations of every country in which they are manufactured, used, or sold. This means some pesticides and genetically engineered crops must meet the standards of more than 100 different regulatory agencies around the world. Product registration is supported by robust data assessed by independent regulatory authorities. Regulations have been validated successfully over the decades and include many safety factors to eliminate unacceptable risks to human health from dietary, occupational, and residential sources and to protect the environment, including soil health, water quality, and biodiversity. Product developers must conduct extensive studies that follow globally harmonized guidelines from the Organisation for Economic Co-operation and Development (OECD). The studies are also conducted under the Good Laboratory Practices (GLP), which ensure the reliability and reproducibility of the results. GLP is a globally agreed quality system (OECD 1998) and is part of the U.S. Code of Federal Regulations (U.S. EPA 2021a). GLP studies follow rigorous processes and checkpoints and are subject to regulatory agency inspections, providing transparency and trust. Regulatory authorities review and independently analyze these data to determine if the proposed uses are acceptable or if mitigations are needed. After the initial registration, there is a required periodic reevaluation of the safety of pest management products, ensuring that new regulations are applied. For example, pursuant to FIFRA section 3(g) (7 U.S.C. 136a(g)) and the Procedural Regulations for Registration Review (40 CFR part 155, subpart C), the EPA reviews pesticide registrations every 15 years (U.S. EPA 2025), and any registration can be removed or additional information and studies required if there is a question of safety for consumers or the environment. Tolerances (least material requirement, LMR) are also reviewed and reset or cancelled during the periodic reviews of existing registrations.

In addition to the rigorous regulatory process for active substances, the registration of crop protection materials for minor-use crops (i.e., specialty crops; AMS-USDA 2025) often involves the public sector and philanthropic involvement to enable access to safe and effective crop protection technology for specialty crop farmers. USDA's IR-4 Project in the U.S. (IR-4 Project 2025) and global counterparts, e.g., Agriculture and Ag-Food Canada's Pest Management Centre and the Minor Use Foundation, help these high-value, low-acreage "orphan crops/uses" secure modern technology. Most of these minor-use projects annually hold a prioritization process to obtain stakeholder engagement. Field efficacy and residue trials and lab analysis protocols are implemented and data collected under GLP, and final data packets are submitted to the EPA and global counterparts for review. These public sector/philanthropic investments in crop protection allow tools that can change lives—such as that of Veronica Kioko, the mango farmer in Kenya—to be available while ensuring no unacceptable risk.

RCP Must Be Economically Viable

RCP practices support the economic livelihood of farmers and consumers. RCP champions access to adequate, affordable, diverse, and nutritious food for all people. Compared with other farm inputs (such as fertilizers, capital investments, and labor) that affect income directly, the use of crop protection tools (such as pesticides, genetically engineered crops, and biocontrol agents) has an indirect effect on income by reducing crop losses.

During the 1970s and 1980s, expected yield losses from insects and pathogens without the use of insecticides and fungicides ranged from 1–26% for large-acreage crops such as corn, soybeans, and wheat (Fernandez-Cornejo et al. 1998). In addition, crop losses from weeds in the absence of herbicide use ranged from 0–53% for the crops studied. The prevention of pest-related crop losses helps make farming operations economically viable because it allows for a more abundant, high-quality harvest. A recent review and Life Cycle Assessment study conducted by the University of Arkansas for CropLife America revealed that in the U.S. corn, cotton, and soybean productivity could decrease by as much as 70% without the use of pesticides (Thoma et al. 2024). Thus, for many crops, it is not economically viable to produce enough yield to recover investments without the use of crop protection products.

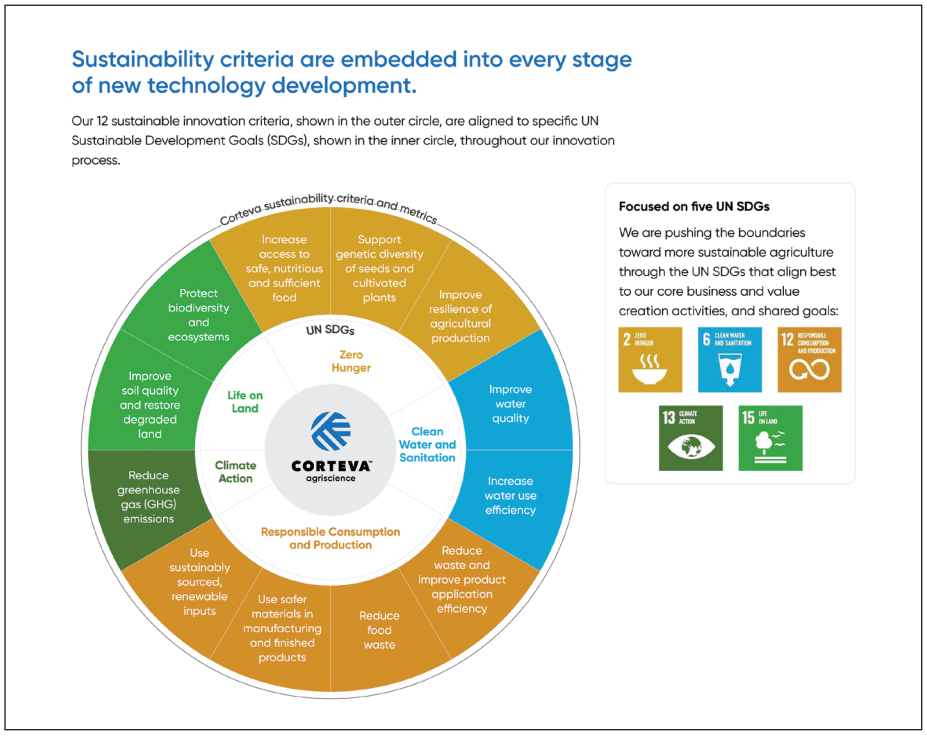


Fig. 5. Corteva Agriscience incorporates the United Nations Sustainable Development Goals into the crop protection development process.

Moreover, pesticides help protect farmers' investments in seeds, fertilizers, and other inputs by ensuring that crops reach maturity without significant pest damage. This protection extends to the quality of the produce, as pesticides reduce blemishes and contamination caused by pests. Higher-quality produce can lead to better crop marketability for farmers (USDA-ERS 2020).

Finally, responsible use of pesticides supports the sustainability and scalability of all farming operations. Pesticides enable farmers to manage large-scale farms more effectively, preventing catastrophic pest outbreaks that could lead to total crop failure. For smallholder farmers, effective pesticides enable production of food and income for families (Fahad and Wang 2018). In the context of global food insecurity, being economically viable is tied to adequate and efficient food production. Where soil is poor, the use of fertilizer and herbicides can mean protecting the soil from erosion caused by tillage and lead to a healthier, more abundant crop that provides the necessary calories for local populations (Lotter 2015). RCP should support economic benefits for diverse farming operations and consumers.

RCP Includes Public Engagement and Communication at All Stages

RCP only exists when all five tenets are present and interact. Ultimately, IPM, technology innovation, and policy should support economic viability, but they can only be deployed effectively with public engagement and communication.

RCP includes proactive and responsive communication with the public (i.e., those not engaged in agriculture) on the policies and processes related to food production. Those involved in agricultural production must engage with local communities, governments, NGOs, and other stakeholders to explain their needs and the crop protection practices that ensure sustainable use for generations to come, and to align with broader societal and environmental values. The concept of "responsible" regarding crop protection provides a consensus framework that is difficult to refute. RCP provides both the criteria for evaluation and the tenets of what it takes to meet those criteria, giving agricultural professionals a starting point that is likely to find common ground with diverse audiences.

Contemporary issues with poor science and scientific literacy aside, the public is generally interested in and fascinated by

Fig. 6. Bayer OpenLabs platform for exploring the crop protection solution development process.

science. For example, television, streaming, and internet shows devoted to science are popular (e.g., *Cosmos*, hosted by Neil deGrasse Tyson). Although there are currently numerous challenges to scientific expertise because of political polarization, polls continue to show that scientists are trusted by a majority of the public (Pew Research Center 2023).

Most people exhibit confirmation bias, rejecting facts that contradict their pre-existing beliefs because of the mental discomfort of cognitive dissonance that this creates. Communication with the public works best when it connects with people at a personal level and affects their hearts much more than their brains. To use an oft-repeated axiom, no one will care how much you know until they know how much you care. So, empathy is key. Communication needs to be about real people living in real places, not abstract and unrelatable concepts. Listening to the needs and concerns of farmers and consumers regarding impacts on their lives will foster more interest in crop protection than graphs. Information is better received when it is presented in a manner that affirms rather than threatens people's values (Kahan 2010). In addition, that information should be vouched for by a diverse set of trusted experts. When considering communication and its resulting influence, simple guidance includes (1) validating emotions, (2) establishing a shared set of goals, (3) generating logical steps to solve a problem, and (4) implementing steps and monitoring results (Cialdini 2001; CFI 2025).

When it comes to crop protection safety, product developers (i.e., companies) follow international safety standards and guidelines, as already described. However, communicating such efforts to the public can be challenging due to the complexity of this work and suspicion toward this industry (and sometimes toward science in general). But crop protection solutions require coordination with industry to bring the solutions to market (Krell et al. 2016). Therefore, it is crucial to increase understanding of industry-sponsored science and build public trust through transparency (Rinaldi et al. 2025). Crop protection companies have transparency initiatives to shine a light on the development process and associated data to bring a product to market (BASF 2025; Bayer 2025a; Corteva 2025c).

A specific example is Bayer CropScience's transparent communication initiative, providing public access to Bayer-owned safety study reports of their crop protection and genetically modified crop products. Since its launch, its transparency website has received over 400,000 unique visits. Hundreds of Bayer-owned study reports have been delivered to academic researchers, journalists, regulators, investors, private individuals, and organizations. In 2020, Bayer extended its commitment to transparency through the OpenLabs program, allowing the public to virtually observe how a residue regulatory study is conducted in laboratories and in the field (Fig. 5 and 6). Additionally, Bayer's approach to responsible crop protection development involves the establishment of two key advisory bodies: the Bayer Bioethics Council (Bayer 2025b) and the Sustainability Council (Bayer 2025c). The two councils work concurrently to offer guidance on relevant bioethical questions and help shape decision-making processes while providing oversight on Bayer's sustainability initiatives and promoting collaboration with various stakeholders, including society, academia, industry, and regulatory policy makers. Crop protection developers are committed to RCP because meeting RCP criteria through the above tenets benefits everyone.

Why Does Advocating for RCP Matter?

Entomologists are uniquely positioned to advocate for policies to promote RCP because of the critical role that insects play in crop production, both as pests and as beneficials. Embedding IPM, technology innovation, regulations that protect health, economics, and communication as requirements to achieve RCP ensures that pest management extremes of the past are not repeated. The Entomological Society of America took a proactive step to be an

RCP relies on decision making that is science-informed, socially responsive, effective, safe, and socioeconomically beneficial.

advocate for science by creating the Science Policy Committee in 2013, leading efforts to establish a science policy agenda and provide the framework to influence policy and interact with institutions developing science policy (ESA 2025a; ESA 2025b).

RCP promotes actions that support the aims of all entomologists: advocating for the use of modern, highly selective pest control tactics to ensure that pests are controlled, while protecting beneficials. There is a path to responsible use of crop protection products when the tenets of RCP are followed, endorsed, and advocated by all stakeholders involved in their development and use. By creating a collective voice on this topic, entomologists and the Entomological Society of America can play a significant role in supporting policies that will benefit society and have a positive global impact for crop production and food security, but these concepts can extend to crop protection for pests in other environments.

The reality is that our food system is more fragile than it looks upon entering the grocery store in a developed country. In the early months of the COVID-19 pandemic, we saw barren grocery store shelves and were left wondering how one public health crisis could disrupt our access to food so quickly. The introduction of just one change into a crop system can have devasting effects. For example, the citrus industry in Florida declined because of citrus greening, and canola production in Europe was lost without access to effective insect management products. We are already challenged to meet global nutrition security, and our food system is particularly vulnerable to abiotic stressors such as climate change and biotic stressors such as pests. Crop pests are often invasive insects, which are anticipated to increase 36% by 2050 (Seebens et al. 2020).

RCP relies on decision making that is science-informed, socially responsive, effective, safe, and socioeconomically beneficial. We propose that RCP creates a positive framework for policymaking that addresses social concerns and finds common ground regarding our universal desire for diverse, abundant, accessible, and affordable food for all. Veronica Kioko's access to innovative crop protection for her mangoes changed her family's life and her community. Choosing how and what we eat is a human right, and we should advocate for the choice to eat food grown in diverse ways for all. "Responsible" should be a concept in which we can find common ground about crop protection with diverse stakeholders. RCP criteria and tenets can guide these critical conversations to help us advocate for a food-secure and peaceful world.

Acknowledgments

The authors appreciate the insightful reviews provided by Leon Higley, Tara Massad, and Kevin Steffey. Additionally, we are thankful for the reviews of many colleagues at Corteva Agriscience. The input resulted in a more effective paper that we hope will meet the need for an effective framework for constructive advocacy and communication about the global need for crop protection.

Rayda K. Krell *is a technical knowledge solutions scientist at Corteva Agriscience, where she creates educational materials about products and agricultural concepts.* **Jerry Baron** *is executive director of the IR-4 Project based at North Carolina State University.* **Manojit Basu** *is vice president of science policy and regulatory affairs at CropLife America.* **Ana R. Cabrera** *is a principal scientist and pollinator safety expert at Bayer CropScience.* **Boris A. Castro** *is a technical knowledge solutions scientist at Corteva Agriscience, where he creates educational materials about insecticides, nematicides, and enabling technologies for agriculture.* **Luis Gomez** *is a principal investigator in crop health at Corteva Agriscience, where he oversees global planning and strategy for insecticide research.* **Amanda Jacobson** *is a technology characterization lead in crop health at Corteva Agriscience, where she oversees global planning and strategy for insecticide research.* **Robert K. D. Peterson** *is a professor and department head in the Department of Land Resources and Environmental Sciences at Montana State University, where he teaches courses in biological risk assessment and insect ecology and mentors students.* **Sonny Ramaswamy** *retired recently from his role as president of the Northwest Commission on Colleges and Universities, following his service as director of the National Institute of Food and Agriculture and in academic and administrative roles at several universities. He remains a passionate advocate for science to support agriculture and is a member of the Bayer Bioethics Council.* **Carmen Tiu** *is a retired global regulatory leader at Corteva Agriscience and current consultant in global food standards consulting; in 2024, she joined the board of directors of the American Vanguard Corporation.* **Meng Wang** *is transparency lead at Bayer Crop Science, where she has led the OpenLabs 360° initiative to allow virtual visitors to see how genetically modified crops are tested.* **John C. Wise** *is a retired professor in the Department of Entomology at Michigan State University and the former north central regional director of the IR-4 Project.*

DOI: https://doi.org/10.1093/ae/tmag004

References Cited

(AMS-USDA) Agricultural Marketing Service United States Department of Agriculture. 2025. USDA definition of specialty crop. https://www.ams.usda.gov/sites/default/files/media/USDASpecialtyCropDefinition.pdf

BASF. 2025. Committed to regulatory data transparency. https://agriculture.basf.com/global/en/business-areas/crop-protection-and-seeds/services/regulatory-data-transparency

Bayer. 2024. Designing the keys to unlock the future of sustainable protection. https://www.bayer.com/en/agriculture/article/designing-the-keys-to-unlock-the-future-of-sustainable-protection

Bayer 2025a. Transparency at Bayer. https://www.bayer.com/en/sustainability/transparency

Bayer. 2025b. The Bayer bioethics council. https://www.bayer.com/en/sustainability/the-bayer-bioethics-council

Bayer. 2025c. The Bayer sustainability council. https://www.bayer.com/en/sustainability/bayer-sustainability-council

(CFI) The Center for Food Integrity. 2025. Building trust in today's food system. https://www.foodintegrity.org/home

Concern Worldwide. 2024. World hunger facts: what you need to know in 2024 (and 2025). https://www.

concern.org.uk/news/world-hunger-facts-figures
ChemicalSafetyFacts.org. 2022. "The dose makes the poison." 17 Aug 2022. https://www.chemicalsafetyfacts.org/health-and-safety/the-dose-makes-the-poison/
Cialdini RB. 2001. Influence: science and practice. Needham (MA): Allyn and Bacon.
Corteva Agriscience. 2025a. Impact Report 2024. https://reports.corteva.com/sustainability/impactreport2024/p001-welcome-to-our-impact-report-2024-13962-T01.html
Corteva Agriscience. 2025b. Our commitment to sustainable innovation. https://www.corteva.com/sustainability/sustainable-innovation.html
Corteva Agriscience. 2025c. Corteva's commitment to transparency. https://www.corteva.com/our-impact/transparency.html
Dara S. 2019. The new integrated pest management paradigm for the modern age. J. Integr. Pest Manag. 12:1–9. http://doi.org/10.1093/jipm/pmz010
(ESA) Entomological Society of America 2025a. Science Policy Committee. https://entsoc.org/advocacy-initiatives/science-policy/committee
(ESA) Entomological Society of America 2025b. Science Policy and Advocacy. https://entsoc.org/advocacy-initiatives/science-policy
Fahad S, Wang J. 2018. Farmers' risk perception, vulnerability, and adaptation to climate change in rural Pakistan. Land Use Policy 79:301–309. https://doi.org/10.1016/j.landusepol.2018.08.018
(FAO) Food and Agriculture Organization. 2021. Measuring food safety: indicators to achieve Sustainable Development Goals (SDGs). https://openknowledge.fao.org/server/api/core/bitstreams/ea1fe5c6-bb6b-40a8-b388-66413887bcb4/content
Fernandez-Cornejo J, Jans S, Smith M. 1998. Issues in the economics of pesticide use in agriculture: a review of the empirical evidence. Rev. Agric. Econ. 20: 462–488. https://doi.org/10.2307/1350002
Haas J, Nauen R. 2021. Pesticide risk assessment at the molecular level using honey bee cytochrome P450 enzymes: a complementary approach. Environ. Int. 147: 106372. https://doi.org/10.1016/j.envint.2020.106372
Geier PW, Clark LR. 1960. An ecological approach to pest control, pp. 10–18. *In* Proceedings of the eighth technical meeting, International Union of Conservation of Nature and Natural Resources, Warsaw.
IR-4 Project. 2025. Pest management solutions for specialty crops and specialty uses. https://www.ir4project.org/
Kahan D. 2010. Fixing the communications failure. Nature 463:296–297. https://doi.org/10.1038/463296a
Kearney J. 2010. Food consumption trends and drivers. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 365: 2793–2807. https://doi.org/10.1098/rstb.2010.0149
Kogan M. 1998. Integrated pest management: historical perspectives and contemporary developments. Ann. Rev. Entomol. 43:243–270. https://doi.org/10.1146/annurev.ento.43.1.243
Krell RK, Fisher ML, Steffey KL. 2016. A proposal for public and private partnership in extension. J. Integr. Pest Manag. 7:4. https://doi.org/10.1093/jipm/pmw001
Lotter D. 2015. Facing food insecurity in Africa: why, after 30 years of work in organic agriculture, I am promoting the use of synthetic fertilizers and herbicides in small-scale staple crop production. Agric. Hum. Values 32:111–118. https://doi.org/10.1007/s10460-014-9547-x
Minor Use Foundation. 2024. Impact: Kenya mango project. https://www.youtube.com/watch?v=-owr_f1kML4
Muriithi B, Franchini R, Kolhoff P, et al. 2024. Gendered barriers and opportunities for scaling integrated pest management practices along the mango value chain in Kenya. *J. Integr. Pest Manag.* 15:5. https://doi.org/10.1093/jipm/pmad034
(OECD) Organisation for Economic Co-operation and Development. 1998. OECD Series on principles of Good Laboratory Practice and compliance monitoring, Number 1. https://doi.org/10.1787/9789264078536-en
Pedigo LP, Rice ME, Krell RK. 2021. Entomology and pest management. Long Grove (IL): Waveland Press, Inc.
Peterson RKD, Higley LG, Pedigo LP. 2018. Whatever happened to IPM? Am. Entomol. 64:146–150. https://doi.org/10.1093/ae/tmy049
Pew Research Center. 2023. Americans' trust in scientists, positive views of science continue to decline. https://www.pewresearch.org/science/2023/11/14/americans-trust-in-scientists-positive-views-of-science-continue-to-decline/
Pew Research Center. 2024. Americans' top policy priority for 2024: strengthening the economy. https://www.pewresearch.org/politics/2024/02/29/americans-top-policy-priority-for-2024-strengthening-the-economy/
Rasoulpour RJ, Batra A, Shan G. 2025. Threading the eye of the needle: designing the next generation of crop protection solutions in an increasingly deglobalized regulatory landscape. J. Agric. Food Chem. 73:1801–1803. https://doi.org/10.1021/acs.jafc.4c08769
Relief Web. 2024. Global terrorism index 2024. https://reliefweb.int/report/world/global-terrorism-index-2024
Rinaldi A, Jalaluddin NSM, Hussain RBM, et al. 2025. Building public trust and acceptance towards spray-on RNAi biopesticides: lessons from current ethical, legal and social discourses. GM Crops and Food 27:398–412. https://doi.org/10.1080/21645698.2025.2510735
Roser M. 2023. Employment in agriculture. https://ourworldindata.org/employment-in-agriculture
Seebens H, Bacher S, Blackburn TM, et al. 2020. Projecting the continental accumulation of alien species through to 2050. Glob. Chang. Biol. 27:970–982. https://doi.org/10.1111/gcb.15333
Stapleton CE, Langehennig SR. 2024. Partisanship and voting behavior reconsidered in the age of polarization. Elect. Stud. 88:102752. https://doi.org/10.1016/j.electstud.2024.102752
Stern V, Smith R, van den Bosch R, et al. 1959. The integrated control concept. Hilgardia 29:81–101.
Tal A. 2018. Making conventional agriculture environmentally friendly: moving beyond the glorification of organic agriculture and the demonization of conventional agriculture. Sustainability 10:1078. https://doi.org/10.3390/su10041078
Thoma G, Matlock M, Lawrence K, et al. 2024. Life cycle assessment of impacts of eliminating chemical pesticides used in the production of U.S. corn, soybeans, and cotton. https://www.croplifeamerica.org/news-releases/life-cycle-assessment?rq=LCA
(U.S. EPA) U.S. Environmental Protection Agency. 2014. Guidance for assessing pesticide risks to bees. https://www.epa.gov/pollinator-protection/pollinator-risk-assesment-guidance
(U.S. EPA) U.S. Environmental Protection Agency. 2021a. Code of Federal Regulations, Title 40 – Protection of Environment, Part 160 – Good Laboratory Practice Standards. https://www.govinfo.gov/content/pkg/CFR-2011-title40-vol24/xml/CFR-2011-title40-vol24-part160.xml
(U.S. EPA) U.S. Environmental Protection Agency. 2021b. New approach methods work plan. https://www.epa.gov/chemical-research/new-approach-methods-work-plan
(U.S. EPA) U.S. Environmental Protection Agency. 2024. Sequence alignment to predict across species susceptibility (SeqAPASS) resource hub. https://www.epa.gov/comptox-tools/sequence-alignment-predict-across-species-susceptibility-seqapass-resource-hub
(U.S. EPA) U.S. Environmental Protection Agency. 2025. Strategy to protect endangered species from insecticides. https://www.epa.gov/endangered-species/strategy-protect-endangered-species-insecticides
(USDA-ERS) United States Department of Agriculture Economic Research Service. 2020. Economic drivers of food loss at the farm and pre-retail sectors: a look at the produce supply chain in the United States. Economic Information Bulletin No. 216. https://www.ers.usda.gov/publications/pub-details?pubid=95778
(USDA-ERS) United States Department of Agriculture Economic Research Service. 2025. Food security and nutrition assistance. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-security-and-nutrition-assistance/
Walsh M, Squires C, Coleman G, et al. 2020. Tillage based, site-specific weed control for conservation cropping systems. Weed Tech 34:704–710. https://doi.org/10.1017/wet.2020.34
Wise J, Whalon M. 2009. A systems approach to IPM integration, ecological assessment and resistance management in tree fruit orchards, pp: 325–345. *In* Ishaaya I, Horowitz AR (eds.). Biorational control of arthropod pests: application and resistance management. New York (NY): Springer Publishing Ltd.
Zhou W, Arcot Y, Medina RF, et al. 2024. Integrated pest management: an update on the sustainability approach to crop protection. ACS Omega 9:41130–41147. https://doi.org/10.1021/acsomega.4c06628