Organic Insect Pest Management

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The Federal National Organic Program (NOP) guidelines for insect pest management can be viewed as constraining to certified organic growers due to the disallowance of certain tactics such as synthetic insecticides and transgenically derived pest resistant crops. The types of insect pest management tactics that are promoted by the NOP require in-depth entomological knowledge for successful management such as pheromone disruption, augmentation and conservation biological control. There are significant gaps in the Federal NOP guideline recommendations, such as insect identification and population monitoring, that if included could aid in grower adoption of practices that inform better decision making and efficacy. This review promotes the idea that these issues can be overcome by utilizing experiential learning programs to educate growers and paid professionals like those who are a part of the California system of state licensed Pest Control Advisors (PCA) and having those paid advisors provide much needed individualized, hands-on grower guidance. If the PCA or paid professional is regarded as a valued partner in the educational and extension process of addressing pest management issues, they can be an effective advocate, educator, mentor and assessor for the growers; ultimately reaching more growers to ensure effective adoption and use of a variety of management tactics. This model has the capacity to achieve the NOP's philosophical goal of a production system managed to respond to site-specific conditions by integrating cultural, biological and mechanical practices for effective pest management.

Keywords: National Organic Program ; biology ; biological control ; pest management ; monitoring ; identification ; pest control advisor ; cooperative extension ; education

1. Introduction

Insect pest management is one of the most challenging aspects of agricultural production that growers face. The economic success of a grower hinges on their ability to readily identify pest presence and injury levels to make informed management decisions using tactics outlined in the National Organic Program (NOP) (see Federal NOP §205.206). However, the list of acceptable practices is often described by growers as a “limited toolbox” of tactics, mainly associated with the lack of synthetic pesticides, thus making managing insect pests far more challenging than in conventional systems.

Two issues arise from the idea of a limited pest management toolbox. First, growers need to be made aware of any new advances and techniques in pest management through robust educational systems that focus on one-on-one interactions and demonstrations. Second, since the NOP guidelines serve as a point of certification and reference, they need to accurately reflect the comprehensive nature of organic pest management and specifically include pest identification and monitoring as first steps as these data inform the application and assessment of all other management tactics.

Insect pest communities in agricultural systems are dynamic and for organic growers to be successful pest managers, they must have a substantial entomological knowledgebase that is continually updated through education. Education programs need to focus on timely delivery of new pest management research and pest identification and monitoring techniques. Many organizations support the transfer of knowledge to organic growers, such as universities, extension services, non-profits, and state and federal agriculture departments. Although the goal of these agencies is to empower growers, the learning modality is typically passive listening at a workshop rather than experiential learning and assessment that ensures mastery of the information and adoption of the techniques. Further, educational programs may be infrequent or lacking for those in rural areas, making educational programming at the local level a critical priority.

2. Challenges to Organic Pest Management

The Federal NOP guidelines include lists of actions for growers to implement for their organic certification process. Preventative measures include crop rotation, but this may be impractical for many growers due to space constraints, agronomic knowledge, their business model, the cost of leasing land to grow a no-value cover crop, or desire.they may

want to grow only one type of crop. Prevention also focuses on enhancing soil health to impart pest resistance to crops. Although, there is recent research activity, there remains very little evidence for data-based grower recommendations.

Augmentation biological control methods are key to successful organic insect pest management, but the biological knowledge needed to implement such practices, even for just a single pest/natural enemy is extensive[1][2] and only increases when considering a diversified farming system that also uses conservation biological control techniques[3]. Growers are best served for augmentation advice by biological pest management companies that offer field representative services who participate in grower educational programs and have a strong online presence with information based on academic research and documented field experience.

Conservation biological control is promoted by the Federal NOP guidelines either by using selective chemicals that reduce harm to already present natural enemy populations or development of habitat on farms that promote and benefit natural enemy populations [4][5][6][7][8][9][10][11][12][13]. Extensive biological and cropping system knowledge are needed for effective implementation of these methods that will lead to predictable management outcomes. Conservation biological control approaches have yet to reach their full potential, but they do lend themselves to experiential educational programs conducted by the academic community that facilitate technology transfer to the grower community [14][10][11][15].

For growers willing to embrace farm diversity, there must be the ability, resources, and the will to conduct in-field experimentation to achieve site-specific validation of the tactics due to differences in regional climate and crop diversity. Risk-averse growers may find the practices described above are difficult to enact or that they alter the way they grow to such an extent as to be impractical or undesirable[16][1][2][7]. They may also question the return on investment. If these methods were reasonable to implement and ensured a decent return on effort and expense, they would be more widely accepted and adopted. Without guidance and assurances, it is likely these avenues will remain passed over by growers opting for more reliable methods that offer broad pest management solutions with minimal farm specific pest knowledge.

Despite the best efforts at prevention and mechanical/physical control, pest problems will occur and growers are told to use chemicals only as a last resort. The Federal NOP does not explicitly state, but implies, that chemical pesticides be chosen to prevent environmental harm, which is another facet of conservation biological control—the use of selective chemicals. These chemicals are physically or physiologically selective to specifically preserve currently active natural enemies from harm. Ironically, in spite of the NOP's emphasis on prevention, Goldberger and Lehrer[1] validated the work of earlier studies[2][3] that showed growers more readily adopted the tactics of reducing harm to natural enemies by using selective pesticides rather than adopting the practices of beneficial habitat development or even augmentation due to their familiarity with the pesticide application process and rapid tangible results.

Growers want to use chemical pesticides when they feel the need arises[17]. They may work at preventative measures, but growers will use chemicals in response to any perceived economic pest threat and not as a last resort. As much as academics want growers to adopt various ecologically based pest management approaches, growers need to know that their investment and income can be protected from pests at a moment's notice. Others argue that the suite of chemical options should be broadened for organic.growers with mounting evidence that organic pesticides are ineffective, resulting in more applications, are harmful in other ways to the environment, have non-target issues, and are not imparting the perceived health benefits when compared to conventionally grown crops[18][19][20]. McGuire[20] specifically argues that banned synthetic pesticides reduces avenues for enhancing organic pest management. This again points to the constraints on the grower toolbox.

The Federal NOP does not mention monitoring, and concomitant pest identification, as part of pest management but these activities should be explicitly listed among the first preventative tactics so that they filter through the entire certifying/educational infrastructure to the grower. For many pest management control tactics, a robust monitoring system is required for a grower to determine if an application is warranted and to time it with confidence. Insect pest population assessment, specifically determining the presence, density and dispersal of a variety of insect pest species and their natural enemies is a daunting aspect to pest management for growers and advisors alike[21], but with robust benefits.

Monitoring or scouting is a time-consuming constraint on growers due to the need for consistency and follow up to determine treatment efficacy[21]. Monitoring a cropping system requires extensive knowledge of weeds, pathogens, arthropods and vertebrates. For diverse cropping systems the knowledge burden is compounded by the number of different crops. The benefits of consistent monitoring allow for early detection that is necessary to time and select pest management actions, especially for tactics slow to develop, such as inoculation augmentation biological control, or conservation biological control tactics, such as insectary plantings[22]. Determining if an insect pest population represents an economic concern is an additional layer of complexity that requires current and historical knowledge[23]. Assessing economic injury levels and action thresholds require accurate, consistent field information[24] and most growers rely on "nominal thresholds"[25] that are based on a grower's experience rather than a formal economic injury level calculation[26].

The lack of meaningful thresholds for most pests and cropping systems is a well-known gap that can be bridged by consistent monitoring, but the results of such monitoring need to be a part of the annual certification process to ultimately develop appropriate thresholds for individual farmers.

3. Overcoming Challenges and Looking to the Future

All told, the knowledge burden is increasing, and the grower's need for information and validation for taking a particular pest management action are getting more intense. After reviewing these challenges and contemplating how to move forward, a quote from Dr. Joseph Morse, Emeritus Entomologist, UC Riverside, serves as a guiding principle. He stated to the growers and academics at a California Citrus Research Board grower education meeting in 2003 that, "Either growers will become better biologists, or they'll need to pay someone who is."

The focus for the next section will attempt to lay the framework for an education-based system for empowering growers and their advisors to be better biologists, or specifically for this review, better entomologists, in their pest management efforts. Achieving this goal will require creating free or affordable access to meaningful, regionally appropriate educational programs from academics and individualized on-farm advising through the use of a model similar to the California Pest Control Advisor's (PCA) program[27].

The typical transfer of information to growers begins with academic experts conducting research through a series of five steps referred to as the Atwater Directives[28]. The final step is where the Cooperative Extension Service steps in to enhance and impart research findings to the growers; a model with a long history of success Figure 1[29]. These services are state-funded and provide information free of charge. However, cooperative extension budget reductions have made it nearly impossible for the extension service to provide the full number of individualized, hands-on advising and follow-up visits that are needed for today's grower community[30].

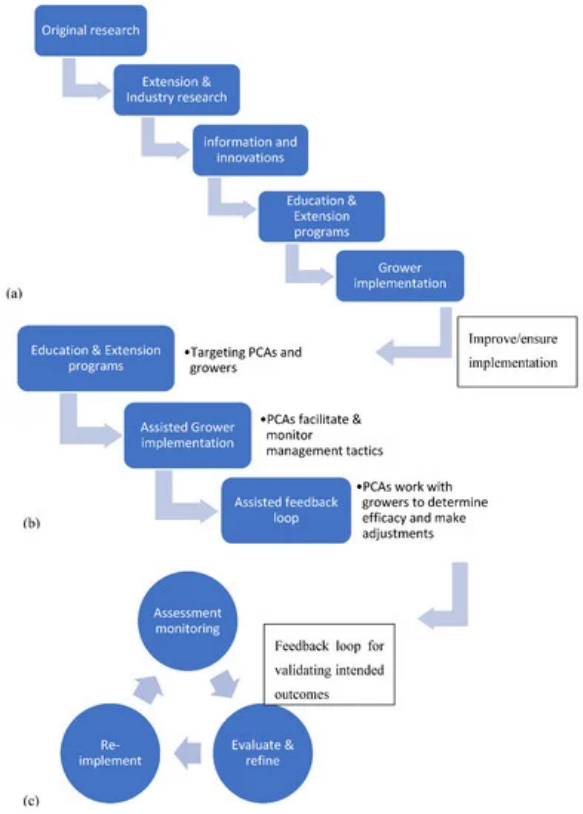

Figure 1. An illustration of pest management information flow. (**a**) Information typically flows from original research to extension and private industry research to innovations/modifications in pest management tactics to the end user by way of educational programs conducted by academics, extension agents, state and local agriculture departments, non-profits, private industry, professional societies. (**b**) Effective grower implementation is uncertain and can be improved/aided with additional professional guidance from a Pest Control Advisor (PCA). Ensuring the PCA is included in the educational process enhances their knowledgebase and consistent messaging to growers. (**c**) Finally, the PCA provides the necessary skillset of monitoring for effective outcomes and advice on improvements that feeds back into future implementation.

In California, the reduction of the cooperative extension program has been buffered by the Department of Pesticide Regulation's PCA licensing program and grower reliance on PCAs for pest management information and advice has continued to grow since its inception[31]. In a recent law review, Vanzant[32] listed the following statistics for PCA reliance. In 1983, 75% of a large survey of tomato growers ranked PCAs as their "most important source of pest control information"; in 2000, a survey of 453 almond growers in the San Joaquin and Sacramento Valleys revealed that 97% of those growers relied on PCAs for advice regarding pest management; and in 2007, a survey of 266 California cotton growers showed that 99% of those growers relied on PCAs for their pest management needs. In a more recent study, Goldberger and Lehrer[1] showed PCAs and chemical company field representatives were the primary source of pest management information for walnut and pear growers in the Pacific northwest.

These reports indicate a line of information transfer from the researcher to the grower that includes the PCA as a key information and recommendation resource for growers. The role of the PCA as a source of information has been acknowledged by the Department of Pesticide Regulation as they require 40 h of continuing education every two years to maintain the PCA license. The educational programs that are designed and delivered by the academic community for CEUs in California focus on having the PCA as part of the audience and in some cases as presenters. In other states, Certified Crop Advisors (CCA) or graduates of Plant Doctor programs (University of Nebraska-Lincoln and University of Florida) play a similar role to the PCA. Thus, licensed professionals such as PCAs do the leg work and develop management plans that are then discussed with individual growers.

Organic growers are able to utilize the services of PCAs, and California and Arizona require a PCA recommendation for certain microbial pesticides. They also offer advice regarding the use of natural enemies and cultural controls to tailor university-derived research to the specific crop/region and available resources to best serve the grower[33][34]. Ehler and Botrell [35] termed it "supervised" help for pest management.

If pest management information transfer were to include a licensed professional such as a PCA whom the grower will pay to be the better entomologist, then that idea needs to be tempered with the fact that there will be a conflict of interest for PCAs that are employed by pesticide distribution companies[32][35]. It will be critical for growers to ensure that they hire independent PCAs for objective information but also have the choice to use company representatives for specific product recommendations.

The use of social media is having an impactful role in the transfer of information to and among growers. Social media is a tool that provides valuable opportunities, but also spreads misinformation quickly and broadly. There are no studies that currently quantify the reliance that growers have on social media platforms for pest management information, but it's importance and ubiquity in pest management information exchange has been discussed in detail by Holt et al.[36]. Social media can be effective in information transfer[37][38] but possibilities of abuse and misinformation make it a challenge to ensure growers can distinguish between evidence-based reliable information and inaccurate or misleading information. Solis-Toapanta et al.[39] recently conducted a fascinating study of Reddit threads involving pest management information exchange; the amount of misinformation is not inconsequential. This should be carefully considered because growers have stated that the importance of information obtained from other growers was at times on par with, or in some instances more important than, university scientists and extension personnel [1].

Ultimately, with a PCA-included educational model, university-derived education programs become "train the trainer" programs with significant benefits[30]. The benefit to the grower is having both extension personnel and paid professionals with a consistent message. As stated by Baker et al.,[40] education that follows appropriate research is a key to successful technology transfer[41]. The benefit for the organic grower will be professional advisors with an enhanced knowledgebase related to organic pest management tactics, such as Farmscaping, augmentation biological control, and microbial pesticides, and will likely amplify their adoption by growers due to the well-established relationship of most growers having PCAs as their preferred/primary source of such information[1][32].

The mechanisms of information transfer to the grower envisioned here would be through site visits with individualized explanations of concepts using visual graphics, then revisiting to determine the efficacy of tactics and finally a feedback loop for assessment of the education process itself. If the process works, the grower will see the results; in other words, their assessment will be measured as the net return after harvest. For the PCA, the assessment will be based on the success of the grower relationship and its continuation. For the academics, especially the extension agents, there must be an accounting to close the loop—using metrics and assessment of impacts that are not just "number of attendees" but actual documented in-field successes such as yield increases, reduced pesticide applications, areawide adoption of reduced-risk management tactics, etc.

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