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Source: Florida Entomologist, 92(1) : 24-28

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.092.0105

ASSESSMENT OF IMPLEMENTATION AND SUSTAINABILITY OF INTEGRATED PEST MANAGEMENT PROGRAMS

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ABSTRACT

All parties involved in growing the world's food, including growers, crop consultants, university researchers, extension personnel, national and regional regulatory agencies, and the agrochemical and seed industry, spend significant time, money, and effort to solve the problems associated with growing food. The needs of these parties are varied and sometimes in conflict, which is not always conducive to developing and implementing integrated pest management (IPM) systems that are both sustainable and economical. IPM encompasses simultaneous management of multiple pests, regular monitoring of pests and their natural enemies and antagonists, use of economic or treatment thresholds when applying pesticides, and integrated use of multiple, suppressive tactics. IPM components with the greatest impact on resistance management are rotating classes of chemistry, use of recommended rates, not exceeding label restrictions, and avoiding sequential treatments of products with the same mode of action. The best way to insure that these components are followed is to have pesticide record keeping and reporting. However, pesticide use record keeping and reporting are not currently required in all areas. Other activities that can be integrated include educational workshops on IPM, resistance monitoring of pests to pesticides, proper identification of pests and natural enemies, real time scouting reports on the pests that are being found, maintenance of a data base on the effects of various products on natural enemies, and field validation of IPM use.

Key Words: *Frankliniella occidentalis*, pepper, eggplant, tomato, strawberries, integrated pest management, resistance management, implementation, assessment, sustainability

RESUMEN

Todos los grupos envueltos en la siembra de alimentos para el mundo, incluyendo los productores, asesores de cultivos, investigadores universitarios, personal de extensión, agencias regulatorias nacionales y regionales y las industrias de agroquímica y de semilla, gastan tiempo, dinero y esfuerzo significativos para resolver problemas asociados con la siembra de alimentos. Las necesidades de estos grupos son diversos y a veces están en conflicto, lo cual a veces no es bueno para el desarrollar e implemento de sistemas de manejo integrado de plagas (MIP) que son sostenibles y económicos. El MIP abarca el manejo simultaneo de plagas múltiples, el monitoreo con regularidad de plagas y sus enemigos naturales y antagonistas, el uso de umbrales económicos o de tratamiento cuando aplican pesticidas, y el uso integrado de tácticas supresivas múltiples. Los componentes de MIP de mayor impacto sobre el manejo de resistencia son el alternar diferentes clases de químicos, el uso de la cantidad recomendada del producto, no exceder las restricciones de etiqueta, y evitar tratamientos secuenciales de productos con la misma moda de acción. La mejor manera para asegurar que estos componentes son seguidos es mantener un registro de los pesticidas usados y reportarlos. Sin embargo, el mantenimiento de un registro y el reporte de los pesticidas usados no es requerido actualmente en todas las áreas. Otras actividades que pueden ser integrados incluyen talleres educativos sobre MIP, el monitoreo de resistencia de las plagas hacia los pesticidas, la identificación correcta de plagas y enemigos naturales, informes en tiempo real de los inventarios de cultivos sobre las plagas que se encuentran, el mantenimiento de un base de datos sobre los efectos de varios productos sobre los enemigo naturales, y la validación del uso de MIP en el campo.

Many parties, including growers, crop consultants, university researchers, extension personnel, the federal and state regulatory agencies, and the agrochemical and seed industry are involved in managing pests that reduce the yield and quality of food crops. "Pest management stakeholders" spend significant time, money, and effort to solve the technical, economic, and social issues associated with growing food crops. The needs of stakeholders are varied and sometimes in conflict.

Growers want simple, effective, and inexpensive solutions to pest problems and they expect new products with better attributes to replace older products. Crop consultants need to balance the cost or scheduling demands of the grower with what the consultant knows is the best prescription for the problem. University researchers want to develop science-based and holistic IPM solutions and extension personnel want to successfully implement these programs. The agrochemical industry strives to develop products that are IPM-compatible, with a long effective life (20+ years), competitive with alternative products, and to provide an economic return to the company's shareholders. To meet their individual needs, the pest management stakeholders must look for common ground and work together to develop and implement IPM systems that are sustainable and economical.

To successfully develop and implement sustainable and economical IPM systems, the stakeholders must first agree on the scope of the desired outcomes. Ehler et al. (2006) state that for the IPM practitioner, IPM encompasses the simultaneous management of multiple pests, regular monitoring of pests and their natural enemies and antagonists, use of economic or treatment thresholds when applying pesticides, and integrated use of multiple suppressive tactics. Integration of IPM tactics may be vertical or horizontal. "Vertical" IPM refers to the integration of multiple, compatible tactics to control one group of pests (insects/arthropods or pathogens or weeds). "Horizontal" IPM refers to the integration of multiple, compatible tactics to control more than 1 group of pests (insects/arthropods, pathogens, and weeds). Although full horizontal integration is clearly the ideal result to strive for, in practice, achieving vertical integration of IPM tactics for a single pest takes significant effort. Pest management stakeholders should start with realistic expectations about the scope of their efforts to assess the implementation and sustainability. We recommend starting at a relatively small level of integration, namely a single insect pest across a range of crop systems. With the scope of IPM established, stakeholders can assess the implementation and sustainability of IPM programs.

Our analysis and discussion will relate to assessing the implementation and sustainability of IPM tactics for western flower thrips (WFT), *Frankliniella occidentalis*, in Florida tomatoes, peppers, eggplant, blueberries, and strawberries. A number of specific IPM tactics have been developed and are recommended for managing WFT in fruiting vegetables (Reitz et al. 2003; Momol et al. 2004; Funderburk et al. 2008). Among these tactics are thrips identification, use of treatment thresholds, use of *Orius:*WFT population ratios, conservation of biological control, natural enemy refugia, use of ultraviolet-reflective mulches, integrated resistance management, use of selective insecticides that have minimal effects on natural enemy populations, care to not overuse pesticides and especially those that induce WFT, and good sanitation. Thrips identification is important because thrips species other than *F. occidentalis* generally do not cause economic damage. The use of treatment thresholds and use of *Orius*:WFT population ratios are important because if *Orius* parasitoids are in sufficient numbers, they will keep WFT under control. Conservation biological control, natural enemy refugia, and the use of ultraviolet-reflective mulches, reduces initial WFT immigration into a field. Integrated resistance management includes the rotation of insecticides from different chemical classes, thus preventing the overuse of pesticides. The use of selective insecticides that have minimal effects on natural enemy populations, is vital in the control of WFT.

The primary selective insecticide used for WFT management is spinosad. Spinosad insecticide products were first introduced in the late 1990s and have been highly effective in controlling western flower thrips and widely used for this purpose (Eger et al. 1998). There have been isolated incidents of resistance to spinosad in several insect pest species. In these cases, resistance has been recessive and reducing spinosad use to reduce selection for resistance has resulted in regaining susceptibility in most cases. Spinetoram, a new and more active insecticide, was registered for use in 2008.

CASE STUDY WESTERN FLOWER THRIPS RESISTANCE, PALM BEACH FL

In 2006, a grower in Palm Beach County FL reported that spinosad was not providing the expected level of WFT control in his bell pepper fields. Spray timing, use rate, product quality, application quality, and application equipment were examined and eliminated as possible factors in lack of performance. WFT were collected from the grower's field and bioassayed by the method developed by Eger et al. (1998) to determine if susceptibility to spinosad had changed. This WFT strain was exposed to 11 PPM and 123 PPM, the LC_{90} and LC_{99} values established for spinosad from baseline susceptibility testing (Eger et al. 1998). Mortality was less than 20% at each concentration, indicating that tolerance to spinosad had developed in this population.

The initial perception of the grower was that any thrips present would threaten the quality of his high-value pepper crop. However, WFT was not always among the thrips species present in the field, so the grower was making many unnecessary insecticide applications to control non-threatening thrips. In late 2006 and early 2007, Glades Crop Care consulted with the grower to identify the thrips species present and to make recommendations on when to treat and what other IPM tactics to follow. The result was acceptable WFT management for a full crop season avoiding the re-development of a highly resistant population during that period (Fig. 1). During this time, however, spinosad-resistant populations were detected in fields belonging to other growers in the same area.

As a mitigation effort, workshops to make growers aware of WFT resistance were held in Homestead and Palm Beach, FL in May 2007. The objectives of these workshops were to explain effective IPM practices, and to emphasize the need to implement these practices in order to maintain effective chemical control options. Additional meetings and visits to individual growers occurred between Oct 2007 and Jan 2008 to further educate growers and to monitor WFT population dynamics and spinosad susceptibility levels. In Jan 2008, a meeting was held to train consultants and extension agents in the area to identify thrips species. The result of all of these efforts was that several growers in the area adopted IPM tactics to varying degrees. On the other hand, several growers did not adopt any IPM tactics and continued to rely primarily on chemical control. Western flower thrips susceptibility to spinosyns was maintained in those fields where IPM tactics were adopted while it did not improve in those fields where control was relied only on chemical control (Figs. 2 and 3). This data suggests that in areas where resistance is present, the level of WFT resistance on a farm can be directly related to the level of IPM practiced by the grower.

Integrated resistance management (IRM) programs are closely related to IPM programs but IRM programs are focused only in the chemical component of IPM programs. A successful IRM program involves the following concepts: rotation of several classes of chemistry with different mode of action (MoA), the use of recommended rates, the limitation of maximum number of applications and product per acre per year or season, and to avoid sequential treatments within a single planting and across sequential crops/plantings.

Mandatory pesticide use record keeping and reporting is needed to determine the level of adoption of IPM and IRM programs by growers. These records should include the products used, the rates applied, the frequency and timing of appli-

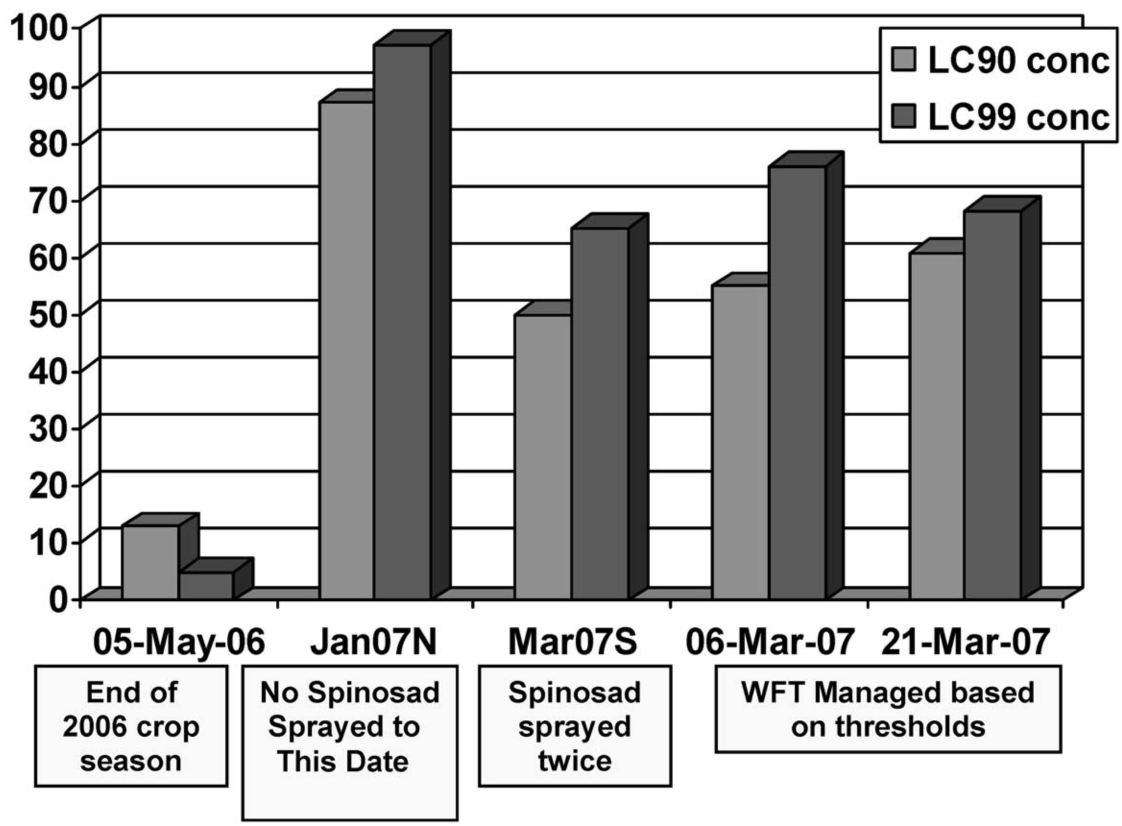

Fig. 1. Bioassays of Spinosad toxicity of adult western flower thrips collected from a farm in Palm Beach Co., Florida.

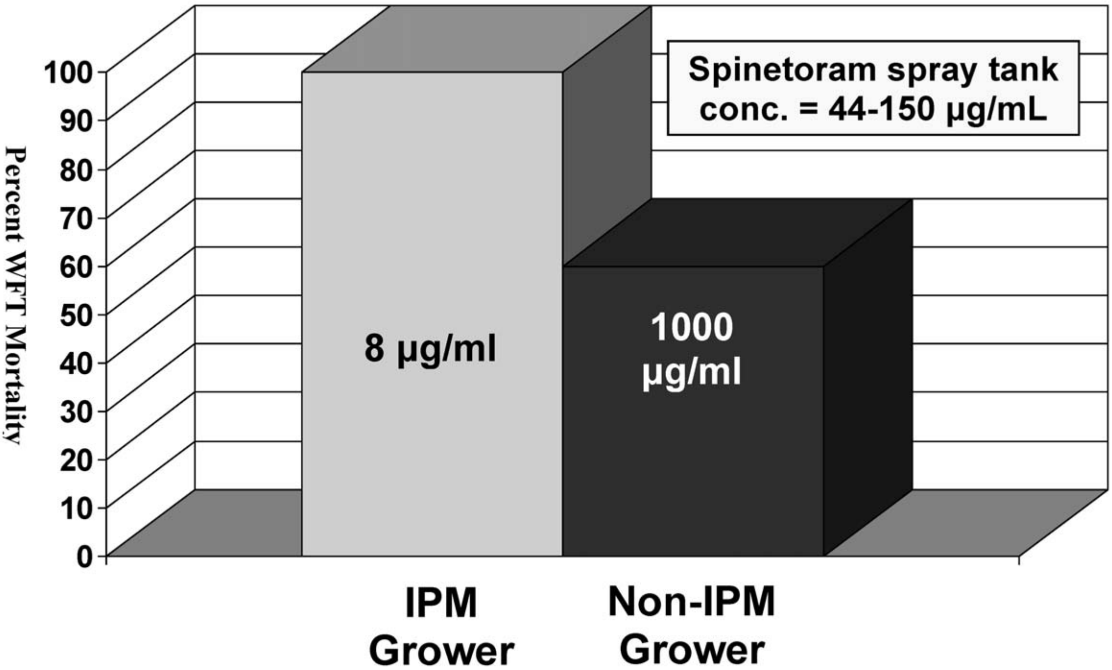

Fig. 2. Effect of IPM vs no IPM. Bioassay of Spinetoram toxicity to WFT collected from a pepper farm where the grower employed IPM and another pepper farm where the grower relied on calendar sprays of insecticides, Palm Beach Co., Florida.

cations, and the sequences of pesticide treatments. State-wide pesticide record keeping and reporting is currently not a legal mandate in Florida.

So, what else can be done to measure IPM implementation? We must first start with education efforts with the objectives to scout, identify thrips species, and to implement IPM tactics. State wide educational efforts are targeted at extension agents, consultants, industry, growers, and others. Measurement on the success of this would be in the form of Continuing Education Units (CEU) or Certified Crop Advisor (CCA) credits at each session. Tracking of attendance and results of a pre and post workshop test also should be tracked. This will encourage participants to learn and retain the information about the various IPM tactics. The trainers should compare pre- and post-test scores to measure the effectiveness of training.

An indirect way to assess the effectiveness of these workshops will be to monitor for resistance with the objective to have each company work with university researchers to set up monitoring procedures and to evaluate the extent of resistance development. University researchers would be in charge of maintaining the data base to assess progress.

University extension specialists need to develop specific management recommendations for fruiting vegetables, strawberries, and blueberries that are vertically integrated and that are specific to different locations. This will help educate on the tactics and tools needed to practice IPM and IRM effectively. Use of the National Distance Diagnostic & Identification System (DDIS) will facilitate the proper identification of thrips.

Real-time scouting information available on a website that is crop and location specific will be an important component to continuously connect with consultants, extension agents, growers, and industry. The reports will include county location, the proportion of each thrips species in field, the effects of management tactics, and the susceptibility of western flower thrips populations to insecticides. This information will allow everyone to know in real time when population shifts are occurring to enable effective changes in tactics to be utilized.

Another important component of this program will be development of a database for the effects of pesticides on natural enemies. The University of Florida will create a database that would include all pesticides (fungicides, herbicides, and insecticides) to determine the effects of these pesticides on beneficial insects. To develop the database the University of Florida will start evaluating the effect of chemicals commonly used in these crop systems on natural enemies of thrips.

Field validation of IPM implementation is a must. County extension will be responsible for as-

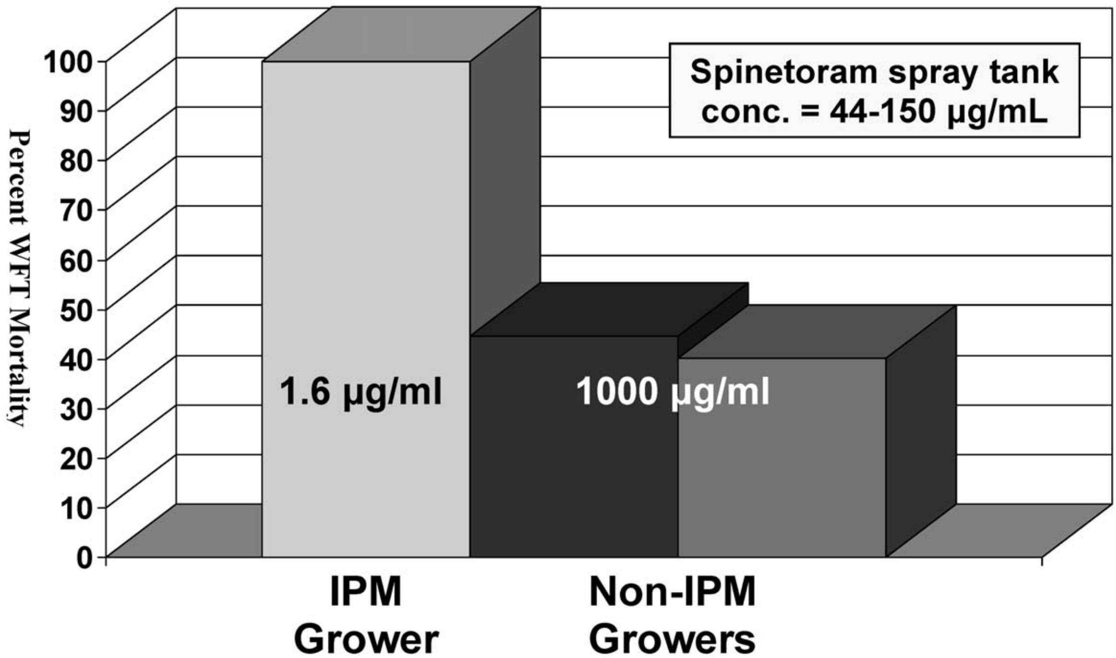

Fig. 3. Effect of IPM vs no IPM. Bioassay of spinetoram toxicity to WFT collected on strawberries.

sessing IPM implementation of individual growers and for educating individual growers in the principles and practice of IPM.

To make the whole process user friendly, an interactive website containing educational materials, current recommendations, and real-time population information is needed. The University of Florida has taken on the project and will continue to manage this system.

Conclusion

Enforceable reporting of pesticide use would provide a clear measure of IPM and IRM use by showing long-term trends in the use of chemical control measures. Chemical control tends to be over-used where IPM is not being practiced. Thus, a reduction in pesticide use while maintaining crop yield and quality should be expected to occur when IPM is being practiced. Additional ways to assess implementation and sustainability of IPM programs involve measuring the use and effectiveness of specific program components. The inclusion of tools that record attendance and proficiency at educational sessions, requests for IPM education documents, use of systems such as the University of Florida's Distance Diagnostic Identification System (DDIS), measuring use of computer-accessible real-time pest scouting reports, the use of a database for pesticide effects on natural enemies, and surveys to validate IPM use in the field will serve as a way to document progress. An indirect way to measurement sustainable IPM implementation will come from resistance monitoring and evaluation of resistance development. In the example of western flower thrips management in Florida previously described, the level of insecticide resistance was a very clear indicator of the adoption and use of IPM and IRM programs.

Acknowledgments

We thank Charles Mellinger, Glades Crop Care, for help, and M. Srivistava for bioassays.

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