Second Edition - 2009

Revised Copy

Best Management Practices for Pest Control in Vegetables

Vegetable Entomologist Workshop
Dallas, Texas May 2009

Acknowledgements

This report summarizes the discussion and subsequent general Best Management Practice (BMP) recommendations of research and Extension vegetable entomologists and crop consultants from primary vegetable-producing states. During a meeting held in May 2008 in Monterey, California, the group discussed pest-management issues, challenges and opportunities confronting the fresh and process vegetable industry today. Topics included shifts in pest spectrums; emergence of insect-vectored diseases as significant risks to profitable production; availability of advanced insecticide and acaricide technologies; the need for resistance management in pest control; the challenges of a shrinking agricultural infrastructure; and regulatory trends.

In a continuation of the 2008 meeting, another workshop was conducted in Dallas, Texas in May of 2009. The workshop format was similar and participants continued to refine the BMPs for vegetable insect control. They addressed experiences with old and new chemistries, and discussed strategies related to insecticide resistance management. The information-exchange format, featuring a facilitated discussion, allowed the group to identify key success factors and focus on BMPs in a non-commercial context.

Workshop Goals

- Brainstorm issues, challenges and opportunities for control of insects and mites in vegetable crops;
- Develop contemporary BMPs that optimize the performance of new insecticide technologies for controlling insects and mites; and
- Discuss new insecticide technologies available to the vegetable industry and their fit in the BMPs.

Best Practices for Successful Insect Management

BMP #1 Coordination and communication of management activities between growers and consultants are essential for safe, efficient crop production.

BMP #2 Adopt cultural practices as a solid first line of defense to avoid or prevent the buildup of insect pests. Cultural practices, such as crop rotation, sanitation, crop/residue destruction, host-free period and use of bed and row covers, are an important part of the planning process.

- Plan and implement crop management practices including variety selection, irrigation timing and fertilization for rapid emergence and growth, as related to historical pest trends to assist in cost-efficient pest management.
- Area-wide crop considerations can help minimize insect pest pressure by maintaining a host-free environment at certain times of the year.
- Other cultural practices, such as timely crop destruction and weed or host plant management, will minimize or sometimes eliminate breeding sites for insects. Herbicide resistance may become more problematic in the future.
- Cultural practices also can have a long-term impact on cost-effective pest control in the future. When making insecticide choices, pay particular attention to plant-back restrictions to avoid issues in successive seasons.

BMP #3 Monitor and sample for the presence of pests by crop stage and pest species. Scouting in accordance with a scientifically validated sampling plan is required to quantify pest numbers, by species, to determine the need for control based on economic injury theory.

BMP #4 Develop scouting, monitoring, and control plans in light of the biology and ecology of the insect pest, target crop, and intercropping relationships of the agricultural landscape. Vegetables are produced in a dynamic biological system that must be understood to adequately manage insect pests.

Know the spectrum of pests, as well as trends of pests in the area and in the cropping system during the growing season. A thorough understanding of the pesticide's biological activity and the biology/ecology of the target pest is essential for application timing and post-treatment evaluation.

BMP #5 Accurate identification of insect species is essential before making any pest management decisions.

- Correctly identify pests and species composition, and quantify populations, including presence of natural enemies.
- Sample fields regularly throughout the growing season.
- Build a historical database, geo-referenced by field and crop, as well as insect-flight timing by heat units, weather and crop stage.

BMP #6 Select the correct pesticide for the need when pest populations reach an action threshold and control is necessary:

- Choose pesticides by value, efficacy, residual activity and spectrum of control.
- Consider eco-friendly pesticides whenever possible.
- Resistance management is of paramount concern in today's environment. Preserve the effectiveness of available chemistry by rotating modes of action to reduce the risk of resistance among pests.
- Employ insecticide use patterns and/or modes of action that are compatible with the activity of beneficial arthropods. Natural enemy conservation is critical to a cost-effective pest management program.
- Avoid broad-spectrum insecticides to conserve natural enemies.

BMP #7 Correct timing of pesticide applications according to thresholds published by each state's Cooperative Extension Service is critical, both for the cost-effectiveness of a treatment and to maintain the beneficial complex throughout the season. Two pest management models apply:

Preventive model. This generally would be associated with systemic, at-planting applications, which would include the use of seed treatments or soil-applied products. These applications would conserve the beneficial complex and would minimize or delay the need for foliar applications of pesticides. In specific situations, a cost-effective application of a selective insecticide may be warranted to treat expected pest trends based on historical data, while also maintaining beneficial populations. Application methods may include chemigation, as well as foliar treatments. Other forms of a preventative model can be cultural, such as ensuring that transplants are not contaminated before use.

Feedback model. Using proven scouting techniques to quantify pest and beneficial populations, treat on pest thresholds, based on crop stage or level of pest tolerance. Timeliness of this foliar application is critical.

BMP #8 Use weather patterns as a predictive model for insect pressure, population growth or insect stages by temperature/heat unit accumulation, and for choosing the correct insecticide.

- Rain-fastness and penetrability (translaminar or systemic) are important characteristics, particularly east of the Mississippi River, where rain can be a daily factor.
- Temperature also is important when choosing which insecticides and adjuvants/surfactants to use. Forecasts for cooler temperatures can greatly slow the metabolism or breakdown of insecticides and effectively extend the pre-harvest interval (PHI) beyond the point where growers can legally harvest and market their crops. Conversely, phytotoxicity can be a problem at high temperatures for certain insecticides and adjuvants, particularly with leafy vegetables.

BMP #9 Crop, contract or market trends will help quantify crop value in assessing the risks and benefits of insecticide applications. Vegetable growers must have a quality crop when prices are right or when locked-in to a delivery contract.

New Pesticide Technologies

New, more selective, pesticide technologies provide growers a range of benefits and advantages for cost-effective, season-long insect pest management. To better develop BMPs to exploit their value, it is important to understand their individual strengths and weaknesses. The following exercise addresses this need.

RADIANT™ (spinetoram) • IRAC MOA 4: Nicotinic acetylcholine receptor (nAChR) allosteric activators

Strengths	Weaknesses
• Broad crop registrations • Controls thrips leps, leafminer (*A. trifolii* sp. but not *A. huidobrensis*) • Low impact on predator mites • Good Toxicology/Environmental profile (worker safety, mammalian toxicity) • Translaminar activity	• Resistance problems • Photosensitive • Effects on parasitoids • Acutely toxic to bees • Needs adjuvant in some crops

Notes:

- The best technology for thrips control.
- Save for thrips where they are a problem (i.e., peppers, lettuce).
- Performance for specific pests like leafminers enhanced with adjuvants.
- Residual control for 4-6 days has been observed.
- pH sensitive; will break down in pH solutions < 6.
- Not labeled for some crops in Georgia and Florida due to resistance.

PYRIFLUQUINAZON • No IRAC classification

Strengths	Weaknesses
• Whiteflies • Residual of at least 21 days for aphids • Psyllid • Thrips (onion and western flower) • Green peach aphid • Suppression of some viruses • Melon aphid (Riley)	• Inconsistent western flower thrips suppression in leafy vegetables

Notes:

- Unknown mode of action and there has been limited public testing.
- Has shown suppression of virus symptoms in melons.
- Significant reduction of tobacco thrips in broccoli in Georgia and sap beetles in Florida has been observed.

OBERON® (spiromesifen) • IRAC MOA 23: Lipid synthesis, growth regulator

Strengths

- Mites, whiteflies, psyllids
- Active against all mite stages
- Translaminar activity
- Adjuvant flexibility
- Wide spectrum of activity
- Minimal risk to beneficials
- Toxicology profile/environmental fate package very good (short half-life)

Weaknesses

- Moderate adult knockdown (requires an adulticide)
- Slow mortality, little knockdown of whitefly adults (reduces oviposition and egg hatch from affected females)
- No systemic activity which can be a problem in melons and other crops with new growth

Notes:

- Good fit in Florida, where both mites and whiteflies are a problem.
- Does not require an adjuvant, although performance can be improved.
- Cross-resistance an issue where Oberon and Movento are used consecutively, in multiple applications.
- Oberon preferred if mites are prevalent.
- Residual activity against whitefly nymphs and mites up to 21 days.
- Up to 14-21 days control of whiteflies on melons.
- At higher rates, there can be a reduction in natural predators.

MOVENTO™ (spirotetramat) • IRAC MOA 23: Lipid synthesis, growth regulator

Strengths

- Whiteflies (early life stages), aphids, psyllids
- Systemic activity as a foliar spray
- Good residual control
- Application flexibility (volumes, methods, coverage)
- Good toxicology /environmental fate profile (short half-life)
- Rapid feeding cessation of nymphs
- Good on root aphids when applied over-the-top
- Easy on beneficials, parasites, and predators

Weaknesses

- Poor control of adult whiteflies (need an adulticide)
- Slow mortality of aphids and whiteflies (5-7 days)
- Not as good on worms as Coragen
- Penetrating adjuvant required

Notes:

- Some data suggests suppression of viruses when used with an adjuvant (MSO).
- As a drench in tomatoes, data suggest better control of whitefly nymphs than Venom and Admire.
- Anecdotal evidence suggests some positive PGR activity.
- Buffering water to adjust pH to < 7 in the spray tank is suggested.

RIMON® (novaluron) • IRAC MOA 15: Inhibitor of chitin biosynthesis

Strengths

- Lepidopteron (fall and beet armyworm, diamondback moth)
- Leaf beetle, lygus, sweet potato weevil, Potato psyllid
- Inexpensive
- Long residual
- Good rotational product

Weaknesses

- Quick resistance can develop if not used judiciously
- IGR (Slow acting)
- Can be hard on beneficials
- pH sensitive
- Phytotoxicity problems in leafy greens
- Weak on loopers

Notes:

- Do not use surfactants.
- Labeled on all fruiting vegetables.
- Significant reduction of tobacco thrips in broccoli in Georgia and sap beetles in Florida has been observed.

CORAGEN® (chlorantraniliprole, rynaxypyr) • IRAC group 28: ryanadine receptor modulator

Strengths

- Broad spectrum of Lepidopteron control (including pinworm)
- Leafminer control
- Rapid residual control
- Application flexibility (soil/foliar)
- Translaminar as a foliar spray
- Environmental /toxicology profile good

Weaknesses

- Not consistent for whitefly control; suppression at best
- Requires an adjuvant for some pests/crop situations; but, label does not allow for adjuvant use on some crops (cantaloupes, watermelons, spinach)

Notes:

- Residual control up to 40 days on drip in Arizona.
- Armyworm control up to 70 days on tomatoes applied in drip or drench.
- Good control of whitefly in Georgia when used with an adjuvant, but not comparable to Movento®, insect growth regulators (IGRs) or neonicotinoids.
- Persistence in field and prevalence in many premixes may encourage overuse and subsequent resistance problems.
- Insolubility of the formulation can make placement critical for success.
- Wireworm control has been observed with banded applications in Texas.
- Some observations indicate a possible positive PGR response in the plant.

SYNAPSE™ (flubendiamide) • IRAC group 28: ryanadine receptor modulator

Strengths

- Most Lepidopteron species (pinworm, diamondback moth, armyworms)
- Good rotation partner
- Easy on beneficials
- Good environmental profile (does not leach; stays in soil profile)
- Good toxicology profile (worker safety, mammalian toxicity)
- Easy on beneficials, parasites, and predators

Weaknesses

- Narrow pest spectrum (Lepidopteron only)
- Pickleworm
- Spray coverage important

Notes:

- Position Synapse™ early in stand establishment and later in the season when fresh produce pest tolerance is low.
- Stand establishment is especially important in Southern California, because of the need for Lepidopteron control.
- May require tank mixture with pyrethroid to control secondary pests, such as flea beetles.
- Similar environmental fate package as Coragen®.

Cyazypyr (Cyantraniliprole) HGW86 • IRAC group 28: ryanadine receptor modulator

Strengths

- Whitefly as foliar spray
- Psyllids
- Leafminer
- Leps
- Thrips (western flower thrips)
- Aphids (cotton and green peach) as a foliar
- Squash bugs
- Leaf-footed bugs

Weaknesses

- Harsh on whitefly beneficials as foliar spray
- Same mode of action as Coragen but not as good on worms
- Not as much residual as Coragen

Notes:

- Some data suggests suppression of viruses when used with an adjuvant (MSO).
- As a drench in tomatoes, data suggest better control of whitefly nymphs than Venom and Admire.
- Anecdotal evidence suggests some positive PGR activity.
- Buffering water to adjust pH to less than 7 in the spray tank is suggested.

Issues, Challenges and Opportunities in the Control of Insects in Vegetable Crops: A Changing Environment

Agriculture is undergoing a rapid transformation in the United States and around the world, which is reflected in the fresh vegetable industry. Genetically modified (GMO) vegetable crops will likely expand in the future, but changing cropping patterns may have the greatest impact, especially in the West, where tree and vine acreage have rapidly expanded.

The U.S. agricultural industry also is facing competitive changes. Third World nations now control a range of crops, such as cotton and rice. Some of these nations are supplying an increasing volume of United States fresh fruit and vegetable needs, as outsourcing of food production expands. A concern among many in the domestic vegetable industry is that food safety standards are lower in many other countries than they are in the United States.

In fact, changes in the vegetable industry may be more acute than in larger crop sectors because of industry concentration; fragmentation of fresh and process commodities; increasing regulatory issues; and other challenges, such as declining research and Extension staffing and overall budget reductions among Land-Grant institutions. The primary areas of discussion among workshop participants centered on challenges, issues and trends in the vegetable industry. The following is a summary of these discussions:

Shifting pest spectrums.

From east to west, pest spectrums have shifted because of widespread use or loss of specific pest-control chemistries, changes in cropping patterns and rotations, and cultural practices adopted by growers to reduce production costs. Whiteflies are the primary issue in Florida, for instance, while desert production areas of Arizona and California tend to deal with a broader spectrum of "primary" pests. One emerging insect across the country is thrips, particularly western flower thrips and onion thrips. Whiteflies, aphids and thrips are concerns for all areas because they vector an ever-increasing number of viruses that are becoming much harder to control. Because of a lack of effective disease-management alternatives, virus control falls to the effective use of insecticides to control insect vectors, thus avoiding infections.

The good news is that there are more insecticide alternatives than ever before. Many of these alternatives are new, highly efficacious, selective chemistry technologies which are currently in the market or in the queue for EPA approval. Unfortunately, the knowledge required in the marketplace to most effectively implement these new insecticide tools is mediocre at best.

Other difficult pests common in all growing regions are a complex of lepidopteran larvae that annually require control to prevent economic damage. Diamondback moth (DBM) may rank as the most difficult, because of its resistance to pyrethroids, *Bacillus thuringiensis* kurstaki and spinosin (in Georgia).

Wireworms are emerging as a significant problem across the United States, because a very limited number of effective insecticides are labeled for their control, particularly in vegetables. In fact, some vegetables have no effective wireworm control material labeled; growers must rely on cultivation practices and birds to control the pest. Phorate and ethoprop registrations and labels are under continuous review by EPA, with a goal of eliminating their use. In addition, with the reduction and elimination of methyl bromide use, the vegetable industry may be faced with no effective wireworm control products for a majority of the crops. Only sweet corn has an effective tool for the control of wireworms, a seed-applied insecticide.

In the Southeast, whitefly is the dominant insect problem, and its control goes hand-in-hand with virus management. In pockets, such as South Georgia, the fall whitefly is problematic, and control is difficult at best. Western flower thrips also has emerged as a major pest over the last few years, vectoring TOSPO (impatiens necrotic spot and tomato spotted wilt) viruses and attacking a wider variety of vegetables.

Growers of sweet corn are experiencing problems controlling not only lepidopteran pests, such as fall armyworm, but also diptera pests, such as an expanding complex of "corn silk flies." This latter pest complex encompasses four species that are not at all affected by Bt-enhanced cultivars and frequently require daily treatments to produce a marketable sweet corn crop. The range of corn silk flies is rapidly expanding north and west from Florida.

The diamondback moth is an annual problem, especially in Georgia, where resistance issues garner greater attention. In addition to severe problems in Georgia, Florida also experiences serious problems with diamondback moth and other, lesser known lepidopteran pests that, without control, would push damage beyond acceptable levels for harvest. Therefore, other notable pests in the Southeastern United States also include fall, beet and southern armyworms, pepper weevil and many species of aphids.

At this time, control of pepper weevil requires the use of broad-spectrum insecticides, which also disrupt natural enemies that entomologists rely upon to control thrips in peppers. This forces growers fighting weevils to also have to fight thrips.

Other notable pests in the Southeast include russet, two-spotted spider and broad mites, which create a multifaceted control challenge for crop consultants and growers.

In addition, control of nematodes, wireworms, seed corn maggot and slugs were singled out as concerns, because of the loss of methyl bromide. Costs associated with the loss of methyl bromide and the use of alternatives has created other issues, including worker safety.

The Rio Grande Valley has seen a significant shift in pest spectrums. The most notable change is western flower thrips, which now comprises a significant portion of thrips pressure in the region. Onion thrips was the only species present in the recent past. Grower reluctance to rotate crops or pesticides has facilitated the shift to western flower thrips and emergence of potato psyllid and leafminers as serious pests. The Hawaiian beet webworm is another significant pest that has emerged in South Texas on spinach, Swiss chard and beets.

In desert vegetable-production areas of the West, the pest spectrum may not be increasing in breadth, but there is no single dominant pest. Primary pests include whiteflies, aphids, leafhoppers and thrips, all of which vector diseases. Beet armyworm and cabbage looper are particularly important pests in fall lettuce production. Secondary pests, such as seed corn maggot, flea beetles and slugs, also are having more impact on vegetable production.

Complicating the situation in the West is the emergence of naturally occurring microbial pathogens, such as *E. coli,* which indirectly affect pesticide applications because of the care required to avoid using contaminated water in the spray tank.

Hawaii. Vegetable production in the Aloha State is robust, but it also is difficult to maintain an acceptable service life for pesticides because of resistance problems. Diamondback moth is the most prevalent and difficult-to-control, but specific pests also include other lepidopterans, such as pickleworm. Resistance is managed with grower cooperation using mode of action (MOA) rotations. Month-long MOA windows have been effective in delaying DBM resistance to new products. DBM susceptibility to spinosad (and spinetoram), indoxacarb (Avaunt) and novaluron (Rimon) has been regained by 4-5 months of non-use. Excellent management programs have been developed for the Tephritid fruit fly, which has enhanced local production of cucurbits and melons. This could provide new opportunities for winter exports if an irradiation treatment facility is approved and constructed in Honolulu.

Trend toward selective pesticide technologies.

Positive trends in the marketplace include the availability and use of selective pesticide technologies and maintenance of the beneficial, predator-insect complex as a means to cost-effectively control critical pests. Preservation of natural enemies is seen as a key part of an IPM program, although even beneficial insects must be “cleaned up” in the field before harvest because of low tolerances for insect contaminants (or “insect debris”) in vegetable produce crops (e.g., lady beetle larvae in lettuce). In addition, many new products are considered expensive and tend to increase grower costs as broad-spectrum pesticides are phased out. These new technology pesticide products for the most part are being used in old management practices; thus, updating BMPs is necessary for growers to recognize the economic benefits of these technologies.

Concerns about development of resistance among specific insect pests continue, despite the proliferation of new insecticide technologies. For instance, an interesting over-the-counter trend now emerging is the use of pre-mixes, which effectively create broad-spectrum products. However, the use of pre-mixes risks accelerating selection for resistance by increasing exposure of pests to specific modes of action. It would be foolish to squander these new tools by using them to recreate broad-spectrum insecticides. Therefore, the continued availability of older, broad-spectrum chemistries is considered important. With up to 11 modes of action now available to vegetable growers, none should have to be relied upon excessively. Producers would be well-advised to use new pest management insecticide technologies and strategies efficiently and prudently to maintain efficacy as long as possible.

Some Currently Available Premixes*

Product	Company	Actives	MOAs
Volium Xpress	Syngenta	Lambda-cyhalothrin	3a
		Chlorantraniliprole	28
Volium Flexi		Thiamethoxam	4a
		Chlorantraniliprole	28
Derivo		Thiamethoxam	4a
		Chlorantraniliprole	28
Vetica	Nichino	Buprofezin	15
		Flubendiamide	28
Leverage	Bayer CropScience	Imidacloprid	4a
		Clyfluthrin	3a
Hero	FMC	Zeta-Cypermethrin	3a
		Bifenthrin	3a
Cobalt	DowAgroscience	Chlorpyrifos	1b
		Gamma cyhalathrin	3a

** Similar premixes expected with Cyazypyr (Cyantraniliprole)*

Another concern related to new, selective technologies involves their methods of use by the industry. Many growers, consultants, pest control advisers (PCAs) and crop protection retailers are using the new insecticide technologies as they would the older, broad-spectrum chemistries. Because of their greater efficacy, increased persistence or longer residual, optimal use of new insecticide technologies requires continued education of the technical community and producers. A current challenge confronting the industry is integrating season-long pest management programs - keeping resistance management front and center - into a contemporary set of BMPs.

With selective insecticides, parameters of pest control need to be redefined, particularly between target and non-target pests. Thresholds and application timing also must be readdressed, as well as expectations after an application is made. For example, some new insecticides are slower to control pests; although the pest stops feeding immediately, limiting injury or damage to the crop.

Ultimately, more education and training are needed for growers, consultants, pest control advisors (PCAs), crop protection retailers, field reps and others influencing crop protection decisions.

Shrinking Extension/Applied Research Support.

Complicating the need for more agronomic and technical education and training among a wide range of audiences is the general lack of funding and support for applied agriculture science at Land-Grant universities and within the Cooperative Extension Service. The greatest potential impact, and a real threat to the integrity of the agriculture infrastructure, is the sharply reduced number of personnel, which diminishes the services once provided to growers, consultants, retailers and others. It is a primary symptom of a festering problem that is rooted deeper, leading to a range of negative implications throughout the industry.

Less value or recognition is assigned to applied research at Land-Grant institutions across the United States. According to current perceptions among workshop participants, academic credit for research is based on the number of publications in prestigious journals and the acquisition of competitive research grants. In addition, a consolidation of Extension programs, because of reduced state and federal funding, has resulted in fewer specialists by discipline, particularly in the West. And where the infrastructure interfaces with production agriculture, a system of county agents has given way to regional agents. In many states, Extension specialists not only must conduct problem-solving, adaptive research but also design and conduct extensive outreach programs to keep growers, consultants and PCAs informed of new developments.

The downward trend for adequately trained human resources, including university research and Extension personnel, crop protection retailers, PCAs, consultants and farm advisors, is expected to continue. The vegetable sector may be one of the least-supported of the commodity groups, and this problem is compounded by the number of vegetable crops produced.

On one hand, various audiences involved in vegetable production need to be trained. On the other hand, buy-in for changing production practices must be received from a wide range of downstream audiences, as well. With limited funds funneled to public programs and away from production agriculture, research and Extension staffs are shrinking, as well as the information and education programs they traditionally managed. The crop protection industry and commodity groups will need to adopt a more significant role in the development of data and information, as well as its delivery to a wide range of audiences.

In summary, the infrastructure of agriculture - the Land-Grant University and Cooperative Extension Service - is suffering from a severe reduction in support and resources that is compromising the development and delivery of empirical data and new information. This trend shows no signs of abating. Perhaps only a food crisis would force more recognition for agriculture.

Miscellaneous challenges, issues and trends.

Resistance management. Although addressed in the "Trend toward selective pesticide technologies" section earlier, cross-resistance and resistance management among insects, diseases and weeds are major issues for everyone in agriculture, not just vegetable production. Because resistance management programs need to be developed for specific cropping systems, industry must take on greater responsibility in the development of BMPs, as well as education of growers, consultants, PCAs, crop protection retailers and others.

Use of adjuvants with pesticides. It is a common belief that adjuvant use with pesticide applications is "all over the board -- a can of worms," according to one participant. Another noted that "with adjuvants -- when in doubt, leave them out." The bottom line is that, in some situations, adjuvants are required to gain a higher level of performance and efficacy from specific pesticides. The risk of phytotoxicity on specific crops makes the use of adjuvants a serious management decision. For example, adjuvants should never be used on spinach for phytoxicity reasons. More research is needed by pesticide formulation, by specific vegetable crop and by environmental conditions, although specific research with new pesticide technologies indicates that adjuvants have a place and are crop-safe if used correctly.

Distribution channel. In some growing areas within the U.S. profit-driven recommendations are made at the retailer level, and, in many cases, the crop protection retailer is misinformed and lacks the training required for such consultation. An example of this is recommendations for pre-mixes in pest control programs, which are contrary to Cooperative Extension philosophy. But in an environment where input prices change daily, the crop protection retailer has a heavy influence on purchase decisions.

The industry should focus on **training** crop protection retailers to provide correct agronomic and technical information to growers and their advisors. All too often, they are misinformed. Although pest control recommendations should be in the hands of trained and licensed entomologists (i.e., PCAs in Arizona and California), the retailer often influences decisions on the farm. This underscores a bigger issue for the industry, which is the conflict of interest retailers face by selling a particular product based on their own bias or profit motive.

Regulatory. Increasing regulations are recognized at all levels of the vegetable industry, including public perception-driven issues. The result is inflated costs, which affect growers' ability to compete within the United States or with foreign producers.

Maximum residue limits (MRLs) are an issue; tolerances of some active ingredients are set too high by some foreign markets. Moreover, MRL standards are different for different shippers which can greatly complicate pest control measures within a farm and even within a single field. With changing cultural practices over the past decade, labeling issues are becoming problematic, particularly where various crop mixes are planted side by side. This creates a planning issue for the use of pesticides. Identifying crop groups on labels would be helpful to growers and their advisors.

Regulatory timeliness to obtain labels is a critical issue for the vegetable industry. One participant suggested a "super-crop-group" concept to be identified on product labels. Two problems with any changes to the regulatory process are restructuring the guidelines, which may be an insurmountable obstacle, and inadequate funding to acquire the additional data required. Consequently, the IR-4 program may become increasingly important for registering insecticides on vegetable crops.

Water shortages and contamination also will need to be considered in the future, especially regarding potential drinking water and the environment.

Consumer perceptions. Downstream education is needed. On the public side of the vegetable sector is a general lack of confidence among consumers about production of fresh and processed food. The general public perceives conventional management practices employing commercial fertilizers and pesticides as unhealthy; in extreme cases, some may see the grower as an enemy. In contrast, the public perceives U.S. food production to be the safest in the world.

The *E. coli* scare in spinach and the *Salmonella* issue in tomatoes, cilantro, and jalapeno and serrano peppers in 2008 have taken the spotlight for the time being, but the attention likely will rotate back to pesticides in the future. Microbial contaminants, such as *Salmonella* and *E. coli,* are aggressively monitored in vegetables, and for good reason; these "natural pathogens" can be deadly in fresh produce. The sources of the contaminants include frogs, mice, rats, wild pigs, birds and other wildlife. To date, food safety programs have increased grower costs; but, they have not been passed on to the consumer.

Further exacerbating this situation is urban encroachment into farming areas, which makes insect management a challenge. This situation has been, and will continue to be, problematic for pest management.

The selection of pesticides often is limited by urban/public interface issues.

Farm ownership. More prime farmland is being lost to real estate developers every year. Growers close to urban areas find that selling land for development can be much more lucrative than farming. But another concern for agriculture in the future is that more and more farmland is owned by off-farm individuals. Today, farmland is viewed as more of a commodity, which encourages investors.

Human resources. The reservoir of human resources in agriculture, from scientist to farm labor, not only is dwindling in number; its impact is felt in a drain of expertise from the agriculture industry. There is a general lack of knowledge in the industry about the fundamentals of insect biology, ecology and toxicology. An example of the dearth of expertise is seen in the maintenance of accreditation; PCA licenses are difficult to maintain in the West because of a shortage of classes and training programs. At the same time, too many farm operations practice "haphazard or lazy IPM" instead of knowledge-driven IPM. The lack of focus on resistance management may be but one symptom.

Knowledge-driven decision-making is supported by scientifically validated methodologies that enable accurate assessment of pest and beneficial population densities, provide interpretation with respect to economic injury level and action thresholds, and provide expert guidance on the most appropriate and effective control measures. With lazy IPM, insufficient attention or respect is paid to assessment and interpretation of pest densities in the context of economic injury theory. Control decisions are based more on perception than on rigorously collected and evaluated data, and choices of chemical treatment too often ignore a resistance management framework.

From a labor standpoint, access to qualified workers is becoming a greater concern than ever. Exacerbating the situation is an ever-increasing scrutiny of worker safety and protection, which increases costs to the producer and, ultimately, to the consumer.

Economics. Keeping growers profitable is a challenge throughout the U.S. vegetable production industry. Florida growers struggle to compete with Western growers in production costs, although this may change as transportation costs skyrocket. Transporting a trailer load of lettuce from the Salinas Valley to New York, as of May 2008, cost $10,000. Increasing transportation costs may force a restructuring of fresh fruit and vegetable production markets, making the development of local or regional BMPs even more critical to the industry.

Furthermore, the availability of generic insecticide products is increasing, and growers are more willing to use them, as input costs for fuel and fertilizer continue to soar. The impact of this trend on industry development and innovation may limit pest management choices in the future.

Actions to be taken

An integrated resistance management plan is needed for lepidopteran chemistries, which can be managed through the IRAC MOA number system.

- A resistance management coordinator could establish a repository and monitor protocol.
- Standardized techniques and reports would be required for participants.
- A standard, pre-commercialization baseline for pests could be established.
- Crop protection chemical manufacturers should place more emphasis on and more prominently display IRAC mode of action numbers and information on pesticide labels and promotional material.

In the absence of a formalized resistance management program, a simple set of guidelines should be communicated to growers and PCAs to help minimize resistance development.

Minimize insecticide use. Avoid preventive or prophylactic treatments with insecticides. Implement cultural (sanitation, early planting, plow-down, etc.) and conservation bio-control (refuge strips, selective insecticides) to suppress pest populations.

Diversify insecticide use. Avoid using the same mode of action more than once per crop season. Develop a provisional insecticide use strategy that primarily anticipates the number of treatments that may be required in all crops throughout the year. Devise a deployment schedule that minimizes overlap in modes of action while maximizing effectiveness of each insecticide application.

Refine insecticide use. Obtaining an understanding of the modes of action of all chemistries in the repertoire of pest managers is essential to optimal insecticide performance, with minimal impact on beneficial insects. Refinement of insecticide use is a process of identifying patterns of target pest infestations in crops requiring protection, and development of sampling plans and economic thresholds for application timing. The process also incorporates eco-toxicological information regarding impact on beneficial insects to minimize collateral damage from an insecticide treatment.

Understand and manage within the entire landscape. Cross-commodity interactions are important to managing resistance because insect pests frequently just move from one commodity to another. In some states and production areas, the entire agricultural landscape is so diverse that identifying and understanding pest shifts are often more important than identifying new pests. Wireworms and stinkbugs are cited as examples of shifting pest complexes that affect multiple crops.

In-can pre-mixes are strongly discouraged by entomologists. Producers should be better educated in their selection of insect management systems and the consequences of using the broad spectrum pre-mixes.

- Entomologists are concerned about active ingredient levels in the mix.
- Pre-mixes should never be used unless all components are needed.
- Pre-mixes can exacerbate resistance issues.
- Pre-mixes are confusing to growers; name recognition will be an issue.
- Pre-mixes complicate tracking of modes of action for cost-effective pest control and resistance management.

Industry should take a more active role in development of IPM programs and BMPs.

- Partnerships among academia, industry and commodity groups to support students and research programs should be actively promoted.
- Support will be needed by applied university researchers in the future for more than just collecting efficacy data, such as development of thresholds and determining cost-effective and environmentally friendly use patterns for new and existing active ingredients.

Industry should take a more active role in developing technologies for the control of emerging pests, such as wireworms, pepper weevil and other secondary pests.

The pest control sector of the vegetable industry must be prepared for the transfer of Bt and trait technology to the marketplace.

- General education of all audiences is required.
- New pest management regimes to cost-effectively exploit emerging technologies are critical.

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