More information about chlorine-based systems and ORP is available in*Oxidation-Reduction Potential (ORP) for Water Disinfection Monitoring, Control and Documentation*, University of California publication 8149, available from ANRCatalog, anrcatalog.ucdavis.edu.

More information about GAPs is available in:

- Food Safety for Fruit and Vegetable Farms, ag.purdue.edu/hla/foodsafety/Pages/default.aspx.
- U.S. FDA, www.fda.gov/food/guidanceregulation/fsma/ucm253380.htm.
- *Guidance for Industry: Guide to Minimize Microbial Food Safety Hazards of Fresh-cut Fruits and Vegetables*, U.S. FDA, www.fda.gov/food/guidanceregulation/guidancedocumentsregulatoryinformation/produceplantproducts/ucm064458.htm.
- GAPsNET, Cornell University, www.gaps.cornell.edu.
- *On-farm Food Safety: Guide to Good Agricultural Practices (GAPs),* Iowa State University Extension publication PM1974a, available from the Extension Online Store, store.extension.iastate.edu.
- Good Agricultural Practices, U.N. Food and Agriculture Organization, www.fao.org/prods/GAP.

Insect Management Strategies

Effective insect and mite management involves at least seven steps:

1. Preventive practices.
2. Properly identifying key pest insects and mites, and beneficial organisms.
3. Selecting and using preventive pest management practices.
4. Monitoring the current status of insect and mite populations.
5. Determining the pest's economic loss potential
6. Selecting the proper pest control option.
7. Evaluating the effectiveness of previously used control options.

Preventative Insect Management Practices

There are a number of practices that can reduce insect numbers before you actually see the insects in the field. Often, decisions about these practices must be made based on past experience with the insect rather than current knowledge of the severity of the infestation. Many of these practices are good management practices for weeds and diseases as well, so they can easily be incorporated into an overall insect management program.

Resistant Varieties: There are not many vegetable varieties that have been bred for insect resistance. However, there are some varieties of cabbage that are resistant to onion thrips. Selection of sweet corn varieties that have husks that completely cover the ear tip and fit tightly around the ear can reduce the amount of corn earworm damage. Short season varieties of potatoes should be grown when possible to give Colorado potato beetles less time to feed and reproduce. This is not resistance, but it is a method that growers can use to reduce insect damage by varietal selection.

Crop Rotation: Rotating crops can reduce the severity of a number of pest problems. Rotating potato fields can greatly increase the amount of time it takes Colorado potato beetles to colonize a field, thereby reducing the time the beetles have to increase to damaging levels. Don't plant crops that are susceptible to wireworm or white grub damage in fields that were previously in sod or heavily infested with grassy weeds. In addition, it is a good idea not to plant cabbage or onions next to small grain fields, because onion thrips build up to very high levels in small grains and may move into cabbage or onions when the small grains dry down or are harvested.

Crop Refuse Destruction: Destroying the plant residue after harvest can reduce the damage experienced the next year from a number of insects. Destroying squash and pumpkin vines after completion of harvest can greatly reduce the overwintering population of squash bugs and squash vine borers. Early vine killing in potatoes will reduce the potato beetle populations for the following year.

Tillage: Fields that receive reduced amounts of tillage or have some sort of grass windbreaks are often more susceptible to damage from insects such as cutworms and armyworms. These cultural practices may have other advantages that outweigh the potential insect problems, but growers should be aware of the potential for increased insect activity.

Time of Planting: Because insects tend to become active at specific times each year, varying the time of planting can sometimes help prevent serious insect problems. Corn earworms and fall armyworms are usually a much more serious problem on late-planted sweet corn. If the option is available, planting sweet corn so that it has no green silks before large numbers of earworm moths are flying can reduce earworm problems. Root maggots are usually more serious during cool, wet weather. Waiting until soil temperatures are adequate for rapid plant growth will help reduce maggot problems.

Biological Control: Conserving natural enemies is one aspect of biological control that can effectively reduce pest populations and damage. This can be accomplished in several ways, but the most important is reducing the number of insecticide applications. Each time a spray is applied, more predators and parasites are killed. When deciding to use an insecticide, you should consider the impact that application will have on beneficial insects. *Bacillus thuringiensis* products, for example, do not harm beneficial insects.

Proper Identification

Properly identifying pests is the foundation on which a good insect management program is built. If the pest is not properly identified, the chances of selecting the correct control strategies are greatly diminished. Many insects and mites can be correctly identified simply because they are encountered so often. However, it never hurts to back up your knowledge base with some reference materials. Your county Extension office has a number of bulletins available that will help you properly identify insect pests. There also are a number of good books available with color photographs of many of the common insect pests. Most entomologists don't like to admit it, but we often identify unfamiliar insects by comparing them to pictures in a book.

As will be discussed in the next section, beneficial organisms can be important components of an effective insect management program. Being able to distinguish the good guys from the bad guys may help you avoid unnecessary and possibly disruptive pesticide sprays. Some common beneficial organisms all growers should be able to identify include lady beetle larvae and adults, lacewing larvae and adults, and syrphid fly larvae.

In addition to proper identification, it is helpful to know as much as possible about the insect's biology. All growers should know the difference between insects with incomplete metamorphosis and those with complete metamorphosis.

Insects with incomplete metamorphosis have juvenile stages — called nymphs — that resemble the adults, except that they are smaller and don't have wings. The feeding behavior is usually the same for nymphs and adults. For example, squash bugs are an insect with incomplete metamorphosis.

Insects with complete metamorphosis have a larval stage that is completely different in appearance from the adult. They also have an intermediate stage, known as a pupa, between the larval and adult stages. Larvae never have wings and are not capable of reproducing. Larvae go through a series of molts (shedding their skins) in order to grow. Larvae and adults frequently, although not always, feed differently. Adult insects never grow, so little beetles don't grow up to be big beetles. For example, caterpillars are larvae. In their adult stage, these larvae become moths or butterflies.

For important insect and mite pests, it also is helpful to know the overwintering stage, life cycle length, and number of generations per year that can be expected. Again, most of this information can be found in Extension bulletins.

Monitoring

Vegetable growers must make insect and mite pest management decisions on an almost daily basis during the growing season. To make the best decisions, it is often useful to have information regarding the current status of a pest's population. This can be accomplished through some sort of sampling or monitoring program. There are several methods to monitor insect populations.

Pheromone traps can be used to determine when moths are flying. This information can be used in several ways. First, catching moths in the trap can alert growers to begin looking for the pest in the field. This can save time because the grower won't be looking for the pest before it is present. Second, pheromone trap catches can be used to time insecticide applications. Third, for some pests, such as corn earworms, the need to spray can be determined from the number of moths caught in the trap. Pheromones are available for many of the caterpillar pests of vegetables.

The most common method for monitoring insects is by scouting fields. Scouting can be formal, such as counting insects on a given number of plants throughout the field, or it can be informal, with the grower walking through the field and looking for insects on the plants. Formal scouting may be more accurate, but the most important thing is for growers to regularly walk their fields looking for insects or insect damage. Some pests, such as mites, may require the use of a hand lens to see. Others may require the use of equipment such as a sweep net or a beat cloth. Most can be monitored just by close inspection of the plants. Regular (weekly) monitoring will allow growers to make informed management decisions.

Determining the Potential for Economic Loss

Unfortunately, we do not have economic thresholds for many vegetable insect pests. Whenever possible, we have listed the best thresholds available along with control options in the crop-specific sections of this manual. Although some of these estimates have not been verified by research in each state, they have been derived from scientific research or extensive observations. Growers may wish to adjust these thresholds based on past experience. Extension bulletins also are useful sources of information regarding potential losses from insects. Growers should remember that some crops, such as snap beans and potatoes, can suffer a great deal of defoliation before there is any effect on yield. Sometimes, plants with considerable amounts of insect damage will yield as well as plants that have no insect feeding. If the pest is one that feeds on the marketable portion of the plant, then less damage can be tolerated.

Before considering a management option, it's important to first correctly identify the insect responsible for plant feeding. This is a European corn borer attacking a pepper fruit.

Proper Selection of a Pest Control Option

In vegetable crops, the selection of a control option during the growing season usually means doing nothing or selecting a pesticide. Although we always encourage growers to read and follow label directions, the one area where the label is not necessarily the best source of information is concerning which insects the insecticide will control. The insecticides recommended in this book for control of various pests are listed because they are legal to use and because they have been found to be effective by the authors. Consider insecticide costs, application costs, relative effectiveness, gain in profits that can be expected from the application, whether it will control other pests, and how it will affect predators, parasites, and pollinators. Growers should refrain from "revenge spraying," that is, spraying after the damage is already done. At that point, spraying is a waste of money and may actually increase pest damage by killing beneficial insects.

Evaluation

Growers should always evaluate the effectiveness of a pest control action. Inspecting the field a couple of days after an insecticide is applied will help the grower determine the necessity for additional control measures in that field, as well as provide information about the insecticide's effectiveness for future reference. Growers should pay attention to whether the insecticide killed all stages of the pests or if only small larvae or nymphs were killed. They should also notice the effects on other pests in the field and on beneficial insects.

Resistance Management

It is important to occasionally rotate products with different modes of action in order to reduce the potential of insect and mite populations developing resistance to products with specific modes of action. A pesticide's mode of action is how it affects the metabolic and physiological processes in the pest (in this case, the pests are insects or mites). Many product labels contain resistance management information or guidelines that will help vegetable growers determine which products they should rotate with others. For more information associated with rotating different modes of action, contact your state or regional extension entomologist.

Table 19: Preharvest Intervals (Days) and Re-Entry Intervals (Hours) for Insecticides/Acaracides Registered for Use on Midwest Vegetables 2017[1]

	Acramite®	Actara®	Admire PRO®	Agri-Mek®	Ambush®	Asana®	*Assail®*	Avaunt®	Bacillus thuringiensis	Baythroid®	Belay®	Beleaf®	Brigade®	Coragen®	Cryolite®/Kryocide®	Danitol®	Dimethoate®	Entrust®	Exirel®	Fulfill®	Intrepid®	Lannate®	Larvin®	Lorsban®	Malathion®	Movento®	Mustang Maxx®	Neemix®	Oberon®	Orthene®	Platinum®	Proclaim®	Radiant®	Rimon®	Sevin®	Sivanto®	Venom®	Verimark®	Voliam Flexi®	Voliam Xpress	Warrior®
Asparagus							1		0					1			180	60		110		1		1	1			0					60		1						
Beet		7	21					7	0		3		1	1				3				0			7		1	0			X		7		7	7					
Broccoli		0	X		1	3	7	3	0	0	24	0	7	3	7	7	7	1	1	7	1	3	7	X	2	1	1	0	7		30	7	1	7	3	1	X	X	3	3	1
Brussels Sprouts		0	X		1	3	7	3	0	0	24	0	7	3	7	7	10	1	1	7	1	3		X	2	1	1	0	7	14	30	7	1	7	3	1	X	X	3	3	1
Cabbage		0	X		1	3	7	3	0	0	24	0	7	3	14	7		1	1	7	1	1	7	X	7	1	1	0	7		30	7	1	7	3	1	X	X	3	3	1
Cantaloupe	3	0	21	7	0	3	0	3	0	0	7	0	3	1	14	7	3	3	1	0	3	X			1		1	0	7		30		3	1	3		21	1	1	1	1
Carrot		7	21			7			0	0		3	21	1				3			14	1			7		1	0			X		3		7	7					
Cauliflower		0	X		1	3	7	3	0	0	24	0	7	3	7	7	7	1	1	7	1	3	7	X	2	1	1	0	7	14	30	7	1	7	3	1	X		3	3	1
Celery		7	45	7	1		7	3	0	0	X		7	1			7	1			1	7	14		7		1	0		21	30	7	1		14			X	7		
Chinese Cabbage		7	X		1	3	7	3	0	0	X	0	7	3		7		1	1	7	1	10		X	7	1	1	0	7		30	7	1	7	14	1		X	7	3	1
Collard		7	X		1	7	7	3	0	0	24	0	7	3	14			1	1	7	1	10		X	7	1	1	0			30	14	1		14	1	X	X	7		
Cucumber	3	0	21	7	0	3	0	3	0	0	7	0	3	1	14	7		1	1	0	3	X			1		1	0	7		30		1	1	3		21	1	1	1	1
Eggplant	3	0	X	7	3	7	7	3	0	7	7	0	7	1	14	3		1	1	0	1	5			1	1	1	0	1		30	7	1	1	3	X	X	1	1	5	5
Endive		7	X	7	1		7		0	0	X	0		1			14	1	1	7	1	X	14		7	3	1	0	7		30	7	1		14	1	X	X	7		
Green Onion			21	30	1		7		0				1	1				1	1		1	7			3	X	7	0					1								14
Head Lettuce		7	X	7	1		7	3	0	0	X	0	7	1	14			1	1	7	1	X	14		14	3	1	0	7	21	30	7	1		14	1	X	X	7	1	1
Kale		7	X				7	3	0	0	24	0	7	3			14	1	1	7	1	10		X	7	1	1	0			30	14	1		14	1	X	X	7		
Kidney Bean	7		X	7		21	7		0	7			14	1			X	28			7	14		X		7	24	0		14			28	1	X	7					24
Leaf Lettuce		7	X	7	1		7	3	0	0	X	0		1	14		14	1	1	7	1	X	14		14	3	1	0	7		30	7	1		14	1	X	X	7	1	1
Lima Bean	3		X				7		0				3	1			X	3			7	X		X		1	1	0		1			3	1	X	7					7
Mint	7	7		28				7	0					3				7			14	14		90	7			0		14			7						7		
Mustard		7	X			7	3	3	7	0	24	0	7	3			14	1	1	7	1	10			7	1	1	0			30	14	1	1	14	1	X	X	7		
Okra	3		X				7		0			0	7	1				1	1		1				1		1						1		3	1					
Onion Bulb			21	30	1		7		0					1				1	1			7		X	3	X	7	0					1								14
Parsley		7	X	7	1		7	3	0	0	X	0		1				1	1	7	1	X	14		7	3	1	0	7		30	7	1		14	1	X	X	7		
Parsnip		7	21						0					1				3			1				7			0			X		3		7						
Peas	3		X			3	7		0				3	1		7	X	3			7	1		X	3	1		0					X		X	7					7
Pepper	3	0	X	7	3	7	7	3	0	7	1	0	7	1	14	3	2	1	1	0	1	3			1	1	1	0	1	7	30	7	1	1	3	X		1	1	5	5
Potato		14	X	14	14	7	7	7	0	0	14	7	21	14	0		X	7		14		6			0	7	1	0	7		X		7	14	7	X		X	14	14	7
Pumpkin	3	0	21	7	0	3	0		0	0	7	0	3	1	14	7		3	1	0	3				1	3	1	0	7		30		3	1	3		21	X	1	1	1
Radish		7	21			7			0	0			21	1							1			X	7			0			X		3		7	7		X			
Rhubarb		7	45	7	1		7		0	0	X	0	7	1				1	1	7	1		14				1	0			30	7	1		14	1			7		
Rutabaga		7	21						0			3	21	1								X			7	1					X			3	7	7					
Snap Bean	3		X			3	7		0				3	1			X	3			7	X		X	0	1	1	0					3	1	X	7					7
Spinach		7	X	7	1		7	3	0	0	X	0	40	1				1	1	7	1	X	14		7	3	1	0	7		30	7	1		14	1	X	X	7		
Summer Squash	3	0	21	7	0	3	0	3	0	0	7	0	3	1	7	7		3	1	0	3	X			1		1	0	7		30		3	1	3		21	1	1	1	1
Sweet Corn					1	1	7	3	0	0			X	1				1			3	0	0	X	5		3	0	5				1	1	2						X
Sweet Potato		14	X	14	7		7	7	0	0	14	7	21	1				7		14	7			X	3	7	1	0	7		X		7	14	7	7		X	14		7
Tomato	3	0	X	7	0	1	7	3	0	0	7	0	1	1	14	3	7	1	1	0	1	1			1	1	1	0	1		30	7	1	1	3	X	X	1	1	5	5
Turnip		7	21		1	7	3		0	0	X	3	21	1			14	3	1	7	1	10		X	1		1	0			X	14	3			7		X			
Watermelon	3	0	21	7	0	3	0	3	0	0	7	0	3	1	14	7	3	3	1	0	3	X			1		1	0	7		30		3	1	3		21	1	1	1	1
Winter Squash	3	0	21	7	0	3	0	3	0	0	7	0	3	1	14	7		3	1	0	3				1		1	0	7		30		3	1	3		21	1	1	1	1
Re-Entry Intervals (hours)	12	12	12	12	12	12	12	12	4	12	12	12	12	4	12	24	X	4	12	12	4	48	48	X	X	24	12	12	12	24	12	12	4	X	12	4	12	4	12	24	24

X=check label for details.

[1]Check label directions before applying any of these pesticides.