Cucumber Beetles: Organic and Biorational Integrated Pest Management

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Updated by
Steve Diver and
Tammy Hinman
NCAT Agriculture
Specialists

Cucumber beetles are present throughout the United States and cause serious damage to cucurbit crops. Overwintering adult insects cause feeding damage on young plants, larvae in the soil feed on plant roots and second-generation adults cause feeding damage on plant leaves, blossoms and fruits. Adult insects transmit bacterial wilt and squash mosaic virus. Organic and biorational integrated pest management measures include delayed planting, trap crops, floating row covers, parasitic organisms and botanical pesticides. Field scouting or yellow sticky traps can monitor insect populations.

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Introduction

Cucumber beetles are pests of cucurbits in most areas of the United States. Cucumber beetles transmit bacterial wilt, squash mosaic virus and can increase the incidence of powdery mildew, black rot and fusarium wilt. They also damage plants directly by feeding on roots, stems, leaves and fruits.

This publication will focus on organic and biorational control methods that fit into an integrated pest management approach. Organic control measures include delayed planting, floating row covers, trap crops and using predatory organisms and botanical or biorational insecticides.

Biorational pest controls are commonly known as least-toxic pest controls or soft pesticides. Biorational pest controls are preferred in biointensive integrated pest management because they usually target the pest and spare beneficial organisms, are relatively non-toxic to humans and have few environmental side effects.

Species of cucumber beetles

There are six species of cucumber beetle in the United States. Striped cucumber beetles in the *Acalymma* genus and spotted cucumber beetles in the *Diabrotica* genus are collectively known as diabroticine or diabroticite beetles. The diabroticines, which include the closely related species known as western corn rootworm *(Diabrotica virgifera virgifera)* and northern corn rootworm *(Diabrotica barberi)*, have similar yet distinct ecological and behavioral characteristics. Correctly identifying the pest that occurs in each geographical region is the first step toward devising a pest management strategy.

The striped cucumber beetle is about 1/5 inch long and yellowish-green with a black head and yellow thorax. It has three parallel and longitudinal black stripes along the length of its wing covers. The eastern striped cucumber beetle *(Acalymma vittatum)* is found mostly east of the Mississippi River and the western striped cucumber beetle *(Acalymma trivittatum)* is found mostly west of the Mississippi.

Striped cucumber beetle. *Photo by Ken Gray, courtesy of Oregon State University.*

Related ATTRA publications

Biointensive Integrated Pest Management

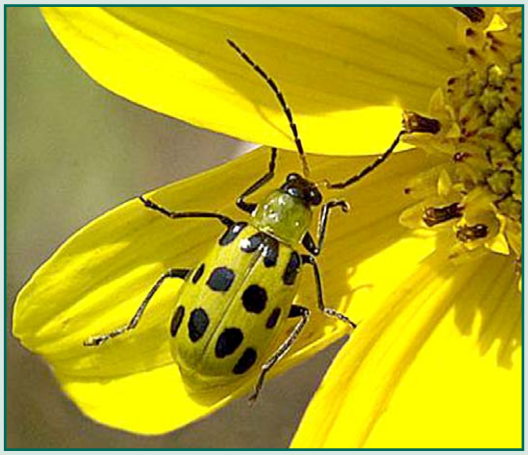
Farmscaping to Enhance Biological Control

Organic IPM Field Guide

Organic Pumpkin and Winter Squash Production

Biorationals: Ecological Pest Management Database

The spotted cucumber beetle *(Diabrotica undecimpunctata howardi)* is about 1/3 inch long and greenish-yellow with a black head and lime-green thorax. It has 12 black spots on its wing covers. The larval stage is known as the southern corn rootworm.



Spotted cucumber beetle. *Photo by Charles Schurch Lewallen.*

The western spotted cucumber beetle *(Diabrotica undecimpunctata undecimpunctata)* is similar in appearance to the spotted cucumber beetle, but is slightly smaller. It is found in Arizona, California, Colorado and Oregon, though it is more prolific and destructive in the southern part of its range (EPPO, 2003).

Western spotted cucumber beetle. *Photo by Jack Kelly Clark, courtesy of UC Statewide IPM Project, © 2000 Regents, University of California.*

The banded cucumber beetle *(Diabrotica balteata)* is found throughout the southern United States from North Carolina to southern California (Capinera, 1999). It is about 1/5 inch long and greenish-yellow with a red head and black thorax. It has three greenish-blue bands running horizontally across its back and a thin green band along the center of its back.

Banded cucumber beetle. *Photo by Kim Davis and Mike Stangeland,* www.texasento.net/beetles.htm.

Adult western corn rootworms *(Diabroctica virgifera virgifera)* can be found crawling on cucurbit plants, but the rootworms cause little feeding injury to cucurbits and do not transmit bacterial wilt or virus diseases. The female adult looks very similar to a striped cucumber beetle, so it is important to distinguish which insect is present. Striped cucumber beetles have black abdomens underneath the wing cover, while western corn rootworms have yellow abdomens. In addition, the center stripe on the striped cucumber beetle extends to the tip of the abdomen, while the center stripe on the western corn rootworm extends about three-quarters of the way. Finally, striped cucumber beetles have faint yellow markings on their legs while the western corn rootworm has solid black legs.

Adult western corn rootworm. Photo by Jim Kalisch, CropWatch, University of Nebraska-Lincoln Extension.

Notes on terms used in organic production

Organic production of crops and livestock in the United States is regulated by the U.S. Department of Agriculture's National Organic Program. The program is an organic certification and marketing program that ensures food and food products labeled as organic meet standard guidelines. Land must be free of synthetic pesticides and fertilizers for three years before it can be certified organic. After that, producers can only use approved organic pest control strategies and fertilizers.

Producers who want to label or market their produce as organic need to gain certification through a USDA-accredited certifying agent. This process involves the development of an organic system plan describing details about soil fertility planning, seeds and seedlings, weed and pest management practices including materials the grower plans to use, and storage and handling routines (Kuepper, 2002). A recordkeeping system and an annual farm inspection are also required.

For more information, see the ATTRA publication *Organic Farm Certification and the National Organic Program.* Please note that farmers involved with organic certification should check with an accredited certifying agent before using any pest control material mentioned in this publication, whether it is described as organic or biorational, to verify approved status.

Biorational products include botanicals, horticultural oils, insecticidal soaps, biopesticides (biofungicides and microbial antagonists), mineral-based products, parasitic nematodes, anti-feedants, plant extracts and pheromones. Organic farmers commonly use biorational product formulations of natural origin.

Biorational pest controls also include reduced-risk pesticides and insect growth regulators that are not allowed in organic production. In addition, organic farmers are not allowed to use certain botanical insecticides like nicotine and rotenone or specific formulations of biorational pesticides. For example, the commercially available Entrust formulation of spinosad is allowed, but many other spinosad formulations are not.

The Organic Materials Review Institute is a nonprofit organization that reviews products used in organic crop production for the purpose of fertility and plant stimulation, as well as for weed, insect and disease control. Manufacturers submit product data, ingredients and related proprietary information to the institute for evaluation of suitable materials according to standards established by the USDA National Organic Program.

The OMRI Products List is a directory of products reviewed and approved by the institute for use in organic crop production. These products may display the **OMRI Listed** seal on labels and in advertising literature. The OMRI Products List is a convenient way for farmers to identify which biorational pest control products are approved for use in organic production.

Resources:

The National Organic Program
USDA – Agricultural Marketing Service
www.ams.usda.gov/nop/indexNet.htm

The OMRI Products List
Organic Materials Review Institute
www.omri.org

Organic regulation, certification, transition and history
ATTRA – National Sustainable Agriculture Information Service
www.attra.ncat.org/organic.html

Life cycle of the cucumber beetle

Understanding the life cycle of an insect pest is critical to using control measures effectively. Integrated pest management pest-control strategies require knowledge of the pest's life cycle to:

- Adjust planting times so crops are not in a susceptible growth stage when the pest is most active
- Distract insects from susceptible crops by using pheromones or trap crops
- Disrupt the pest's ability to reproduce or grow

Applications of biorational insecticides are most effective and least costly when based on knowledge of:

- The pest's life cycle
- The life stage(s) of the pest that will damage the crop plant
- The life stage(s) of the crop plant most susceptible to the pest
- The life stage of the pest that is easiest to control
- Local climate and ecological conditions and how they affect plant growth and insect movement

Refer to the ATTRA publication *Biointensive Integrated Pest Management* for an introduction to integrated pest management concepts and practices.

Cucumber beetles overwinter as unmated adults in bordering vegetation, plant debris, woodlots and fence rows. Cucumber beetles are active in spring when temperatures reach 55 to 65 degrees Fahrenheit and feed on alternate host plants until cucurbit plants appear in vegetable fields.

Striped cucumber beetles are monophagous during the larval stage, meaning the beetles only feed on roots of cucurbit plants. Overwintering adults feed on the pollen, petals and leaves of early blooming plants, especially flowering plants in the rose family, in spring before migrating to cucurbit fields. Adults also feed on the leaves and flowers of corn, beans and peas during the growing season and on goldenrods, sunflowers and asters later in the season. However, both species of striped cucumber beetles are known as specialist feeders because the beetles highly prefer cucurbit plants and fruits. The beetles produce one or two generations per growing season in northern regions and two or three generations in southern regions.

High-altitude currents can carry striped cucumber beetles up to 500 miles in three to four days.

Spotted cucumber beetles are polyphagous during the larval stage, meaning the beetles feed on the roots of multiple host plants. The larvae are commonly known as rootworms because they are injurious feeders on roots of corn, peanuts, small grains and grasses. Adult spotted cucumber beetles feed on the pollen, petals and leaves of more than 200 alternate host plants. Adult spotted cucumber beetles overwinter in southern states and migrate into northern states in June and July, appearing two to four weeks later than striped cucumber beetles. Adults are strong fliers and disperse rapidly from field to field during summer. High-altitude currents can also carry striped cucumber beetles up to 500 miles in three to four days. (EPPO, 2003). Spotted cucumber beetles produce two or three generations in a growing season.

The banded cucumber beetle is polyphagous during the larval stage and can be an injurious feeder on roots of soybeans and sweet potatoes in addition to cucurbits. Adult banded cucumber beetles feed on a wide range of plants in the cucurbit, rose, legume and mustard families. Banded cucumber beetles can produce up to seven generations per year in the Deep South.

After feeding and mating on cucurbit seedlings, female cucumber beetles oviposit eggs in the soil near the base of plants. Egg production ranges from 200 to 300 eggs per female, laid in clusters over the course of several weeks, for the spotted cucumber beetle and up to 1,500 eggs per female for the striped cucumber beetle. Eggs usually hatch in five to 10 days with larval development from 11 to 45 days. Pupae reside in the soil for four to seven days and then emerge as adults. Depending on weather and temperature, peak activity can spike every 30 to 60 days as new generations emerge. Adults can live up to 60 days or more (Capinera, 2001).

Damage to plants by cucumber beetles

Cucumber beetles injure cucurbit crops directly and indirectly. Direct feeding by larvae can injure crop roots and disrupt plant growth. Direct feeding by adults can stunt seedlings and damage maturing fruits. Cucumber beetles transmit bacterial wilt, which causes plants to quickly wilt and die. Bacterial wilt is a major problem for many vegetable growers.

Feeding damage

Cucumber beetles inflict feeding damage three times during their life cycle:

- Overwintering adults feed on emerging cucurbit plants in the spring. These adults can kill or severely stunt young plants by feeding on stems and cotyledons. Adult cucumber beetles also transmit bacterial wilt.
- Larvae from eggs laid by overwintering adults feed on plant roots. Larval tunneling can stunt crop plants, especially seedlings, and predispose the plant to soilborne diseases such as fusarium wilt.
- Second- and third-generation adults emerging from pupae during the

growing season or migrating into the area at mid-season feed on foliage, flowers, stems and fruit. These adults damage maturing fruits and transmit bacterial wilt. Feeding damage is less serious to plants that are already leafed out. Damage to fruits results in scarring and decreases the marketability and storage life of the crop.

Cucumber beetles preferentially feed on different cucurbit species. The approximate order of susceptibility to feeding damage may vary with geographical regions.

Some varieties of a cucurbit species are more attractive to cucumber beetles than others. For example, cucumber beetles preferentially feed on muskmelon varieties in the following order, from greatest to least (Foster et al., 1995):

1. Makdimon
2. Rocky Sweet
3. Cordele
4. Legend
5. Caravelle
6. Galia
7. Pulsar
8. Passport
9. Super Star
10. Rising Star

See Table 1, *"Ranking of cucurbits by cucumber beetle feeding preference,"* for susceptibility ratings of other cucurbit species.

Vegetable Insect Management with Emphasis on the Midwest **(Foster et al., 1995) lists susceptibility, from greatest to least as:**

1. Cucumber
2. Cantaloupe
3. Honeydew
4. Casaba melon
5. Winter squash
6. Pumpkins
7. Summer squash
8. Watermelon

Jude Boucher from the University of Connecticut ranks susceptibility in the northeast from greatest to least as:

1. Bitter gourds
2. Winter squash *(C. maxima)* such as Turk's Turban, Blue Hubbard, etc.
3. Cucumbers
4. Summer squash
5. Cantaloupe
6. Honeydew
7. Butternut winter squash
8. Casaba melon
9. Watermelon

Table 1. Ranking of cucurbits by cucumber beetle feeding preference (Jarvis, 1994).

Higher ranking numbers indicate more preferred varieties by cucumber beetles. Rankings: 1 to 14 means not preferred, greater than 45 means highly preferred.

Summer squash		Winter squash	
Variety	**Ranking**	**Variety**	**Ranking**
Yellow		***Acorn***	
Sunbar	1	Table Ace	6
Slender Gold	2	Carnival	7
Early Prolific Staightneck	20	Table King (bush)	12
Goldie Hybrid	32	Tay Belle (bush)	14
Sundance	33	***Butternut***	
Straightneck		Zenith	13
Seneca Prolific	4	Butternut Supreme	16
Goldbar	5	Early Butternut	25

Table 1. *Continued*			
Higher ranking numbers indicate more preferred varieties by cucumber beetles. Rankings: 1 to 14 means not preferred, greater than 45 means highly preferred.			
Summer squash		**Winter squash**	
Multipik	37	Waltham	28
Crookneck		***Buttercup***	
Yellow Crookneck	8	Honey Delight	43
Sundance	34	Buttercup Burgess	44
Scallop		Ambercup	55
Peter Pan	9	***Pumpkins***	
Zucchini		Baby Pam	10
Gold Rush	39	Munchkin	11
Zucchini Select	40	Seneca Harvest Moon	15
Ambassador	41	Jack-Be-Little	17
President	45	Jackpot	18
Black Jack	46	Tom Fox	19
Green Eclipse	50	Baby Bear	21
Seneca Zucchini	51	Howden	22
Senator	52	Spirit	23
Super Select	54	Wizard	24
Dark Green Zucchini	56	Ghost Rider	26
Embassy Dark Green Zucchini	57	Big Autumn	27
Other summer squash		Autumn Gold	29
Scallop	3	Jack-of-All Trades	30
Cocozelle	48	Rocket	31
Caserta	58	Frosty	35
Melon		Spookie	36
Classic	59	Connecticut Field	38
		Happy Jack	42
		Big Max	47
		Baby Boo	53

Bacterial wilt

In addition to direct feeding on plants, cucumber beetles are vectors for bacterial wilt caused by the bacterium *Erwinia tracheiphila*. While foliage-feeding adult cucumber beetles can injure crops, especially seedlings, the transmission of bacterial wilt disease is a more serious concern because the disease causes rapid wilting and death of cucurbit plants.

While horticultural literature commonly explains that bacterial wilt overwinters in the intestinal tract of adult cucumber beetles, plant pathologists now believe the *Erwinia* bacterium overwinters in the sap of alternate host plants. These plants remain asymptomatic, or do not exhibit symptoms of the disease (Latin, 2000). Adult cucumber beetles feed on these alternative host crops, become infected with bacterial wilt and then transmit the disease to squash, melons or cucumbers by feeding on the crop plants or through fecal contamination of wounded leaves and stems.

Following infection, the *Erwinia* bacterium spreads throughout the vascular system of the plant, causing blockage of xylem vessels. The formation of bacterial-exuded gums and resins results in restricted movement of water and nutrients and the plant starts to wilt. The incubation period from time of infection to expression of wilting symptoms ranges from several days to several weeks. Young, succulent plants are more susceptible to cucumber beetle feeding and disease transmission than older, mature plants.

To determine if a plant is infected with bacterial wilt, use the following diagnostic tests:

- Squeeze sap from a wilted stem cut near its base. Press a knife against the stem and slowly pull it away about a centimeter. The appearance of fine, shiny threads indicates bacterial wilt (Snover, 1999).

- Immerse a newly cut stem in a glass of water. If the plant has bacterial wilt, milky strands of bacterial ooze will leak from the stem in five to 10 minutes.

- Cut the stem with a knife and then push the cut ends together and slowly pull them apart. Sticky, viscous strands of bacterial slime indicate bacterial wilt (Latin, 2000).

The sap of a healthy plant is watery and will not exhibit stringing and bacterial oozing (Snover, 1999).

Bacterial wilt is most severe on cantaloupe and cucumber, less damaging on squash and pumpkin and rarely affects established watermelon plants. Wilt-resistant varieties are available for some cucurbits, but still lacking for others. For example, County Fair 83 and Saladin are resistant varieties of cucumber, but resistant varieties of muskmelon are not developed.

Squash mosaic virus

The western striped cucumber beetle and the spotted cucumber beetle are alternate vectors for another disease: squash mosaic virus. Aphid insects are the primary vector. While the virus is seed-borne, the incidence of this disease is enhanced through cucumber beetle feeding and transmission. Squashes and melons are particularly susceptible to this disease because of a greater occurrence of infected seeds in these species.

The symptoms of squash mosaic virus vary according to host species and cultivar, but include mosaic patterns, leaf mottling, ring spots, blisters and fruit deformation (Provvidenti and Haudenshield, 1996). Besides the use of certified virus-free seeds, control measures are aimed at minimizing the presence of cucumber beetles. (Provvidenti and Haudenshield, 1996 and Davis et al., 1999).

Bacterial wilt is most severe on cantaloupe and cucumber, less damaging on squash and pumpkin and rarely affects established watermelon plants.

Organic control measures

Organic control measures for cucumber beetles fall into five categories, each discussed in detail in the following sections:

- Population monitoring
- Cultural practices
- Trap crops, trap baits and sticky traps
- Predators and parasites
- Botanical and biorational insecticides

Population monitoring methods like crop scouting and sticky traps are commonly used as monitoring tools to help growers detect insect pest populations and make informed and timely pest management decisions. Growers can use threshold data established by university Extension entomologists to determine when control measures, like a knock-down insecticide, prevent crop damage and disease transmission.

Cornell University recommends crop scouting twice a week, with emphasis on the inspection of young cucurbit plants with fewer than five leaves. Monitoring should involve thorough inspection of five plants at each of five locations in a field. Pay special attention to the undersides of leaves and plants at field edges. These population counts are used to calculate the average number of beetles per plant (Petzoldt, 2008).

Economic thresholds for cucumber beetle control depend on the type of cucurbit, age of plants and susceptibility to bacterial wilt. Once cucurbit vines are well-established, plants can tolerate a 25 to 50 percent loss of foliage without a reduction in yield. However, seedling cucurbits can be seriously injured or killed by heavy feeding from cucumber beetles. When bacterial wilt is present, risk is greater among cucurbit varieties that are most susceptible. Entomologists in the Midwest use a threshold of one beetle per plant for insecticidal control when bacterial wilt disease is present.

Growers can use homemade yellow sticky traps or purchase commercial yellow sticky cards for detection of cucumber beetles. Homemade and commercial insect attractants can enhance the trapping effect. Cucumber beetles and most insets are attracted to the color yellow.

To make a simple sticky trap, coat an 8-ounce yellow plastic cup with insect glue, like commercially available Stickum Special or Tangle-Trap. Invert the cup and secure it on a 2-foot wooden stake (Levine and Metcalf, 1988). Eugenol, a naturally occurring insect attractant found in clove oil (82 to 87 percent eugenol), allspice oil (65 to 75 percent eugenol) and bay oil (40 to 45 percent eugenol), lures diabroticine beetles (Peet, 2001 and The Scientific Community on Cosmetic and Non-food Products, 2000). Cinnamaldehyde, found in cassia oil and cinnamon bark oil, functions as an insect attractant and natural cucumber beetle bait (Environmental Protection Agency, 2007). Attach a cotton swab soaked in these aromatic oils to increase the sticky trap's trapping effect.

Integrated pest management suppliers sell rectangular yellow sticky cards imprinted with grid patterns for detection of diabroticine beetles. These include the Pherocon AM trap card from Trece, Inc., the Intercept AM trap card from Advanced Pheromone Technologies, Inc., the ISCA yellow sticky card from ISCA Technologies, Inc. and the Olson yellow sticky card from Olson Products, Inc. These products are listed under the **Products** section of **Resources** at the end of this publication.

Researchers at Southwest-Purdue Agricultural Center in Vincennes, Ind., determined that 20 striped or spotted cucumber beetles per trap during a 48-hour period correspond to one beetle per plant. That is the threshold for treating cucurbits in the Midwest, especially with melons and cucumbers, to prevent excessive loss from bacterial wilt (Lam and Foster, 2005). If fewer than 20 beetles are found on the traps, it means that beetle populations are not at an economic threshold and treatment is not warranted. Growers should repeat this monitoring procedure through critical parts of the growing season.

Volatile chemicals known as kairomones attract diabroticine beetles. Kairomones include cucurbatacins, indoles and floral volatiles as well as specific kairomonal analogs like 2,3-benzopyrrole and 1,2,4-trimethoxybenzene. Since each species of cucumber beetle responds to unique kairomones, separate commercial lures are available for each type of cucumber beetle. There are two manufacturers of kairomone lures: Trece, Inc., which sells the Pherocon CRW series, and Advanced Pheromone Technologies, Inc., which sells the APTLure series.

Cultural practices are land and crop management practices that affect the reproduction of pests or the time and level of exposure crops have to pests. Cultural practices that can protect against cucumber beetles include:

- Delayed planting
- Floating row covers
- Mulching
- Cultivation and residue removal
- Insect vacuuming

Crop rotation within a field, a well-known pest management tool for disease control, is ineffective to control cucumber beetles since the beetles migrate from areas surrounding the fields. Since these insects survive on a number of wild hosts, the removal of alternative hosts from the farm would be difficult and ineffective because of immigration. A two-year study in Massachusetts compared the effectiveness of synthetic and biorational insecticides on the control of striped cucumber beetles and the occurrence of bacterial wilt in direct-seeded and transplanted pumpkin using the susceptible Merlin variety. Results of the trial indicate the need for long-distance crop rotation for insecticides to be most effective. Rotation to an adjacent field close to the pervious year's cucurbits did not reduce beetle numbers (Andenmatten et al., 2002).

Delayed planting is an effective pest management strategy in some regions and cropping systems. Growers can avoid the first generation of cucumber beetles by keeping fields cucurbit-free until the establishment of summer cucurbits like cucumbers, pumpkins and squash intended for fall harvest. Delayed planting is an especially useful cultural strategy in cucurbits because this technique also bypasses first-generation squash bugs. However, this method is not relevant for plantings of early-market spring cucurbits like cucumbers, squash and melons or in regions with short growing seasons.

Floating row covers physically exclude both cucumber beetles and squash bugs during the seedling stage of plant growth. Providing a bug- and beetle-free period allows the plants to thrive and develop a mass of leaf and vine growth by the time row covers are removed at bloom. At this stage of vegetative growth, plants can withstand moderate pest attacks. In regions with established cucumber beetle populations, row covers can make the difference between a harvestable crop and crop failure. Row covers are removed at the onset of flowering to allow for bee pollination and to release vine growth. Applying botanical and biorational pesticides provides season-long protection, depending on location and pest pressure, after row covers are removed.

Weed control is a special consideration when using floating row covers over cucurbit seedlings in bare, moist soil. Row covers create a favorable environment for the germination and growth of weeds. Periodic removal of row covers for mechanical cultivation to stir the soil and disrupt weed seedlings is not very practical. Row covers are normally used for the first 30 to 40 days of vine growth until the onset of flowering. This corresponds to the critical weed-free period for cucurbit plant growth, when weeds should be controlled and excluded as much as possible. In organic production, row covers are commonly used in combination with weed-suppressive mulches like plastic mulch, geotextile weed barriers, straw, hay and paper.

Mulching can deter cucumber beetles from laying eggs in the ground near plant stems. Mulches can also function as a barrier to larval migration and feeding on fruits (Cranshaw, 1998 and Olkowski, 2000). Tunneling larvae need moist soil to damage ripening fruit. Limiting irrigation at this time can minimize damage (Cranshaw, 1998). Mulches are known to harbor squash bugs, however, and mulches do not deter beetles from feeding on leaves, flowers and fruits of cucurbits.

In regions with established cucumber beetle populations, row covers can make the difference between a harvestable crop and crop failure.

Researchers at Virginia Tech showed a dramatic reduction in the occurrence of striped cucumber beetles in a Meteor cucumber crop and similar reductions in both striped and spotted cucumber beetles in a General Patton squash crop by comparing aluminum-coated and aluminum-striped plastic mulches to black plastic mulch (Caldwell and Clarke, 1998). On various sampling dates, yellow sticky traps located next to the aluminum-coated plastic mulches had two, four and six times less cucumber beetles than stick traps located next to black plastic mulch. Researches, after correlating the number of beetles found on sticky traps to the integrated pest management threshold, concluded that reflective mulches reduced cucumber beetle populations to below treatment levels.

The Virginia Tech research article contains a brief economic comparison between costs of production and prices received for organic squash versus conventional squash gown on reflective mulches. Researchers emphasized the ability of reflective mulches to reduce bacterial wilt and virus transmission by cucumber beetles and aphids.

Cultivation and residue removal can help reduce over-wintering populations of cucumber beetles. Cornell University research suggests deep tillage and clean cultivation following harvest (Petzoldt, 2008). However, an organic farming sequence that shreds crop residues, incorporates fall-applied compost or manure and establishes a winter cover crop will facilitate decomposition of above- and below-ground residues.

Insect vacuuming is a form of pneumatic insect control that dislodges insects from plants through high-velocity air turbulence and suction. Large, mechanized bug vacs gained notoriety in the 1980s for control of the lygus bug in California strawberry fields. Hand-held and backpack vacuuming equipment is available through integrated pest management suppliers. Market farms use the equipment to collect beneficial insects and control pest insects in combination with perimeter trap cropping.

The D-Vac, a commercially available vacuum, evolved from insect sampling research by the biological control pioneer Everett Dietrick (Dietrick et al., 1995). Insect vacuuming combined with perimeter trap crops is an appealing non-chemical control strategy. Researchers have employed this dual technique in attempts to control flea beetles in brassica fields (Smith, 2000). This dual technique has also been suggested for mass trapping of cucumber beetles followed by vacuuming as a pest reduction strategy and as an alternative to insecticide applications (Olkowski, 2000). The next section explains how pheromones attract cucumber beetles to perimeter trap crops where beetles congregate in great numbers. The efficacy of this dual technique for control of cucumber beetles is not verified in field trials and is mentioned here as an experimental approach that organic market farmers may wish to explore.

Entomologist Sam Pair inspects squash plants for cucumber beetles and squash bugs lured to this trap crop and away from developing melons. Photo by Scott Bauer, USDA-ARS 2008.

Trap crops, trap baits and sticky traps, if positioned correctly, can intercept beetles through the use of smell, color and pheromonal attraction.

Trap crops release chemicals known as kairomones, which are highly attractive to insects. Kairomones produced by cucurbits include cucurbitacin, the characteristic bitter substance in cucurbitacae that stimulates compulsive feeding behavior in diabroticine beetles, and a mixture of floral volatiles that lure adult beetles from some distance.

Cucurbit trap crops are designed to lure and concentrate cucumber beetles where control measures using insecticides or vacuuming can be focused, reducing the need for field-scale insecticide applications.

Pioneering research in the 1970s and 1980s by Robert L. Metcalf (Ferguson et al., 1979) in Illinois, as well as more recent research in Texas, Oklahoma, Maine, Connecticut and Virginia, shows that certain species and varieties of cucurbits can serve as trap crops next to larger fields of cucurbits (Stroup, 1998, Suzkiw, 1997, Radin and Drummond, 1994, Boucher and Durgy, 2004 and Caldwell and Stockton, 1998). Diabroticine beetles preferentially congregate, feed and mate on these kairomone-effusive trap crops. *Table 1* ranks the feeding preference of cucumber beetle on different varieties of cucurbits.

Researchers at Cornell University found cucumber beetles highly prefer the following varieties of *Cucurbita maxima* and *Cucurbita pepo* squash and pumpkin types (Grubinger, 2001):

Black Jack zucchini
Big Max pumpkin
Cocozelle summer squash
Green Eclipse zucchini
Seneca zucchini
Senator zucchini
Baby Boo pumpkin
Super Select zucchini
Ambercup buttercup squash
Dark Green zucchini
Embassy Dark Green zucchini
Caserta summer squash
Classic melon

Researchers elsewhere used Lemondrop summer squash, Peto 391 summer squash, NK530 squash, Blue Hubbard squash and Turk's Turban squash. However, experience shows that cucurbit varieties highly susceptible to bacterial wilt, such as Turk's Turban, should be avoided as a trap crop (UMass Extension, 2002).

Early research in Maine examined the percentage of land devoted to the trap crop. When researchers grew NK530 squash as a trap crop on 15 percent and 50 percent of the cucumber crop acreage, the trap crop attracted 90 percent of the cucumber beetles (Radin and Drummond, 1994). The researchers concluded that strategically placed strips of squash plants could be more advantageous.

In Oklahoma, Lemondrop and Blue Hubbard squash planted as trap crops and occupying just 1 percent of the total crop area highly attracted cucumber beetles in cantaloupe, squash and watermelon crops (Pair, 1997). The Oklahoma researchers also showed that small squash plants in the four- to six-leaf stage are vastly more effective as trap crops than large squash plants in the more-than-six- to 12-leaf stage, which corroborates findings that cucurbitacin occurs in higher concentrations in young leaves. Recent integrated pest management field trials suggest that perimeter trap cropping, where border rows encompass all four sides of the field, is a pragmatic and an effective approach (Boucher and Durgy, 2004 and Boucher and Durgy, 2005).

To deter entry into the field by cucumber beetles and minimize the spread of bacterial wilt:

- Plant trap crops on the perimeter of the field as border strips. Plant multiple rows if beetle pressure is extreme.
- Plant trap crops a week or two earlier than the primary cucurbit acreage since insects migrate to the earliest emerging cucurbit plants in the field.
- In organic production, apply botanical and biorational insecticides to the trap crop before the beetles migrate into the cucurbit patch. In integrated pest management production, several synthetic insecticides can be applied to the trap crop for beetle control. Vacuuming is a novel approach to controlling beetles that congregate on the trap crop.
- Use yellow sticky ribbons in combination with trap crops to enhance the attractant effect and perform mass trapping.
- Remove and destroy diseased plants from border strips and the main field.

Trap baits for cucumber beetles contain insect-attracting kairomones, floral volatiles, buffalo gourd root powder, eugenol, cinnamaldehyde and cinnamyl alcohol mixed with small amounts of insecticides. Metcalf and coworkers pioneered the identification of cucurbitacin analogs used in attracticidal baits (Metcalf and Lampman, 1991).

Trap baits on field borders intercept beetles as beetles migrate into cucurbit fields early in the season. Great numbers of beetles die when they are lured into these attracticidal baits in a feeding frenzy. Cidetrak CRW is a commercially available gustatory stimulant for diabrotica that growers can mix with synthetic or biorational insecticides in a trap bait. It is available through Trece, Inc., a company that specializes in pheromone traps. See the **Products** section listed under **Resources** for Trece, Inc. contact information. While most of the field trials and commercial applications with attracticidal baits employed systemic insecticides, Michael P. Hoffman at Cornell University investigated the use of trap baits in combination with botanical and biorational insecticides and cultural controls (1998).

Hoffmann's field trials in New York were part of a USDA Sustainable Agriculture Research and Education research project to reduce insecticide use in cucurbit crop production (Hoffman, 1998). Employing a mass-trapping technique, Cornell researchers reduced cucumber beetle populations by 65 percent in pumpkin fields using trap baits containing a mixture of cucurbit blossom volatiles and very small amounts of insecticide. Researchers found positioning trap baits with a highly preferred Seneca zucchini squash trap crop enhanced trap baits, achieving 75 percent control with this dual method.

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In support of organic production, the project examined the effectiveness of botanical and biorational pesticides. The researchers used buffalo gourd root powder as a feeding stimulant in trap baits laced with neem and full or half rates of rotenone (botanical) and cryolite (sodium aluminoflouride). Neem had little effect on beetle survival or mortality, but its antifeedant trait significantly reduced plant damage caused by beetles. Rotenone and cryolite were both effective.

Overall, researchers favored the half-rate of rotenone mixed with buffalo gourd root powder treatment. However, in the interim period since Hoffmann's research in 1999, both of these biorational products were prohibited in organic production under the National Organic Program. Neither is listed with the Organic Materials Review Institute. It seems reasonable that other biorationals approved for organic production might be effectively used in a trap bait.

Yellow sticky traps are commonly used to monitor insect pests. Yellow sticky ribbon is available from commercial integrated pest management suppliers in dimensions of 2 to 12 inches wide by several hundred feet in length. In cucurbits, yellow sticky ribbon can be used for mass trapping of cucumber beetles when placed with cucurbit trap crops. Kairomone lures, available through commercial integrated pest management suppliers, can enhance the trapping effect.

William Olkowski, co-founder of the Bio-Integral Resource Center, conducted an Organic Farming Research Foundation-funded study on mass trapping of cucumber beetles using six different framed and strip traps.

The Bio-Integral Resource Center Trap, a wooden-legged trap that held upper and lower strips of yellow sticky ribbon 10 feet long and oriented parallel to the ground, was highly effective in trapping cucumber beetles. The 6-inch wide yellow sticky ribbon is mounted on a spool and requires periodic uptake to expose fresh sticky tape. Since the upper strip, located 20 to 26 inches above the ground, captured far more cucumber beetles than the lower strip, located 12 to 18 inches above the ground, researchers discontinued the lower strip in later trials. The trap is mobile and can be placed in cucurbit trap crops.

The *OFRF Information Bulletin No. 8,* published in the summer of 2000, is available as a Web download and is useful to develop an understanding of how to design and use the trap (Olkowski, 2000).

Predators and parasites that prey on cucumber beetles include hunting spiders, web-weaving spiders, soldier beetles, carabid ground beetles, tachinid flies, braconid wasps, bats and entomopathogenic fungi and nematodes. Braconid wasps *(Centisus diabrotica, Syrrhizus diabroticae)* and tachinid flies *(Celatoria diabroticae, C. setosa)* are important natural enemies of cucumber beetles, with parasitism rates reaching 22 percent and 40 percent, respectively (Capinera, 2001 and Kuhlmann and van der Burgt, 1998). Carabid beetles *(Scarites* spp. and *Evarthrus sodalis)* consumed all three life stages (larvae, pupae, adults) of spotted cucumber beetle, striped cucumber beetle and squash bugs in a laboratory feeding trial (Snyder and Wise, 1999). Biological control from natural enemies varies widely between locations and is not dependable as the only control strategy in commercial cucurbit production. Providing beneficial insect habitat can enhance cumulative bio-control results in organic farming systems.

David H. Wise and co-workers in the department of entomology at the University of Kentucky thoroughly investigated spider predation of cucumber beetles (Snyder and Wise, 2000, Williams et al., 2001 and Williams and Wise, 2003). Wise found that both striped and spotted cucumber beetles reduce their feeding rate and emigrate from cucurbit plants in the presence of the large wolf spiders *Hogna helluo* and *Rabidosa rabida.* Spider presence reduced plant occupancy of diabroticine beetles by 50 percent. Curiously, adult female beetles are far more responsive to the presence of wolf spiders and alter their behavior to avoid capture. Consequently, males were 16 times more likely than females to be killed by *R. rabida* in one experiment; only 5 percent of males survived a two-day exposure to *H. helluo* in a second experiment. In general, populations of predaceous spiders and ground beetles can be enhanced through habitat modification using straw mulch (Snyder and Wise, 1999), straw shelters (Halaj et al., 2000) and beetle banks (Master, 2003).

Bats are voracious eaters of insects and more farmers are erecting bat houses to enhance biological control of crop pests. John O. Whitaker, Jr., a vertebrate ecologist at Indiana State University, used data partly derived from studies on the evening bat *(Nycticeius humeralis)* to estimate that a typical Midwestern colony of 150 big brown bats *(Eptesicus fuscus)* might consume 38,000 cucumber beetles, 16,000 June bugs, 19,000 stink bugs and 50,000 leafhoppers in one season (Whitaker, 1993).

In a detailed follow-up study where he dissected fecal pellets of big brown bats from Indiana and Illinois, Whitaker calculated that a colony of 150 bats might consume 600,000 cucumber beetles, 194,000 scarabaeids, 158,000 leafhoppers and 335,000 stinkbugs in one season. Assuming that half of the cucumber beetles were female, and using a value of 110 eggs per female, this means the potential destruction of 33 million diabrotica larvae (Whitaker, 1995).

Male wolf spider. Photo by Patrick Edwin Moran, Courtesy of Creative Commons.

An April-June 2006 article in *California Agriculture* evaluated the best way to attract bats to farms through the placement, shape, size and color of bat houses (Long et al., 2006). For more information about creating on-farm bat habitat and the use of insectary plantings to attract beneficial insects, see the ATTRA publication *Farmscaping to Enhance Biological Control.*

Entomopathogenic fungi, commonly grouped among biopesticides, produce infective spores that attach to the larval host and then germinate and penetrate. The fungi multiply inside the host, acquiring nutrient resources and producing conidial spores. This causes the infected larvae to reduce their feeding and die, releasing fungal spores into the soil environment and further distributes the entomopathogen.

The two fungal organisms most widely used as biopesticides, *Beauveria bassiana* and *Metarhizium anisopliae,* have been evaluated for suppression of diabroticine larvae with varying levels of biocontrol. Mycotrol-O is a commercially available, Organic Materials Review Institute-approved biopesticide containing *Beauveria bassiana* and cucumber beetle is listed as a target pest on the label. See the section on **botanical insecticides** below with notes from Reggie Destree for foliar mixtures containing Mycotrol-O.

Entomopathogenic nematodes, commonly known as parasitic nematodes, actively find and penetrate soil-dwelling larvae of insect pests. The nematodes release toxins and transmit bacteria that is lethal to the larval host. Both species of commercially available parasitic nematodes, *Steinernema* spp. and *Heterorhabditis* spp., are effective in biological control of diabroticine beetle larvae.

Researchers in Pennsylvania obtained a 50-percent reduction in striped cucumber beetle larvae using *Steinernema riobravis* in organic and conventionally managed plots of cucumbers under field conditions (Ellers-Kirk et al., 2000). The decrease in cucumber beetle larval populations resulted in superior root growth under both soil management systems.

Nematodes release toxins and transmit bacteria that are lethal to insect pests' larvae.

The researchers suggested delivery of parasitic nematodes through drip irrigation in combination with plastic mulch, since earlier studies showed that plasticulture provides an environment conducive to nematode survival while increasing effective control of cucumber beetle larvae.

The Insect Parasitic Nematode Web site, developed and maintained by the department of entomology at The Ohio State University, contains information on the biology and ecology of nematodes and how to use them for pest control in different crops (Grewal, 2007). It features an extensive list of commercial suppliers of parasitic nematodes.

Based on results from seven published studies, Dr. David Shapiro-Ilan, a research entomologist with the USDA Agricultural Research Service in Georgia, found that parasitic nematodes provide approximately 60 percent control of diabrotica larvae (Shapiro-Ilan, 2006 and Grewal et al., 2005). Ilan added that it is important to put entomopathogens, whether fungi or nematodes, in perspective. Since diabroticine beetles migrate in from surrounding borders, these biological control measures have little effect on adult beetle feeding and disease transmission. However, decreasing larval populations through the use of entomopathogens can have a cumulative biocontrol effect in organic farming systems.

Botanical and biorational insecticides like azadarachtin, an extract from the neem tree, have anti-feedant and insecticidal properties. Alone, azadarachtin is not effective against adult cucumber beetles. However, recent studies by Reggie Destree, a crop consultant, indicate that a mixture of neem with karanja oil derived from the tree *Pongamia glabra*, which grows in India, can reduce cucumber beetle populations by 50 to 70 percent overnight (personal communication). Alone, neem oil applied as a soil drench acts as an ovicide and is effective against larval damage (Destree, 2006). Please see the **Products** section in **Resources** below for sources of commercial neem and karanja products.

Destree recommends a three-part management regime for cucumber beetles:

- The neem blend described above has a dual mode of action. It is a systemic product that will suppress insects that feed on the plant and it has fungicidal properties.
- Use 1 pint Cedar ACT cedar oil to 10 gallons water as a repellent or pheromone disruptor during the first flight of the cucumber beetle in May and the second flight in September. Exact dates depend on location. Destree advises applying the mixture every five to seven days when the fields are square or short rectangles. Pheromone disruption does not work well for long, narrow fields. Adding Cedar ACT to the weekly foliar program works well.
- Mycotrol-O is a commercially available mycoinsecticide formulation containing spores of the entomopathogenic fungus *Beauveria bassiana* GHA strain. Use Mycotrol to suppress future populations. Destree found this program works well for all overwintering insects. A fall soil treatment of the Mycotrol-O added to a fall residue program will insure that the active ingredient, *Beauvarria bassiana*, will be reproducing in the soil and will eventually infect

overwintering beetles in the soil (Destree, 2006).

ATTRA note: Reggie Destree is a crop consultant and distributes the above products. This information has not been validated by university-based research.

The botanical pesticides sabadilla, rotenone or pyrethrum have moderate effectiveness in controlling cucumber beetles (Caldwell et al., 2005). Sabadilla is toxic to bugs and honey bees, and sabadilla should not be applied when bees are present. Pyrethrum is also toxic to all insects, including beneficial species. These botanical pesticides are also highly toxic to fish until degraded (King County Hazardous Waste Program, 1997).

One way to enhance the effectiveness of these materials while reducing overall management costs is to combine the materials with perimeter trap cropping so that sprays can be concentrated on the border. See the above section on trap cropping for more on this topic. Some growers use pyrethrum or rotenone in combination with the commercially available particle film barrier Surround WP Crop Protectant (Grubinger, 2001). Note that rotenone is currently not approved by the National Organic Program.

Results of a two-year study comparing the effectiveness of insecticides on management of striped cucumber beetles and bacterial wilt in direct seeded and transplanted pumpkin showed the need for long-distance crop rotation for insecticides to be most effective. When the rotation was to an adjacent field in different land, but close to the previous year's cucurbits, it did not reduce beetle numbers and insecticide effectiveness tended to decline (Andenmatten et al., 2002).

Particle film barriers provide a promising new approach to insect control for organic producers. Surround WP acts as a repellent, mechanical barrier and irritant, and disrupts the beetles' host-finding abilities. The active ingredient in this product is specially processed kaolin clay, an edible mineral used as an anti-caking agent in processed foods and products like toothpaste. According to the former product representative for Surround WP, John Mosko of the Engelhard Corporation, kaolin clay provides good suppression of cucumber beetles. He recommends:

- Using an air blast sprayer to achieve good coverage
- Applying the product under the leaves where cucumber beetles congregate
- Applying Surround WP early in the growing season before cucumber beetle populations increase. Surround can provide remedial control of cucumber beetles, but field trials show early applications deter beetles from initially entering the field and are more effective
- Reapplying after a heavy rain
- Continually agitating the solution while applying it
- Cleaning harvested fruits with a moist cloth or a post-harvest rinse to remove any film residue of the kaolin clay left on the crop after harvest

Ruth Hazzard with the University of Massachusetts Extension recommends using Surround WP Crop Protectant in combination with other tactics like rotation, row cover, using transplants so plants are bigger when beetles arrive, and delaying planting until late June to avoid beetles. Surround can be applied to transplants before setting them in the field (Andenmatten et al., 2002). See the **Products** section of **Resources** below for information on how to obtain this product.

The timing and usage of either botanical or chemical insecticides should be based on observed population thresholds or measured risks of population build-up. Determining when spring flight begins forecasts the arrival of cucumber beetles in each geographical region.

Only treat hot spots or areas of high infestations if possible. Insecticide applications made between dawn and dusk, when the striped cucumber beetle is most active, may be more effective.

For more information on biorational insecticides, or formulations with little or no long-lasting environmental impact, see ATTRA's online Biorationals: Ecological Pest Management Database, *http://attra.ncat.org/index.html.*

Resources

Information:

Bio-Integral Resource Center (BIRC)
For a publications catalogue, contact:
P.O. Box 7414
Berkeley, CA 94707
510-524-2567
510-524-1758 fax
birc@igc.apc.org
www.birc.org

The Bio-Integral Resource Center is a leader in the field of integrated pest management. BIRC publishes the IPM Practitioner and Common Sense Pest Quarterly. They also publish a directory of IPM products and beneficial insects and offer booklets and reprints on least-toxic controls for selected pests.

Insect Parasitic Nematodes

Sponsored by SARE and the Lindberg Foundation.
Department of Entomology, The Ohio State University.
www.oardc.ohio-state.edu/nematodes/default.htm

This Web site provides information on the biology and ecology of parasitic nematodes, how to use nematodes to control plant diseases and a comprehensive listing of companies that sell nematodes.

Hunter, C.D. 1997. *Suppliers of Beneficial Organisms in North America.* California Environmental Protection Agency. Department of Pesticide Regulations Environmental Monitoring and Pest Management Branch
1020 N Street, Room 161
Sacramento, CA 95814-5624
916-324-4100
www.cdpr.ca.gov/docs/ipminov/bensup.pdf

Products:

Advanced Pheromone Technologies, Inc.
P.O. Box 417
Marylhurst, OR 97036-0417
315-299-2598
815-425-6149 fax
aptsales@advancedpheromonetech.com
http://advancedpheromonetech.com

BioWorks, Inc.
345 Woodcliff Dr.; First Floor
Fairport, NY 14450
800-877-9443

Mycotrol is available through Bioworks.
www.bioworksinc.com/mycotrol/mycotrol.html

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Sabadilla and Safer soap

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P.O. Box 5266
Riverside, CA 92517
951-686-5008
815-346-1722 Fax
info@iscatech.com
www.iscatech.com

Neem Resource.Com
Contact: Usha Rao
952-943-9449
www.neemresource.com

Sources of karanja oil and neem

Olson Products, Inc.
P.O. Box 1043
Medina, OH 44258
330-723-3210
www.olsonproducts.com

Peaceful Valley Farm Supply
P.O. Box 2209
125 Springhill Blvd.
Grass Valley, CA 95945
Orders: 888-784-1722.
Questions: 530-272-4769

contact@groworganic.com
www.groworganic.com/default.html
Sabadilla and Safer soap and Eugenol, a pheromone attractant for northern corn rootworm

Surround WP
Nova Source, a division of Tessenderlo Kerley, Inc.
Phone: 800-525-2803
Email: *novasource@tkinet.com.*
www.novasource.com/products
NovaSource is now the distributor of the kaolin clay-based products Surround WP and Surround CF.

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P.O. Box 129
Adair, OK 74330
918-785-3061
918-785-3063 Fax
custserv@trece.com
www.trece.com
Also Source of CideTrak CRW

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Updated by Tammy Hinman
NCAT Agriculture Specialist

Holly Michels and Karen Van Epen, Editors
Amy Smith, Production

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