Vegetable Crop Insect Update

By Joanne Whalen
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Lima Beans
Continue to sample for mites since early detection is necessary to achieve effective control. We are starting to see an increase in stinkbug and plant bug populations. As soon as pin pods are present, be sure to watch carefully for plant bug and stinkbug adults and nymphs. As a general guideline, treatment should be considered for lygus if you find 15 adults and/or nymphs per 50 sweeps. For stink bugs, the threshold should be reduced by one half.

Melons
Continue to scout all melons for aphids, cucumber beetles, and spider mites. It is also the time of year to start watching for caterpillars that feed on rinds which can include beet armyworm, yellow striped armyworm, and cabbage looper larvae. If beet armyworm is in the mix, it is important to select a material that is effective on this insect (refer to the Commercial Vegetable Recommendations) – the pyrethroids do not provide effective control. Be sure to read all labels carefully for pollinator protection statements, rates and restrictions. Some materials are restricted to only one application as well as ground application only.

Peppers
Depending on local corn borer trap catches, sprays should be applied on a 7 to 10-day schedule once pepper fruit is ¼ – ½ inch in diameter. At this time, you will also need to consider a treatment for pepper maggot. Be sure to also watch carefully for beet armyworm larvae since they can quickly defoliate plants. In addition, be sure to use a material that provides beet armyworm control – the pyrethroids have not provided control of this insect in past years.

Snap Beans
Depending on local trap catches, sprays may be needed at the bud and pin stages on processing beans for corn borer control. As earworm trap catches increase, an earworm spray may also be needed at the pin stage. You will need to check our website for the most recent trap catches to help decide on the spray interval between the pin stage and harvest for processing snap beans. Once pin pods are present on fresh market snap beans, a 7 to 10-day schedule should be maintained for corn borer and corn earworm control.

Sweet Corn
Continue to sample all fields through pre-tassel stage for whorl feeders (corn borer, corn earworm and fall armyworm). A treatment should be applied if 12-15% of the plants are infested with larvae (regardless of the species). The predominant whorl feeder being found at this time is the fall armyworm. Since fall armyworm (FAW) feed deep in the whorls, sprays should be directed into the whorls and multiple applications are often needed to achieve control. FAW can also be a problem in silk stage sweet corn, especially in outbreak years. The first silk sprays will be needed for corn earworm as soon as ear shanks are visible.

IPM Threshold Guide for Vegetable Crops
ECONOMIC THRESHOLD - Level of pest activity when control action is suggested to prevent economic injury Online at: https://extension.umd.edu/sites/default/files/_docs/IPMGuideVegetables2009.pdf
Vegetable Disease Update
By Kate Everts
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Downy mildew is active in both Maryland and Delaware on cucumber and cantaloupe (muskmelon). Muskmelon was first reported in the past week.

Powdery mildew is also present on cucurbit crops. Stay on a good fungicide management program.

Late blight is also present in four counties in Maryland, including on the shore adjacent to Delaware. Recent hot weather has slowed the spread of late blight, however as we move into a period of cooler temperatures and longer nighttime dew periods, late blight is likely to increase in prevalence again.

Gummy stem blight on watermelon (Fig. 1A) and melon (Fig. 1B) and anthracnose on watermelon (Fig. 2, note leaf also has gummy stem blight lesions) are also widespread.

Maximize Your Land Use with Midsummer Plantings
By Andrew Archer Kness
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Around August we begin to enter a transition phase in vegetable production. Early spring planted crops such as corn, tomatoes, cabbage, celery, squash, cucumbers, melons, and carrots begin to decline and approach their final harvest (or have so already), but our growing season is far from over. Our first fall frost typically occurs around October 30, and with the dog-days of June and July behind us that typically bring our hottest temperatures, this is the time of year to get those cool-tolerant vegetables in the ground—or plant them again for a second harvest. Midsummer vegetables can be planted behind early planted vegetables that have stopped producing. This allows for more production and profitability from the same land area, and has the added benefit of suppressing weeds (compared to a fallow field) and will aid in nutrient and soil retention. Before planting, be sure your soil has adequate fertility; you may need to add a balanced fertilizer to replace the nutrients removed by earlier crops.

Cole crops are particularly suited for mid to late summer plantings. Increasing day length and summer heat will cause them to bolt, and summer harvested cole crops will often have an undesirable bitter taste, therefore making fall harvested plantings superior. Most
cole crops mature between 50-80 days, so they can be planted in mid to late summer for a fall or early winter harvest. If temperatures remain high after planting, the implementation of row covers or shade cloth may be necessary to successfully establish the seedlings. Many cultivars of kale, cabbage, Brussels sprouts, broccoli, and spinach (not a cole crop) can survive a light to moderate frost down to 20 °F; spinach may even overwinter.

Other crops to consider are scallions (sometimes called green onions) and garlic. Since scallions are grown for their tops they can be cultivated for a fall harvest, whereas bulb onions cannot. Bulb onions require 12-16 hours of daylight to produce a bulb, therefore midsummer and fall plantings are not possible in our area. Scallions can tolerate moderately cold temperatures, down to about 30 degrees, so they will be winterkilled. Garlic on the other hand, will overwinter in the ground and can be harvested around July. Legumes, such as bush beans and peas, are versatile crops that can also be planted in midsummer; but keep in mind that they will mature a bit slower in late summer and fall due to the change in day length. Beans will be killed by frost, while peas can tolerate temperatures into the high 20s. Finally, carrots and beets are additional crops to try as late plantings.

In addition to planting edible plants as midsummer crops, consider green manure crops or cover crops as well. Cover crops will help scavenge nutrients, as well as suppress weeds and reduce soil erosion. When the cover crop is incorporated it will provide nutrients for your subsequent crop, as well as improve overall soil health and organic matter content as it decomposes. Green manure crops generally add more biomass to the soil than cover crops and will supply more nutrients to the subsequent crop, but they take a bit more intensive management since they generally require more fertilization to maximize their biomass production. Some cover crops and green manure crops to think about are: cereal rye, hairy vetch, crimson clover, spring oats, wheat, barley, triticale, mustard and rapeseed. Mustards and rapeseed are particularly good at scavenging nutrients and can produce a lot of biomass. Some of the tillage/forage and oilseed radish type mustards have very large tap roots that are good for breaking up compacted soil, making them an attractive option for a no-till situation. Many also have biofumigation properties that, when used properly, may help suppress weeds and soil borne pests and diseases. Many of the mustard cultivars will typically winterkill; however, some do not. Also, keep in mind that cultivars that typically winterkill in average years can survive a mild winter. Spring oats will not overwinter. Cereal rye, hairy vetch, crimson clover, wheat, barley, and triticale will all overwinter and produce additional biomass into the spring as long as they are properly established before winter sets in. Cereal rye is particularly fast growing and will provide a lot of biomass in the spring. Be sure to keep an eye out for seed production in your cover crops in the spring—if they start to produce seed, mow or kill the crop to prevent the plants from self-seeding and creating a weed problem in your next vegetable crop.

Taking the time to plan and grow a midsummer crop for fall harvest can bring added revenue and value for growers, or extend the harvest for homeowners that wish to enjoy fresh vegetables into the fall and early winter. The addition of a midsummer or early fall-planted cover crop also has its benefits and can pay-off over the long term. For more information, contact your local University of Maryland agriculture agent, or visit www.extension.umd.edu.

Why so Little Yellow Shoulders in Tomatoes this Year?

By Jerry Brust
IPM Vegetable Specialist, UME

Normally at this time of year I’d be writing about how bad yellow shoulders and other fruit ripening problems are in Maryland tomatoes. But this has been a strange season with May weather in March and March weather in May, which caused a great deal of catfacing problems this year. However, except for a few fields in a few places there have been far fewer troubles with tomato yellow shoulders or fruit ripening problems than we normally see this time of year—at least for now. Why is this? The one big thing I have found is that when I randomly take petiole samples from fields I visit they have come back with potassium levels at or above 3.5% with some fields at 6% in mid-July. This is extraordinary, normally potassium (K) levels drop precipitously after the plant puts on a heavy fruit load in July. The levels drop down to somewhere around 2-3% in July when they were at 4-6% just a month earlier. This drop in K is not enough to show up as a deficiency in the plant, but shows up in problems with fruit ripening. Even in my
tomato research plots, where I have seen K levels drop over the last 10 years to an average of 1.8% in July and August. K levels were at 6% or above this July and early August. So why was there no or just a small drop in K values this season in many of our tomato fields? I’d like to think that is was all the talks that we have given over the years about making sure your K levels do not drop in tomatoes and this is what I tell my bosses. But that unfortunately does not explain it. Since the small drop in K is happening over a fairly large area across many types of production systems I have to think it is environmentally induced. Exactly what in this strange year’s weather patterns allowed plants to continue to take up K in the amount the plant and fruit needed is something I’ll be looking at in weather data over the next few months. If nothing else this odd season does show that if K levels are maintained in tomatoes through fruiting there is a corresponding reduction in fruit ripening problems.

Sunburn in Fruiting Vegetables and Fruit Crops and Sunburn Protection
By Gordon Johnson,
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With the expected high temperatures this weekend and next week, there is high potential for sunburn in fruits and fruiting vegetables. Growers may need to consider ways to protect against sunburn. Sunburn is most prevalent on days with high temperatures, clear skies and high light radiation. We commonly see sunburn in watermelons, tomatoes, peppers, eggplants, cucumbers, apples, strawberries, and brambles (raspberries and blackberries).

There are three types of sunburn which may have effects on the fruits. The first, sunburn necrosis, is where skin, peel, or fruit tissue dies on the sun exposed side of the fruit (Figure 1). Cell membrane integrity is lost in this type of sunburn and cells start leaking their contents. The critical fruit tissue temperature for sunburn necrosis varies with type of fruit. Research has shown that the fruit skin temperature threshold for sunburn necrosis is 100 to 104°F for cucumbers; 105 to 108°F for peppers, and 125 to 127°F for apples. Fruits with sunburn necrosis are not marketable. Injury may be white to brown in color.

The second type of sunburn injury is sunburn browning. This sunburn does not cause tissue death but does cause loss of pigmentation resulting in a yellow, bronze, or brown spot on the sun exposed side of the fruit. Cells remain alive, cell membranes retain their integrity, cells do not leak, but pigments such as chlorophyll, carotenes, and xanthophylls are denatured or destroyed. This type of sunburn browning occurs at a temperature about 5°F lower than sunburn necrosis (i.e. 115 to 120°F in apples). Light is required for sunburn browning. Fruits may be marketable but will be a lower grade.

Figure 1. Sunburn necrosis on pepper fruit.

The third type of sunburn is photooxidative sunburn (Figure 2). This is where shaded fruit are suddenly exposed to sunlight as might occur with late pruning, after storms where leaf cover is suddenly lost, or when vines are turned in drive rows. In this type of sunburn, the fruits will become photobleached by the excess light because the fruit is not acclimatized to high light levels, and fruit tissue will die. This bleaching will occur at much lower fruit temperatures than the other types of sunburn. Damaged tissue is often white in color.

Genetics also play a role in sunburn and some varieties are more susceptible to sunburn. Varieties with darker colored fruit, those with more open canopies, and those with more open fruit clusters have higher risk of sunburn. Some varieties have other genetic properties that predispose them to sunburn, for example, some blackberries are more susceptible to fruit damage from UV light.

Control of sunburn in fruits starts with developing good leaf cover in the canopy to shade the fruit. Fruits most susceptible to sunburn will be those that are most exposed, especially those that are not shaded in the afternoon. Anything that reduces canopy cover will increase sunburn, such as foliar diseases, wilting due to inadequate irrigation, and excessive or late pruning. Physiological leaf roll, common in some solanaceous crops such as tomato, can also increase sunburn.

In crops with large percentages of exposed fruits at risk of sunburn, fruits can be protected by artificial shading using shade cloth (10-30% shade). However, this is not practical for large acreages.
Recent storms have caused canopies in vine crops to be more open, exposing fruits to a high risk of both sunburn necrosis and photooxidative sunburn.

For sunburn protection at a field scale, use of film spray-on materials can reduce or eliminate sunburn. These materials are kaolin clay based, calcium carbonate (lime) based, or talc based and leave a white particle film on the fruit (such as Surround, Screen Duo, Purshade and many others). There are also film products that protect fruits from sunburn but do not leave a white residue, such as Raynox. Apply these materials at the manufacturer’s rates for sunburn protection. They may have to be reapplied after heavy rains or multiple overhead irrigation events.

While particle films have gained use in tree fruits, their usefulness in vegetables is still unclear. Research in a number of states has shown reduced fruit disorders such as sunburn in peppers and white tissue in tomatoes when applied over those crops. Watermelon growers have used clay and lime based products for many years to reduce sunburn in that crop in southern states. There are some drawbacks to the use of particle films. If used for sunburn protection on fruits, there is added cost to wash or brush the material off at harvest. Where overhead irrigation is used, or during rainy weather, the material can be partially washed off of plants, reducing effectiveness and requiring additional applications. Produce buyers can also have standards relating to the use or particle films and may not accept products with visible residues. For example, some watermelon brokers will accept watermelons where calcium carbonate protectants have been used but will not accept watermelons sprayed with clay based products.

We have seen southern blight on several farms this year, mostly on tomato crops. Unlike many other root rot diseases, southern blight prefers warmer conditions, making it a problem in the hotter summer months. Growers will typically notice a few plants wilting during the hottest part of the day followed by complete collapse of the plant within a week or two. A brown to black area can be seen at the base of plant where the stem meets the soil line. Careful observation will show a whitish growth surrounding the stem and extending into the soil, as well as the presence of small sclerotia that resembles mustard seeds embedded in the white growth. It is a serious disease in southern states, and an occasional problem in our area. Southern blight is not easily controlled with fungicide applications. Preliminary research studies have shown some activity on tomatoes from the fungicides Fontelis and Priaxor when sprays are directed towards the base of the plants. Growers should use an integrated approach for satisfactory control. This includes crop rotation, burying crop debris and sclerotia through deep plowing, and controlling other foliar diseases.

Fusarium Crown Rot
By Ben Beale, Extension Educator
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For the second year in the row, Fusarium Crown rot has been confirmed in high tunnel tomato houses and in field production on multiple farms. Plant injury and fruit loss can be significant. Plants begin to wilt during the hot part of the day and recover at night. Often the lower leaves will also yellow from the ground up. The wilt is typically noticed just before the main harvest of fruit. Wilting continues until the plant eventually dies. Careful observation will reveal a chocolate brown lesion that begin on the lower stem at or below the soil line and extends up the main stem up to 6-8 inches. The roots will be dis-colored and often rot.

Fusarium crown rot is caused by the fungal organism Fusarium oxysporum f. sp. radicis-lycopersici. Fusarium crown rot is different than fusarium wilt, which is caused by a related species Fusarium oxysporum f. sp. Lycopersici. This is an important distinction as there is widespread resistance to fusarium wilt in most modern tomato varieties. Resistance to fusarium crown rot is available but is limited.

Fusarium crown rot will remain viable in the soil for several years. Fumigation, steam sterilization and longer rotations will help reduce the amount of inoculum in the soil. The disease must enter the plant through natural or artificial openings in the roots. We often see the presence of root knot or other nematodes present in conjunction with fusarium diseases. The nematode injures the plant roots allowing an entry point for the disease. Grower should be careful not to sucker plants and plant too deeply below the suckering point, as this also provides an entry point for the disease.

Edema (Oedema) on Pepper Fruit
By Gordon Johnson,
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With recent wet, cloudy weather we are seeing some edema (or oedema) on bell pepper and banana pepper fruits. Edema is also called water blistering. The most common cause of edema is warm wet soils, high humidity in the air, low wind, and overcast (cloudy) skies. Under these conditions the roots of the pepper plant absorb water at a rate faster than is lost through transpiration. Excess water accumulates in the developing fruit, some fruit cells enlarge, stomatal openings become blocked by these enlarging cells, and water continues to accumulate in the fruit. The enlargement of these fruit cells then causes a rupture of the epidermis leaving raised bumps and scarring. To reduce edema, limit irrigation during cloudy, humid weather.

An excellent article from the University of Tennessee on tomato wilt diseases is available at: https://ag.tennessee.edu/EPP/Extension%20Publications/Tomato%20Wilt%20Problems.pdf.
Edema in Banana Pepper Fruits. Note the raised brown bumps and scarring.

Magnified picture of ruptured epidermis on edema affected banana pepper fruit.

Orchard Update
Western Maryland
By Bryan Butler
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Overall other than the cold start to the year which rendered two chemical thinnings on apples totally ineffective the followed by hot conditions disease and insect control have been very manageable. The peach crop was light but we did have a crop at WMREC which is not the greatest site for peach production. There were many split pits however, and the majority of the crop came on very early. As for apples as I mentioned the cold spring did not hurt the crop load at all. The crazy season then worked in our favor as it appears it was too cool then too hot for any significant fireblight infections. Last year WMREC apples were significantly affected and it appeared many trees would be lost. However to this point in the season we have only lost one tree to fireblight and one tree (G41 rootstock) to snapping off.

Although there appeared to be a large overwintering population of BMSB to this point they have not made a very significant showing. We did have native Brown Stink bugs in peach at WMREC this season but to this point BMSB has been almost nonexistent. It has seemed this season, as we have seen in the last couple of years that BMSB has been looming in the borders and in wooded areas since June. Every once in a while they seem to be moving into orchards and other crops but damage has not appeared to be significant in horticultural crops that are being well managed, i.e. not letting adults lay eggs in the field or allowing nymph populations to persist in the field.

As we move into the end of the 2016 season and as the number of crops in the field begin to decrease, it is important to remember BMSB numbers tended to increase in the 2008-2010 seasons and in 2012 it was not till the end of the season that damage occurred at a significant level in orchards, mainly because we thought he danger had passed but it hadn't. That could mean trouble for late crops again this year so it is important to stay vigilant in terms of scouting especially around the borders this year and remember we do have section 18 labels again this year for bifenthrin and dinotefuron so you do have two elect weapons if BMSB should become a major problem on your farm.

As far as SWD late season pressure has caused some of the greatest struggles in management. For now, it is important to plan your strategy for sprays and harvest to prevent from leaving yourself open to infestation. It has seemed over the last several years that being proactive leads to a much better crop than letting the population build and possibly losing the crop because the infestation cannot be controlled.

Below is a link to FS-1023 Spotted Wing Drosophila Monitoring and Management factsheet which lists products that have efficacy against SWD. Please read and understand the label on all the products and make
sure they fit for your crop and your harvest schedule. To avoid resistance, consider using the same product twice in a row then switching to a different material in a different group and using that twice in a row and following that pattern to avoid resistance development. Any attempts at increased sanitation in the fields will certainly be useful but a seven day spray schedule is probably more practical in pick your own situations.

http://media.wix.com/ugd/1ae478_33312e43f4da404c94625a808d7a1108.pdf

Be sure to read the label and make sure the crop is on the label and be aware of REI and PHI as well as other limits on the label as far as number of applications and amounts allowed on a crop per season.

Grapes and Fruit

Information and Resources for Commercial Grape & Fruit Growers

http://www.extension.umd.edu/smallfruit

Pre-Harvest (August)

- Brown Marmorated Stink Bug (BMSB) - Part 1
- Brown Marmorated Stink Bug (BMSB) - Part 2
- Brown Marmorated Stink Bug (BMSB) - Part 3 (Fruit Damage and Juice/Wine Taint)
- Crop Development Sampling
- Crop Management
- Disease Management - Botrytis
- Early Warning: Multi-Colored Asian Ladybeetle (MALB) for Grape Growers
- Evaluating Grape Samples for Ripeness
- Grape Berry Moth
- Harvest Priorities
- Nematode Sampling
- Pre-Harvest Disease Management
- Round Two: Multi-colored Asian Ladybeetle (MALD) Management for Grape Growers
- The Spotted Wing Drosophila (SWD) - Part 1: History, Background, and Damage
- The Spotted Wing Drosophila (SWD) - Part 2: Management

By Joe Fiola
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Organic Vegetable Production at Maryland Vegetables

Public awareness and interest in how food is produced is an increasing concern for today's society. Growing organically is an ever increasing market that has evolved to address society's concerns on food production. Organic production has continued on an increasing trend since the mid 1990's. Organic food sales now represent approximately two percent of U.S. food sales (Hunsburger et. al., 2010) with the future outlook looking very positive.

Organic production requires a different approach to traditional farming production methods. It requires more physical input towards production in addition to critical thinking when approaching pest management and soil fertility.

Because organic vegetable production is so complicated we at the University of Maryland Extension developed this Organic Vegetable Production Manual, to help those growers who are new to organic vegetable production practices or for those growers who have been growing organic vegetables for only a few years. And while the manual is not meant for experienced growers there are some chapters that even the most experienced grower may find interesting and helpful. The Introduction/Authors section explains how the manual is set-up and who reviewed the chapters. In addition all the author information is presented in this section. Each chapter is listed separately and can be downloaded by the grower for their use, but not for any commercial use unless permission is granted by the Editors. http://extension.umd.edu/mdvegetables
http://extension.umd.edu/mdvegetables/organic-vegetable-production

Organic Vegetable Production Articles:

- Organic Weed Management in Vegetables (Hooks, Leslie, Chen) - 5/2016
- Cantaloupe (Muskmelon) in Maryland
- Plants that Attract Pollinators and Natural Enemies (presentation) - 6/2015
- Managing the Weed Seedbank with Cover Crops and Tillage
- Offing Cover Crops for Weed Suppression: Featuring the Roller Crimper and Other Mechanical Contraptions
- The Plight of Clint and His Monoculture Practices
- Using Flowering Plants to Help Parasitic Wasps Attack Stink Bug Eggs
Spiders Abundant in August
By Stanton A. Gill
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In August we see a lot of activity from the orb spiders that spin silken webs on plant branches to capture prey. Some landscape managers are reporting their customers are upset about the spider webs in their landscape. What their customers are finding offensive is that in the morning hours when the dew settles it highlights how many spider webs they have in their landscape and they find this disconcerting. One landscape managers said they were walking in their landscape the spider webs caught them in the face and they want revenge immediately.

We realize that not everyone is a spider lover but try to reason with your customer's and tell them the spiders are one of the most beneficial arthropods you can find in a healthy landscape. They control many species of plant damaging insects. A vibrant well balanced landscape is going to have spider activity and this is a good thing. They can try wearing a wide brimmed hat when walking through the landscape so the brim catches any spider webs when walking though the landscape.
3) Invasive Plant ID: [http://extension.umd.edu/events/sat-2016-09-03-1000-invasive-plant-id](http://extension.umd.edu/events/sat-2016-09-03-1000-invasive-plant-id) - September 3rd, 2016 from 10:00 AM to 1:00 PM.

Join Calvert County Master Gardeners at the county extension office for a workshop that will help you identify invasive plant species commonly found in landscaped and natural areas. Hands-on demonstrations will include cut samples from live plants. There will also be an outdoor activity that will enable you to put your new skills to the test. The workshop is free of charge, and may run a bit longer than three hours. For more information, go to [http://extension.umd.edu/events/sat-2016-09-03-1000-invasive-plant-id](http://extension.umd.edu/events/sat-2016-09-03-1000-invasive-plant-id).


The University of Maryland Extension and the Howard County Forestry Board will host a "Woods in Your Backyard" workshop over two consecutive Thursday evenings at the Maryland Extension office in Ellicott City, MD. This workshop is designed for landowners with 1-10 acres who wish to learn about getting more out of their land, converting lawn to woodland, habitat management, and much more. Class sessions will feature presentations by foresters, arborists, landscape designers, and Master Naturalists. The cost for both evenings is $25.00 per person or $30.00 per couple. For more information and how to register, go to [http://www.howardcountyforestryboard.org/index.cfm?objectid=FF8064B0-265C-11E6-9F6A0050560F037A](http://www.howardcountyforestryboard.org/index.cfm?objectid=FF8064B0-265C-11E6-9F6A0050560F037A).

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Maryland Department of Agriculture Announces Record Cover Crop Sign-up

ANNAPOLIS, MD (August 17, 2016) —The Maryland Department of Agriculture today announced another record-breaking sign-up by Maryland farmers for its highly touted Cover Crop Program. During the program’s three week sign-up period held earlier this summer, 1,853 farmers visited the state’s network of local soil conservation district offices to apply for grants to plant 691,743 acres of protective cover crops on their fields this fall. Cover crops have been shown to reduce nutrient runoff, control soil erosion and protect water quality in streams, rivers and the Chesapeake Bay.

“Maryland’s cover crop program has the potential to do more for the Bay than ever before,” said Governor Larry Hogan. “We commend and thank all farmers who continue to voluntarily take strong conservation actions on their farms, diversify their operations and use new technologies as they become available.”

Maryland farmers have exceeded every Chesapeake Bay milestone goal for cover crops since the Environmental Protection Agency established nutrient and sediment limits for the Bay in 2010 known as the Total Maximum Daily Load (TMDL). Based on the newly released 2016-2017 Cover Crop Program sign-up figures, farmers are on track to exceed the next two-year milestone commitment to be completed by June 2017. In addition, cover crops are considered one of the most cost-effective means of helping to restore the Chesapeake Bay. The State has allocated $22.5 million for the 2016/2017 Cover Crop Program.

“Year after year, our farmers demonstrate their commitment to clean water and healthy natural resources by planting cover crops on their fields,” said Maryland Agriculture Secretary Joe Bartenfelder. “The 2016-2017 sign-up represents an increase of 35,000 acres over last year, which is remarkable when you stop to consider that the signup last year was the largest in our state’s history.”

The environmental and agronomic benefits of planting cover crops are well documented. As they grow, cover crops protect water quality by recycling unused plant nutrients remaining in the soil from the preceding summer crop. Once established, cold-hardy cover crops work all winter to shield fields from erosion caused by wind, rain, snow and ice. Cover crops improve soil health by increasing organic matter in the soil, reducing weeds and pests, and providing habitat for beneficial insects.

Maryland’s Cover Crop Program provides farmers with grants to plant small grains such as wheat, rye, or barley and certain other crops on their fields immediately following the summer crop harvest of corn, soybeans and vegetables. Grants help offset seed, labor and equipment costs associated with planting cover crops. Farmers may sign up to plant traditional cover crops, which are not eligible for harvest, or commodity cover
crops, which may be harvested. Incentives are available for planting cover crops early; however, all cover crops must be planted by November 5, 2016 and certified with the soil conservation district by November 14, 2016 to qualify for payment. Other conditions and restrictions apply.

**Top counties ranked by highest acreage of cover crop signup:**
- Queen Anne’s (76,369)
- Kent (71,520)
- Talbot (66,318)
- Caroline (58,703)
- Frederick (56,613)
- Dorchester (56,434)
- Worcester (45,950)
- Carroll (40,646)
- Wicomico (34,217)
- Harford (25,550)

For a chart showing cover crop acres and applications, 2007 to 2016:

For enrollment statistics by county, visit:

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**Nutrient Management Plan Writing Workshops Offered September 26 and 30**
The Maryland Department of Agriculture and University of Maryland Extension will offer two, one-day workshops titled, *How to Write a Nutrient Management Plan* on Monday, September 26, at the Wye Research and Education Center in Queenstown and Friday, September 30, at the Montgomery Extension Office in Derwood. The workshops are designed for people who are new to the nutrient management plan-writing process. Participants will learn how to write a nutrient management plan using *NuMan Pro*, a nutrient management planning software, while earning six credit hours toward the Maryland Nutrient Management Program’s continuing education requirement. To register, call 410-841-5959 or visit the department’s website. Cost is $20. Register by mail before September 21.

**LEAD Maryland Accepting Applications for Next Class of Fellows**
The LEAD Maryland Foundation is seeking applicants for its next class of Fellows. Applications are due October 1, and are available at the foundation’s website. Participants will complete a series of multi-day seminars held throughout Maryland and Washington, D.C. in 2017 and 2018 along with a travel study tour and class project. LEAD is a partnership 501 (c) (3) nonprofit dedicated to identifying and developing leaders to serve Maryland’s agriculture, natural resources, and rural communities. For more information, contact Susan R. Harrison at 410-827-8056 or leadmd@umd.edu.

**Homeowners Urged to Use Responsible Lawn Care Practices During Summer Months**
With summer in full swing, the Maryland Department of Agriculture urges homeowners to allow established lawns to go dormant during the hot, dry weather. Applying fertilizer to force a lawn to turn green during its dormancy period can damage the grass and contribute to nutrient pollution in streams, rivers and the Chesapeake Bay. Dormant lawns will green up when cooler temperatures arrive and rainfall increases. To help shade grass and conserve moisture, raise the mower’s cutting height by ½ inch to 1 inch during periods of hot, dry weather and leave grass clippings on the lawn as a source of free fertilizer. For more tips and information on Maryland’s Lawn Fertilizer Law, visit department’s fertilizer website or UMD Extension.

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**Hello from Baltimore City!**

My name is Neith Little, and I am Maryland’s new Extension Educator for urban agriculture. I’d like to use this column to introduce myself, my position, and a few resources that I hope you’ll find as useful as I have.

I grew up in Western New York, near the northern edge of the Chesapeake Bay watershed. That means water from the river that runs through my hometown eventually flows through the Susquehanna River into the bay near Baltimore, which I think is kind of a cool coincidence. I studied Human Ecology at College of the Atlantic in Maine, then went back to school for a Masters in Soil and Crop Science at Cornell, where I got to spend a lot of time digging holes, chasing crows away from my corn, and doing research on weed science and nutrient management. I then spent two years at Hampshire College Farm, where I worked as Assistant Grower on the farm’s 250-share vegetable CSA, helped with the bid process for the college’s new dining services...
contractor, drafted the college’s policy for local and sustainable food sourcing, and worked with the farm managers to develop a farm business plan. Finally, I spent the last two years in Minnesota, working as an Extension Educator for Dakota County, part of the Twin Cities metro area. There I got work with both commodity crop farmers and direct-to-consumer vegetable growers on topics like nitrogen management, pesticide safety, and cover cropping.

I’m honored to be joining the Maryland Extension team. My position as urban agriculture Extension Educator is located in Baltimore City, but I have some flexibility to collaborate with people in other Maryland urban communities. My role is to develop and deliver Extension educational programs that help urban farmers use research-based information to improve their own farms and their larger communities, much as my colleagues in more rural communities work with rural farmers. Being less than a month into the job, I am only beginning to develop what those programs will look like, based on conversations with urban farmers and gardeners, so don’t be surprised if you get a survey from me in the next year!

In the meantime, I’d like to recommend two of the resources that I’m finding particularly helpful, in addition to Maryland Extension’s agriculture website. At a national level, the USDA recently published an urban agriculture “toolkit” that offers a lot of information about how urban farmers can connect to the USDA’s farm support structure. And at a very local level, Baltimore City’s “Homegrown Baltimore: Grow Local” plan has a lot of great Baltimore-specific information.

And if you are an urban farmer in Maryland, I would love to talk with you. Please feel free to e-mail me at nglittle@umd.edu

Thank you for reading, and stay cool out there!

Neith

Vegetable & Fruit News
A timely publication for the commercial vegetable and fruit industry available electronically in 2016 from April through October on the following dates: May 13; June 9; July 21; August 18; September 8; and October 20.

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See the Attachments!

1) Cover Crop Management Workshop
2) Foodborne Illness Liability and The Food Safety Modernization Act
   By Ashley Ellixson and Sarah Everhart
3) Managing Weeds in Vegetables Organically By Cerruti R2 Hooks, Alan W. Leslie & Guihua Chen

Article submission deadlines for 2016 at 4:30 p.m. on: May 12; June 8; July 20; August 17; September 7; and October 19.

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Cover Crop Management Workshop
at Chesapeake College
1000 College Circle
Wye Mills, MD 21679
Phone: (410) 778 – 1661

August 30th, 2016
6 – 8 PM

Conservation Innovation – Getting the Most from Your Cover Crops
See the Results!

6:00 – 6:30 PM – Registration and heavy hors d’oeuvres
6:30 PM – Welcome
Nate Richards, Kent County Agricultural Educator, University of Maryland Extension
6:45 PM – Impact of a cover crop on water available to a corn crop
Dr. Steven B. Mirsky
7:15 PM – Cover Crop’s effect on nitrogen program in corn
Dr. Steven B. Mirsky
7:45 PM – Management strategies of cover crops: late kill vs. early kill
Nevin S. Dawson, Sustainable Agriculture Coordinator, University of Maryland Extension
8:00 PM – Evaluations and closing
Nate Richards, Kent County Agricultural Educator, University of Maryland Extension

Please RSVP to the Kent County Extension Office: (410) 778 – 1661

If you require reasonable accommodation to participate in the event, please contact the UMD Extension Office no later than August 26th, 2016

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Foodborne Illness Liability and The Food Safety Modernization Act
Ashley Ellixson and Sarah Everhart

This is meant to be a general summary of a very complex legal topic not a thorough analysis.

Foodborne Illness Liability

The Center for Disease Control and Prevention (CDC) estimated in 2011 that each year 48 million people, or 1 in 6 Americans, get sick, 128,000 are hospitalized, and 3,000 die of foodborne diseases. Ingesting food contaminated with disease-causing microbes, pathogens, poisonous chemicals, or other harmful substances causes foodborne illness. When an individual becomes sick or dies from a foodborne illness, the individual or family often pursue legal action to compensate for their losses and related damages.

Most civil foodborne illness cases are brought to court under one of these theories of liability:

- **Strict Product Liability:** Legal doctrine under which a party whose business is selling or distributing products, and who sells or distributes a defective product, is liable, without proof or fault, for harm to an injured person caused by the defect.

- **Breach of Implied Warranty of Merchantability:** Similar to strict liability where no fault is required, liability is established if the evidence shows 1) the product was not reasonably fit for the ordinary purposes for which it was sold and 2) such a defect caused injury to the ultimate consumer based in contract law.

- **Negligence:** Although not commonly used in Maryland and other states with strict product liability, a negligence claim can be made if the defendants in the lawsuit were negligent in their handling of the contaminated food which led to their sickness. Negligence can be established if the manufacturer or distributor failed to "exercise reasonable care" in producing the product.

One of the most challenging parts of a foodborne illness case is causation. Namely, was the consumed food contaminated and did the contamination cause the illness or injury? For example, in a case of E. coli or Salmonella, the link between the foodborne illness and the producer can be very difficult to prove, unless part of a wider outbreak. If causation is proven, everyone in the chain of distribution, no matter where in the chain the contamination occurred, is potentially liable including farmer, processor, and/or retailer.

Some of the possible defenses in a civil foodborne illness lawsuit are:
• **Assumption of Risk**: If the user or consumer discovers the defect and is aware of the danger, and nevertheless proceeds unreasonably to use the product and is injured by it, the consumer may be barred from recovery of damages.

• **Contributory Negligence**: If the plaintiff’s negligence contributes in any degree to the injury, the contributory negligence is a complete bar to recovery. This is not a defense to strict liability but could be a defense to a negligence claim.

• **Product Misuse/Mishandling**: This defense applies where the injury results from abnormal handling or misuse of the product. Example: Undercooked meat.

• **Directions and Warnings**: This defense applies when a consumer disregards warnings or instructions supplied with the product where, if used correctly, the product would be safe.

• **Sealed Container Defense in Maryland**: This defense protects the seller from product liability when the seller received a sealed product and could not have known of the defect/adulteration or caused the defect/adulteration. Example: A produce stand operator selling honey in jars.

In contrast to the civil liability theories listed above, there is also the potential for criminal liability in foodborne illness cases under the Federal Food, Drug, and Cosmetic Act. A felony violation, punishable by jail time and substantial fines, can be sought for intentionally adulterating or misbranding a food product and putting it into interstate commerce. A misdemeanor conviction can be sought for a person in a position of responsibility or authority who could have prevented such a violation, and intent need not be shown. Convictions under the misdemeanor provisions are punishable by up to one year imprisonment or a $1000 fine.

**The Food Safety Modernization Act**

In response to the growing concern over foodborne illness, the U.S. Congress passed the Food Safety Modernization Act (FSMA) on December 21, 2010. FSMA is the most sweeping reform of our country’s food safety laws in more than 70 years. The purpose of the law is to ensure the U.S. food supply is safe by shifting the focus from responding to contamination to proactively preventing it. FSMA gives the Food and Drug Administration (FDA) broad new powers to prevent food safety problems, detect and respond to food safety issues, and improve the safety and quality of imported foods. These regulations focus on addressing food safety risks from microbial pathogen contamination (e.g., Salmonella, E. coli, etc.). FSMA does not address food safety risks from genetically engineered crops, pesticide use, or antibiotic resistance.
The FDA is responsible for FSMA implementation, and two of the major FSMA rules applicable to Maryland processors and producers of human food are now final and coming into effect:

1) **Preventive Controls for Human Food** (which applies to processors)

2) **Produce Safety Standards** (which applies to producers)

**Preventive Controls for Human Food Rule**

The key requirements for the Preventive Controls for Human Food rule (Preventive Rule) as finalized September 17, 2015 are:

1. Covered facilities (facilities that manufacture, process, pack and hold human food) must establish and implement a food safety system which includes an analysis of hazards and risk-based preventive controls. Covered facilities must have a written food safety plan which includes hazard analysis, preventive controls, and oversight and management of preventive controls.

2. Farms, as defined by the Preventive Rule, are not subject to the Preventive Rule. The definition of farms includes:
   - Primary Production Farm is under one management in one general but not necessarily contiguous location devoted to growing crops, harvesting crops, raising animals (including seafood), or any combination of these activities.
   - Secondary Activities Farm is an operation not located on the primary production farm which is devoted to harvesting, packing, and/or holding raw agricultural commodities, and must be majority owned by the primary production farm.

3. The Preventive Rule mandates that a manufacturing/processing facility have a risk-based supply chain program for those raw materials and other ingredients with a hazard requiring a supply-chain applied control.

4. The Preventive Rule requires that manufacturers use Current Good Manufacturing Practices (CGMPs). Management must ensure all employees who manufacture, process, pack, or hold food are qualified to perform their assigned duties. Such employees must have the necessary combination of education, training, and/or experience necessary to manufacture, process, pack, or hold clean and safe food. Individuals must receive training in the principles of food hygiene and food safety, including the importance of employee health and hygiene.
The compliance dates for the Preventive Rule are:

- Very small businesses averaging less than $1 million per year in both annual sales of human food plus the market value of human food manufactured, processed, packed, or held without sale have until September 17, 2018 to comply, three years after the publication of the final rule.

- Small businesses with fewer than 500 full-time employees have until September 17, 2017 to comply, two years after the publication of the final rule.

- All other businesses have until September 17, 2016 to comply, one year after the publication of the final rule.

The Preventive Rule has two main exemptions:

- Facilities/activities covered by pre-existing regulations such as juice, seafood, and dietary supplements and facilities solely in the business of storing agricultural commodities such as grain elevators may be exempt.

- Those businesses defined as very small or facilities averaging less than $500,000 in annual gross sales of all food in a previous three-year period and selling the majority of their food directly to consumers, restaurants, or retailers in the same state or within a 275 miles from the facility may be eligible to receive a modified exemption of the requirements of the Preventive Rule from the FDA.

### Produce Safety Standards Rule

The key requirements for the Produce Safety Standards Rule (Produce Rule) published November 27, 2015 are:

1. **Worker Training**: The Produce Rule requires training for supervisors and farm personnel who handle produce covered by this rule.

2. **Health and Hygiene**: The Produce Rule requires farm employees to follow sanitary practices, including but not limited to hand washing, not working when sick, and maintaining personal cleanliness.

3. **Biological Soil Amendments of Animal Origin**: The Produce Rule specifies types of treatments, methods of application, and time intervals between applications of certain soil additions. This includes manure, composted manure, and practices during crop harvest.
4. **Domesticated and Wild Animals**: The Produce Rule requires certain standards for domesticated animals, such as waiting periods between grazing and crop harvest. For wild animals, the rule requires farmers to monitor wildlife intrusion and not harvest visibly contaminated produce.

5. **Equipment, Tools, and Buildings**: The Produce Rule sets standards for tools and equipment that come into contact with produce as well as for buildings and other faculties where raw fruits and vegetables will be held or packaged.

6. **Sprouts**: The Produce Rule sets standards for sprout production, including treatment of the seeds and beans before sprouting and testing of irrigation water for pathogens.

7. **Agricultural Water**: The Produce Rule establishes two sets of criteria for microbial water quality, both of which are based on the presence of generic *E. coli*, which can indicate the presence of fecal contamination. The Rule also establishes requirements for water testing with the frequency of testing depending on whether the water used is ground or surface water.

The compliance dates for the Produce Rule are:

- Very small businesses with more than $25,000 but no more than $250,000 in average annual produce sales during the previous three-year period have four years + 60 days from the publication of the final rule to comply.
- Small businesses of more than $250,000 but no more than $500,000 in average annual produce sales during the previous three-year period have three years + 60 days from the publication of the final rule to comply.
- All other farms have two years + 60 days from the publication of the final rule to comply.
- Certain aspects of the water quality standards and related testing and recordkeeping provisions have compliance dates an additional two years beyond each of the compliance dates outlined above.

The Produce Rule does not apply to:

- Produce that is not a raw agricultural commodity
- Produce that is rarely consumed raw
- Food grains
- Farms with an average annual value of produce sold during the previous three years of $25,000 or less
- Produce receiving commercial processing which adequately reduces the presence of microorganisms of public health significance, under certain conditions
The Produce Rule also provides a qualified exemption and modified requirements for certain farms. To be eligible for a qualified exemption, the farm must meet two requirements: The farm must have food sales averaging less than $500,000 per year during the previous three years; and the farm’s sales to qualified end-users must exceed sales to all others combined during the previous three years. A qualified end-user is either (a) the consumer of the food or (b) a restaurant or retail food establishment located in the same state or the same Indian reservation as the farm or not more than 275 miles away.

Conclusion

Many processors and producers fear compliance with FSMA will cause more problems, strain resources, or create more disruption than they are prepared to handle. However, the implementation of preventive food safety procedures will ultimately help processors and producers provide safe food to consumers and reduce liability stemming from foodborne illness outbreaks.

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Managing Weeds in Vegetables Organically

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Introduction

Weed management is more challenging in organic crops and accounts for a large portion of production costs. As such, managing weeds is a major economic constraint to the organic vegetable industry, and comparisons of weed communities between conventional and organic farming systems consistently demonstrate higher weed levels in organic systems. For years, organic growers have identified weed management as a top production constraint and research priority with some specifying that they have “serious difficulty” managing weeds. Hand-weeding is impractical if significant human labor hours are needed and the cost of organic herbicides makes their use impractical when used over the entire field at rates necessary for adequate weed suppression. Clove oil, for example, can control broadleaf weeds at high concentrations. However, its cost makes broadcast applications impractical, even in high-value vegetable production systems. Further, organic herbicides when used after crop emergence may result in crop injury, and many organic acceptable herbicides are only moderately effective.

Currently, most strategies utilized for managing agricultural weeds in many organic cropping systems rely heavily on tillage, but repeated soil disturbances have a detrimental impact on soil structure and overall health. These aforementioned hindrances are coercing organic producers to seek other weed management solutions; and overcoming these issues requires organic farmers to adopt an integrated approach to managing weeds. Integrated weed management (IWM) combines the use of chemical, cultural, genetic, biological and mechanical practices, so as to reduce reliance on a single weed management tactic. None of these tools if used individually are expected to provide acceptable levels of weed suppression for an extended time period. Thus, multiple tactics that enhance weed control by preventing weed seed germination and reducing the weed seedbank must be combined for best results. If various IWM tools are employed in a methodical manner, over time, acceptable and sustainable weed management levels can be achieved.

Plant diversity & cover crops. Increasing cropping system diversity has been advocated as a means of reducing chemical inputs for weed control. Many studies have compared weed populations in simple and diverse crop plantings including organic systems. Growing two or more crops within the same field can result in fewer weed problems because the soil is more covered. Generally speaking, intercrops that include species with rapid, early growth and dense, vigorous canopy formation over the soil surface will be most weed suppressive. A leek-celery intercrop decreased relative soil cover of weeds by 41% and reduced the density of common groundsel (Senecio vulgaris) by 58% compared to sole cropping. However, some difficulties of mixed cropping are intercrop competition and added intricacies associated with managing two
crops within the same field. Thus, from a weed management perspective, inter-planted “smother crops” may be viewed as a valuable tool for suppressing weeds or a hindrance to efficiently managing weeds using conventional methods. In principle, companion crops can be chosen to complement the main crop in resource use while directly or indirectly interfering with weeds, thereby suppressing weed but not crop growth.

Cover crops can be used also to increase within crop diversity. Research has shown that cover crops can be used to help manage weeds and that they can play an important role in an IWM vegetable system. Cover crops can generate a competitive crop environment for water, light and nutrients within 4 to 8 weeks after sowing. Weed suppressive ability of cover crops can be attributed to their fast emergence, rapid canopy development and root growth. Thus, highly competitive cover crops that grow rapidly and develop a dense canopy are more likely to prevent weeds from establishing. Cover crops prevent weed germination and seedling establishment via allelopathy, altered environmental conditions and/or formation of physical barriers. Cover crop species sown in late summer can reduce growth of winter annual and perennial weeds such as quackgrass (*Elymus repens*) during fall and winter. Annual or short-term perennial cover crops can be used on otherwise fallow fields to compete with weeds for resources needed to proliferate in a field.

After cash crops are planted, cover crops may still be used as residue or living mulch to continuously suppress weed populations during the cropping cycle. One of the most effective methods is using cereal or legume cover crops with physical and allelopathic weed-suppressing properties. Residues of some mulched and undersown cover crops can prevent weed seed germination and growth, especially in spring when these residues decompose into chemical constituents. If inter-planted with a vegetable crop as a living mulch, the cover crop chosen should complement the main crop in resource use while directly or indirectly suppressing weed growth, thereby inhibiting weeds without negatively impacting the crop. For more information on cover crops and weed suppression refer to: ([https://extension.umd.edu/learn/offing-cover-crops-weed-suppression Featuring roller crimper and other mechanical contraptions](https://extension.umd.edu/learn/offing-cover-crops-weed-suppression Featuring roller crimper and other mechanical contraptions)).

**Tillage/cultivation.** Organic farmers have several options for suppressing weeds after they have emerged including hand removal (pulling, hoeing, digging, or cutting), herbicides, mowing, and cultivation. There are a variety of cultivation tools that can be used to control emerged weeds and disrupt their lifecycle including mechanical and flame cultivation. Mechanical cultivation is a mainstay of many organic weed management programs. The effectiveness of inter-row cultivation in suppressing weeds in organic production systems is well known. Cultivation is influenced by weather, soil type and crop canopy features. The timing of cultivation will vary according to weed species present in the field but should be based on the critical weed-free period of the cash crop. Cultivation suppresses weeds by burial, uprooting, root desiccation, and/or a physical separation or crushing of plant parts.

When perennial weeds are present, tillage may be the most viable option. For example, in a field where multiple perennial weed species are uncontrollable by other means, intensive post-harvest cultivation followed by deep inverting tillage can diminish the weed problem. This
An extreme approach should be limited to the smallest area possible to quell the problem. The type of tillage equipment used will be mostly dependent on the targeted weed rooting system. For example, if the weed requires the root be broken up into fragments, a rotovator or cultivator can be used. Some rhizomes require that they be dragged and exposed to the soil surface or removed. A cultivator or harrow may be used to accomplish these tasks. Tubers or bulbs need to be cut when the rhizomes are present and dug up for exposure to adverse conditions (frost or drought), which can be done with moldboard or disk plowing. There are a number of new tillage and cultivation instruments on the market that may be used on annual and perennial weeds. The success of many mechanical operations targeting perennial weeds depends on timing of their execution. However, it is critical to have reliable information on the weed’s biology so that the best equipment and timing of operation for exploiting the targeted weed’s weak link are used.

Though tillage/cultivation has been a keystone in weed management, limitations with current cultivation tools include: high purchase and maintenance costs, marginal efficacy, excessive soil disturbance, stimulation of latent weed seed germination, and narrow applicability across a range of soil types, soil moisture conditions, and weed growth stages. Some fear that soil quality and health may decrease under continuous cultivation. Frequent inter-row cultivation is associated with enhanced soil erosion and new weed flushes. Further, tillage uses large amounts of fossil fuel and is the most energy-consuming task among all field operations, subsequently representing an additional cost to farmers. The distribution of weed seeds through the soil profile can be associated with the amount of soil disturbances, and changes in tillage practices can influence weed seed viability, weed size, and weed community composition and diversity.

High fuel costs and the need for soil conservation have prompted the adoption of conservation tillage practices for vegetables. Reduced or conservation tillage is any method of soil cultivation that leaves plant residue on fields before and after planting the next crop. There are several different conservation tillage practices. No-till and strip-till involve planting crops directly into residue that either hasn't been tilled (no-till) or has been tilled only in narrow strips while the rest of the field remains untilled (strip-till). Ridge-till involves planting row crops on permanent ridges about 4-6 inches high. The previous crop's residue is cleared off ridge-tops into adjacent furrows to make way for the new crop being planted on ridges. Mulch-till is any other reduced tillage system that leaves at least one third of the soil surface covered with plant residue. In conservation tillage systems, cover crop residue that remains on the soil surface may prevent weed establishment. In addition to residue, cover crops can be used as living mulch (living ground cover) to help prevent weed establishment. In reduced-tillage systems, most weed seeds remain at or near the soil surface, where they are exposed to greater mortality from predation and decay and are more susceptible to sterile seedbed tactics. In combination with proper weed suppression, weed seedbanks can diminish over time in reduced-tillage systems. Benefits of reduced tillage include less fuel use, reduced soil erosion, and water conservation. Growers can save from 30 to 40% in time, labor, machinery investment, and fossil fuels in conservation compared with conventional tillage.
Although reduced-tillage offers many ecofriendly and monetary benefits, a major compromise to operating under less tillage is the loss of a weed control tool. Hand-weeding is labor intensive and time-consuming, so it is not a practical alternative in large-scale production. Moreover, yields under reduced-tillage may not be comparable with conventional tillage if weeds are not managed, and may increase the chance for the occurrence of perennial weed problems.

Flaming. Flaming has been historically used primarily as a preemergence treatment, either prior to planting or before crop emergence. Alternatively, flaming can be used after crop emergence or planting in tolerant crop species, a process referred to as selective flaming. Flamed weeds either die or their competitive ability with cash crops can be severely reduced. Flaming may be used for instances in which cultivation or other weed management tactics are not practical. For example, controlling weeds in crops with shallow roots such as onion through cultivation can be challenging as cultivating too close to the crop can easily damage the root system. Therefore hand-weeding is often required but at considerable expense. Although interrow weeds can be effectively controlled through mechanical cultivation, weeds that grow within the row are more difficult to control as cultivation is either ineffective or causes unacceptable levels of crop damage. Flame weeding can be used to control weeds within the crop row where mechanical cultivation is difficult and help reduce or eliminate the amount of costly hand-weeding required. Some hand-weeding or mechanical measures may be required in addition to flaming in order to reduce weed populations sufficiently to maintain yields, and the susceptibility of weeds to flaming, largely depends on their heat avoidance, heat tolerance or both. Some studies have shown plants to be more sensitive when flamed in the afternoon than early in the morning. It is believed that this coincides with the time plants have the lowest relative leaf water content. As such, flaming in the afternoon might result in better weed control. Another potential pitfall of flaming is that studies have shown flaming to have a greater effect on broadleaf than grass weeds. Thus, if grass weeds are the dominant problem, flaming may not effectively suppress weed growth.

Land selection. A general rule is to avoid planting vegetables in fields with a history of heavy weed infestations, especially perennial weeds. Vegetables should be grown on land with at least a two-year history of effective weed control. If weed-infested fields can’t be avoided and planting vegetables is the only option, the most competitive crops should be planted in the most weed-infested fields and the least competitive in the cleanest fields. Examples of good vegetable competitors include cabbage and artichokes. Relative to many other vegetables grown in temperate latitudes such as onions, carrots, or peppers, these two crops quickly cover the soil making it more difficult for weeds to get established. Crops that grow slowly and cover the soil sparsely may suffer competition for water, nutrients, light, and space. When possible, heavily weed-infested fields should be set aside or planted as fields with non-row crops such as alfalfa or perennial cover crops. This long term coverage should help prevent further buildup of weeds.

Crop rotation. Crop rotation is probably the most important IWM tool and should be the cornerstone of any weed management plan. Crop rotation was considered an essential practice
for obtaining healthy crops and yields but as more agrochemicals and genetically modified crops came on the market, crop rotation became less utilized. Continuous planting of a single crop or crops having similar management practices allows certain weed species to become dominant in the system and, over time, these weed species become hard to manage. A good crop rotation scheme is not simply an avoidance of planting the same crop continuously in one area. To be most effective, crop rotation should involve a more elaborate system. Each crop within a rotation should differ drastically from its predecessor in one or several important characteristics such as planting or maturation dates, growth habit, competitive ability, associated cultural practices, and fertility requirements. The goal of crop rotation is to create an ever-changing environment within the field so as to prevent the dominance of particular weed species. Knowledge of potential weed problems in a field is critical as it allows farmers to implement a rotation strategy that is best suited for a particular field. For example, if late-germinating weeds are problematic, planting an early crop that gets established and covers the ground early may be a viable option.

For any rotation plan, related vegetables should not be grown in the same location in successive years as this produces predictable environmental conditions that weeds will exploit. In addition, alternate crops with different types of vegetation such as leaf, root, bulb, and fruit crops, rotate grass and dicots (e.g., field corn, vegetables), alternate different crops with different planting times as changing the seeding date from year to year means that specific weeds cannot become accustomed to environmental situations. Avoid planting crops of the same family back to back such as Solanaceae (e.g., tomato after eggplant), Cucurbitaceae (e.g., summer squash followed by cucumbers), Brassicaceae (e.g. broccoli after cauliflower), and alternate poor (e.g., onion) and high weed competitors (e.g., potato). Weeds tend to thrive in the presence of crops whose growth necessities and features are similar to their own. In such instances, production practices meant to benefit the cash crop may promote the growth and development of certain weed species. Thus, if there are problematic weeds in a field that are associated with a particular crop or that do well within a specific crop, avoid planting that crop in fields in which those weeds exist and instead plant crops which make conditions less conducive for those weeds to proliferate.

Another tactic is to rotate cool- with warm-season crops such as winter grains or sods with vegetables. Crops with different lifecycles provide more opportunities for growers to control weeds before seeds are produced. For example, most vegetables are summer annuals. As such, the inclusion of winter annual crops such as wheat into rotations may be an important tool for disrupting the lifecycle of problematic summer annual weeds in vegetable systems. Because winter wheat is well established in early spring, problematic summer annual weeds have little chance of establishing and producing seeds. Therefore, for weed species with low seed persistence, avoidance of seed production may result in rapid reductions in weed seedbank densities. For example, seed production of warm-season weeds can usually be eliminated during years in which early planted, cool-season crops are grown, with similar control of cool-season weeds occurring during years of warm-season crops. By preventing replenishment of the seed
bank, the natural decline of weed seed density in soil through time reduces the number of seedlings emerging in crops in later years.

Remember, a successful crop rotation plan changes conditions within the field habitat to the point that weeds’ lifecycles are disrupted. With that in mind, farmers should design a rotation so that weeds in their fields are constantly encountering varying or unpredictable environmental conditions from year to year. The greater the complexity and diversity of the rotation scheme the less likely a particular weed or additional crop pest will proliferate. A study was conducted in organic soil in Canada were there are severe infestations of nodding beggarticks (*Bidens cernua*), Canada fleabane (*Conyza canadensis*), and root-knot nematode (*Meloidogyne hapla*) due to continuous production of carrots in the same fields. A study was conducted to compare six 3-year crop rotation schemes with 3-years of carrot monoculture in a field in which carrot had been repeatedly grown for 10 years. Onion (*Allium cepa*), barley (*Hordeum vulgare*) or a weed fallow were included in the rotation. Each rotation ended with carrots being planted in year 3. Results showed that two consecutive years of row crops such a carrot-carrot or carrot-onion favored the maintenance of high weed pressure but weed populations decrease with barley in the rotation. When considering all aspects of the problems encountered in the field (weeds, root-knot nematodes, soil erosion and subsidence), the 3 year crop rotation sequence consisting of onion and barley performed the best, and was the wise alternative to carrot monoculture. Reviews of studies comparing simple with diverse crop rotations in the absence of herbicides suggest that more diverse rotations result in lower total weed density and greater weed diversity than simple rotations. Diverse crop rotations may reduce the dominance of a narrow range of weed species, since they confront weeds with more complex patterns of stress associated with different management practices. At the same time, diverse cropping sequences promote diversity by creating niches for a wider range of weeds than monocultures. Still, rotations should be evaluated regularly to make sure that no problems weeds are “beating” the crop rotation system and to make adjustments as needed.

Increasing crop rotation interval may not be viable economically for growers with limited good land and a high level of crop specialization. Improving the cropping system with use of cover crops between and within growing seasons might be more acceptable as it is less disruptive to the production system. In addition, the impact of a particular crop sequence may be less important than weed management practices used in that sequence, and in those instances that a “good” crop rotation scheme cannot be implemented, it is important that diverse management tactics are implemented. In high-value vegetable crops with few herbicide options, crop rotation can be an especially important component of an IWM program. Within these systems, rotation strategies to reduce weed density include (1) inserting highly competitive and easy to weed “cleaning” crops like potato (*Solanum tuberosum*), (2) rotating crops with different planting timings and durations, and (3) including cover crops during periods when soils might otherwise be bare. Rotations involving different planting dates and duration can be particularly beneficial for managing certain weeds.
Sanitation. Human activity can be the main culprit for introducing weeds onto a farm and into new areas within the farm. Appropriate sanitation can prevent weeds from spreading between fields and reduce the spread of weeds from neighboring landscape to crop fields. Farm equipment should be cleaned regularly. A study at Montana State University showed that a vehicle driven through a spotted knapweed infestation picked up about 2000 seeds of the weed, of which 90% dropped within 10 miles. Contaminated seed and uncleaned agricultural implements can be common sources of weed invasions. Using certified seed that is free of weed seeds and cleaning farm equipment after use in weed-infested fields are two simple practices that can be used to help prevent weeds from entering fields and spreading throughout the farm. Seeds should be purchased from reputable sources and inspected prior to and after planting. All soil should be cleaned from cultivation, tractor, mowing, and harvesting equipment, and other farm supplies such as pallets and bins. Power washes will do a better job removing soil than a garden hose. Animal manures and other material should be composted thoroughly to kill off weed seeds. Any mulch or compost that is applied should be free of weed seeds prior to use. Practices such as cleaning vehicles, equipment, animals, or maintaining livestock in weed-free areas before moving them can prevent dispersal, establishment, and persistence of weed seeds or rhizomes in previously weed-free areas.

Uncropped areas can be important sources of weeds and new weed invasions. Prevent weed influxes by scouting field edges and neighboring crop fields for weeds. Keep alleys and areas on the farm mowed or harrowed. Ditch banks can be major sources of problematic agricultural weed seeds that ingress into neighboring crop fields. Remove problem weeds in ditches and growing around buildings. Weeds outside of fields should not be taken lightly, if left unchecked, they will eventually make their way into nearby production fields. Paying close attention to sanitation and seed sources and managing weeds outside crop fields are all important in helping to prevent the introduction and movement of weeds into a farm and between areas within a farm.

Weed seed mortality. A primary aim of integrated weed management should be to prevent weeds from setting seeds, which will reduce weed pressures in future growing seasons. Many weeds are adapted to produce huge amounts of seeds, in some cases thousands of seeds per plant. This means if even a few plants escape control, they can contribute to future weed problems. In these cases, mortality by weed seed predators and pathogens can provide effective control of seeds that have already been shed, and can significantly reduce the number of seeds surviving in the soil to germinate in the future. Common seed predators in agriculture include birds, small rodents, and insects, such as ants, ground beetles, and crickets, which are all ubiquitous residents of agricultural fields. Other causes of mortality to weed seeds include infection by bacteria or fungi and desiccation from remaining on the soil surface. Agricultural practices that maintain stable habitats for seed predators have been shown to increase rates of seed predation. For example, the presence of cover crops and cover crop residue provides favorable habitat for seed-eating ground beetles. Reduced tillage practices can also increase rates of seed predation by minimizing disturbance of the habitat and by preventing seeds from being buried, where they would be safe from predation. Also, more diverse and varied agricultural landscapes can increase
seed predation by birds as well as insects. Organic farms typically support a greater abundance and diversity of seed predators than conventional farms.

Natural seed predation is known to reduce contributions to the standing seedbank, but developing specific recommendations for augmenting seed predation by natural populations of seed predators has been complicated by several factors. For example, some studies show that providing habitat refuges in the form of non-cropped buffer strips do not always result in increased rates of seed predator activity in the field, and in some cases may attract seed predators away from the field. Effective removal of weed seeds from the seed bank ultimately depends on seed predators being active at the time and place where the seeds are shed. Unlike herbivores, seed predators may not be able to follow chemical or visual cues to track food sources, and the foraging process may be more random. Many studies of seed predation have measured large amounts of variability in the rates of seed removal within individual fields, making it hard to generalize about factors that tend to increase predation rates. Quantifying the effect of seed predators in the field may be difficult since the rates of weed-seed removal may depend on species composition and density of weed seeds as well as seed predators; both of which can vary widely within a field and between seasons. These variations in rates of removal at shorter time scales and smaller spatial scales make it difficult to estimate the cumulative effects of seed predators on the seed bank. This is an active area of weed research, and future management recommendations for augmenting natural seed predation are promising for organic vegetable farming.

Soil-dwelling fungi and bacteria can cause significant mortality to weed seeds, even after they have been buried and are unavailable to seed predators. In some cases, pathogenic bacteria may be present in the seeds before they drop from the plant. In order cases, soil-borne bacteria may be able to follow chemical cues in the soil environment to migrate towards buried seeds. Some soil bacteria can also secrete chemicals that are toxic against weed seeds, acting like natural pre-emergent herbicides. Many weed seeds are protected from fungal or bacterial degradation by a hard seed coat, but any mechanical damage to that coat by seed-feeding insects or from heat or desiccation can make seeds more vulnerable to pathogens. In warmer climates, soil solarization can be used to directly destroy dormant seeds, and to increase the pathogenicity of soil microbes against seeds. Solarization involves using plastic covers to heat the soil to temperatures over 150 °F, which causes direct damage to seeds that are not heat-tolerant, and also increases the metabolic rate of soil microbes. There are few instances where soil microorganisms have been successfully applied as organic bioherbicides against weed seeds, due in part to species-specific pathogens that would be unable to control a diverse set of weed species. Organic vegetable production would be a likely target niche for any future bioherbicide innovation due to the high value of the crops and relatively few existing formulations on the market to compete with. Methods for conservation of existing soil microbes for control of weed seeds is an active area of research, and some results indicate that practices to promote soil health, such as cover cropping, reduced tillage, and crop rotation may help to manage beneficial soil-dwelling microbes.
Crop competitiveness. Crops and weeds directly compete with one another for resources such as sunlight, space, water, and nutrients. If the competitive ability of crops can be enhanced such that they acquire a greater proportion of the resources available in the field, then they may be able to suppress the growth of weeds, leading to lower establishment of weeds and lower production of weed seeds for future growing seasons. In many agricultural systems, water and nutrients are added through irrigation and fertilization to optimize plant growth and yield, and would therefore not be limiting factors for weed growth. Therefore, sunlight and space represent the resources that crops must exploit better than weeds in order to gain a competitive advantage. There is a wide range of competitive abilities between crop species, with few species being very good competitors against weeds. Within crop species, different cultivars may show variation in competitive ability against weeds, and those cultivars should be selected as a part of an IWM strategy. For example, it has been suggested that producers anticipating weed problems should select a pea cultivar with a long vine length within the appropriate market class as vine length is correlated with crop competitiveness. In modern conventional agriculture, the widespread use and high efficacy of herbicides has reduced the reliance on crops to have to outcompete weeds. This has led to modern cultivars being developed that often have reduced competitive ability as a tradeoff for increased yield. Chemical inputs to control weeds are often impractical or ineffective in organic agriculture, so being able to select crop varieties with the ability to suppress weed pests in the field is a valuable tool for organic farmers.

Many studies have shown that early season vigor is the most important characteristic for determining whether a crop cultivar will compete well against weed species. Rapid, early season growth allows the crop to take up water and nutrients, and more importantly to develop a canopy that takes up light and space before weeds have time to germinate and become established. Ensuring early season vigor in crops can be done in a variety of ways. The early portion of the growing season may have substantially cooler temperatures than later in the season. Selecting a cultivar that has rapid growth under cooler conditions may promote growth during the cooler period of the early season. Conversely, accurately timing planting to coincide with optimal conditions for the crop will ensure rapid, early growth. Ensuring optimal water and nutrients through irrigation and fertilization will help crops to develop rapidly. When possible, using transplants rather than direct-seeding vegetables can give crops a direct advantage over weeds as the crop has developed biomass before ever encountering weeds, and can therefore immediately begin to compete for resources. The period by which weed control must be carried out to prevent yield loss also known as the critical period of weed control (CPWC) is generally longer in direct-seeded than in transplanted crops. As a result, some crops that are direct-seeded as opposed to transplanted must receive weed control earlier during their cropping cycle and for a longer period of time following planting. Transplanting gives the crop a head-start against weeds when it comes to early season growth and competition for light and space.

In addition to vigorous, early season growth, there are other characteristics of crops that tend to make them more competitive against weeds. In general, taller, more erect plants are better at competing for light and space and will tend to shade out smaller plants around them. Plants that
develop a large, dense canopy, or have large leaf area also tend to compete well for light and will shade out weeds below them. However, for many crops, modern breeding programs select for plants with reduced vegetative growth in exchange for greater yields of seeds or fruits. Some plants, including some cereal crops are known to be able to suppress weed germination through defensive chemicals exuded through the roots, which is known as allelopathy. Developing varieties of crops with increased allelopathy is still in its infancy, and cultivars of vegetable crops have not yet been bred with increased allelopathic chemicals. However, allelopathic cultivars could provide a means of weed suppression for organic systems in the future. Crops will only be able to compete with weeds if they are healthy, so choosing varieties that are resistant to local pest and disease pressures will help to maintain the competitive ability of the crop over weeds. Any additional source of stress such as insect grazing, plant-parasitic nematodes, or fungal infection can be compounded by stress from weed pressure, and the combination could lead to crop failure, even if the crop could tolerate either stress on its own.

**Planting pattern.** Altering the spacing arrangement of crop plants can help to maximize the crop’s ability to take up resources and make them unavailable to weeds. Reduced row spacing and increased seeding density can help to maximize the area occupied by the crop and reduce areas where weeds can germinate and grow. Reducing the area of the inter-row space allows canopy closure by the crop to keep sunlight from reaching weeds within and between rows. Many studies show that reducing inter-row spacing to the same distance as the intra-row spacing can maximize weed suppression by the crop. This uniform planting pattern maximizes inter-specific competition between crop plants and weeds while minimizing intra-specific competition among crop plants. In addition to more canopy closure, more of the below-ground space is occupied by crop roots, allowing more of the water and nutrient resources to be taken up by the crop and possibly preventing germination of more weed seedlings. Increasing the seeding density can also help by producing more plants per unit of area. Increased crop density produces more crop plants to take up limited resources per unit of area, which keeps those resources from being used by weeds. Decreasing inter row distance and increasing seeding density effectively increase the leaf area index (LAI) of the crop, which is a measure of the area of available crop leaves per unit area of bare ground. At higher values of LAI, a greater proportion of sunlight is taken up by the crop, leaving less sunlight available to weeds.

There are some drawbacks to applying narrow row spacing and increased seeding rates in organic vegetables. Organic seeds can be very expensive, which may mean yield gains from increased weed suppression may not outweigh reductions in yield per plant that may occur at higher crop densities. In some cases, increased crop densities can increase the spread of disease, as plants are closer to one another and the microclimate of the crop is more homogeneous with narrow row spacing. Narrow row spacing may also prevent any rescue weed control through tillage if machinery cannot fit between rows. Narrow row spacing and increased crop density would also not work for vegetables where crowding causes a significant reduction in fruit size. This limits the applicability of this method for most vegetable crops, but could be applied in systems like sweet corn and vegetable bean crops, such as lima or snap beans. These methods
could also be applied to cover crops grown before or after vegetable crops for the purpose of suppressing weeds before or after the vegetable crop’s growing season.

The timing of planting can also be altered to ensure maximum competitive ability of crop plants by avoiding periods when problematic weeds are growing. Altering the planting date of a vegetable crop requires knowledge of what weed species are present in the field and what conditions favor the growth of those weeds. Planting dates can be shifted earlier or later to avoid periods where conditions would be more favorable to weed growth than crop growth. Weeds that germinate at the same time as the crop are typically better at competing for resources than weeds that germinate after the crop is established. If early season weeds would present a problem to a particular crop in a particular field then delaying planting time until later in the growing season allows weeds to be controlled by cultivation or herbicide application prior to crop planting. Planting later in the season could also allow faster growth for the crop in warmer soil and a reduced CPWC. If problematic weed species tend to germinate later in the season, then planting crops earlier may help to achieve canopy closure in the crop and a better competitive ability before those weeds have a chance to germinate. At that time the crop may be at a size where it is better able to compete with weeds and would not suffer any yield loss.

**Fertilizer.** Healthy, vigorous crops will compete better with weeds for resources. As such, cash crops should be supplied with adequate amounts of water and nutrients. When applied appropriately, these resources will only be accessible to the crop, and not weeds. Therefore, suitable amounts, placement, and timing of nutrient application in relation to the crop are important in assuring a competitive crop. This is because when located in the same area, weeds are usually more competitive than crops for nutrients. Broadcasting fertilizers (phosphorus and nitrogen) not only increases weed biomass but also enriches the weed seedbank when compared to subsurface application. This is because when broadcasting fertilizers, the entire field receives the application instead of just crop rows, which will more likely feed weeds. Addition of nitrogen fertilizer stimulates germination of dormant weed seeds, which encourages a new flush of weeds. Wise management of soil fertilizers is therefore crucial in reducing weed pressure in both short- and long-term scales. Avoiding pre-plant broadcasting of fast-releasing N fertilizers or controlling the resulting flush of weeds (such as stale seedbed techniques) before planting/transplanting cash crops would help to limit competition from the weed population.

One way to limit “feeding the weeds” is placing the fertilizer as close to the crop as possible so that it is more likely consumed by the crop. Banding fertilizers close to the crop row and applying it at the appropriate time enhances the crop’s accessibility to the fertilizer and avoids feeding weeds located between crop rows. Applying fertilizer below the soil surface (subsurface banding or injection) would further eliminate flushes of new weeds. Another method is to substitute N fertilizer with a legume green manure or other organic fertilizers. A study demonstrated that using crimson clover as a green manure has the potential to reduce the need for herbicide as well as N fertilizer applications in subsequent crops. However, in the aforesaid study, synthetic N fertilizer was used. Although crimson clover significantly reduced weed growth, it did not entirely eliminate weed interference with sweet corn growth, indicating that
this strategy should be used in conjunction with other weed management tools. Studies have demonstrated that in the long term, using organic N amendments reduces the weed seedbank when compared to continuous use of mineral N fertilizers.

**Mulching.** Mulching can be a handy practice for managing weeds. The underlying mechanism of weed suppression by mulching is to reduce light transmittance, which is more important than allelopathy (release of chemical to inhibit weed seed germination) or physical impedance. Besides infield crop residue, many materials can be used for mulching including natural products such as bark, straw, leaves, paper, and compost and synthetic plastic mulch. Natural mulches are not feasible for use over large acreage because of the difficulties of application but may work well in small, specialized farming situations. Natural mulches should be evenly spread and thick enough to prevent light from reaching the soil surface. Research suggests that organic mulches be at least 1.5 inches thick and heavy enough that they are not easily displaced by wind or water. Further, they should be free of weed seeds and other pests and should not cause specific problems such as attracting rodents and slugs. An additional benefit of some natural mulches is their ability to add organic matter to the soil.

Synthetic mulches may be more reliable for blocking weed establishment than natural mulches and provide other benefits such as conserving moisture, increasing soil temperature, and are easier to place over a large area. By increasing the soil temperature, they enhance early season growth of some warm-season crops such as solanaceous and cucurbitaceous crops. Weed seed germination and seedling growth can be suppressed at high soil temperatures through solarization. Clear plastic and UV-absorbing clear plastic can be used to raise soil temperatures to temperatures which are above the thermal death point for most weed seedlings. Clear plastic mulch decreased pigweed (*Amaranthus retroflexus*) populations within two weeks to less than 10% for one year, demonstrating the sensitivity of some annual weeds to solarization. Solarization has also been demonstrated to be effective for controlling yellow and purple nutsedge (*Cyperus esculentus* and *C. rotundus*), which are difficult to control with conventional methods. In addition, solarization has been widely used to manage plant-parasitic nematodes in vegetable crops. A pitfall of using plastic mulches includes material expense, machinery, and energy input for layout and removal, labor cost, and problems of disposal after use. There are also problems of weeds growing in row middles between plastic beds and runoff during heavy periods of rainfall.

**Abrasive weeding.** Weed blasting is a newer weed management tactic where air-propelled abrasive grits are used to physically abrade and kill weeds. It was demonstrated that granulated walnut shells could be used to kill small lamb’s quarters (*Chenopodium album*) seedlings. Field research has shown the potential use granulated maize cobs to control small broadleaf weed seedlings within maize (*Zea mays*) and soybean (*Glycine max*) rows. Because this tactic indiscriminately abrades stem and leaf tissue of weeds and crops, the success of the tactic depends on a size differential between weeds and the crop. A field study was conducted to determine the effect of air-propelled abrasive grit type, including organic fertilizers, and application frequency on weed density and biomass in organic tomato (*Solanum lycopersicum*)
and pepper (*Capsicum annuum*) cropping systems. Abrasive-grits, including granulated walnuts shells and maize cobs, greensand fertilizer, and soybean meal, were applied via compressed air between one and four times within planting holes of plastic mulch. Two applications of abrasive grits, regardless of grit type, reduced weed density by 63% and 80% in tomato and pepper, respectively. Broadleaf weeds were more susceptible to abrasive-weeding than grass weeds. Abrasive-weeding reduced final weed biomass by 69-97% compared with the weedy control, regardless of grit type or application frequency.

**Herbicides and stale seed bed.** Organic farmers need new methods to improve weed management within crop rows. The potential use of natural products has received substantial interest. Products that are made through natural processes and have herbicidal properties are permissible for use in organic agriculture. Materials including vinegar, citric acid, and essential oils can supplement in-row hand weeding, cultivation, plastics, flame weeding, and other practices. There are practical limitations to the use of organic herbicides in vegetable crops. Organic herbicides are mostly nonselective products which means they can injure the exposed parts of cash crops and they can be too costly when broadcast at the rates necessary for adequate weed control. Thus, successful integration of natural products for weed control after the crop is planted will require development of application technologies that can minimize crop injury and lower usage volumes. Thus, when organic herbicides are used, one goal should be limiting the amount of treated area. If herbicide applications can be limited to a band within the crop row, herbicide use can be reduced by up to 75% or more compared to broadcast applications covering entire fields. Further, banding herbicides over crop rows optimizes their use compared to broadcasting it over the entire field. Weeds within the cropping row are then suppressed and another tactic such as the placement of straw, cover crop residue or growing a living mulch can be used to manage weeds between crop rows. Banding an application to target only in-row weeds could substantially reduce the volume of product used, while providing control where it is most needed.

The stale seedbed method, which is sometimes used in vegetable plantings, may be an ideal tactic to use in collaboration with organic herbicides. This method is executed by preparing a field and delaying crop planting (2-3 weeks) to allow weed flushes that can be killed just before planting. If killed with little soil disturbances (e.g., light cultivation, flaming, herbicide, etc.), the weed seedbank in the upper few centimeters of the soil will be depleted, restricting weeds in the ensuing crop. If time allows, this can be done two times prior to planting. This may be recommended for the slowest growing crops. An advantage of this method is that the crop emerges in a weed-free environment giving it a competitive edge over later-emerging weeds. In some instances, this technique may provide an opportunity for crop emergence and establishment before the next weed flush occurs. Despite use by some organic growers, this practice has received limited attention. However, research as shown that stale seedbed when used in combination with other weed management tactics has effectively reduced weed densities in peanuts, lettuce, snap beans, and cucumbers. If application of the stale seedbed method can limit
herbicide sprays to narrow strips within crop rows, this could result in significant savings while suppressing weeds in areas where it is most crucial.

A variety of organic-compliant techniques (flamer, rotary cultivator, rotary hoe, and top knives) may be used effectively to form stale seedbeds. Techniques that do not disturb the soil surface generally have fewer weeds germinating with the crop. The appropriate implement may vary between growers, and should be selected based on operating cost, on-farm availability, and efficacy. A more detail discussion of the stale seedbed technique can be found at (https://extension.umd.edu/learn/stale-seedbed-technique-relatively-underused-alternative-weed-management-tactic-vegetable).

**Summary**

Weeds are very well adapted to colonizing, reproducing, and surviving in agricultural fields. The goal of IWM is to keep weeds off-balance by making it hard for them to adapt to field conditions where multiple tools are being used to exploit their weak links. In this document, we introduced a number of concepts and tools that should be considered when devising an organic weed management program. Adapting truly IWM practices into vegetable production will allow for a more sustainable weed suppression program that limits reliance on any single management tactic like tillage. In addition, non-chemical weed control methods are now the subject of many research programs that strive towards overcoming this main challenge remaining in organic agriculture. As such, a conscious effort should be made to keep up with the latest research in which information can be used to help manage weeds organically. It is also highly recommended that organic producers conduct small on-farm experiments. This can be done by combining different types of weed management tactics and comparing them with current weed management practices. This will allow producers to see first-hand which practices are most ideal for managing weeds according to their field environment.

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