A. General Production Recommendations

1. Varieties

New varieties are constantly being developed throughout the world and it is impossible to list and describe all; only those that are available and adapted to the mid-Atlantic region are listed in this publication (see crop sections in chapter F). While all efforts are made to have comprehensive lists, not all varieties may be listed. New varieties or varieties with a limited release will have the designation "trial"; they should be evaluated in smaller plantings first. The ultimate value of a variety for a particular purpose is determined by the grower: performance under his or her management adaptation to specific environmental conditions, as well as having desired horticultural characteristics.

Some Variety Selection Criteria:

Yield: The variety should have the potential to produce crops at the same or better yield and quality to those already grown. Harvested yield may be much less than potential yield depending on markets and quality factors.

Days to Harvest: Choose varieties that meet market requirements based on days to harvest. Earliness is a major selection factor for first spring plantings and days to harvest is a critical selection factor for late summer and fall maturing crops, especially in shorter season areas of the region. Days to harvest in seed guides are based on the most common planting date and may be considerably longer in cooler periods or shorter in warmer periods. A more accurate guide to maturity will be Growing Degree Days (GDD), which are calculated for a specific crop using daily highs and lows and a base temperature. GDD information for different vegetable crops such as peas and sweet corn are available from seed suppliers and breeders.

Disease and Insect Resistance, Herbicide Resistance: The most economical and effective means of pest management is through the use of varieties that are resistant or tolerant to diseases caused by fungi, bacteria, viruses, or nematodes. When all other factors are equal, select a variety with needed disease resistance or tolerance. In some vegetables, such as sweet corn, insect resistant varieties are also available and should be considered where they fit your requirements. Herbicide resistant varieties of sweet corn are also available to allow for the use of post emergence non-selective herbicides for weed control. The continuous or intense production of herbicide or pest-resistant varieties can potentially lead to herbicide-tolerant weeds and new, more virulent pest strains. Adherence to vender or Extension recommendations and a long-term crop rotation plan should minimize this risk.

Resistance to Adverse Environmental Conditions: Choose varieties that are resistant to environmental conditions that are likely to be encountered. This includes heat or cold tolerance (disorders such as tuber heat necrosis or frost tolerance); drought tolerance; resistance to wet weather (disorders such as cracking and edema); and resistance to nutrient disorders such as blossom end rot, leaf tip burn and hollow stem.

Horticultural Quality: Choose varieties that meet market quality requirements. Quality attributes such as taste, texture, size, shape, color, uniformity, and defects will often dictate variety selection. Grades, percentage by grade, or pack-outs are key quality attributes for some markets. Variety test data such as soluble solids (sugars or sweetness), acidity, pungency, fiber content and consumer taste panel information can assist in variety selection where available. Processing performance is of major concern for frozen, canned or pickled vegetables. Other considerations include the ability to handle mechanical harvest or the ability to be packed and shipped distances with minimum damage in contrast to vegetables that are adapted only to hand harvest and local sales or short distance shipping. Other quality characteristics to consider include holding or storage ability, ripening characteristics, nutritional content, and culinary qualities.

Plant Characteristics: Plant characteristics that may be considered in variety selection include plant form such as bush, upright, or vining; plant height; plant size; location of harvested part on the plant (such as top set in beans); and ease of harvest.

Adaptability: Successful varieties must perform well under the range of environmental conditions and production practices commonly encountered on individual farms. Seasonal adaptation is another selection consideration. Please note that varieties listed under the "Recommended Varieties" section for individual crops in chapter F may not be adapted to all areas of the Region (*e.g.*, mountain vs coastal growing areas).

Market Acceptability: The harvested plant product must have characteristics desired by both you and your buyers. Consider the requirements or desires of consumers, packers, shippers, wholesalers, retailers, or processors. Included among these qualities are flavor, pack out, size, shape, color, culinary qualities, nutritional quality or processing quality. Specialty markets such as ethnic markets, restaurants, or gourmet sales will have very specific variety requirements. Many vegetable seed companies offer varieties that are transgenic or "GMO" (genetically modified organism). GMO varieties feature a small amount of DNA from a source outside of the crop species gene pool; another plant species, bacterium, virus, or even animal. This foreign DNA is either the direct source of a new trait such as herbicide, or disease or insect resistance or is needed to assist the gene insertion process. GMO products in the food chain are of concern to some consumers and buyers. Be aware of potential adverse public sentiment before growing and marketing GMO varieties of vegetable crops.

Variety selection is a very dynamic process. Some varieties retain favor for many years, whereas others might be used only a few seasons. Companies frequently replace varieties with newer ones. In the mid-Atlantic, variety selection often requires special regional consideration due to the wide range of climatic variations. **There are many sources of information for growers to aid in choosing a variety**. University trials offer unbiased comparisons of varieties from multiple sources. Commercial trials from seed distributors also offer multiple source comparisons. Seed company test results offer information about that company's varieties. Check results from replicated trials and multiple sites, if available. Trials conducted in similar soils and environments and local trials are the most reliable indicators of what will have the potential to perform well on your farm. Visits to local trials can provide good visual information for making decisions. Where quality is a prime concern, look for trials with quality data. Small trial plantings for 2 to 3 years on a grower's farm are suggested for any variety or strain not previously grown. For a true comparison, always include a standard variety, one with proven consistent performance in the same field or planting.

Plant Resistance or Tolerance Listed in Tables

If a specific disease (or insect) is a serious threat to a vegetable crop, genetic resistance is an effective and often low-cost strategy of disease avoidance. Pathogens are highly changeable, and a resistant variety that performs well in one year may not necessarily continue to do so. There are cases where purported resistance to pathogens breaks down. This may be due to genetic shifts in the pathogen, the development of different strains and races of disease-causing organisms or environmental conditions that favor the organism or reduce natural plant resistance. In the chapter F variety tables, disease and insect resistances and tolerances are listed in the tables and footnotes. The disease, insect or insect reactions listed in this book are from source seed companies or from University trials as noted and are not necessarily verified by Cooperative Extension.

2. Seed Storage and Handling

Both high temperature and high relative humidity will reduce seed germination and vigor over time. Do not store seeds in areas that have a combined temperature and humidity value greater than 110, for example 50°F + 60% relative humidity. Ideal storage conditions for most seeds are at a temperature of 35°F (2°C) and less than 40% relative humidity. In addition, primed seeds pretreated with salt or another osmoticum do not usually store well after shipment to the buyer. Seed coating/pelleting may or may not reduce germination rate. When storing coated/pelleted seed, perform a germination test to assess viability before using in subsequent seasons.

Corn, pea, and bean seeds are especially susceptible to mechanical damage due to rough handling. Seed containers of these crops should not be subjected to rough handling since the seed coats and embryos can be damaged, resulting in nonviable seeds. If you plan to treat seeds of these crops with a fungicide, inoculum, or other chemical application, apply the materials gently to avoid seed damage.

3. Specialty Vegetables

Specialty vegetables are grown for specific markets and include: unique varieties or types within standard vegetable categories (different colors, shapes, flavors), varieties that are harvested at different sizes or stages than conventional (baby, mini, or micro types), vegetables grown for ethnic markets, "heirloom vegetables", "gourmet" vegetables, and others grown for niche or specialty markets. In general, market demand for "heirloom" vegetables and types of commodities that cater to the special needs and preferences of ethnic groups have expanded. Specialty vegetable categories also include different growing methods such as organic, "natural" and hydroponic. **See "Specialty Vegetables" in chapter F for more details.**

4. Organic Production

Organic sales in the US continue to rise creating an opportunity for certified organic farmers. Upfront costs can be high, due mainly to certification costs, but returns can be higher than for conventional production. The United States Department of Agriculture (USDA) regulates the term "organic" to protect the industry from dishonesty. To become certified organic, you must follow production and handling practices contained in the National Organic Standards (NOS; see *https://www.ams.usda.gov/rules-regulations/organic*) and be certified by a USDA-accredited agency such as the New Jersey Department of Agriculture (*http://www.state.nj.us/agriculture/*) or Pennsylvania Certified Organic (PCO; *http://www.paorganic.org/*). If annual gross income from organic products is $5,000 or less, a farm can be exempted from certification, but production and handling practices must follow the NOS and some restrictions regarding labeling and combination with other organic products apply. Certified organic production typically begins with a 3-year transition phase during which soil and farming practices are adapted to NOS.

Successful organic production is a long-term proposition. It usually takes a couple of years, and may take as many as four years, for a site managed organically to reach full potential for profitability. Organic production is knowledge- and management-intensive. Organic certification can increase market access but requires learning new production methods and documenting production practices through careful record keeping. However, when implemented well, organic methods can improve soil fertility and tilth through increased numbers of soil microorganisms and improved organic matter recycling. Test new products and methods on a small scale prior to large-scale adoption. Consider the following questions before initiating organic production:

- Does a market for organic vegetables exist?
- Are adequate resources available?
- Would you be able to ride out possible reduced yields without premium prices during the 3-year transition phase?
- Are you willing to devote more time to monitoring pests?
- Are you willing to devote more time to managing soil fertility?
- Are you willing to devote more time to record keeping?

If you answered "yes" to all the above questions, organic production may be for you. If you are beginning the transition phase from non-organic to organic production, consider a pre-transition phase if pest pressures are high in the planting area. A pre-transition phase is intermediate between organic and non-organic production. During the pre-transition phase conventional pest management tactics are used along with organic tactics to reduce pest pressures. Once pest pressures are reduced, organic pest management tactics are used exclusively.

The steps for becoming certified organic can be found in the publication "Organic Vegetable Production" at *https://extension.psu.edu/organic-vegetable-production.*

5. Transplant Production

These recommendations apply only to plants grown under controlled conditions in greenhouses or hotbeds. Field-grown plants are covered under the specific crop in chapter F.

Producing quality transplants starts with disease free seed, a clean greenhouse and clean planting trays. Many vegetable disease problems including bacterial spot, bacterial speck, bacterial canker, gummy stem blight, bacterial fruit blotch, tomato spotted wilt virus, impatiens necrotic spot virus, and Alternaria blight can start in the greenhouse and be carried to the field. A number of virus diseases are transmitted by greenhouse insects.

Buy disease-indexed seeds if available. To reduce bacterial seed-borne diseases in some crops (*e.g*., tomatoes, peppers, cabbages), seeds can be hot water treated. For some crops, chlorine treatment can also be useful but this will not kill pathogens inside the seed. For more detailed seed treatment recommendations, see section E 4.3. Disease Control in Seeds, Plant Growing Mix, and Plant Beds.

Prior to seeding in greenhouse areas, remove any weeds and dead plant materials and clean floors and benches thoroughly of any organic residue. Irrigation systems should also be cleaned to remove dirt and microorganism buildup (biofilms). Growing benches can be washed with a detergent to remove soil and residues. Growing areas should then be sanitized with an antimicrobial compound.

<u>Sanitizing Greenhouse Surfaces and Treatment of Flats and Trays</u>:

There are several different groups of sanitizers that are recommended for plant pathogen and algae control in transplant greenhouses. Alcohol is often used to disinfect grafting tools. All these products have different properties:

- **Quaternary ammonium chloride salts** (Q-salts such as Green-Shield®, Physan 20®, KleenGrow™) are labeled for control of fungal, bacterial and viral plant pathogens, and algae. They can be applied to floors, walls, benches, tools, pots and flats as sanitizers.
- **Hydrogen Dioxide, Hydrogen Peroxide, and Peroxyacetic Acid containing products** (ZeroTol® 2.0, OxiDate® 2.0, SaniDate®12.0) kill bacteria, fungi, algae and their spores on contact. They are labeled as disinfectants for use on greenhouse surfaces, equipment, benches, pots, trays and tools.
- **Chlorine bleach** may be used for pots or flats, but is not recommended for application to walls, benches or flooring. When used properly, chlorine is an effective disinfectant. A solution of chlorine bleach and water is short-lived and the half-life (time required for 50 percent reduction in strength) of a chlorine solution may be as little as a few hours.

New flats and plug trays are recommended for the production of transplants to avoid pathogens that cause damping-off and other diseases. If flats and trays are reused, they should be thoroughly cleaned and disinfested as described below. Permit flats to dry completely prior to use. Styrofoam planting trays can become porous over time and should be discarded when they no longer can be effectively sanitized.

- **Sanitizing trays with Chlorine**: Dip flats or trays in a labeled chlorine sanitizer at recommended rates (3.5 fl oz. of a 5.25% sodium hypochlorite equivalent product per gal of water) several times. Cover treated flats and trays with a tarp to keep them moist for a minimum of 20 minutes. Wash flats and trays with clean water or a Q-salts solution to eliminate the chlorine. It is important that the bleach solution remains in the pH 6.5-7.5 range and that a new solution is made up every 2 h or whenever it becomes contaminated (the solution should be checked for free chlorine levels at least every hour using test strips). Organic matter will deactivate the active chlorine ingredients quickly.

Transplant Production: Transplant growth is affected by many factors including temperature, fertilization, water, and spacing. A good transplant is grown under the best possible conditions. A poor transplant usually results in poor crop performance. Transplant production includes germination, growth, and hardening off phases. Table A-1 presents optimum and minimum temperatures for seed germination and plant growth, the time and spacing (area) required to produce a desirable transplant, and number of plants per square foot. Seedless watermelon transplant production has specific requirements (see chapter F Watermelons). Details on sweet potato plant production can be found in chapter F Sweet Potatoes.

Table A-1. Temperature, and Planting Recommendations for Transplant Production

Crop	Optimum Day Temperature (F°)	Minimum Night Temperature (F°)	Weeks to Grow	Square Inch per Plant	Number of Plants per Square Foot	1020 tray size cells
Broccoli	65-70	60	4-7	2-3	48	72
Cabbage	65	60	6-7	2-3	48	72
Cauliflower	65-70	60	6-8	2-3	48	72
Celery	65-70	60	9-12	2-3	48	72
Cucumber[1]	70-75	65	2-4	4	36	50 or 72
Eggplant	70-85	65	6-9	4	36	50 or 72
Endive, Escarole	70-75	70	5-7	2	72	72 or 96
Lettuce	60-65	40	4-6	1	144	96 or 128
Melon[1]	70-75	65	2-4	4	36	50 or 72
Onion	65-70	60	9-12	0.5-0.65	220-288	288 or 312
Pepper	70-75	60	7-9	2-3	48	72
Summer squash[1]	70-75	65	2-4	4	36	50 or 72
Tomato	65-75	60	5-6	2-3	48	72
Watermelon (seeded)[1]	70-75	65	3-4	4	36	50 or 72

[1]Seed directly in container; do not transplant prior to setting in the field.

Making a Plant-Growing Mix: Pre-mixed growing media are available commercially (see below), but a good, lightweight, disease-free, plant-growing material can also be made from peat and vermiculite/perlite. The main challenge of making one's own mix is having uniform and consistent composition, but it can also be less costly. Formulas for simple mixes can be found in chapter G Resources and Records (Tables G-4 and G-5).

Commercial Plant Growing Mixes: Commercial media are available for growing transplants and are generally recommended to grow vegetable transplants. Most of these mixes will produce high quality transplants when used with good management practices. However, these mixes can vary greatly in composition, particle size, pH, aeration, nutrient content, and water-holding capacity. Commercial growing media will have added lime and may or may not have a starter nutrient charge (added fertilizer). Plants grown in mixes without fertilizer will require supplemental liquid feedings after seedling emergence. Plants grown in mixes with added fertilizers will require liquid feeding starting 3-4 weeks after emergence. If you experience problems with transplant performance, the growing medium should be sent to a testing laboratory. It is recommended to mix 3 to 4 bags of commercial product together before filling trays. Baled commercial mixes must be loosened before mixing. Before filling trays media should be moistened so that it feels slightly damp to the touch but not wet. Media should be used in the growing season it is purchased.

Transplant Trays and Containers: Most transplants are grown in plastic trays with individual cells for each plant. Standard 10 x 20-inch plug trays (or more commonly 11 x 22-inch) can have 32 to over 500 cells. Larger cell sizes (32, 50, or 72) are best used for vine crops and for rooting strawberry tips. 72-cell and 128-cell trays are suitable for tomatoes, peppers, eggplant, and cole crops. Smaller cell sizes (128, 200, 288) may be appropriate for lettuce and onions. Larger Styrofoam and heavy plastic transplant trays are also available in similar cell sizes. Larger cells hold more growing mix/soil and result in better transplant survival in the field but use more greenhouse space and it takes longer to produce the root ball. Individual plant-growing containers may also be used for vine crops and early market crops of tomatoes, peppers, and eggplant. Various types of fiber or plastic pots or cubes are available for this purpose. If plastic pots or trays are reused, disinfest as described previously.

Seed Planting and Germination: Seeds that are over-sown in flats without cells to be "pricked out" (thinned or transferred bare rooted at a later date) should be germinated in 100% vermiculite (horticultural grade, coarse sand size) or a plant growing mix. It is recommended that no fertilizer is included in the mix or the vermiculite until the seed leaves (cotyledons) are fully expanded and the true leaves are beginning to unfold. Fertilization should be in liquid form and at one-half the rate for any of the ratios listed in the "Liquid Feeding of Transplants" paragraph below. Seedlings can be held for 3 to 4 weeks if fertilization is withheld until 3 to 4 days before "pricking out." These then can be transplanted into individual cell trays or grown on to use as bare-root transplants. This system can be used for tomatoes, peppers, eggplant, cole crops, and lettuce. Do not use for cucurbit crops.

More commonly, one seed is planted per cell directly in planting trays. Seed that is sown in tray cells, pots or other containers can be germinated in a mix that contains fertilizer.

For earlier, more uniform emergence, germinate and grow seedlings on benches with bottom heat or in a floor-heated greenhouse. Minimum growing temperatures are listed in Table A-1. Germination rooms or chambers also insure even germination where higher temperatures can be maintained for the first 48 h. Trays may be stacked in germination rooms during this period but must be moved to the greenhouse prior to seedling emergence.

Plant Growing Facilities: Good plant-growing facilities (greenhouses) provide maximum light to the seedling crop. The greenhouse cover material (glass, plastic, fiberglass) should be clean, clear, and in good repair. The ideal greenhouse will provide good heating and ventilation systems for effective environmental control. For hot air heating systems, place thermostats at plant level to maintain proper growing medium temperature. Combustion heating units located inside the greenhouse must be vented and have outside fresh-air intake and exhaust systems to provide air to and from the heater. Ventilation units must be adequate in size, providing 1.2 to 1.4 sq ft of opening for each 1,000 cubic feet per minute (cfm) fan capacity. The heat requirement of a greenhouse depends on the local winter climate, the plants to be grown, the framing and covering materials of the greenhouse, and the total exposed surface area. The heat system rating (in BTU/hour) must equal the heat requirement of the greenhouse. The heat requirement (H, in BTU/hour) of a greenhouse is determined according to the formula: $H = (U)(A)(t_1 - t_0)$

1. U = heat transfer of covering and framing material in BTU/hr/ft^2/ºF. The value for double poly is 0.8; a single poly is 1.6; and single glass is 1.1.
2. A = area in square feet. Find the total exposed area of the sides, ends, and roof of the greenhouse in square feet.
3. $t_1 - t_0$ = inside and outside temperature difference in °F. Determine the temperature difference between the temperature to be maintained in the greenhouse, t_1, and the lowest outside temperature in your area, t_0.

Bottom-heating systems using circulating hot water, either on the benches or on the floor, are better than hot air systems for germinating seeds and growing uniform transplants. This system heats the area around the plants, not the whole greenhouse and can also result in reduced heating costs.

Liquid Feeding of Transplants: In most instances, additional nutrients will be needed by growing transplants. Commercially available 100% water soluble greenhouse fertilizer formulations are recommended (see also chapter C Irrigation Management, section C 3 Fertigation). For most crops use a formulation with lower P than N and K levels (*e.g.*, 21-5-20, 13-2-13, 20-10-20, 17-5-17, 18-9-18). If you plan to fertilize with every watering, begin with N concentrations in the 30 to 50 ppm range and modify the concentration as needed. Use higher rates for tomato, pepper and cole crops and lower rates for cucurbits (*e.g*., watermelon, squash). Use higher rates when temperatures are high (late spring and summer) and lower rates when temperatures are cooler. Fertilizer requirements may vary substantially with crop and growing conditions. For example, if fertigation is scheduled only once a week, N concentrations of 200 to 250 ppm may be required. Some growers may use a growing medium with no starter fertilizer. If that is the case, use 50 ppm N from emergence to first true leaf every 3 days, and 200 ppm N every other day from first true leaf to second true leaf.

For a less sophisticated way of applying nutrients, the following materials can be used for general use on transplants. Over an area of 20 sq ft, use 1 to 2 oz of 20-20-20 dissolved in 5 gal of water, or 2 oz of 20-10-15 dissolved in 5 gal of water. Rinse leaves after liquid feeding. Applications should be made weekly using these rates.

When using starter solutions for field transplanting, follow manufacturer's recommendation. If concentrations are above recommended levels, they can cause excessive growth and reduce transplant quality. Highly concentrated nutrient solutions often can cause plant salt injury and leaf burning. Over-fertilized transplants will often "stretch" and have impaired field survival. **Caution: High rates of starter solution can become concentrated and burn transplant roots when the soil becomes dry.**

Watering: Keep mix moist but not continually wet. Water less in cloudy weather. Watering in the morning allows plant surfaces to dry before night and reduces the possibility of disease.

Transplant Height Control: One of the most important considerations is managing "stretch" or height of transplants. The goal is to produce a transplant with a size that can be handled by mechanical transplanters or hand without damage, and that is tolerant to wind.

Most growth regulators that are used for bedding plants are not registered for vegetable transplants. One exception is Sumagic® which is currently registered for use as a foliar spray on tomato, pepper, eggplant, ground cherry, pepino and tomatillo transplants. The recommended label rate is 0.52 to 2.60 fl oz/gal (2 to 10 ppm) and 1 gal should be sprayed so it covers 200 sq ft of transplant trays (use 2 qt per 100 sq ft). The first application can be made when transplants have 2 to 4 true leaves. One additional application may be made at the low rate, 0.52 fl oz/gal (2 ppm), 7-14 days later, but do not exceed 2.60 fl oz per 100 sq ft for a season. Growers are advised to perform small-scale trials on a portion of their transplants under their growing conditions before large scale use.

For other crops alternative methods for height control must be used, *e.g.*, the use of temperature differential or DIF, the difference between day and night temperatures in the greenhouse. In most heating programs, a greenhouse will be much warmer during the day than the night. The critical period during a day for height control is the first 2-3 hours after sunrise. By lowering the temperature during this 3 hour period, plant height in many vegetables can be modulated. Drop air temperature to 50-55°F for 2-3 hours starting just before dawn, and then return to 60-70°F. Crops vary in their response to DIF, *e.g*., tomatoes are very responsive, while curcurbits are much less responsive.

Mechanical movement can also reduce transplant height. This may be accomplished by brushing over the tops of transplants twice daily with a pipe or wand made of soft or smooth material. Crops responding to mechanical height control include tomatoes, eggplant, and cucumbers. Peppers are damaged by this method.

For some vegetables, managing water can be a tool for controlling stretch. After plants have reached sufficient size, expose them to stress cycles, allowing plants to approach the wilting point before watering again. Be careful not to stress plants so much that they are damaged.

Managing greenhouse fertilizer programs is another method for controlling transplant height. Most greenhouse growing media come with a starter nutrient charge, good for about 2 to 3 weeks after emergence. After that, apply fertilizers, usually with a liquid feed program. Fertilizers that are high in phosphorus will promote transplant stretch.

Hardening: It is recommended that transplants be subjected to a period of "hardening" prior to transplanting to the production field. Reducing the amount of water, lowering temperatures, and limiting fertilizers causes a check in growth (hardening) which prepares plants for field settings. When hardening vine crops, tomatoes, peppers, or eggplants, do not lower temperature more than 5°F (3°C) below the recommended minimum growing temperatures listed in Table A-1. Too low temperature may injure plants and delay regrowth after transplanting. Exposing plants to outside conditions is used for the hardening off process prior to transplanting. You can also use this for transplant height control during the production period. Roll-out benches or wagons that can be moved outside of the greenhouse for a portion of the day can be used for this purpose (see below).

A new tool is available for reducing transplant shock. The chemical 1-methylcyclopropene (1-MCP) which is marketed as the product LandSpring reduces ethylene production and stress on young plants. Ethylene is the plant hormone released when plants are injured or under stress, as is common during transplanting. Excess ethylene can cause leaf drop and wilting and can increase transplant losses. 1-MCP blocks ethylene from causing damage. LandSpring is labelled on broccoli, Brussels sprouts, cabbage, cantaloupe, cauliflower, cucumber, eggplant, muskmelon, bell pepper, non-bell pepper, summer squash, tomato and watermelon. Apply to seedlings 1-5 days before transplanting,

Common Problems: Poor growth and yellow or stunted plants may be attributable to the greenhouse growing medium. Greenhouse media manufacturers use good quality control measures but things can go wrong, *e.g*., through inadequate mixing, missing or the wrong proportions of critical components (wetting agents, fertilizers, lime), or defective components (poor quality). Media can also be affected by poor handling and storage, most commonly when media are stored outside and bales or bags get wet, or if stored past the shelf life. Old media often are dried out and hard to rehydrate. If the medium is over a year old or possibly compromised, it should not be used (contact your supplier for inspections and tests on any suspect media). Avoid using overly dry or caked media, media that are difficult to loosen, media with a bad odor, water logged media or media that are resistant to wetting.

Most (but not all) media include a starter lime and fertilizer charge. The fertilizer is designed to provide 3-4 weeks of nutrients. If the fertilizer is missing, improperly mixed, or in the wrong proportions, seeds will germinate but seedlings will remain stunted. In this case, liquid fertilizer applications should start early.

Peat-based media are acidic in nature. Plants will perform well from pH 5.4 to 6.4. Lime is added to peat- based media and reacts over time with water to increase pH. Above pH 6.4, iron deficiencies in transplants are common. This also occurs if irrigation water is alkaline (has high carbonate concentrations).

In high pH situations (over 7.5), use an acidifying fertilizer (high ammonium content) for liquid feeds. Use of iron products such as chelated iron as a foliar application on transplants can accelerate plant recovery prior to the pH drop with the acid fertilizer. In cases with very high media pH, use of iron sulfate solutions may be needed to more rapidly drop the pH. Addition of dilute acid solutions to greenhouse irrigation water may also be considered in cases of excess alkalinity (*e.g*., diluted muriatic acid).

If lime is missing or inadequate from the growing medium, and pH is below 5.2, plants may exhibit magnesium deficiencies or iron or manganese toxicities. This also occurs in media that have been saturated for long periods of time. To correct this situation, apply a liquid lime solution to the medium and irrigate liberally.

Media that are difficult to hydrate may not have sufficient wetting agent or the wetting agent may have deteriorated; additional greenhouse grade wetting agent may be needed.

If the initial medium fertilizer charge is too high, or if excessive liquid or slow-release fertilizer feed is used, high salt concentrations can build up and stunt or damage plants (possible symptoms: leaf edge burn, “plant burn”, plant desiccation). Test the media for electrical conductivity (EC) to see if salt levels are too high. The acceptable EC will depend on the type of test used (saturated paste, pour through, 1:1, 1:2) so the interpretation from the lab will be important. If salt concentrations are too high, leaching the growing media with water will be required.

Poor transplant growth or injury can also result from the following:

- Heater exhaust in the house caused by cracked heat exchanger, inadequate venting, use of non-vented heaters.
- Phytotoxicity from applied pesticides.
- Use of paints, solvents, wood treatments, or other volatiles inside the greenhouse.
- Use of herbicides in the greenhouse or near greenhouse vents.
- Low temperatures due to inadequate heater capacity or heater malfunction or excessively high temperatures due to inadequate exhaust fan capacity or fan malfunction.

Grafting Vegetables: Utilizing rootstocks for grafting has resulted in increased yields, fruit quality, and tolerance to abiotic and biotic stresses. Research on annual vegetable crops was limited until the last decade when the grafting movement started in Asia and Europe. Grafting is used extensively in the production of watermelon, cucumber, melon, tomato and eggplant. Grafting can overcome tissue damage and/or plant mortality caused by the soil-borne diseases Fusarium and Verticillium wilt, bacterial wilt, and nematodes. Grafting may reduce or eliminate the use of certain pesticides (especially soil fumigants) because the appropriate rootstocks will provide tolerance to many soil insect and disease pests. Grafting is also used to impart additional vigor to plants and to increase yields. Specific rootstocks have been developed for grafting the vegetables listed above. Selection of rootstocks will depend on the specific goals for grafting. There are often many rootstocks available. Consult your seed suppliers for more information.

Some commercial nurseries are starting to feature grafted transplants. As a rule, they are substantially more expensive than conventional transplants, so there should be reasonable assurance of the economic benefit. Any grower seeking to perform large-scale grafting should first consult technical resources, such as the websites in this section. Upgraded facilities and employee training will likely be necessary.

Two successful and easily performed grafts are the tube and cleft graft. The tube graft uses a 45° cut in the rootstock and the scion. The two pieces are subsequently joined together with the angles complementing each other and held together with a clip. The cleft graft utilizes a 90° cut in the rootstock perpendicular to the soil surface. The rootstock stem is then cut in half down the center; this cut should be around ½ inch depending on the size of the rootstock stem and scion. The base of the scion is then cut to form a "V" that will fit the notch that was cut into the rootstock. A grafting clip is secured around the graft junction. This type of graft often requires a larger grafting clip than the tube graft. It is important that both the scion and rootstock stem diameter are similar. Several trial seedlings should also be grown prior to any large grafting operation to insure that the rootstock and scion seedlings grow at the same rate; if not, the stem diameters may not coincide, which can lead to a poor graft union.

Cucurbits such as watermelons, cucumbers, and muskmelons are often grafted using the one-cotyledon splice graft method. In this method, rootstock seedlings should have at least one true leaf and scion seedlings should have one or two true leaves. With a single angled cut, remove one cotyledon with the growing point attached. It is important to remove the growing point and the cotyledon together so that the rootstock seedling is not able to grow a new shoot of its own after being grafted. Cut the scion and match the rootstock and scion cut surfaces, and hold in place with a grafting clip.

One of the most crucial aspects of producing grafted seedlings is healing the graft junctions. After the grafts are clipped back together they need to be placed in a high humidity environment known as a healing chamber. A healing chamber can be constructed in various ways using wooden or metal frames and a plastic covering. The goal is to create a closed environment in which the humidity can be increased and the temperature can be controlled. Open water pans or commercial humidifiers can be used to increase humidity. Propagation heat mats can be placed on the floor to control temperature and warm water pans to increase humidity. For the first several days in the healing chamber, light should be excluded as much as possible. The increase in humidity and decrease in light slow transpiration to keep scions from desiccating while vascular tissue reconnects the scion and rootstock. After 5 to 7 days in the healing chamber, seedlings can harden off in a greenhouse for several weeks before moving to the field. Grafting generally adds 2 weeks to seedling production. Grafting can be performed at various plant growth stages ranging from the 2 true leaf stage on.

6. Conservation Tillage Crop Production (No-Till, Strip-Till)

Conservation tillage crop production systems are beneficial for a variety of reasons, but they require different management than conventionally tilled soils. Some benefits from no tillage can be observed quickly, such as reduced soil erosion, conservation of soil moisture, and reduction in fuel and labor costs. Others benefits occur over time, such as reduction in soil compaction, improved soil structure, and increased soil organic matter. Eliminating tillage can also influence weed and disease severity and produce cleaner harvested products in vegetables growing on the ground.

Conservation tillage crop production systems can also pose several crop management challenges. Soil temperatures do not warm up as quickly in the spring and this can affect seed germination, nutrient cycling from crop residues, and transplant vigor. Type of crop residue, amount of residue, and desiccation timing all impact soil temperature and should be taken into consideration. Modifications to planters and heavier equipment may be needed to accommodate no-till production. Small-seeded crop species may be more difficult to plant in no-till systems.

Conservation tillage systems eliminate mechanical weed control. Since tillage used for seedbed preparation is eliminated, fields receive additional herbicide treatments to control emerged weeds and vegetation prior to or at planting. Thermal weed control (such as flamers) may be an option, but most other tactics (*e.g.*, mowing) are not effective. Interrow cultivation with no-till cultivators has been used with some success in conservation tillage programs for weed management, but these implements are not readily available.

Nitrogen fertilizer must be managed properly when utilizing a conservation tillage production system. Crop residues typically contain an enzyme (urease) which can increase nitrogen volatilization from urea-containing fertilizer sources such as urea, liquid urea ammonium nitrate, or a variety of blends currently available. Management practices such as banding or incorporating nitrogen fertilizer with irrigation or rainfall should be considered to reduce urea-containing fertilizer contact with urease.

Nitrogen management in conservation tillage systems must account for microbial "tie-up". High levels of crop residue, cover crops, or weed vegetation on the soil surface will result in microbes assimilating nitrogen and immobilizing it (*i.e.*, it is unavailable to the crop). Research has shown that 25% or more nitrogen fertilizer may be necessary in the initial conversion years from conventional to conservation tillage until the soil reaches an equilibrium. Previous crop residue (type and amount), current soil nitrogen concentrations, fertilizer sources, application timing, and application methods all need to be considered when making necessary nitrogen rate calculations.

Maintaining proper soil pH is one of the most important crop production considerations in conservation tillage and has significant impact on nutrient availability and toxicity. Mixing lime into the soil with tillage is not an option with no-till systems, so consider adjusting pH to the optimal level prior to initiating a continuous conservation tillage system. Lime has relatively low water solubility and leaches slowly through the soil profile. Eventually, fertilizer, organic matter decomposition, and rain will lower soil surface pH, but changes to subsoil pH will take a longer time. Continued liming based on soil test recommendations will maintain the proper pH.

Strip-till is a blend of tillage and no tillage within the same field. A narrow strip of soil is mechanically tilled with specialized tools to incorporate fertilizers and plant residues, warm soils, and improve soil to seed contact. The area between the crop rows is managed as no-till.

No-till and strip-till production systems often use cover crops to provide a mulch that the vegetable crops are grown on. Rye, hairy vetch, crimson clover, and mixtures of theses crops provide biomass that forms this mulch. Hairy vetch and crimson clover also provide nitrogen in the system. These mulches are often rolled with a roller-crimper prior to planting to provide the mulch base.

Under conventional tillage the plant residue is incorporated into the soil. However, in no-till systems, the cover crops may add additional plant residue that needs to be considered with management decisions such as pre-plant vegetation control, slower soil warming, plant residue management at planting, and fertility management. The amount of cover crop biomass (determined by when the cover crop is terminated) will dictate whether additional management is necessary.

7. Mulches and Row Covers

A favorable environment for plant root systems can be achieved by using plastic mulches and drip irrigation. Additional advantages of using row covers early in the season include increasing day time air temperatures and holding ground heat over night. This improvement in temperature can speed plant growth resulting in earlier harvest. Mulches may discourage weeds and insect pests depending on the type.

<u>Plastic Mulches</u>: Black and white-on-black polyethylene film (0.75-1.25 mil) are the most popular mulches. Other mulches include blue, red, green IRT and metalized. Black mulches are generally used to warm the soil and white-on-black mulches are generally used to cool the soil. Different mulch colors and compositions impart new functional properties to mulch. Green 'IRT' types increase soil temperatures more than black plastic and suppresses most weeds including nutsedge. Results for other colored mulches such as red and blue have been inconsistent. Metalized or aluminized mulches repel certain insect pests (aphids, thrips, whiteflies) early in the crop growing cycle due to the reflectance of UV rays, but this benefit is lost once the crop canopy covers the mulch. This can be useful in cucurbit and tomato crops to delay the onset of certain virus diseases vectored by thrips, aphids, and whiteflies. Yellow mulches attract cucumber beetles and may also attract other insect pests. Note that planting date and environmental conditions influence crop responses to mulch color.

Soil fumigation may be used in conjunction with any type of plastic for weed, disease, and insect management, depending on the fumigant label. As the cost of soil fumigation increases, growers will likely need to reduce application rates to maintain profitability. New mulches have been developed that have decreased permeability to fumigants. These "virtually impermeable film" (VIF) mulches keep the fumigant in the ground longer which allows for reduced application rates while maintaining efficacy. VIF mulches come in various colors for fall and spring plantings. Consult the fumigant label for the allowable reduction in use rate under VIF mulch and plant back restrictions. The cost of VIF mulches is higher than that of low-density mulches but this increase is usually offset by the savings gained from reduced fumigant rates. Another mulch type has been developed that is more retentive than VIF mulch, *i.e.*, "totally impermeable film" or TIF. Soil fumigant use rates may be further decreased if used in combination with TIF, consult the fumigant label (see also section E 1.5 Soil Fumigation).

Fertilization: Measure soil pH before considering a fertilization program for mulched crops. If a liming material is needed to increase the soil pH, the material must be applied and incorporated into the soil as far ahead of mulching as practical. For most vegetables, the soil pH should be at or near 6.5. If the pH is below 5.5 or above 7.5 nutrients may be present in the soil, but not available to the plants.

Ideally a drip irrigation system is used with plastic mulch. When using plastic mulch **without** drip irrigation, all plant nutrients recommended for standard cultural practices should be incorporated in the top 5 to 6 inches of soil before laying the mulch. If equipment is available, apply all the fertilizer required to grow the crop to the soil area that will be covered with mulch. This is more efficient and effective than a broadcast application over the entire field. Non-localized nutrients may promote weed growth.

All essential plant nutrients, including major nutrients (N, P, K) as well as secondary and micronutrients, should be applied according to needs from soil test results and incorporated in the manner described above. Placing some of the required N under the mulch and then side dressing the remainder of the needed N along the edge of the mulch or in the row alleys after the crop becomes established has been found to be ineffective.

Applying some of the required N under the mulch and the remainder through the drip irrigation system is an effective way to fertilize. If using drip irrigation, see "Drip/Trickle Fertilization" in the crop sections in chapter F (*i.e*., eggplants, muskmelons, peppers, and tomatoes) for specific application rates.

Soil Conditions for Laying Mulch: Soil texture should be similar and plastic should be laid so that it is tight against the soil in a firm bed for effective heat transfer. Prepare the soil by incorporating crop residues, minimizing large soil clods, and removing rocks and other debris that could interfere with good contact between the soil and plastic. Plastic can be laid flat against the ground or on raised beds. Raised beds offer additional soil drainage and early warming. Use of a bed shaper prior to laying plastic allows for fertilizer and herbicide incorporation and can assist in forming a firm bed. Combination bedder-plastic layers are also widely used.

Before any mulch is applied, check the soil moisture level. Optimally the soil moisture level is at or near field capacity (field capacity is the amount of moisture left after a rain or irrigation event after surplus water has moved out of the root zone by gravity). Being at field capacity is extremely important when drip irrigation is not used because this moisture is critical for early growth of the crop plants as soil moisture cannot be effectively supplied by rain or overhead irrigation to small plants growing on plastic mulch.

Biodegradable Mulches: Biodegradable plastic mulches have many of the same properties and provide comparable benefits as conventional plastic mulches. They are made from plant starches such as corn or wheat. These mulches are weakened by exposure to sunlight but are designed to degrade into carbon dioxide and water by soil microorganisms when soil moisture and temperatures are favorable for biological activity. Soil type, organic matter content, and weed pressure are other factors affecting breakdown. Unlike petroleum-based mulches, biodegradable mulches will usually be retained on the surface of the soil rather than be blown away from the application site. Most of the biodegradable mulch will eventually degrade or fragmentize, including the buried tucked edges. However, biodegradation is often unpredictable and incomplete. It is recommended that biodegradable mulch be incorporated into the soil at the end of the harvest or growing season. Cover crops can be planted the day after biodegradable mulch has been disked into the soil. In 2012, the National Organic Standards Board passed a motion allowing the use of 'biodegradable bio-based mulch film' provided that the mulch is 'produced without organisms or feedstocks derived from excluded methods' and meet certain degradation standards (at least 90% degraded in 2 years or less). However, currently only certain paper mulch products meet the organic requirements.

Field research has demonstrated that crop yields are comparable between biodegradable and non-degradable plastic mulches. Growers may be apprehensive about the cost of biodegradable mulch and the unpredictability of degradation rate. However, the initial cost is somewhat offset because disposal costs are eliminated. Below are some tips on using biodegradable mulch (excerpted from A. Rangarajan, Cornell University):

Storage	Buy what you need each year. Product performance will be best with new product. More rapid degradation may be seen with older product. Store mulch rolls upright, on ends. Pressure created from stacking may lead to the mulch binding together or to degradation. Store mulch rolls in a cool, dark and dry location. These products will start to degrade if stored warm, in sunlight and if rolls get wet.

Continued on next page

Tips on using biodegradable mulch - continued

Application	Do not stretch biodegradable mulch as tightly over the bed as standard plastic mulches (contrary to recommendations for standard plastic that performs best when laid tightly over the bed). Stretching starts the breakdown of the biodegradable mulch. and will increase the rate of breakdown. The product will mold to the bed like commercial food wrap soon after application. Apply immediately prior to planting. If applied too far in advance of planting, the mulch may not last as long as needed. Sunlight and moisture will start breakdown.
Incorporation into Soil	Chisel or till the mulch into the soil as soon as possible after harvest to maximize breakdown. Breakdown requires warm soil temperature and moisture. If mulch is incorporated after soil temperatures have dropped it may still be visible in the spring. However, as the soil warms, the product will further degrade and fragment. Rototilling will result in smaller mulch pieces that breakdown faster. Mulches will break down more quickly in soils with higher organic matter content.

Floating Row Covers and Low Tunnels: These systems are being used for frost, hail, and wind protection, to hasten the maturity of the crop and to effectively exclude certain insect pests. Vented clear and translucent plastic covers are being used in low tunnels, supported by wire hoops placed at 3 to 6 feet intervals in the row. Porous floating row covers are made of lightweight spun fibers (polyester or polypropylene). They may be supported with wire hoops, PVC pipes or metal conduit hoops for plants that require a higher volume to grow or they can be placed loosely over the plants without wire hoops for low growing plants such as vine crops and strawberries. Upright plants have been injured by abrasion when the floating row covers rub against the plants.

Clear plastic can greatly increase air temperatures under the row cover on warm sunny days, resulting in a danger of heat injury to plants. Therefore, vented materials are recommended. Even with vents, clear plastic has produced heat injury, especially when plants have filled a large portion of the air space in the tunnel. Heat injury has not been observed with translucent materials.

Row covers are usually installed over plastic mulch using a combination of mechanical application and hand labor. Equipment that will cover the rows in one operation is available. However, farmer-made equipment in conjunction with hand labor is currently the most prevalent method used.

When considering mulches, drip irrigation, and/or row covers weigh the economics involved. Does the potential increase in return justify the additional costs? Are the odds of getting the most benefit in terms of earliness and yield from the mulch, drip irrigation, or row covers favorable? Does the market usually offer price incentives for the targeted earlier time window? Are you competing against produce from other regions? Determine the costs for your situation, calculate the potential return, and come to a decision as to whether these strategies are beneficial.

Plastic Mulch Removal: Several methods of plastic mulch removal have been tried, but on small acreages it is removed by hand by running a coulter down the center of the row and picking it up from each side. Commercial tractor mounted mulch removal equipment is also available. High-quality, plastic mulch can be used for two successive crops during the same season when care is taken to avoid damage to the film. Thin wall (4 to 8 mil) drip irrigation tape cannot be removed and reused. However, high-quality, 16-mil drip tubing can be used a second season provided that damage is minimal and emitters do not become clogged. Crop foliage and weeds may hamper mulch removal. Prior to replanting or removing mulch, vegetation may be eliminated by using herbicides (see specific crop sections in chapter F), or delay removal until after frost.

Plastic Mulch Disposal: Dispose of plastic in an environmentally responsible manner. Disposal regulations vary between states and municipalities. Contact your local solid waste authority for recommended methods of disposal in your area. Some states have developed recycling programs for agricultural plastics; consult state authorities.

8. Staking and Trellising

Many vegetable crops benefit from the addition of structural supports in the field. The benefits include: 1) better use of the available space and light; 2) improved air flow and more rapid drying of foliage; 3) reduction in certain disease pathogens; 4) protection against plant breakage; 5) protection of developing fruits and other plant parts against rain, dew, and sun; 6) ease of harvest, and 7) possible higher net yields. The disadvantages include the cost of materials, installation and disposal. Assess on a case-by-case basis if a structural support system is desirable.

Structural support systems have been used successfully for fresh market slicing, cluster, grape and cherry tomatoes, peppers, eggplants, cucumbers, climbing beans, and peas. The types of materials and how they are assembled differ for each crop. Specifics of the design and installation are included in chapter F. If materials fail during the growing phase, the resulting damage can be catastrophic. Use high quality construction materials and adhere to minimum size and spacing recommendations. For wooden stakes, it is recommended that a clear hard wood source be used.

It is a common practice to re-use wooden stakes over many seasons. Because stakes are in contact with the environment and plant material, there is a significant probability that surfaces will become infested with pathogens, especially bacteria. If left untreated, infested stakes may re-introduce diseases into the field, although the extent of this problem has not been determined. It is recommended that stakes are thoroughly disinfested before re-use.

The preferred (and most expensive) method of stake disinfestation is heat treatment. Pathogens are eliminated from wooden stakes with exposure to ≥ 220°F for ≥ 15 minutes. This can be accomplished in a large capacity autoclave, or seed dryer. It is unlikely that most growers will have access to such equipment. Alternatively, therefore, stakes may be exposed to disinfectants such as commercial chlorine solutions (sodium hypochlorite) or Oxidate® (hydrogen dioxide; see below). Research has shown that a 20-minute soak in a solution made of 5 to 20 parts by volume sodium hypochlorite (commercial bleach) to 80 to 95 parts by volume water is effective in eliminating pathogens **only from the surface** of wooden stakes. It is crucial to maintain the pH of the bleach solution within the 6.0 to 6.5 range, as effectiveness decreases at lower and higher pH levels.

Studies on stakes treated with bleach solutions show that pathogens may still be present beneath the surface at depths ≥ 1/16th inch. Pathogens embedded within the stake may be able to migrate back to the surface and re-infest plants, although this has not yet been demonstrated. To improve the effectiveness of procedures for removing microbial pathogens from stakes, consider the following: Add a non-ionic surfactant to the disinfesting solution; increase the soaking time to ≥ 1 h; apply a vacuum during the stake soak; use a higher concentration or more potent source of hypochlorite (such as “heavy duty” or swimming pool grade chlorine); or use stakes comprised of non-absorbent stake materials (such as plastic or metal). Many growers have successfully used the commercial product Oxidate® or chlorine dioxide to disinfest stakes. Oxidate® is OMRI certified and had been demonstrated to be an effective control agent for several important plant pathogens. However, data on the efficacy of this treatment as compared to using heat or commercial chlorine solutions are not available.

9. High Tunnels

High tunnels are low-cost, plastic-covered structures which extend the traditional growing season and protect the crop from stress. In the mid-Atlantic region, year-round production of specialty crops is possible using freestanding high tunnels (Table A2). High tunnels are either freestanding or connected at the gutters to cover larger areas. Freestanding tunnels are generally between 14-36 ft wide and up to 120 ft long. High tunnels are typically tall enough for a person to stand straight up in at least part of the structure. While high tunnels are not greenhouses (generally no heat or automatic ventilation), the greenhouse principle is the basis for their function and design.

Taking the time to level the tunnel site prior to construction will make subsequent steps much easier. Spacing between high tunnels should be approximately 1.5 times the height of the nearest structure to facilitate snow removal, to provide for cross ventilation, and to reduce mutual shading. For freestanding high tunnels, metal bows approximately 1.75-2 inches in diameter are used as the support frame for a single or double layer of polyethylene covering (typically 6 mil greenhouse plastic that lasts 3-4 years). These bows are spaced 4 feet apart and are connected to metal posts, which are driven at least 2 feet deep into the ground. End walls can have removable framing to allow the use of power tillage and bed maker/mulch layer equipment within the tunnel.

A soil nutrient test should be conducted prior to constructing the high tunnel. Once the high tunnel is covered with plastic film, prepare the soil, apply and incorporate lime and preplant fertilizer as recommended for the intended crop or crops (See chapter F). High tunnels can considerably increase yield potential, thereby increasing nutrient requirements. Plant tissue testing should be conducted at important growth stages during the season to ensure adequate fertility requirements are maintained. See chapter B Soil and Nutrient Management for more details. Make beds, if needed, and install drip irrigation to supply moisture. Using a small bed maker/mulch layer, cover soil or beds with black or clear polyethylene to warm soil for spring crops. When transplanting crops into tunnels during July and August, use white or silver polyethylene mulch on the soil or beds rather than black polyethylene to reduce soil temperature and excessive heat buildup in tunnels.- Shade fabric may be needed in areas with high summer temperatures.

For freestanding high tunnels, snow removal from the top of the tunnels may be necessary after heavy snowfalls. Snow may need to be removed from the sides of the tunnels as well to reduce/eliminate outside water intrusion into tunnels and collapse of tunnel sidewalls. Gutter-connected high tunnels are constructed with much lighter posts and bows and cannot be used for crop production during the winter. During the winter season, the plastic on gutter-connected high tunnels must be bundled and moved to the gutters for storage. Hence, freestanding high tunnels allow for year-round production while gutter-connected tunnels do not.

The keys to successful production of vegetable and other horticultural crops in high tunnels are crop scheduling, fertilization ventilation and irrigation. Table A-2 provides a relative planting and harvesting schedule for some vegetable crops produced using freestanding high tunnels in the mid-Atlantic region. When planting high tunnel crops in the spring, it is generally recommended to transplant vegetable crops 2-4 weeks earlier than the earliest planting date in the field on bare ground. If unusually cold night temperatures are experienced several days to weeks after planting vegetable crops in high tunnels, floating row covers, low tunnels, thermal blankets and/or portable clean burning propane heaters (11,000 to 44,000 Btu per hour) can be placed in high tunnels until more seasonal temperatures return.

The most critical component of the system is ventilation. In freestanding high tunnels, ventilation is accomplished by rolling up the side walls to the batten boards, approximately 5-6 ft above the ground on each side of the tunnel. In gutter-connected high tunnels, ventilation is accomplished by sliding the plastic covering aside creating ventilation openings in the roof bows, as well as by opening the end walls. The use of a ridge vent may significantly reduce relative humidity and temperature fluctuations. Maintaining optimum growing conditions inside high tunnels without having extreme fluctuations in temperature and/or high humidity conditions can lead to early, high yielding and high quality crops. Checking and adjusting high tunnel internal temperature and humidity conditions several times a day will help ensure increased crop yields and profitability.

Depending on the crop to be grown, there are several production systems that can be used in high tunnels. Conventional tillage and establishment of crops may be efficient for cool season crops that can be direct seeded or transplanted such as, lettuce, onions, Swiss chard, spinach, collards or kale. For warm season crops, especially cucurbits (cucumbers, squash, cantaloupe and watermelon) and solanaceous crops, (potato, tomato, pepper and eggplant) use of raised beds with plastic mulch and drip irrigation is required for optimum yield, maturity and quality. Warm season vegetable crops dramatically benefit from higher soil temperatures in early spring in high tunnels. In addition, multiple cropping is possible from the initial raised bed/plastic mulch – drip irrigation system established in the spring. Permanent raised beds with a width of 24-48 inches may also be constructed in high tunnels using wooden boards measuring 2 by 12 inches. Use of permanent raised beds may limit crops grown on them depending on the distance between raised beds (center-to-center) within the high tunnel. Some growers successfully use 30-36 quart potting soil bags that are drip irrigated to grow high tunnel crops. These bags are placed end-to-end in rows and on a landscape fabric. Either one or two drip irrigation lines are inserted in planting holes in each bag. Additionally, small holes are cut on the bottom of the bags for drainage. Warm season vegetables can be grown using conservation or no till production practices within high tunnels. A winter cover crop is established the previous fall and terminated with silage tarps or mowing. The cash crop can be planted directly in the mulch or planted using woven ground cover as the mulch. High tunnel culture minimizes some diseases by reducing splash dispersal. In addition, appropriate adjustment of the plastic sides also will minimize leaf wetness duration.

Some diseases are prevalent in high tunnel environments. Leaf mold, powdery mildew, timber rot and Fusarium wilt can become problematic. Cultural practices such as sanitation (removal of plant refuse), grafting and compost amendment can minimize disease. Fumigants can be used to reduce levels of soil borne pathogens. Conventional fungicides and several fungicides approved for organic production are available for in-season management. When high tunnel sides are raised, fungicides and bactericides labeled for field use are allowed. When sides are lowered, fungicides and bactericides labeled for greenhouse use should be used (see Table E-11 "Selected Fungicides and Bactericides Labeled for Greenhouse Use" for specific disease and crop recommendations). See also Rutgers Cooperative Extension Fact Sheet No. 358 titled: "Important Diseases of Tomatoes Grown in High Tunnels and Greenhouses in New Jersey" (available at *http://njaes.rutgers.edu/pubs/publication.asp?pid=fs358*). This information is applicable to all states in the mid-Atlantic U.S. region.

Table A-2. Planting and Harvesting Schedule for Freestanding High Tunnel Vegetable Crop Production

Crop	Method[1]	Average High Tunnel Planting Dates	Average High Tunnel Harvest Dates
Beet	TRP or DS	February-April; August-October 15	October-May
Bean (Snap)	TRP or DS	April-September 1	June-October
Bok Choi	TRP or DS	February-November	Year-round
Broccoli	TRP or DS	March-April; August	May-June; October- November
Cabbage (Green)	TRP or DS	March 15-May 15; August 1-15	May-December

Table A-2. - continued on next page

Table A-2. Planting and Harvesting Schedule for Freestanding High Tunnel Vegetable Crop Production - continued

Crop	Method	Average High Tunnel Planting Dates	Average High Tunnel Harvest Dates
Cabbage (Chinese)	TRP or DS	February 15-April 15; August 1-September 30	April-June; October-December 10
Cantaloupe	TRP or DS	March 21-May	June-August
Carrot	DS	February 1-April 15; August-October	March-June; November-April
Cauliflower	TRP or DS	March 15-April 15; August	May-June; October-December 10
Chard	TRP or DS	Year-round	Year-round
Cucumber	TRP or DS	April-September 1	May-October
Eggplant	TRP	April 15-August 15	July-October
Garlic	DS	October-November	June-August
Kale	TRP or DS	January-April 15; August-November 1	February-June; September-January
Kohlrabi	TRP or DS	March-April; August-September	May-June; October-December
Leek	TRP or DS	February 15-November 15	April-May; November-April
Lettuce	TRP or DS	Year-round	Year-round
Onion (Bunching Green)	TRP or DS	September-December; February-June	March-December
Onion (Bulb)	TRP	February-March; October-November	May-July
Pea	TRP or DS	February-April	May-June
Pepper (Bell)	TRP	April-July 20	June-November
Potato (Irish)	DS	February 14-March 15; August	May-June; October-December
Radish	DS	February-April; September-December	February-May; November-January
Spinach	DS	January 1-May 1; August-December	January-May; October-December
Summer Squash	TRP or DS	April-May	May-June
Tomato	TRP	March 15-July 15	June 1-December 5
Turnip	DS	February-April; September-December	February-May; November-January

[1]TRP=Transplanting, DS=Direct Seeding.

10. Greenhouse Production

Many growers have an interest in increasing productivity as well as having a seasonal product such as tomato, sweet pepper, cucumber, lettuce, arugula, and herbs in the off seasons or year-round. To do this in the mid-Atlantic U.S., a temperature-controlled greenhouse structure is needed. Greenhouse production requires a much greater level of and often entirely different strategies of management compared to field production. Greenhouse production generally requires different varieties, nutrient sources, plant training, and pest management than field production. Hydroponic systems are commonly used. Other fully lighted "warehouse" or vertical production systems under artificial light have been developed.

The extensive differences between greenhouse and field production preclude the inclusion of these techniques in this guide. There are many complete guides for the production of vegetables in greenhouses that have been developed and distributed through the cooperative extension service in various states. Links to some guides are provided below. This list is not all-inclusive and does not endorse these guides exclusively.

http://edis.ifas.ufl.edu/topic_book_florida_greenhouse_vegetable_production_handbook
https://ceac.arizona.edu/resources/intro-hydroponics-cea

11. Wildlife Damage Prevention

Farms provide food and shelter for a variety of wildlife species. Although many wildlife species do not cause damage to agricultural crops, some can inflict serious economic losses on growers. What often makes effective resolution of conflict situations difficult is that growers have little access to or management capability on surrounding private lands and suburban neighborhoods that provide refuge for wildlife causing damage on farms.

A wildlife damage management plan that, when implemented, proactively prevents or reduces conflict is recommended. As a part of your plan, you should delineate areas of your property where zero tolerance for damage exists, as well as those areas where you may be willing to tolerate some damage. In most instances, wildlife damage represents another cost of doing business; it's the severely damaging episodes that must be avoided. Your plan also should specify what management techniques are to be utilized and when they would be employed. Wildlife damage management practices fall into 3 major categories: husbandry methods, non-lethal techniques, and lethal techniques. This categorization also is the order in which application should be implemented; lethal techniques are methods of last resort, not the option of first choice. Growers should recognize that different strategies will have varying levels of effectiveness and acceptable risk. Generally, an integrated wildlife damage management approach that employs several damage abatement techniques proactively over time will be more effective than a reactive strategy that relies on only a single approach.

A variety of damage management options exists, but not all may be suitable for use in all cases or on all wildlife species. Some options are more effective than others - some are temporary and intended for short-term, localized use, whereas others are more suited to permanent, long-term needs. Each situation where conflict between wildlife and people is occurring is likely to be unique, so management options usually need to be tailored to a specific site.

Acquisition and implementation costs associated with each management option can vary substantially. Before deciding on a management technique, estimate the direct and indirect costs you actually experience from wildlife damage. A direct cost would be the annual yield lost by consumption or ruin of the crop specifically by wildlife. An indirect cost would be the amount of time you spend per year, trying to reduce or eliminate damage. Calculating an estimated total annual cost, in terms of actual economic loss due to wildlife, will help you decide which strategies are the most cost-effective. In some instances, it may be more practical to simply tolerate damage than to attempt to manage it. To determine the need for control, to select the most appropriate control technique, and to evaluate the techniques' effectiveness, it's always best to conduct pre- and post-treatment assessments to gather good estimates of the actual damage you experience.

Prior to employing any damage abatement practice, you must assure that you have correctly identified the species doing the damage. Do not assume that, simply because you see an animal on your farm, it is the culprit responsible for the damage. Wildlife populations are regarded a public resource and many of the animals that may cause damage to your farm are protected by state and federal laws. In addition, many damage management practices (*e.g.*, trapping, shooting, pesticide applications) are species specific and based on established regulation or code. If you mistakenly assign blame for damage to the wrong wildlife species and employ a technique that is not authorized for use on that species, you can be cited for violation. Therefore, before employing any management practices, check with your county extension agent, local conservation police officer, or your district wildlife biologist to review depredation permit requirements and/or legal issues related to "take" or use.

Bears

Damage caused by black bears to field crops often is characterized by localized, circular patches where nearly all stems or plants have been trampled, pulled down, or broken. In corn fields, bears usually will consume most of the kernels on an ear of corn before moving on to another ear. Scat (feces) and footprints typically are present in the area of feeding activity. There are no guaranteed bear management strategies that offer complete protection against crop damage, but several strategies used in combination may offer some relief.

Cultural practices and habitat modification can help to deter bears from entering fields. Restricting access to potential food resources, such as storing feed in bear-resistant containers, disposing of animal carcasses, and removing organic wastes, will lessen the overall attractiveness of the property to bears. Containing livestock in pens away from wooded areas may reduce negative interactions, particularly during calving/lambing season. Because bears generally avoid open areas away from protective cover, maintaining a mowed buffer approximately 50 yards wide around crop fields, particularly where fields are adjacent to the woods, may reduce bear activity. Alternating or strip planting row crops may help reduce protective cover afforded to bears.

Fencing is very effective in reducing bear damage; however, fencing can be expensive and may not be cost-effective for all farmers. Electric fencing is the most effective design and thus is recommended in most instances. To be most effective, fences should utilize high voltage (~6,000 volts), low-impedance (short-pulsed) systems. When first installed, bears should be lured to the fence with an attractant (*e.g.*, peanut butter, sardines) so they learn to associate the fence with a negative consequence. These attractants should be placed at head height of a bear (approximately 3 ft.) along the entire perimeter to encourage shock delivery to the muzzle.

Sensory deterrents or harassment techniques have been used to deter black bears from crop fields. Pyrotechnics, horns, bright lights, propane cannons, and other devices provide both visual and auditory stimulation. When damage coincides with the "bear chase season," allowing a local bear hunt club to run dogs through a field may provide temporary relief against bears that have taken to using these fields. The success of these techniques is highly variable. Bears usually become habituated to consistent or repetitive disturbance, and sensory deterrents should be switched and relocated often. Where bears have become tolerant of human activity, sensory deterrents often will not be effective. Human-conditioned bears can be dangerous, and caution is advised.

Aversive conditioning techniques are intended to more forcibly change or eliminate undesirable bear behavior. Options that potentially may be available to harass a troublesome bear include techniques such as paint balls, projected bean bags, or rubber bullets, all of which are intended to send a strong message but not injure or maim the animal. These approaches may not be allowed in all states, so check with your state wildlife department before use.

Shooting problematic black bears should be viewed as a last resort management practice, but may be necessary as means to reduce persistent crop damage caused by a single returning individual or family group. Special kill permits are required to “take” bears, so farmers need to work closely with their state wildlife agency. Farmers having persistent damage should develop relationships with local bear hunters or chase clubs to increase the level of pursuit activities on or adjacent to the farm as a means of reducing future losses. **This practice is not permitted in some jurisdictions. Consult your local Wildlife Management Authority.**

Birds

Bird damage often consists of holes and/or surface blemishes inflicted from birds pecking at fruits, bulbs, or stems or the total consumption of the commodity being produced. Proper identification of the offending bird species is necessary before implementing any management strategy because many species are protected under federal statutes (*e.g.*, the Migratory Bird Treaty Act). That said, growers who face serious damage events may be allowed certain latitude under special nationwide permits to use certain techniques that might otherwise be prohibited. For example, managing damage inflicted by flocking blackbirds often falls within the provisions of a Nationwide Permit. "Blackbirds" generically refers to a group of about 10 species, often including Common Grackles (*Quiscalus quiscula*), Brown-headed Cowbirds (*Molothrus ater*), and European Starlings (*Sturnus vulgaris*). However, growers need to apply for and receive authorization from the U.S. Fish and Wildlife Service before any lethal action is taken. House sparrows (*Passer domesticus*) and common pigeons (*Columba livia*) also are common to farms, where they inhabit the rafters of barns, warehouses, and other structures. Birds inside packinghouses represent a serious source of fecal contamination, which may violate USDA food standard guidelines. Fecal contamination of fruits and vegetables in the field can occur if fields are located near a bird roost where large numbers of birds congregate. It is imperative to check with the state Fish and Wildlife authority before implementing any management to ensure compliance with state and federal wildlife laws.

Cultural practices and habitat modification may provide some reduction of crop damage. Because the most severe instances of blackbird damage commonly occur within 5 miles of roosts, planting highly attractive crops outside of this radius is recommended. Blackbirds generally do not prefer soybeans, hay, wheat, or potatoes. By planting crops that are more attractive to blackbirds farther from known roost sites, damage from birds to these higher value crops may be reduced. Planting multiple crops at the same time in other nearby fields may reduce damage overall as the abundance of resources simply overwhelms the birds’ needs. Modifying or relocating roost areas may reduce the number of birds in the area. For example, eliminating stands of bamboo or thinning dense conifer stands have been shown to reduce crop damage by dispersing blackbirds away from crop fields. Removal of about 1/3 of a tree’s crown or 1/3 of a stand of trees has been successful in reducing or dispersing birds from a roost. Keep in mind, though, that you also will modify habitat used by other non-destructive and potentially desirable bird species. Providing hunting perches for raptors may reduce blackbird numbers as a result of the threat of predation.

Exclusion (*e.g*., netting) typically is practical only on small acreages or for high-value crops. Lightweight netting has been used successfully to prevent bird damage either by draping it over individual plants or constructing a frame and stretching netting over an entire block of plants. To prevent birds from entering packinghouses, netting or some other type of barrier, should be placed over openings larger than 1/2 inch. In doorways where frequent pedestrian, vehicle, or machinery traffic occurs, hang heavy plastic or rubber strips, or install self-closing doors to prevent birds from accessing the building.

Repellents can be used to mitigate bird damage. Methyl anthranilate, the primary ingredient of artificial grape flavoring, is registered by EPA for use as a bird repellent for certain species. However, methyl anthranilate remains viable for only short periods of time as it loses efficacy quickly when exposed to UV radiation and weathering. Sucrose solutions may be applied to fruits to deter birds, but the efficacy of this method is not well documented and actually may attract other pests, such as Japanese beetles.

Scare tactics have been shown to be effective only for relatively short-term protection of vegetable crops. Blackbirds are intelligent animals and quickly will habituate to repetitive or predictable patterns and disturbances. Frightening methods must be changed and/or relocated often to maintain the desired effect. Frightening devices include both visual and auditory deterrents. Pyrotechnics (*e.g.*, propane cannons and shotguns), Mylar balloons and tape, raptor-shaped kites, scarecrows, flashing lights, water sprayers, and tape-recorded bird-distress calls or predator attack calls all represent examples of harassing techniques, but success of these devices varies substantially.

In general, scare tactics should be activated early to mid-morning and mid- to late afternoon, when birds are most active. For maximum effectiveness, it is best to use two or more devices in combination with each other, vary the times and places they are employed, and be persistent.

Chemical frightening agents mixed into bait piles may be applicable in specific situations. Birds that ingest the treated bait fly in an erratic fashion, produce distress calls, and usually die. This unusual behavior triggers an alarm response among the remaining birds in the flock, causing them to vacate the area. Dead birds should be collected and disposed of properly. NOTE: use of such chemicals typically is restricted only to certified applicators (usually representatives of USDA APHIS-WS), so check with your local pesticide program agent about the legality and possibility of employing chemical frightening agents on your farm.

Miscellaneous notes: Some states allow growers to shoot crows that are in the act of damaging crops, but this may not be universal in all states. Also, European starlings, House Sparrows, and Common Pigeons (Rock Doves) are considered non-native species and thus do not have protection under migratory bird laws. Therefore, farmers are allowed to shoot these species without need for any permit or further authorization, but it is recommended that farmers alert their municipality and/or neighbors to avoid negative consequences from the public.

Deer

Deer damage may occur in the form of feeding, antler rubs, and/or trampling of crops. Deer browsing (feeding) damage can be recognized by a torn, jagged appearance on vegetation or a ragged break on woody material. Most browsing damage occurs from ground level and up to 6 ft. Residual damage may occur from the trampling or matting down of vegetation as deer travel through crop fields or bed down to rest. Antler rub damage, which occurs as males shed the velvet from their antlers each autumn, can be identified as scarred saplings, broken limbs, bruised bark, and/or exposed wood. Rubs usually are located on the trunks of trees up to 3 ft above ground level.

An effective deer management strategy should incorporate several alternatives, considering the full suite of available husbandry, non-lethal, and, where warranted, lethal options. Recognize that each method carries with it both benefits and drawbacks; therefore, an accurate assessment of management needs and likely outcomes is critical.

Habitat modification is a form of husbandry that involves changing the landscape to make an area less attractive to deer. White-tailed deer are creatures of edges; they prefer habitats where two or more vegetation types or age classes meet. Habitat modification usually involves eliminating vegetation, planting non-palatable (“deer-resistant”) species, or creating cover or foraging areas to attract deer away from managed areas. Although these strategies have been used in an attempt to reduce incidences of deer-vehicle collisions and browsing on residential vegetation and commercial landscaping, habitat manipulation alone is unlikely to produce significant reduction in damage.

Harassment or scare tactics are intended to persuade deer to leave an area where they are not desired. Examples of scare techniques include dogs, auditory deterrents, such as propane cannons and sonic devices, and visual deterrents, such as bright lights. Although audio and visual deterrents are used more often on farms, dogs contained within invisible fencing have brought some success on farms, depending on the number and aggressiveness of dogs relative to the size of the area needing protection. Dogs tied to chains or ropes are not effective because deer can detect that the dog’s movement is restricted. Hazing campaigns generally are better suited for areas where damage from deer is minor or where other strategies may be prohibited (*e.g.*, hunting).

Fencing can be an effective management tool for eliminating or reducing deer damage and, in some cases, may be the preferred damage abatement option. When attempting to protect large areas, permanent high-tensile wire (HTW) fences are recommended. These fences consist of a series of electrified smooth wires spaced about 8 inches apart and extend about 10 ft. in height. HTW fences are durable and long-lived, but do require periodic maintenance and monitoring to assure maximum cost-effectiveness. Temporary HTW electric fencing or fences that use polytape strands are other alternatives, usually best suited to smaller acreages or where protection is needed for only a short, but critical, period of time. When using any form of electrified fencing, the unit should be charged at all times to prevent deer from becoming habituated to it and gaining confidence by testing it during down times. Electric fences that have been baited with an attractant (for example peanut butter) demonstrate noticeable enhanced success over non-baited fences, as deer are more likely to develop an immediate association between the fence and its negative consequence when drawn in by baiting. The addition of cloth strips, flagging, and reflectors certainly increases visibility, but have displayed only marginal improvement in efficacy over fences lacking such visual cues. Although other fencing alternatives exist, such as double-barrier fencing (2 rows of fence placed approximately 4 ft apart), heavy plastic fencing, and strands of monofilament line decorated with flagging tape streamers, none provide the level of protection or cost-effectiveness of a well-designed and properly installed and maintained electric HTW fence. It is important to note that no type of HTW fence will eliminate all penetration by deer. If complete and absolute protection from deer is desired, the only fence design that can guarantee that outcome is a 10 foot tall (minimum) woven wire fence. However, in most situations, producers typically cannot justify the costs of procurement and installation of such a fencing system.

Repellents produce tastes, odors, or a combination of taste and odor that animals find offensive and thus encourage deer to avoid the area being protected. There are 2 types of repellents: contact repellents and area repellents. Contact repellents are applied directly to vegetation or objects via spray, shakable powder, or brush. Area repellents are applied in the general vicinity of the protected object and repel primarily by odor. Repellents can be expensive, based on initial cost of materials, but more so by the need for frequent reapplication. Rain can wash repellent off vegetation, even if a "sticker" is used. The attractiveness of the food resource to deer, the density of deer in the area, and the availability of other natural foods in the area all influence effectiveness. Many repellents are labeled for use only on dormant vegetation or on non-consumable products, so growers must be sure to follow the manufacturer's instructions. Repellents used during the growing season must be applied as new plant growth emerges to assure maximum effectiveness. Regardless of the type of repellent used, all repellents are intended to reduce, rather than eliminate, deer damage; repellents should be used in conjunction with other damage abatement techniques to maximize overall success.

Reproductive abatement: Although there is great interest in and much research being conducted on the use of contraceptives (chemicals given to female deer to disrupt reproductive behaviors), only specially trained wildlife professionals are permitted to administer this treatment (typically through use of a dart gun). To date, no effective reduction in population numbers, and thus a concurrent reduction in damage, has been achieved using contraceptives in free-roaming populations of deer. Success has been realized only in isolated contained populations where access to nearly all members of the population can be attained (*e.g.*, on islands, in confined city parks, etc.). This is a labor-intensive and costly strategy, and because individuals consistently move into and out of a population, it is extremely difficult to treat a sufficient number of individuals or to know which individuals already may have been treated. Research to improve fertility control methods is ongoing.

Trap and transfer involves trapping deer in a specific area and physically moving them to another location. There are several techniques for trapping deer, including box traps, Clover traps, netted cage traps, drive nets, drop nets, rocket nets, corral traps, net guns, and immobilization drugs delivered through a dart. This strategy is labor-intensive, costly, and impractical at large scales due to poor survival of translocated individuals, a lack of suitable relocation sites, and the risk of spreading disease. Most states ban the translocation of deer due to concern about the spread of disease and the potential for injury to trapped animals. **This practice may not be permitted in some jurisdictions (*e.g.*, Virginia). Consult your local Wildlife Management Authority.**

Trap and euthanasia involves trapping deer and euthanizing the animal according to methods approved by the American Veterinary Medical Association. Deer are baited to a trap site and captured using box traps, Clover traps, drop nets, or rocket nets. Once captured, deer are anesthetized and immobilized prior to euthanasia. Trap and euthanasia methods are labor intensive and more expensive than other management strategies. **This practice may not be permitted in some jurisdictions (*e.g.*, Virginia). Consult your local Wildlife Management Authority.**

Because deer populations range over multiple parcels or farms, management of deer numbers often cannot be implemented effectively on a single property. Research clearly indicates that greater success in attaining population objectives can be achieved by developing and implementing a comprehensive **Community-Based Deer Management Program**, especially in environments where traditional management methods are not an option. Under this program, the state Fish and Wildlife authority cooperates with municipal, county, and, if applicable, other federal agencies to provide technical assistance in developing alternative deer management options. Some options include employing sharpshooting, noise-suppressed firearms, and methods that otherwise might not be allowed under traditional hunting approaches. State authorities can issue permits to conduct special deer management in areas where regulated hunting is not possible or deemed safe. **This practice may not be permitted in some jurisdictions. Consult your local Wildlife Management Authority.**

Regulated hunting involves the use of hunters to harvest deer in accordance with defined seasons, bag limits, and population objectives. Hunting legally takes place during any of the various deer hunting seasons (archery, muzzleloaders, shotguns, and general firearms) established by the state Fish and Wildlife authority. Regulated hunting is the most cost-effective and efficient method to manage deer populations and is the only means to manipulate deer numbers statewide. See your state Fish and Wildlife authority for details on when the regulated season is open.

Permits to Shoot, commonly referred to as a "Depredation Permit" or "Kill Permit," are issued by the state

Fish and Wildlife authority to owners or lessees of land who are experiencing crop damage. These special permits are highly variable among jurisdictions, but, where available, allow growers a mechanism to manage damage situations during times of the year when the regulated hunting season is closed and "take" normally would not be allowed. Depredation permits can help regulate local deer populations, particularly in areas that receive only limited hunting pressure (*i.e.*, farms surrounded by residential properties). For more information or to apply for a depredation permit, contact your state Fish and Wildlife authority.

Controlled hunts combine conventional deer hunting methods with more stringent controls and restrictions on hunter activities. Participants in controlled hunts are chosen by various methods, ranging from selection by random lottery of interested licensed hunters to a more rigorous process involving assessment of hunting skill and weapon proficiency. Specific restrictions and controls applied to hunting activities depend upon the needs and concerns of landowners, elected officials, and other stakeholders, but usually will be similar to hunting regulations imposed during the normal deer hunting season.

Feral Hogs

The appearance of feral hogs on the landscape is an unfamiliar threat that many commodity producers have never experienced before. New populations of hogs are appearing and spreading rapidly and may prove to be one of the most serious vertebrate threats producers will face. Whether from direct foraging or rooting behavior, the amount of damage inflicted can be extensive and devastating in a short period of time, depending on the size of the sounder (*i.e.*, the family or social grouping) that takes up residence in the area.

Being an introduced, non-native species, the feral hog has no protection under wildlife or game laws, so hogs theoretically may be taken by legal methods at any time. However, it sometimes can be difficult to distinguish true feral animals from domestic swine that recently may have escaped and still constitute the swine owner's property. Thus, in some states, population management and damage mitigation has become complicated by questions of ownership and the legalities related to the take of property - caution is urged before any hog removal action is implemented.

That said, growers confronted by the presence of feral hogs immediately should contact the USDA-APHIS Wildlife Services Office that serves their state and request assistance in devising an effective hog eradication plan. Trap and bait techniques currently have proven to be the most reliable and successful approach to manage hog populations, but such operations take time and persistence to achieve the desired outcome. Shooting alone often proves ineffective in that only a small number of members of a hog social group can be taken at once and those that escape quickly learn to avoid hunters in the future. Although on-going research on potential toxicants has been encouraging, registration of an approved material remains years away. At this time, keen observation and attentiveness to the first sign of hog presence is imperative to stay ahead of the threat.

Groundhogs

The most obvious signs of groundhog presence, aside from actually seeing the animal, are the entrances to a groundhog burrow system. Groundhog burrow systems are characterized by a large mound of excavated earth at the main entrance. The diameter of the main entrance may measure 10-12 inches. There are usually 2 or more additional entrances to a burrow system, and the secondary entrances usually will be well hidden. Although groundhogs prefer leafy vegetable crops, they will utilize many different crops throughout the growing season. Seasonal or cyclic reproductive patterns may influence groundhog abundance and the extent of damage.

Habitat modification is not a feasible strategy for minimizing groundhog damage.

Exclusion with fencing can be an effective short- or long-term strategy, depending on the type of fence and the size of the area to be protected. An electric wire placed 3-4" above the ground can deter groundhogs from entering a protected area. However, a determined groundhog eventually will dig under the wire and gain access to the area.

Woven mesh or chicken wire fencing provides a more permanent solution. Mesh openings should be ≤ 2.5 inches, and the fence should extend at least 3 ft. above the ground. The top 15 inches of the fence should extend backward at a 45^{o} angle to prevent individuals from climbing over the top. To prevent groundhogs from digging under the fence, the bottom edge of the fence should be buried at least 10 inches beneath the ground, with an additional 6-8" section bent outward at the bottom of the trench. Groundhogs are excellent climbers, so fence posts should be placed on the inside of the fence and greater deterrence has been achieved where the fence material is not drawn taut or rigid, but instead left somewhat loose.

Fumigants are effective in reducing groundhogs. Gas cartridges (sodium nitrate) currently are registered for this purpose. Ignited gas cartridges are placed in the burrow system after all but the primary entrance are sealed. As the cartridge burns, thick fumes are emitted and fill the burrow system. Burrows can be treated with gas anytime of the year, but this method is most effective in the spring before the first litter of young emerges. Gas cartridges are a General Use Pesticide (GUP) and can be purchased at most farm supply stores. A note of caution when using gas cartridges – because the gas cartridge must be ignited for proper use, a fire hazard does exist. Therefore, gas cartridges should not be used in burrows located under wooden sheds, buildings, or near combustible materials. New resident animals may recolonize an empty or recently vacated burrow system, so continued vigilance is recommended.

Aluminum phosphide tablets, placed deep inside the main burrow entrance, are another type of fumigant that can provide effective groundhog control. The tablets react with the moisture in the soil, creating hydrogen phosphide gas. Soil moisture and tightly sealed burrow entrances are important for the fumigant to be used effectively. The tablets are approved for outdoor use on non-cropland and orchards. Aluminum phosphide should not be used within 15 ft of any occupied building or in areas where gas could escape into areas occupied by animals or humans. Aluminum phosphide is a Restricted Use Pesticide (RUP) and can be applied only by a certified pesticide applicator.

Trapping is effective in removing particularly problematic individuals. However, new groundhogs from the surrounding area quickly will reoccupy the territory. Steel leghold traps are illegal in some states, so check with your state wildlife agency to determine what is legal. However, a medium-sized live trap baited with a variety of baits (*e.g.*, lettuce, apples or plum tomatoes) can attract a groundhog's attention if placed close to the burrow entrance. Traps should be placed at main entrances or along major travel corridors and checked at least once every 24 hours. Once captured, the groundhog may be killed humanely or released elsewhere on the property. If the groundhog is to be released, some states regulate where and how the live animal is handled. No releases are allowed on federal, state, county, or municipal land. **This practice may not be permitted in some jurisdictions (*e.g.*, Virginia). Consult your local Wildlife Management Authority.**

Shooting groundhogs that are damaging crops or farmland is approved at any time of the year. Although groundhogs are considered a game species in some states (it is a "nuisance species" in VA), farmers do not need a valid hunting license to shoot nuisance groundhogs on their own property. Growers should verify with the state wildlife agency which weapons are legal for this purpose in your state.

Rabbits

Rabbits can damage vegetation by clipping branches, stems, and buds. Damage may become especially pronounced during periods of heavy snow or in the spring when plants are emerging from the ground. Vegetation that has been clipped by rabbits is characterized by a cleanly snipped, 45^{o} angle cut at the point of damage. Rabbit tracks and their pelleted scat often are found in areas of recent damage.

Growers should adopt **cultural practices** and conduct **habitat modification** to maintain well-groomed plots and eliminate brush piles, heavy vegetation, and other cover in and adjacent to crop production sites that serve as nesting and hiding sites. However, removal of such cover may be detrimental to other desirable wildlife species that also depend on brush piles for protection or shelter. Habitat modification techniques that enhance the success of rabbit predators (*i.e.*, fox, coyote, and raptors) will help regulate rabbit numbers. Planting alternative crops in adjacent tracts has been suggested as a means to deter rabbits from high-value crops, but this approach typically serves to attract or support higher numbers of rabbits.

Exclusion of rabbits through use of fencing can be effective. A 2-foot high fence consisting of 1-inch or smaller mesh and constructed of any metal (rabbits will gnaw through plastic) will eliminate most rabbit damage. To prevent rabbits from accessing snow-covered fields, consider increasing the height of the fence to accommodate the effect of deep snow. The bottom of the fence should be buried 12 inches in the ground and bent outward away from the crops at a 90^{o} angle. Larger areas can be protected with "hot" double-strand electric fencing, with the lower strand set close to the ground (*i.e*., within 2-3 inches) and the second strand 2-4 inches above.

Rabbit guards made of metal wire with ¼- to ¾-inch mesh may be effective in protecting individual high value specimens. Hardware cloth can also be used. Rabbit guards should be placed 1-2 inches away from the plant. Do not allow debris to accumulate inside these screen guards as this creates an ideal environment for borer infestation and may attract voles. All guards should be anchored to the ground.

Miscellaneous methods: Harassment techniques, such as dogs and motion detector activated water sprayers, provide only short-term protection. Contact (*e.g.*, thiram-based) and area (*e.g.*, naphthalene) repellents have been used for rabbit control with variable effectiveness; however, most rabbit repellents are not approved for use on foods grown for human consumption, so check the active ingredients of any product before use. Rabbits are classified as a game species and, as such, can be hunted during open rabbit seasons. Finally, trapping rabbits may be a viable option if damage is not too extensive. Consult the state Wildlife agency prior to implementing any hunting or trapping program to assure compliance with existing regulations.

Voles

It is important to determine which species of vole occurs in your crop production sites. Vole species most commonly associated with depredation issues in the Mid-Atlantic region are the **meadow vole** (*Microtus pennsylvanicus*) and the **woodland vole** (*Microtus pinetorum*). Meadow voles, also called meadow mice, are about 5½ to 7½ inches long, with fur that ranges from gray to yellow-brown with black-tipped hairs; they also display a bi-colored tail. Woodland voles are about 4-6 inches long, have red-brown fur, and a tail about the same length as the hind foot. Vole populations are cyclic, where cycle peaks last approximately 1 year before the population abruptly crashes. It is during these peak times where the potential for significant crop damage is greatest.

Because voles remain active year-round, the damage they cause to crops can occur at any time, depending upon the crop. In vegetable crops, damage usually occurs in spring, as young plants are emerging. Voles are generalist herbivores, so they feed on roots, shoots, tubers, leaves, and seeds of many different plants. Meadow voles spend much more time above ground than do woodland voles, but both species inflict serious damage by feeding on the subsurface root systems of plants. Above ground damage frequently consists of their gnawing on woody perennial plants, sprouts, and suckers that emerge from the base of such plants. Meadow voles construct surface runways (approx. 1½ to 2 inches wide) under or within the accumulated organic matter and duff layer that exists in fields; these runs often terminate at a 1" diameter wide hole that drops into an underground burrow network. In contrast, pine voles remain underground and inflict damage in the form of root girdling, which often goes unnoticed until severe damage already has occurred and the plant is in rapid decline. Both species are known for constructing burrows that follow trickle irrigation lines or areas where the soil has been loosened by mechanical planters.

Cultural practices and habitat modification measures are helpful in deterring vole populations. Voles avoid areas with few food resources and little protective cover. Control of ground vegetation with herbicides, mowers, or disking is effective, although voles will travel under snow cover in these areas. Herbicides are the preferred method to eliminate sod. Cultural practices that reduce the amount of organic litter around plants are essential. All areas should be kept clear of debris, stored objects (such as bags, boxes, pruned branches) because these items provide protection to voles and can hinder mowing and proper bait placement. Plastic or synthetic weed barriers will encourage the establishment of vole populations, so use of these materials should be avoided. A final close mowing of the row middles, after harvest, should be utilized annually to further reduce habitat and cover for rodents and to enhance the effectiveness of natural predators (such as hawks and owls).

Exclusion methods are feasible only at small scales and to protect high-value crops. Hardware cloth or woven wire fences (≤ ¼ inch) can be installed to a height of 1 ft above ground and buried to completely contain the rooting system of the plant. There are some newer products composed of sharp-edged rock or pumice granules that can be used to line the planting hole and will act much like a barrier against digging. This requires significant hand installation, so an analysis of cost-effectiveness is necessary before considering such methods.

Repellents that contain predator urine (coyote and fox) have demonstrated limited effectiveness in reducing vole numbers, primarily through the effects of stress on production rates. However, repellents are expensive and offer only short-term relief from damage. Repellents that contain thiram and capsaicin are not approved for use on plants grown for human consumption.

Trapping may be useful only where vole damage is localized (<1 acre). Place snap traps perpendicular to the runway with triggers in the runway at a frequency of 2 to 3 traps per runway. All traps should be covered by a weighted box or pail to prevent non-target captures. Multiple-catch mouse traps also have been used to trap voles. Because the trap holds multiple individuals, fewer traps are necessary. In addition, non-target animals can be released unharmed. Bait multiple-catch trap entrance points with seed. If a trap is unsuccessful for 2 consecutive nights, move the trap to another location.

Toxicants are used to control large vole populations and most are classified as Restricted Use Pesticides (RUP); these products can be applied only by a pesticide applicator who possesses both a general applicator certification and the advanced certification for vertebrate application (Category 7D). In most cases, voles must feed on treated baits multiple times to sustain a lethal dose. Therefore, bait stations must be stocked and maintained to ensure success.

Zinc phosphide is a single-dose RUP available as a concentrate or in pelleted or grain bait applications. Because of its noticeable garlic odor and taste, voles eventually may shy away from or avoid bait stations stocked with ZP. Pre-baiting stations with untreated food for 2 to 3 days prior to applying the pesticide may increase success.

Anticoagulants may also be effective in controlling vole damage. However, anticoagulant baits are slow acting and may take up to 15 days to be successful. Furthermore, most anticoagulants require more than one feeding for maximum effectiveness.

To avoid danger to non-target species, the use of bait stations is recommended and may be required in some states. Broadcasting bait across the ground surface, or placing bait in piles on bare soil, is not allowed. Placing bait beneath asphalt shingles or tires cut in half and used as bait stations may be an acceptable practice under some state Pesticide Laws. However, bait rarely stays dry and can lose efficacy when coming in contact with moist soil. In-furrow placement of zinc phosphide pellets is recommended for corn and soybeans under a no-till management system. Hand placement of baits directly in enclosed runways and burrow openings within the tree drip line is essential for woodland vole control because of their subterranean behavior.

To ensure the legality of a particular toxicant in your state, information can be obtained by calling your Pesticide Control Program. As with all use of toxicant products, follow the product's labeling guidelines.

12. Pollination

Seed and fruit production in many vegetable crops is dependent on pollen transfer within or between flowers. In most cases, pollen transfer is accomplished by insects such as bees or flies, and it is often beneficial to release pollinating insects into the crop during the flowering stage to achieve desirable fruit set and mature quality. Some crops like cucurbits require multiple pollination events for normal fruit development. The size and shape of a mature fruit is usually related to the number of seeds, and each seed is the result of a pollination event. Generally, as the number of bee visits increases there will be an increase in fruit set, number of seeds per fruit, fruit weight, and improved fruit shape. In strawberries, sufficient pollination also results in fruits with a longer shelf life and better color. Delay in pollination affects the timing of fruit set, and lack of adequate pollination usually results in small or misshapen fruit in addition to low yields. Even some crops that are capable of self-pollination (*e.g*., eggplant, lima beans, okra, peppers) often benefit from pollen transfer by insects.

Integrated Crop Pollination

Bees are the most important group of insects for crop pollination. Today's approach integrates managed and wild bee species. More information is available in several resources, see (numbers refer to web sites listed below): "What is Integrated Crop Pollination[1]", "The Integrated Crop Pollination Project[2,3]", "Integrated Crop Pollination for Squashes, Pumpkins and Gourds[4]", "Ensuring Pumpkin Pollination[5]", and the Penn State College of Agricultural Sciences Center for Pollinator Research[6,7]. **All states are developing pollinator protection plans (Table A-3).**

[1]*https://www.youtube.com/watch?v=yMP5dTDRi6g&index=10&list=UUN0Z_G59MEi7IW4e1IfvkgA*

[2]*http://icpbees.org/tools-for-growers/* and [3]*http://icpbees.org/home/videos/#Webinars*

[4]*http://icpbees.org/wp-content/uploads/2014/05/Integrated-Crop-Pollination-for-Cucurbita-crops.pdf*

[5]*https://www.youtube.com/watch?time_continue=26&v=liI63L7oBQQ*

[6]*http://ento.psu.edu/pollinators* and [7]*http://ento.psu.edu/pollinators/information-for-growers*

European honey bees (*Apis mellifera*) and commercial bumble bees are most used for managed pollination services because they can be moved. Populations of wild bees can also be important for vegetable pollination. Wild bees include bumble bees (*Bombus* species), the squash bee (*Peponapis pruinosa*), orchard bees (*Osmia* species), and many species of solitary bees most of which nest in soil. Surveys of wild bees reveals over 500 species in the mid-Atlantic U.S., but not all will necessarily be visiting any given crop. The community of managed or wild bees visiting a crop varies among crops and can be influenced by other flowering plants competing for these same bees.

Activity of managed or wild bees on crop flowers at the correct time will greatly enhance pollination. Individual cucurbit and strawberry flowers are usually open and attractive to bees for a day or less. The opening of the flower, release of pollen, and commencement of nectar secretion normally precede bee activity, and the timing is coordinated with receptivity of the stigma. Pumpkin, squash, and watermelon flowers normally open around daybreak and close by noon, whereas cucumber, strawberry, and muskmelon flowers generally remain open the entire day. Pollination usually takes place on the day the flowers open due to the short periods of pollen viability and stigmatic receptivity.

Activity and behavior varies with the species of pollinator. Bumble bees are active over a wide range of weather conditions and can tolerate foraging in cooler temperatures. Honey bee activity is determined to a great extent by weather and conditions outside the hive. Honey bees rarely leave the hive when the outside temperature is below

55°F (13°C). Flights seldom intensify until the temperature reaches 70°F (21°C). Wind speed in excess of 15 mph seriously impedes bee activity. Cool, cloudy weather and threatening storms greatly reduce honey bee flights. Squash bees are active soon after sunrise in July and August. Most of the feeding of female squash bees is completed by midmorning (9 or 10 AM) after which they return to their nests in the soil. Male squash bees will continue to feed on flowers for a longer time frame, often overnight.

Populations of wild bee species vary in their abundance from year to year. Regular pesticide applications may reduce the abundance and diversity of these pollinators, and some agricultural practices such as tillage may destroy wild bees that nest in the soil. The implementation of conservation tillage practices may reduce nest damage.

Table A-3. State Pollinator Protection Plans

The state regulatory agency, state apiarist (with e-mail address) and the web link to the managed pollinator protection plan made available by each state agency. New Jersey has recognized previous pollinator protection measures that can be found on the bee inspection site linked below.

Delaware Dept. of Agriculture, **Meghan McConnell** (*meghan.mcConnell@state.de.us*), *https://agriculture.delaware.gov/wp-content/uploads/sites/108/2017/12/DelawarePollinatorPlan2016.pdf*
Maryland Dept. of Agriculture, **Cybil Preston** (*cybil.preston@maryland.gov*), *https://mda.maryland.gov/plants-pests/Documents/MP3-Pollinator-Plan.pdf*
New Jersey Dept. of Agriculture, **Tim Schuler** (*tim.schuler@ag.state.nj.us*), *https://www.nj.gov/agriculture/divisions/pi/prog/beeinspection.html*
Pennsylvania Dept. of Agriculture, **Karen Roccasecca** (*kroccasecca@pa.gov*), *https://ento.psu.edu/pollinators/publications/p4-introduction*
Virginia Dept. of Agriculture and Consumer Services, **Keith Tignor** (*keith.tignor@vdacs.virginia.gov*), *http://www.vdacs.virginia.gov/pdf/BMP-plan.pdf*
West Virginia Dept. of Agriculture, **Wade Stiltner** (*wstiltner@wvda.us*), *https://agriculture.wv.gov/SiteCollectionDocuments/WVPollinator.pdf*

Commercially Available Honey Bees

For crops readily visited by honey bees, the most reliable way to ensure pollination is to own or rent strong colonies of European honey bees from a reliable beekeeper. European honey bees are the primary managed pollinators because colonies with large populations can be easily moved to the field each year. With the arrival of parasitic honey bee mites (mainly *Varroa destructor*) along with likely impacts of pathogens, insecticides, and fungicides, the numbers of overwintering European honey bee colonies has significantly decreased in the last 20 years. Abundant colonies of feral honey bees (wild colonies nesting in trees or other cavities) are now uncommon to rare in most areas, and beekeepers are losing large numbers of colonies to mites, disease, and other stress factors. As a result, fewer beekeepers are providing honey bee colonies for pollination services, and some colonies may be of marginal quality for pollination. The Mid-Atlantic Apiculture Research and Extension Consortium is a regional group focused on addressing the crisis facing the beekeeping industry (*https://agdev.anr.udel.edu/maarec/about/contact-2/)*. Additional relevant websites are the Bee Informed Partnership (*https://beeinformed.org/*), the Center for Pollinator Research (*http://ento.psu.edu/pollinators*), and the Honey Bee Health Coalition (*https://honeybeehealthcoalition.org/*).

A brief introduction to best management practices for honeybees can be found at *https://ento.psu.edu/pollinators/publications/p4-best-practices-for-beekeepers/view*. Best practices include: (1) Locating colonies in areas with sufficient flower forage and protected from exposure to sunlight (an east or southeast hive entrance encourages bee flights); (2) Elevating the colony to have the front entrance free of grass and weeds; (3) Allowing a clean water supply within a quarter mile of the hive.

The number of colonies per acre for adequate pollination varies with location, attractiveness of the crop, density of flowers, and length of blooming period, colony strength, and competitive plants in the area. In vine crops and strawberries, recommendations are 1 to 2 colonies per acre, with more hives required for higher density plantings.

To ensure adequate quality and numbers of honey bee colonies, growers should:

- **Contact beekeepers early**. Colonies may be in short supply. If you do not have a past relationship, make initial contact with the beekeeper the previous fall. Beekeepers usually assess the survival and strength of their colonies from mid-February to mid-March. **Requests for hive relocation should be given 48 hours or more in advance.**

Some states have employed a hive registration program or an online registration tool that can help applicators locate and contact nearby beekeepers. Check with the appropriate agency in your state, or contact you state apiarist for more information (Table A-3).

- **Have a written and signed contract between the grower and the beekeeper.** This will ensure that enough pollinators are provided and that beekeepers are protected from pest control practices that may injure bees. The contract should specify the number and strength of colonies, rental fee, time of delivery, and distribution of bees in the field, as well as a plan to manage weeds that may act as competitive bloom. A sample contract is at *http://edis.ifas.ufl.edu/aa169*.
- **Obtain an adequate number of colonies**. This varies among crops, location, attractiveness of the crop, density of the flowers, length of the blooming period, colony strength, and competitive plants in the area. A rule of thumb is to start with one colony per acre and make adjustments from there. Areas well populated with wild bees will not need as many rented honey bee hives.
- **Obtain bees at the appropriate time**. For melons, cucumbers, squash and strawberries, honey bees should be moved in when the crop is flowering adequately to attract bees. Competing food sources from other flowers (*e.g.*, dandelions), should be eliminated by mowing, cultivation, or herbicides (prior to bees being moved there).
- **Locate colonies for maximum effect**. Place colonies in groups of 4 to 8 in favorable locations throughout the farm or field to provide an even distribution of the bees. In large fields, pollination is effective if groups of 10 to 20 hives are distributed in sunny, wind-protected spots. Bales of straw or packing boxes stacked behind colonies offer wind protection. Be aware of the pollination requirements of your specific varieties. Some varieties may require “pollenizers” (sources of viable pollen for sterile varieties) to achieve adequate fruit set. Bees must be located to that they will encounter the pollenizers and carry their viable pollen to the production varieties.
- **Rent honey bee colonies that are healthy and contain a large enough population to do the job**. Packaged bees (bees purchased through the mail) and small hives are inferior to strong, overwintered colonies. Two weak colonies are not equal to one strong colony. However, in some areas colony loss has been so high that it may not be realistic to exclusively rely on overwintered colonies for pollination services. More information is available at: *https://agdev.anr.udel.edu/maarec/about/contact-2/*.
- **Consider the use of bee attractants**. Sugar-based attractant sprays are generally ineffective. Bees collect the sugar off the leaves, usually without visiting flowers. Although this brings more bees into the field, supplemented pollination does not necessarily occur, and the sugar may serve as a medium for sooty molds. Other attractants containing bee derived communication pheromones, such as geraniol, have proven more successful, but further testing is needed. One of the most promising attractants, “Fruit Boost”, contains honey bee queen mandibular pheromone. U.S. distributors of “Fruit Boost” are in the Pacific Northwest. For more information, contact Phero Tech, Inc., 7572 Progress Way Delta, BC, Canada V4G 1E9; phone: 604-940-9944; fax: 604-940-9433.

Honeybee colony size and strength can be assessed in several ways:

1. Inspect hives: This method is most time-consuming, but also most accurate. Colonies used for springtime pollination should have at least: a laying queen, 1½ or 2 stories (hive bodies or boxes) and 4 to 6 frames of brood, and enough adult bees to cover 6 to 8 frames. These are minimum requirements. Stronger colonies with larger populations make superior pollination units and may command a higher price. As these stronger colonies are opened, bees will “boil out” or cover the tops of the frames. When smoked, however, the bees move down onto the frames and may not cover the frame tops. In this case, the frames themselves should be covered with bees. Note that there will be some variability in the quality of the colonies you rent. As a general rule, a group of colonies where 10% fall below the minimum standard is acceptable if also 10% are above the minimum standard. Also, for a variety of reasons, some colonies may become queenless for a time; however, if these colonies meet all the other minimum requirements they still will be effective pollination units.

You can request hives to be inspected. In most states this is a general requirement for sale, and interstate transport. In Pennsylvania, The PA Department of Agriculture Apiary Inspection Service runs a hive evaluation program for colonies used for pollination. Requests may be made by either the grower or the beekeeper and should be arranged through the state apiarist at the PDA Bureau of Plant Industry, 2301 North Cameron Street, Harrisburg, PA 17110; phone 717-772-5225. Requests should be made as early as possible to facilitate scheduling. The beekeeper will be informed if an evaluation is requested by the grower. Colonies are inspected to determine the colony size (number of supers), the presence of a laying queen, the number of frames of brood and adult bees, and the presence of disease and parasites. At least 10% of the colonies in an apiary, or a minimum of 5 colonies, are selected at random for inspection. Inspected colonies are identified by sticker. If selected colonies are banded or stapled, these are not refastened by the inspector. A copy of the evaluation report is given to both the grower and the beekeeper.

2. Assess traffic at hive entrance: This method is less time-consuming but also less accurate. On a calm, warm (70-80˚F, 21-27°C) day between 11 AM and 3 PM, bee traffic at hive entrances should be heavy. During a one-minute observation period, strong colonies should have 50-100 or more bees arriving and leaving the hive. Bees also should be seen arriving with pollen pellets on their back legs. In weak colonies, fewer than 40 bees will be seen arriving and leaving per minute. Colonies that are being used for summer pollination should have heavier traffic at the hive entrance.

Another crude way to assess colony strength is to observe entrances when temperatures are cool (55-60˚F, 13-16°C). In strong colonies, flights will be observed at these cool temperatures, but in weaker colonies bees rarely fly when temperatures are below 60°F. Honeybees very rarely fly when the temperature is below 55°F.

3. Assess bee density on the crop: This method allows you to assess the contribution of feral or other honeybee colonies in the area in addition to rented bees. If you are using rented colonies, however, this method tells you little about the quality of the bees. We suggest that if you use this technique and find that the number of bees on the crop is small, you then use options (1) or (2) to assess colony strength before renting additional bees.

4 Additional information: The following publications are available from the Mid-Atlantic Apiculture Research and Extension Consortium:

- Beekeeping Basics
- Beekeeping Topics: Sources of Bees for Pollination in Pennsylvania, Bees and Insecticides, Pollination Contracts, Basic Biology and Management of the Japanese Hornfaced Bee

Other sources of information for bee guides in your area are:

- State of NJ Department of Agriculture at: *http://www.state.nj.us/agriculture/divisions/pi/*
- The Virginia Fruit Web site at: *http://www.virginiafruit.ento.vt.edu/VAFS-bees.html*
- NCAT - ATTRA Sustainable Agriculture at: *https://attra.ncat.org/attra-pub/summaries/summary.php?pub=76*
- Farm Management for Native Bees, A Guide for Delaware at: *https://agriculture.delaware.gov/wp-content/uploads/sites/108/2017/12/FarmManagementforNativeBees-AGuideforDelaware.pdf*

Commercially Available Bumble Bees

Common Eastern bumble bee (*Bombus impatiens*) colonies may be purchased commercially to use as pollinators in vegetables and small fruits. The behavior, physiology and morphology of bumble bees make them ideal pollinators because of the speed at which they transfer pollen, the efficiency with which they gather pollen within various crops, and their ability to fly in adverse weather for longer periods of time. Bumble bees can also “buzz” pollinate, vibrating their wing muscles at a frequency that dislodges pollen from the flower, a technique not seen in honey bees. Due to their robust body size bumble bees begin foraging earlier and end later in the day and at lower temperatures. Bumble bees are effective in greenhouse and high tunnel settings to pollinate tomatoes and strawberries. They also have been successfully used for field pollination in blueberries and watermelon. However, in pumpkins, efforts to increase pollination by adding commercial bumble bee colonies is not always successful, perhaps due to the presence of adequate wild bee (wild bumble bee or squash bee) populations.

Place bumble bee colonies in the field after crops have begun to bloom. Bees that have found unintended forage in the beginning of the season are likely to continue to forage on this unintended source, especially if it is more favorable than the intended crop.

Follow instructions provided by the supplier. Give the allotted time before opening up the colonies for the first time. Although bumble bees will need to excavate from natural enclosures in order to begin foraging, colonies should be given at least 30 minutes to settle after being handled during shipment and placement. Check each colony 2-3 hours later to ensure that the bees have successfully released and exited the nest. On occasion, bees are not released successfully and will need to be cut out.

Growers are urged to reduce each bumble bee colony entrance to one open hole at least two hours before each pesticide application. This will allow bumble bees to return to the hive and be kept in the colony to decrease exposure to pesticides. Bumble bees accumulate pesticides very easily within the wax and their bodies.

Place bumble bee colonies under shade to increase their productivity and longevity. Units placed in natural shade (along forest/field edges) or fitted with a shade structure last longer and are significantly more productive than those in full sunlight, especially during the warm summer months. Bumble bees constantly and actively strive to keep their colony temperature at around 86°F (30°C). Colonies exposed to direct sunlight use more energy for colony cooling.

Bumble bee colonies should be placed as far from honey bee hives as possible, especially when crops are not in bloom. When forage is low, colonies of pollinators should be more than 1 mile apart. Honey bees are very resourceful and a bumble bee colony is a great source of pollen and nectar. If surrounding forage is low or not agreeable to honey bees, bumble bees will be susceptible to honey bee pollen theft resulting in weakened honey and bumble bee colonies.

Bumble bees may be transferred to another field for additional pollination services throughout a season. Before moving, close the plastic opening tab to the one-hole open position. Allow forager bees at least two hours to return to the colony. The bumble bee colony may then be transferred to another site.

Follow the supplier's recommendations for number of hives to use in a particular crop. Commercial bumble bee hives live for of 6 to12 weeks and must be replaced each year.

Dispose of bumble bee colonies in a timely and humane fashion. There is a risk of commercial bees breeding with native populations. Commercial bumble bees are mass reared, and therefore have less genetic diversity than the wild bees. The genetic integrity of wild bees is important because it allows for adaptation to a wide variety of environmental conditions and various pathogens that they may encounter. Disposal of commercial colonies may also minimize potential transmission of pathogens.

Wild Bees

Many wild bees, including squash bees (*Peponapis pruinosa*), multiple bumble bee species (*Bombus* sp., predominantly *Bombus impatiens*), orchard bees (*Osmia* sp.) and an assortment of other solitary bees (sweat bees, mining bees) are excellent crop pollinators. In the mid-Atlantic regions, wild pollinators have provided sufficient pollination for small, diversified farms located in complex landscapes that include wood lots and unmanaged (fallow) lands in close proximity. The landscape can strongly influence bee populations through the availability of nesting substrates (open soil, fallen logs, abandoned rodent burrows). In diversified farmscapes with a history of growing cucurbits, bumble bees and/or squash bees have provided sufficient pollination to pumpkins regardless of whether managed commercial bees were present. Landscapes utilizing conservation tillage tend to have higher populations of squash bees, presumably due to less habitat disruption.

Availability of additional food resources in nearby wild lands or a diverse (flowering) cropping system can help support wild bee populations throughout the growing season. The USDA National Resources Conservation Service is building efforts to supplement farms with perennial plantings (pollinator strips) or cover cropping schemes designed to provide timely floral resources.

Wild bumble bees live in colonies founded by a queen. The workers, which are daughters of the queen, do the foraging, brood-rearing and defend the nest. New queen bumble bees (called gynes) emerge from their natal nest in late summer or autumn. Each gyne will mate, forage, and then hibernate through the winter in a small insulated cavity. In the spring the gyne will emerge and search for a larger cavity to establish her nest in such as an old rodent nest or beneath clumps of bunchgrass. Colonies will increase in numbers over the spring and summer, reaching a peak of 250-450 individuals (in *Bombus impatiens*) before producing new gynes and males. These new reproductive individuals will disperse and start the cycle over, while their natal colony dies out, leaving the gynes as the only carry-overs to the next year.

Most native bees do not live in groups like honey and bumble bees. Each female solitary bee establishes her own nest which may be located in the ground, an old beetle burrow in wood, or in a pithy stem (elderberry or brambles). Each female gathers pollen and nectar and feeds nest cells, making a pollen ball and laying a single egg in each cell. She repeats this process many times over the duration of her life and will die before her offspring mature. The offspring overwinter in the cell within the nest, emerging the following spring or summer. Female solitary bees are reliable pollinators, visiting many flowers in their lifetime.

Snags or brush piles, along with undisturbed tall grassy areas, provide nesting sites for tunnel-nesting bees and bumble bees. Hedgerows, shelterbelts, and windbreaks containing flowering trees and shrubs can provide nesting habitat for bees as well as food. Deep soil tillage can block or harm ground-nesting bees.

Bees can vary greatly in their foraging range depending on body size and resource availability. Large species like bumble bees can fly long distances, but probably forage within 1 to 3 miles from the colony. Most species stay closer to their nest, no farther than about 0.5 mile. When resources are plentiful, bees are more likely to forage over shorter distances. It may be advantageous to manage farmscapes with these pollinators in mind, reserving bee habitat to benefit the crops and surrounding landscape.

Information for managing wild bees, along with the biology of relevant species can be downloaded at:

- Farm Management for Native Bees, A Guide for Delaware at: *https://agriculture.delaware.gov/wp-content/uploads/sites/108/2017/12/FarmManagementforNativeBees-AGuideforDelaware.pdf*
- Using integrated crop pollination for pumpkins and squash: *http://icpbees.org/wp-content/uploads/2014/05/Integrated-Crop-Pollination-for-Cucurbita-crops.pdf.*
- Squash Bees: *https://www.fs.fed.us/wildflowers/pollinators/pollinator-of-the-month/squash_bees.shtml*, and *https://content.ces.ncsu.edu/squash-bees-in-the-home-garden*

Collections of resources are compiled at:

- The Integrated Crop Pollination Project, Resources for Growers: *http://icpbees.org/tools-for-growers/*
- The Center for Pollinator Research: *http://ento.psu.edu/pollinators/information-for-growers*

There is ongoing research to determine whether reliance on wild bees will be adequate for pollination of large acreages grown for commercial production. The Xerces Society provides guidelines for developing landscapes and farmscapes that encourage conservation of communities of pollinators at: *http://www.xerces.org/pollinator-conservation/*.

Alternative managed pollinators are described in "Managing Alternative Pollinators: A Handbook for Beekeepers, Growers, and Conservationists" (Mader *et al*., 2010, see "Resources" on Xerces Society website).

Recommendations Related to Pesticides and Bees

All bees are vulnerable to many chemicals used to control insects, pathogens and weeds. If insecticides are applied, select those that give effective control but pose the least danger to bees (see Table 4, starting on page 16, in *https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw591.pdf*, chapter F Insect Control tables in this guide, or Tables D1-D3 in the Mader handbook listed above). **Apply pesticides at dusk when the bees are not actively foraging and avoid spraying crops adjacent to foraging bees.** Give the beekeeper a 48 hour notice so that precautions can be taken to protect the hives.

READ THE LABEL AND FOLLOW THE LABEL DIRECTIONS

- Know the pesticides you are using and their toxicity to bees. Check the bee advisory box (**Figure A-1)**.
- Systemic seed treatments may result in residues in nectar and pollen. However, residues tend to be much lower from seed treatments compared to foliar treatments.
- Never use an insecticide on a flowering crop or on flowering weeds if bees are present.
- Flowering time varies among varieties. Bees pollinating one variety or crop may be at risk while another post-bloom crop or variety is being treated. Also, bees may be visiting flowering weeds in and around crops. Be aware of these situations and avoid the pesticide application if there is risk of drift onto blooming crops and weeds if bees are present. If a spray must be applied, use the least toxic material and apply late in the day or at night when bees are not foraging
- Avoid pre-bloom pesticides just before bees are brought onto a crop. If one is needed pre-bloom, select a material with lower bee toxicity and apply only when bees are not foraging, preferably late evening.
- Do not apply pesticides post bloom until after managed colonies are removed.
- Honey bees need water for temperature regulation and brood production. Provide a clean water supply near the hives. Keep wheel ruts and areas around the sprayer fill point drained to eliminate a possible insecticide-laden water source.
- Many fungicides are known to interact antagonistically with insecticides, which can lead to higher toxicity to bees. Avoid fungicide application on flowering crops when bees are present.
- Give beekeepers 48 hours notice to allow for the movement of bees onto or off the crop.

Online resources about pesticides and bees can be found at the following site: *https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw591.pdf*, and *https://pesticidestewardship.org/pollinator-protection/*.

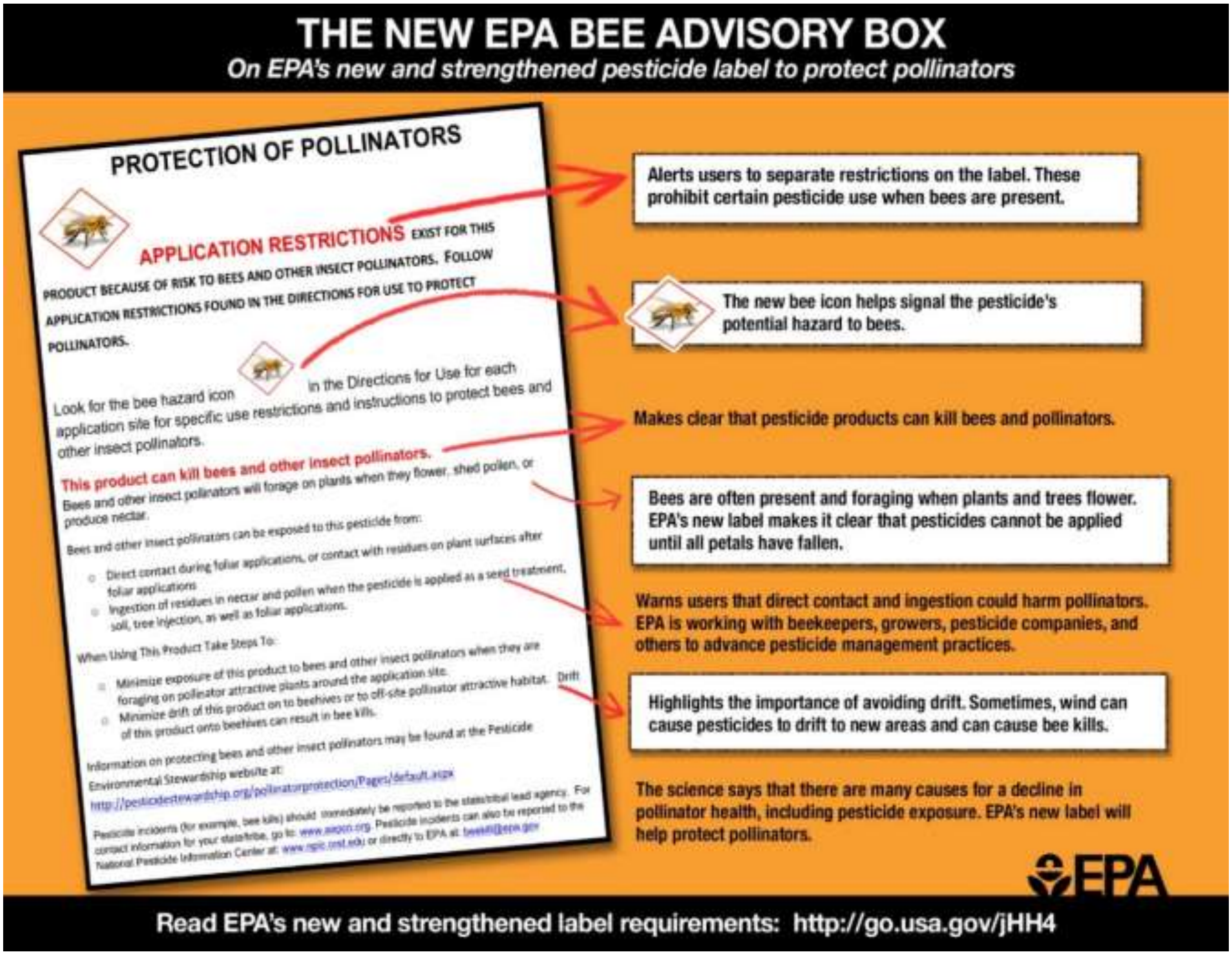
Information about toxicity of organic pesticides to bees can be found at the following site: *http://www.xerces.org/wp-content/uploads/2009/12/xerces-organic-approved-pesticides-factsheet.pdf*

Figure A-1. The Environmental Protection Agency Bee Advisory Box.

All growers should become familiar with EPA's new pollinator protection labeling guidelines and bee advisory box which can be found at *https://www.epa.gov/pollinator-protection/new-labeling-neonicotinoid-pesticides*.

Figure A-1. - continued on next page

Figure A-1. The Environmental Protection Agency Bee Advisory Box - continued.



13. Food Safety Concerns

Reports of foodborne illness attributed to consumption of fresh fruits and vegetables have increased. Unlike processed foods, fresh fruits and vegetables are not heat-treated to eliminate potentially harmful microorganisms. Larger and more centralized farming and improved storage methods have resulted in the distribution of produce over vast geographic areas. Raw fruits and vegetables are also handled more frequently in the distribution chain. Cases of foodborne illness that once were limited to localized areas can now be spread over many states or countries. In addition, new minimal processing technologies have brought to the marketplace, for example fruits and vegetables that have been washed, peeled, and cut into convenient ready-to-eat products. Since these products are subject to more handling and typically are not heat-processed to eliminate harmful bacteria, they are at a greater risk for becoming contaminated and subsequently leading to foodborne illness. Most fresh fruits and vegetables are grown, harvested, and packed under safe and sanitary conditions. However, several highly publicized cases of foodborne illness have been associated with consumption of lettuce, salad mixes, green onions, tomatoes, sprouts, cantaloupe, cabbage, cucumbers, herbs and carrots. Implicated in most of these outbreaks have been the human pathogens: *Salmonella enterica*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Shigella* bacteria; *Cryptosporidium* and *Cyclospora* parasites; and Hepatitis A and Norovirus viruses.

In response to increasing concerns about the safety of fresh produce grown in the United States, the Food and Drug Administration (FDA) published "The Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables" in 1998. This guide is intended to assist growers, packers, and shippers of unprocessed or minimally processed fresh fruits and vegetables by increasing awareness of potential food safety hazards and providing suggestions for practices to minimize those hazards. Many Internet resources on food safety are also available that feature updated information from this guide and other sources.

In 2002, the United States Department of Agriculture (USDA) developed an audit/certification program known as "Good Agricultural Practices" (GAPs) to verify conformance to the 1998 guide. This is a voluntary program, although an increasing number of distribution networks are mandating GAPs or Harmonized Audit certification from each participating grower.

More recently, in 2011, the Food Safety Modernization Act (FSMA) was signed into law. There are seven sections to FSMA with the Produce Safety Rule applying to many growers and packers. The final Produce Safety Rule (under FSMA) was released November 2015, with the first compliance date being January 2018 with complete compliance required by 2022; except for sections under review, *i.e.*, water. The Produce Safety Rule (*https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-produce-safety*) establishes mandatory practices operations must take to prevent microbial contamination of fresh produce. Whether a produce operation needs to comply with the Produce Safety Rule depends on whether it produces fresh fruits and vegetables and sales volume. To help operations prepare for an inspection, state departments of agriculture and cooperative extension in each state are providing individual farm assessments (On Farm Readiness Review). These assessments are free, confidential and take no more than 2 hours to complete.

In the current food safety climate, increased record-keeping and adherence to strict procedures of human hygiene are inevitable. All three resources (the 1998 guide, GAPs and FSMA Produce Safety Rule) identify potential hazards and discuss possible control methods in different aspects of pre-harvest, harvest and post-harvest production, including: 1. Water, 2. Manure and Municipal Biosolids, 3. Wild and Domesticated Animals, 4. Worker Health, Hygiene and Training, 5. Field Sanitation, 6. Packing Facility Sanitation, 7. Transportation, and 8. Product Trace-back. Each section is summarized below.

<u>**1. Water**</u>: Water has the potential to be a source of microbial contamination. Growers and packers should be aware of the source and quality of water that contacts fresh produce and consider practices that will protect water quality. Growers should periodically test irrigation water for the quantity of fecal indicator organisms specifically generic *E. coli* (often represented by colony forming unit (CFU) or most probably number (MPN) of generic *E. coli* per 100 ml water). Groundwater should be tested at least once per year and surface water three times per year (additionally testing may be required under the FSMA Produce Safety Rule if water is directly applied to the harvestable portion of the crop). If irrigation water exceeds the agricultural water standards, water treatment with effective disinfectants would be necessary before continuing to use the water source. Application of SaniDate 5.0 or 12 and calcium hypochlorite tablets (Accutab) have been shown to be effective on the decontamination of bacterial foodborne pathogens. These products are approved by the Organic Materials Review Institute (OMRI) for use in irrigation water. Check the label to make sure the product can be used for this purpose; **the label is the law!** Growers often irrigate field crops using water obtained from rivers, lakes, ponds, or irrigation ditches. However, surface water can become contaminated by upstream animal operations, sewage discharge, or runoff from fields. Drip, trickle, underground, or low volume spray irrigation techniques are ways to minimize irrigation water contact with harvestable portions of the crop. Groundwater is less likely to become contaminated, although wells should be maintained in good working condition including proper backflow devices and be constructed and protected so that surface water or runoff from manure storage areas cannot enter the system.

During harvest and post-harvest operations, only water that meets the standard of no detectable generic *E. coli* based on a 100 ml water sample can be used. Untreated surface water cannot be used for harvest and postharvest activities. Water in dump tanks and flume systems should be changed regularly to prevent the buildup of organic materials. Contact surfaces should be cleaned and sanitized to help prevent cross-contamination. Sanitizers, such as chlorine and peroxyacetic acid may be added to water, but should be routinely monitored and recorded to ensure they are maintained at appropriate levels (*e.g.*, water should be monitored for proper chlorine efficacy; 100 to 150 ppm of free chlorine, and a pH in the range of 6.5 to 7.5).

<u>**2. Manure and Municipal Bio-solids**</u>: Manure may be contaminated with human pathogens and should be properly treated and stored before field application. Store manure and compost away from produce fields and packinghouses to protect the produce crop from seepage and runoff. Physical barriers such as ditches, mounds, grass/sod waterways, diversion berms, and vegetative buffer areas may also help to prevent runoff. Current recommendations are to maximize the time between application of manure to production areas and harvest. For non-composted or raw manure, the recommendation is to wait at least 120 days (4 months) between manure application and harvest and at a minimum two weeks before planting. Growers should be aware that the FSMA Produce Safety Rule

regulations for biosolid of animal origin have not yet been finalized. The Food and Drug Administration allows the use of the National Organic Standards for manure application until the final regulations are written. The National Organic Standards are 1. Incorporated into the soil a minimum of 120 days prior to harvest when the edible portion of the crop has soil contact; OR 2. Incorporated into the soil a minimum of 90 days prior to harvest of all other food crops. Recommendations, guidance, regulations may change; growers are encouraged to consult relevant online resources or county extension offices about up to date manure recommendations and regulations.

Although municipal bio-solids (sewage sludge) are approved for certain agricultural uses, they are not recommended for application to soils used for vegetable production. This is due to the potential for human health issues. See “Sewage Sludge” in section B 4 Nutrient Management.

3. Wild and Domesticated Animals: Wild animals, although more difficult to control, should be discouraged from entering fields; especially where crops are destined for fresh markets. Wildlife prevention may include noise makers, decoys, hunting, fencing or netting. However, the FDA does not authorize farms to take action(s) that would violate the Endangered Species Act or other federal, state, or local animal protection requirements (check with county extension on animal protection requirements). Domestic animals (including livestock and pets) may be a source of contamination and should be excluded from fields during the growing and harvesting season. Growers who use animals (such as horses) during production are advised to do a risk assessment of their operation and have a written plan in place to address possible sources of contamination.

4. Worker Health and Hygiene: Human pathogens can be transferred to produce by workers who harvest or pack fresh produce. Growers should provide sanitary facilities that are accessible, clean, and well equipped (bathrooms or portable toilets with an adequate supply of toilet paper; handwashing stations with basin, microbially safe water, soap, disposable paper towels or other appropriate hand drying devices, and a waste container). All employees (field workers to office administration) should be trained in good hygiene practices, such as to toilet use and proper handwashing. Any worker who shows signs of an illness including diarrhea, coughing, fever, sneezing, sores, or infected wounds should not be allowed to handle produce.

5. Field Sanitation: Fresh produce can become contaminated through contact with soils, pests, equipment, and chemicals, such as fertilizers and pesticides. Growers should clean and or sanitize harvest equipment including knives, pruners, machines, containers, bins, etc. prior to use. Additionally, all equipment should be regularly serviced and inspected for general maintenance.

6. Packing Facility Sanitation: In packing facilities, pallets, containers or bins should be cleaned and sanitized before use and discarded if damaged or in poor condition. Equipment, packing and storage areas should be kept clean; empty or unused pallets, bins, or containers should be kept in a covered location to prevent contamination. Sanitizers, such as chlorine or peroxyacetic acid, may be added to water to prevent cross-contamination of produce during washing or transporting in dump tanks and flumes. If using a sanitizer, monitor the concentration on a regular schedule. It is recommended that the water be changed when it becomes excessively soiled or saturated with organic material. Food contact surfaces should be cleaned and sanitized at the end of each day. A pest control program must be established to prevent or limit rodents, birds, and insects from entering the packing and storage facilities/areas.

7. Transportation: Fresh produce can become contaminated during loading, unloading, and shipping. Inspect transportation vehicles for cleanliness, pests, odors, and obvious dirt or debris before loading. Make sure that fresh produce is not shipped in trucks that have previously been used to transport animals, fish, chemicals, or waste. Refrigeration units in trucks should be turned on before loading to ensure that proper temperatures are maintained during loading and transport.

8. Trace-back: Traceability is defined as a procedure which tracks where a food product came from (for example farm, field, row, date harvested) to where a food product is going (market, distribution center, consumer). Usually adequate trace-back procedures require a grower to track one step backwards and forwards. Growers should be able to trace each lot with the date of harvest, farm identification, and who handled the produce from grower to receiver. The ability to trace the distribution history of food items from grower to consumer will not prevent a foodborne outbreak or recall from occurring; however, traceability procedures may limit the public health and economic impacts of an outbreak or recall.

Additional information to help vegetable growers adopt Good Agricultural Practices on the farm and in the packinghouse; as well as information on the FSMA Produce Safety Rule can be obtained from extension offices or the governmental agriculture authority in your state.