Rutgers
New Jersey Agricultural
Experiment Station

This is a section from the

2016
Mid-Atlantic
Commercial Vegetable Production Recommendations

The manual, which is published annually, is NOT for home gardener use.

The full manual, containing recommendations specific to New Jersey, can be found on the Rutgers NJAES website in the Publications section njaes.rutgers.edu

The label is a legally-binding contract between the user and the manufacturer. The user must follow all rates and restrictions as per label directions. The use of any pesticide inconsistent with the label directions is a violation of Federal law.

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GENERAL PRODUCTION RECOMMENDATIONS

VARIETIES

New varieties of vegetables are constantly being developed throughout the world and it is impossible to list and describe all of them, only those that are available and are adapted to the mid-Atlantic region are listed in this publication. While all efforts are made to have comprehensive lists, not all varieties that are adapted will be listed. Varieties are listed for each specific crop in Section F, either alphabetically or in order of relative time to maturity from early to late (see table footnotes). Those varieties that are new or that have had limited release will have the designation "trial" and should be evaluated in smaller plantings before being grown more extensively. 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, and 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. Is should be noted that 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 which are calculated for a specific crop using daily highs and lows and a base temperature.

Disease and Insect Resistance - The most economical and effective means of pest management is through the use of varieties that are resistant or tolerant to diseases including those 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. 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; low levels of heat induced defects such a tuber heat necrosis; drought tolerance; resistance to cracking, edema, and other wet weather disorders; low occurrence of nutrient disorders such as blossom end rot, leaf tip burn, or hollow stem; and low occurrence of hollow heart.

Horticultural Quality – Choose varieties that meet market quality requirements. Quality attributes such as taste, texture, size, shape, color, uniformity, and amount of 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; and ease of harvest.

Adaptability – Successful varieties must perform well under the range of environmental conditions and production practices usually encountered on individual farms. Seasonal adaptation is another selection consideration.

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 highly controversial, and effects are ongoing to regulate and label them. Be aware of current and pending regulations and 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 if some special situation, such as plant disease or marketing change, develops. Companies frequently replace older varieties with new varieties. Variety selection in the mid-Atlantic 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. Look for results from replicated trials and multiple sites if available. Trials conducted in similar soils and growing environments and local trials are the most reliable indicators of what will have 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 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

Vegetable crops are naturally resistant to most but not all plant pathogens. In cases where diseases are a serious threat, genetic resistance is an effective and 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.

On rare occasions, purported resistance to pathogens breaks down. This may be due to different strains and races of disease-causing organisms and environmental conditions that favor the organism or reduce natural plant resistance. In the Section F variety tables, disease resistance and tolerances are listed in the tables and in the footnotes for each vegetable crop. 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.

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 [12.8°C] + 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. Therefore, if you do not use all coated/pelleted seed, perform a germination test to assess viability before using in subsequent seasons.

Corn, pea, and bean seed 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.

SPECIALTY VEGETABLES

Specialty vegetables are those that are grown for specific markets and include varieties or types within standard vegetable categories that are unique, those that are harvested at different stages that conventional vegetables (baby types), vegetables grown for ethnic markets, "heirloom vegetables", "gourmet" vegetables, or other vegetables 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 has also expanded.

See the "Specialty Vegetables and Herbs" subsection of Section F for more details.

ORGANIC PRODUCTION

You may wish to consider organic production. The initial investment is high, due mainly to certification costs. However, returns can be higher than for conventionally produced products. The USDA regulates the term 'organic' to protect the sector from unscrupulous profiteers. To become certified organic, you must follow production and handling practices contained in the National Organic Standards (NOS see www.usda.gov) and be certified by a USDA accredited certifying agency such as the New Jersey Department of Agriculture and the Pennsylvania Certified Organic (PCO). Growers whose annual gross income from organic products is $5,000 or less can be exempted from certification. In this case growers must continue to use production and handling practices in accordance with the NOS and some restrictions regarding labeling and combination with other organic products apply. Certified organic production is typically preceded by a three-year transition phase during which the soil and farming practices are adapted to NOS.

Growers should recognize that 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 management-intensive, and requires careful attention to the maintenance of a biological equilibrium favorable for crop production. Organic certification gives growers increased 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 soil microorganisms and improved organic matter recycling. Growers should 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 3 or more years of the 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 of the above questions, then 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 http://pubs.cas.psu.edu/FreePubs/pdfs/ua391.pdf.

TRANSPLANT GROWING

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

Producing quality transplants starts with disease free seed, a clean greenhouse and clean planting trays. Many of our 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. Further, a number of virus diseases are transmitted by greenhouse insects.

Buy disease-indexed seeds when they are available. To reduce bacterial seed-borne diseases in some crops such as tomatoes, peppers, and cabbages, seeds can be hot water treated. Chlorine treatment can also be useful on some seeds as a surface treatment but will not kill pathogens inside the seed. See Section E, Disease Management/Seed Treatment for seed treatment recommendations.

Transplants are affected by such factors as temperature, fertilization, water, and spacing. A good transplant is grown under the best possible conditions. A poor transplant usually results in poor crop performance. In certain instances, however, the timely exposure of transplants to specific stresses can enhance later performance by the crop in the field.

Table A-1 presents optimum and minimum temperatures for seed germination and plant growing, the time and spacing (area) required to produce a desirable transplant, and number of plants per square foot.

Table A-1. Optimum and Minimum Temperatures and Planting Recommendations for Transplant Production

Crop	°F Opt. Day	°F Min. Night	Weeks to Grow	Sq In per Plant	Plants per Sq Ft
Broccoli	65-70	60	6-7	3	48
Cabbage	65	60	6-7	3	48
Cauliflower	65-70	60	6-8	3	48
Celery	65-70	60	9-12	3	48
Cucumber[1]	70-75	65	2-3	4	36
Eggplant	70-85	65	7-9	6-9	24
Endive, Escarole	70-75	70	5-7	2	72
Lettuce	60-65	40	5-6	1	144
Melon[1]	70-75	65	2-3	6	24
Onion	65-70	60	9-12	--	--
Pepper	70-75	60	8-9	4-6	36
Summer squash[1]	70-75	65	2-3	4	36
Sweet potato	75-85	70	4-5	in bed	in bed
Tomato	65-75	60	5-6	6-9	24

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

Seedless watermelon has specific requirements: germination at high temperatures for 48 hours (to achieve even germination) then move immediately into a cooler greenhouse to grow out. See the Watermelon subsection of Section F for more details.

Making a Plant-Growing Mix. Many pre-mixed growing media products are available commercially (see below). A good, lightweight, disease-free, plant-growing material can also be made from a mixture of peat and vermiculite. The main advantage of making one's own mix is uniform and consistent composition, but it can also be less costly than commercial products. Formulas for a very simple mix are now located in the Resource Section (R) of this publication.

Commercial Plant Growing Mixes. A number of commercial media formulations are available for growing 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 those without fertilizer will require supplemental liquid feedings after seedling emergence. Plants grown in those with added fertilizers will require liquid feeding starting 3-4 weeks after emergence. If you experience problems with transplant performance, the growing medium (soil) should be sent to a soils laboratory for testing. It is recommended to mix 3-4 bags of commercial product together before filling trays.

For greenhouse growing areas, remove any weeds and dead plant materials and clean floors and benches thoroughly of any organic residue prior to seeding.

Treatment of Flats and Trays. Flats used in the production of transplants should be new to avoid pathogens that cause damping-off and other disease problems. If flats and trays are reused, they should be thoroughly cleaned after use and disinfested as described below. Permit flats to dry completely prior to use. One of the following methods of disinfestation should be used:

<u>Chlorine</u>. 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 gallon 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 (see below) to eliminate the chlorine. It is important that the bleach solution remains in the 6.5-7.5 range and that new solutions be made up every 2 hours 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.

Q-salts (Quaternary ammonium chloride salts). Compounds such as Greenshield, Physan and Prevent can be applied in the final wash of flats and trays during the chlorine treatment. Additionally, they can be used to wash exposed surfaces (benches, frames, etc.) in greenhouses.

Transplant Trays and Containers. Most transplants are grown in plastic trays with individual cells for each plant. Trays vary in size from 32 cells to over 500 cells per standard 12 x 24 inch tray. 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 crops such as lettuce and onions. Larger styrofoam transplant trays are also available in similar cell sizes. Larger cell sizes have better holding ability and survivability in the field but use more greenhouse space and take longer to produce the root ball in the cell. 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 are reused, disinfest as described for flats.

Seed Germination. Normally, one seed is planted per cell. Seeds that are over-sown in flats to be "pricked out" (thinned to a uniform stand) at a later date should be germinated in 100% vermiculite (horticultural grade, coarse sand size) or a plant growing mix. However, it is recommended that no fertilizer be 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 the liquid form and at one-half the rate for any of the ratios listed in the Liquid Feeding paragraph below. Seedlings can be held for 3 to 4 weeks if fertilization is withheld until 3 to 4 days before "pricking out." Seed that is sown in tray cells, pots or other containers and will not be "pricked out" later 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. Germination rooms or chambers also insure even germination where higher temperatures can be maintained for the first 48 hours. 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, or fiberglass) should be clean, clear, and in good repair. The ideal greenhouse will also have floor-on or bottom-heating capabilities, either on the benches or on the floor, and provide good heating and ventilation systems for effective environmental control. Proper growing medium temperature ensures uniformity of crop throughout the greenhouse by moderating normal temperature variations experienced with hot air heating systems. Bottom heating provides for a significant energy savings because the greenhouse does not have to be operated 10°F higher than the required growing medium temperatures for good germination and seedling growth. Internal 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. Seedlings should not be grown or held in areas where pesticides are stored.

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 for this purpose. This is also referred to as “fertigation” (see Section C). For most crops use a formulation with lower P levels than N and K (for example 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 (watermelon and squash, etc.). 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, 200 ppm N every other day from first true leaf to second true leaf.

If concentrations are above recommended levels, they can cause excessive growth, reducing transplant quality. Highly concentrated nutrient solutions often can causesalt injury to plants and leaf burning. Over-fertilized transplants will often “stretch” and have impaired field survival. For a less sophisticated way to apply nutrients, the following materials can be dissolved in 5 gallons of water and used over an area of 20 square feet for general use on transplants:

20-20-20---1-2 oz/5 gal water or

20-10-15---2 oz/5 gal 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. **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 of a size that it can be handled by mechanical transplanters or hand without damage and that are tolerant to wind.

Most growth regulators that are used for bedding plants are not registered for vegetable transplants. One exception is Sumagic® registered for use as a foliar spray on tomato, pepper, eggplant, groundcherry, pepino and tomatillo transplants (no other crops are registered at present). The recommended label rate is 0.52 to 2.60 fluid oz per gallon (2 to 10 ppm) and one gallon should be sprayed so it covers 200 sq ft of transplant trays (2 quarts per 100 sq ft). The first application can be made when transplants have 2-4 true leaves. One additional application may be made at the low rate, 0.52 fluid oz per gallon (2 ppm), 7-14 days later, but you cannot exceed 2.60 fluid oz of total product (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 adoption.

For other crops alternative methods for height control must be used. One such method that is successful is 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 to 3 hours following 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. Vegetables vary in their response to DIF. For example, tomatoes are very responsive, while curcurbits are is 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 with this method.

Managing water can also be a tool to control stretch in some vegetables. 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 yet another method for controlling transplant height. Most greenhouse growing media come with a starter nutrient charge, good for about 2-3 weeks after seedling emergence. After that, you need to apply fertilizers, usually with a liquid feed program. Greenhouse fertilizers that are high in ammonium forms of nitrogen will induce more stretch than those with high relative proportions of nitrate nitrogen sources. Fertilizers that are high in phosphorus may also promote stretch.

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 that can be moved outside of the greenhouse for a portion of the day or wagons that can be moved into and out of the greenhouse can be used for this purpose (see below).

Hardening. It is recommended that transplants be subjected to a period of “hardening” prior to incorporation in the production field. Reducing the amount of water used, lowering temperatures, and limiting fertilizers cause a check in growth (hardening) to prepare plants for field setting. 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. Low temperature causes chilling that can injure plants and delay regrowth after transplanting. Do not harden rosette vegetables (e.g. endive, escarole, celery) by lowering the temperature because low temperature exposure increases early bolting.

Common Problems: Poor growth, yellow plants, or stunted plants are often attributable to the greenhouse growing medium. Greenhouse media manufacturers have good quality control measures in place but things can go wrong on occasion – inadequate mixing, critical components missing or in the wrong proportions (such as wetting agents, fertilizers, lime), or defective components (poor quality). Media can also be affected by poor storage and handling. This occurs most commonly when media are stored outside and bales or bags get wet. In addition, all growing media have a specific shelf life – old media often dry out and are hard to rehydrate.

If the medium is over a year old or possibly compromised, it should not be used. Contact your supplier and have them inspect and run 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 carbonates).

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.

A good publication on media pH management can be found on the web at: http://www.greenhouse.cornell.edu/crops/factsheets/pHGreenhouseCrops.pdf.

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 in such cases.

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. Leaf edge burn, “plant burn”, or plant desiccation will be the symptoms of this condition. 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 salts are too high, then 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. The technique can also help meet the challenge from new strains of soil-borne disease pathogens. There has been limited research on annual vegetable crops until the last decade when the grafting movement started in Asia and Europe. Japan now utilizes extensive grafting in the production of watermelon, cucumber, melon, tomato and eggplant. Grafting can overcome tissue damage and/or plant mortality caused by the soil-bone 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 for grafting will depend on the specific goals for grafting and there are often many rootstocks available. Consult your seed suppliers for more information on rootstock selection. A list of some available rootstocks and suppliers can be found at: http://cals.arizona.edu/grafting/howto or http://www.vegetablegrafting.org/resources/.

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 graft and cleft graft. The tube graft utilizes a 45° cut in the rootstock as well as the scion. The two pieces are subsequently joined together with the angles complimenting each other and held together with a grafting 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 one half 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. A schematic of the cleft graft is illustrated in the eggplant production subsection (Section F). 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 increase and the temperature can be controlled. Open water pans can be placed in the chamber or commercial humidifiers can be used to increase humidity. Propagation heat mats can also be placed in the floor of the chamber to control temperature and as well as 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 five to seven days in the healing chamber, seedlings can be moved back into a greenhouse to harden off for several weeks before moving to the field. Grafting generally adds two weeks to seedling production. Grafting can be performed at various plant growth stages ranging from the two true leaf stage on. More information on grafting can be found at: http://cals.arizona.edu/grafting/home or http://www. vegetablegrafting.org/.

CONSERVATION TILLAGE CROP PRODUCTION

(Also referred to as No-Till Crop Production)

Conservation tillage crop production systems are beneficial for a variety of reasons. Soil compaction is reduced, water infiltration is improved, soil organic matter is increased, microbial biodiversity is increased, disease and weed pressure may be reduced, and soil erosion from wind and water is reduced in conservation compared to conventional tillage systems. Contamination of waterways with nutrients and pesticide residues is also reduced by eliminating or curtailing nutrient and sediment loads in runoff. Crop and cover crop residue on the soil surface can provide mulch that may suppress weeds and reduce herbicide needs. Improvements in soil quality from organic matter additions assist with soil structure formation that increases water infiltration, microbial populations, and reduces compaction.

Conservation tillage crop production systems can also pose several crop management challenges. Soil temperatures will be several degrees cooler than for conventional tillage and it will take longer to warm soils with surface residue. Cooler soil temperatures may impact seed germination, nutrient cycling from crop residues, slow fumigation volatilization, and reduce transplant vigor. Type of crop residue, residue amount, and desiccation timing all impact soil temperature and should be taken into consideration.

Conservation tillage systems may eliminate the mechanical weed control option for managing unwanted vegetation in a field. Weeds are typically controlled using biological, cultural, or chemical practices. Reliance on chemical weed control options in conservation systems increases the possibility of herbicide resistant weed populations. Consequently, expect to invest more time identifying local weed populations and planning herbicide rotation programs (herbicides with varying modes of action to reduce herbicide resistant population development). High residue cultivators have also been used with some success in conservation tillage programs for weed management.

Nitrogen fertilizer must be managed properly when utilizing a conservation tillage production system. Crop residues contain typically 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 incorporation using irrigation or rainfall should be considered to reduce urea containing fertilizer contact with urease. Another nitrogen management strategy in conservation tillage systems needs to include the application rate. As soil organic matter increases over time, more nitrogen fertilizer is needed to bring the conservation tillage system into equilibrium. Microbes will assimilate nitrogen when breaking down crop residue and immobilize plant available nitrogen pools. Research has shown that 25% or more nitrogen fertilizer may be necessary in the initial conversion years of a production system from conventional to conservation tillage. Previous crop residue amount and type, 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 consideration in conservation tillage and has significant impact on nutrient availability and toxicity. Special care needs to be directed to maintaining 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. Therefore, lime should be applied based on soil testing recommendations and incorporated prior to initiating a long-term conservation tillage plan. Eventually, fertilizer, organic matter decomposition, and rain will acidify the soil surface, but subsoil will continue to be at optimal (pH=6.0 to 7.0) levels. Continued liming based on soil test recommendations will maintain the proper pH.

MULCHES AND ROW COVERS

A favorable environment for a plant's root system can be achieved with the use of plastic mulches and trickle irrigation. Early in the season, additional advantages can be obtained by the use of row covers, which increase the daytime air temperature and hold ground heat during the night. This improvement in temperature early in the plant's life cycle can speed plant growth, resulting in earlier harvest. Mulches also discourage weeds and, depending on the type used, insect pests.

Plastic Mulches. The most popular mulches are black and white-on-black polyethylene film (0.75 – 1.25 mil). 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 of plastic mulch increase soil temperatures more than black plastic and also suppresses most weed growth. Other color mulches such as red and blue are available. Results with these mulches 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. 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 color of mulch films. Yellow mulches attract cucumber beetles and may also attract other insect pests. Note that planting date and environmental conditions influence crop responses to color of mulch films.

Soil fumigation may be used in conjunction with any type of plastic for weed, disease, and insect control, 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 mulches keep the fumigant in the ground longer which allows for reduced application rates while maintaining efficacy of the material. These mulches are known as “virtually impermeable film” (VIF). There are several manufacturers of these mulches and they come in various colors for fall and spring plantings. Consult the fumigant label for the allowable reduction in use rate under VIF mulch. One factor that must be taken in to consideration is the plant-back period when using VIF mulches. Consult the label for plant-back period when using VIF mulch. The cost of VIF mulch is also higher than low density mulches but this increase is usually offset by the saving gained from reduced fumigant rates. Another type of mulch has been developed that is more retentive than VIF mulch. This is known as “totally impermeable film” or TIF. Soil fumigant use rates may be further decreased with used in combination with TIF. Consult fumigant labels for allowable use rate reductions with TIF.

Fertilization. Before considering a fertilization program for mulched crops, have the soil pH measured. If a liming material is needed to increase the soil pH, the material should 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 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 recommendations and incorporated in the manner described above. Placing some of the required N under the mulch and then sidedressing 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 specific crops sections (i.e., cucumbers, eggplants, muskmelons, peppers, tomatoes, and watermelons) of Section F for crop-specific application rates.

Soil conditions for laying mulch. Before any mulch is applied, it is extremely important that the soil moisture level be at or near field capacity. This moisture is critical for early growth of the crop plants, because soil moisture cannot be effectively supplied by rain or overhead irrigation to small plants growing on plastic mulch without drip irrigation. Ideally drip irrigation is used with plastic mulch. Soil texture should be even and plastic should be laid so that it is tight against the soil in a firm bed for effective heat transfer. 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.

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 break down of biodegradable mulches. 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. In addition, nearly all of the biodegradable mulch will eventually degrade or fragmentize, including the tucked edges buried in the soil. 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 next day after biodegradable plastic mulch has been disked into the soil.

In 2012, the National Organic Standards Board passed a motion allowing the use of ‘biodegradable biobased mulch film’ providing 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). At present, no biodegradable mulch has been approved.

Field research has demonstrated that biodegradable mulches produce comparable crop yields to non-degradable plastic mulches. Two issues that growers may be apprehensive about are the initial cost of the biodegradable mulch compared to non-degradable mulch and the unpredictability of degradation rate. 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.

Application

- Do not stretch biodegradable mulch as tightly over the bed as standard black plastic (contrary to recommendations for black plastic that performs best when laid tightly over the bed).
- Stretching starts the breakdown of the biodegradable mulch.
- Stretching 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 materials are being used for frost protection, hail protection, to hasten the maturity of the crop and also to effectively exclude certain insect pests. Vented clear and translucent plastic covers are being used in low tunnels and are supported by wire hoops placed at 3- to 6-foot intervals in the row. Porous floating row covers are made of lightweight spun fibers (polyester or polypropylene). Theymay be supported with wire hoops, pvc pipes or metal conduit hoops for plants that require 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 plant.

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

Mulch removal. Several methods of removing the plastic 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, black plastic mulch can be used for two successive crops during the same season when care is taken to avoid damage to the mulch film. Thin wall (4 to 8 mil) trickle irrigation tape cannot be removed and reused. However, high-quality, 16-mil trickle tubing can be used a second season provided that damage is minimal and particles are excluded, allowing pores to be open when carefully removed.

Crop foliage and weeds may increase the difficulty of mulch removal. Eliminate vegetation prior to replanting or removing mulch with herbicides (see Section E), or delay removal until after frost.

Disposal. Dispose of used plastic in an environmentally responsible manner. Regulations on disposal vary according to state and municipality. Contact your local solid waste authority for recommended methods of disposal in your area. Some states have developed specific programs for recycling of agricultural plastics. Individual state authorities should be consulted to learn the specifics.

STAKING AND TRELLISING

Many vegetable crops benefit from the addition of structural supports on which they are grown in the field. The benefits include: 1) better utilization of available space and light; 2) improved air flow for 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 mainly cost of materials and installation, and disposal. Assess your broad situation on a case-by-case basis in deciding whether a structural support system is desirable.

Vegetable crops in which structural support systems have been used successfully include fresh market grape and cherry tomatoes, peppers, eggplants, legumes, cucumbers, and okra. The types of materials and how they are assembled differ for each crop. Specifics of the design and installation of structural support systems are included in Section F. If materials fail during the growing phase, the resulting damage can be catastrophic. It is advisable, therefore, to utilize high quality materials in the construction of all structural support systems, and to 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 production seasons in the field. Since they are in contact with the environment and plant material while being used, there is a significant probability that surfaces will become infested with pathogens, especially bacteria. If left untreated, re-used infested stakes may re-introduce diseases into the field, although the extent of this problem has not been determined. Therefore, it is recommended that re-used stakes be thoroughly disinfested.

The preferred (and most expensive) method of stake disinfestation is heat treatment. Pathogens are completely 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 – 20 parts by volume sodium hypochlorite (commercial bleach) to 80 – 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 6.0-6.5 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 ≥ $1/16^{th}$ inch. Pathogens embedded deep within the stake may be able to migrate back to the surface and re-infest plants, although this possibility has not yet been demonstrated. To improve the effectiveness of strategies to remove microbial pathogens from the surface of re-used stakes, consider the following: Add a non-ionic surfactant to the disinfesting solution; increase the soaking time to ≥1 hour; 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 no research to establish the efficacy as a stake of this disinfesting agent as compared to heat or commercial chlorine solutions is available.

HIGH TUNNELS

High tunnels are designed to improve growing conditions during the early spring and late fall growing seasons and to accommodate workers and equipment. In the mid-Atlantic region. Year-round production of specialty crops is possible using a freestanding high tunnel (Table A2). High tunnels are either freestanding or connected at the gutters to cover larger areas. Freestanding tunnels are between 14 and 30 feet in width and up to 100 feet in length. High tunnels are typically tall enough so that a person can 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 the function and design of a high tunnel.

Taking the time to level the tunnel site prior to construction will make subsequent steps much easier. Spacing between high tunnels should be at least the width of the tunnels to facilitate snow removal to provide for cross ventilation, and to reduce mutual shading. For freestanding high tunnels, metal bows approximately 1.75 to 2 inches in diameter are used as the support frame for a single 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 into the ground. The end walls generally can have removable framing to allow the use of power tillage equipment within the tunnel (see high tunnel component list at the following website: http://plasticulture.cas.psu.edu).

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 section 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 section B for more details. Make beds, if needed, and install drip irrigation to supply moisture. Using a small bedmaker/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 the tunnels.

For freestanding high tunnels, snow removal from the top of the tunnels may be necessary after heavy, wet snowfalls. In addition, it is recommended that heavy snowfall be removed from the sides of the tunnels as needed to reduce/eliminate outside water intrusion into the tunnel and collapse of the 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, ventilation and moisture control. Table A-2 provides a relative planting and harvest 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 the vegetable crop about two to four weeks earlier compared to the earliest planting date in the field on bare ground. If unusually cold night temperatures are experienced several days to weeks after planting the vegetable crop in the high tunnel, 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 the high tunnel until more seasonal temperatures return to the location.

The most critical component of the system is ventilation. In freestanding high tunnels, ventilation is accomplished by rolling up the sides of the tunnel to the batten boards, approximately 5 to 6 feet 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. Maintaining optimum growing conditions inside high tunnels without having extreme fluctuations in temperature and/or high humidity conditions will guarantee early, high yielding and high quality horticultural 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 a high tunnel. Conventional tillage and establishment of the crop in soil may be efficient for cool season crops that can be direct seeded or transplanted such as, 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 inches may also be constructed in the 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 their 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 through each bag. 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 soilborne 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-15 “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 NJ". This can be found at the website njaes.rutgers.edu/pubs/ and select All Fact Sheets and Bulletins. This information is applicable to all states in the mid-Atlantic U.S. region.

Table A-2. Relative planting and harvest schedule for freestanding high tunnel vegetable crop production in Mid-Atlantic region

Crop[z]	**Planting Method**[y]	**Average High Tunnel Planting Dates**	**Average High Tunnel Harvest Dates**
Beet	TRP or DS	February-April; August-October15	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-May15 August 1-15	May-December
Cabbage (Chinese)	TRP or DS	February15-April 15	April-June; October-December 10
Carrot	DS	February 1-April 15 August-October	March-June; November-April
Cauliflower	TRP or DS	March 15-April 15 August	May-June; October-December10
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	August	October-December
Leek	TRP or DS	February 15-November 1	Year-round-
Lettuce	TRP or DS	February 1-October 15	Year-round
Onion (bunching green)	TRP or DS	October-December February-June	March-December
Onion (bulb)	TRP	February-March October-November[x]	May-July
Pea	TRP or DS	February 14-April 15 August-September 10	May-June October-November
Pepper (bell)	TRP	April-July 20	June-November
Potato (Irish)	DS	February 14-March 15 August	May-June October-November
Radish	DS	February-April October-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 25-July 15	June 15-December 5
Turnip	DS	February-April September-December	February-May November-January

GREENHOUSE PRODUCTION

Many growers have an interest in increasing productivity as well as having a seasonal product such as tomato and sweet pepper year round. To do this in the mid-Atlantic U.S., a temperature controlled structure such as a greenhouse 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, and pest management than field production. 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 several have been provided below. This list is not all inclusive and does not endorse these guides exclusively.

http://www.caes.uga.edu/publications/pubDetail.cfm?pk_id=6281

http://msucares.com/pubs/publications/p1828.pdf

http://edis.ifas.ufl.edu/topic_book_florida_greenhouse_vegetable_production_handbook

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 more difficult is that surrounding private lands and suburban neighborhoods provide refuge for wildlife that may be causing damage on farms and to which a grower has no access.

A wildlife damage management plan that 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, while other areas most likely can tolerate some damage. In most instances, wildlife of damage represents another cost of doing business; it's the severely damaging episodes must be avoided. The plan also should specify what management techniques you want to utilize and when they would be employed. Wildlife damage management practices can be divided into 3 major categories: husbandry methods, non-lethal techniques, and lethal techniques. This also is the order in which application should be implemented; lethal techniques are methods of last resort. Growers should recognize that many approaches 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 wide variety of damage management options exists, but not all may be suitable for use in all cases. 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.

Capital and implementation costs associated with each management option also vary. Before you make any decisions regarding the management technique you may choose to employ, estimate the direct and indirect annual losses you actually experience from wildlife damage. An example of a direct cost would be the yield lost by consumption of the crop by wildlife. An indirect cost would be the amount of time you spend, over the course of a year, trying to reduce or eliminate wildlife 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 surveys.

Prior to employing any damage abatement practice, you must assure that you have correctly identified the species doing the damage. Do not assume that because you see an animal on your farm that it is causing 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, in addition to employing a technique that may not be effective, you also may find you are using an illegal approach. Therefore, before implementing 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,

Deer Damage

Deer damage may occur in the form of feeding, antler rubs, and/or trampling of crops. Browsing (feeding) damage from deer can be recognized by a torn, jagged appearance on vegetation or a ragged break on woody material. Most browsing damage occurs from ground level up to 6 feet above ground level. 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 feet 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. This strategy has been used effectively to reduce incidences of deer-vehicle collisions and also browsing on residential vegetation and commercial landscaping.

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 been used with some success on farms, depending on the number and aggressiveness of dogs and size of 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 8-10 feet 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 for smaller acreages. 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 increase 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 feet 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 are 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 by spraying, shakable powders, or using a brush and repel by taste and/or odor. Area repellents are applied in the general vicinity of the protected object and repel primarily by odor. Repellents are can be expensive, based on initial cost of materials, but more so by the need for frequent reapplication. Rain can wash repellent off of protected 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 for 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 be 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, 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 now ban the translocation of deer. **This practice is not 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 may be chemically immobilized prior to euthanasia. Approved methods for inducing death are barbiturate injections delivered intravenously or into the abdominal cavity, inhalant anesthetics, or potassium chloride in conjunction with general anesthesia. Use of a penetrating captive bolt gun is also approved if the animal is restrained to allow for accuracy. Captive bolt gun euthanasia is considered controversial because deer euthanized in this way can experience trauma if the process does not occur quickly. This method also is labor intensive and more expensive than other management strategies. Chemically or captive bolt gun euthanized deer cannot be consumed by humans. **This practice is not permitted in some jurisdictions (e.g.**

Virginia). Consult your local Wildlife Management Authority.

The Community-Based Deer Management Program addresses the need for deer population reduction in environments where traditional management methods are not an option. Under this program the state Fish and Wildlife authority cooperates with municipal, county, and federal agencies to provide technical assistance in developing alternative deer management options. Some options include sharpshooting, noise-suppressed firearms, and controlled hunting. State authorities have issued permits for special deer management areas where alternative control methods may be employed. Alternative control methods may only be employed after a series of municipal and state approvals are granted. **This practice is not permitted in some jurisdictions (e.g. Virginia). 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 these permits.

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. Localized or conditional hunting permits are highly variable among jurisdictions, **consult your local authority**. These permits 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 also may 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 random lotteries of licensed hunters to rigorous hunter-selection processes designed to determine hunting proficiency and disposition as means to reduce conflicts with the public or other hunters. Specific restrictions and controls applied to hunting activities will depend upon the needs and concerns of landowners, elected officials, and other stakeholders, but they usually involve measures similar to hunting regulations during normal deer hunting seasons.

Because deer populations range over multiple parcels or farms, management of deer numbers cannot be implemented effectively on single properties. 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 such a program, the state Fish and Wildlife agency works with municipal, county, and federal agencies to develop alternative deer management options tailored to that specific community. Some options include sharpshooting, noise-suppressed firearms, and controlled hunting. State authorities have issued permits for special deer management areas where alternative control methods may be employed. Alternative control methods may only be employed after a series of municipal and state approvals are granted.

Woodland and Meadow Vole Damage

It is important to determine which species of vole occurs in your crop production sites. The two species of voles 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 5 ½ to 7 ½ 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 to 6 inches in length, 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 being grown. In vegetable crops, damage usually occurs in spring, as young plants are emerging from the ground. 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. Aboveground 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. 1 ½ 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 foot 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). The only General Use Pesticide (GUP) approved for use in vole control is warfarin (alone or in combination with imidacloprid). Individual voles must ingest the bait 3 times to sustain a lethal dose. Therefore, bait stations must be continually 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 foul taste, voles may avoid bait stations. 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 injury to non-target species, the use of bait stations is recommended and may be required in some states. Broadcasting bait across the area, or placing bait in piles or on bare soils, is not allowed. Shingles and tires used as bait stations are acceptable under state Pesticide Laws. However, the bait may not stay dry for long and quickly becomes ineffective when wet. In-furrow placement of zinc phosphide pellets is approved for corn and soybeans under a no-tillage management system. Hand placement of baits directly in 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.

Rabbit Damage

Rabbits can damage vegetation by clipping branches, stems, and buds. Damage may become especially pronounced during the heavy snow cover on overwintering vegetables 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-degree angle cut where the damage has occurred. Rabbit tracks and their pelleted scat are easily recognizable.

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 sites. However, removal of 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 to regulate rabbit numbers. Planting alternative crops in adjacent tracts has been suggested as a means to deter them 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. The bottom of the fence should be buried 12 inches in the ground and bent outward away from the crops at a 90-degree angle. Larger areas can be protected with double-strand electric fencing.

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 to 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 at ground level. A good way to do this is with several shovel-fulls of pea-sized gravel, placed inside and outside the guard. The gravel will also prevent mice from injuring plants.

Miscellaneous Methods. Harassment techniques, such as dogs and water-driven scarecrows, provide only short-term protection. Contact (e.g., thiram-based) and area (e.g., naphthalene) repellents have also 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 usually be hunted during open rabbit seasons. Finally, trapping rabbits using either homemade or commercial live-traps 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.

Groundhog Damage

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 to 12 inches. There are usually 2 or more additional entrances to a burrow system, and the secondary entrances usually will be well hidden. Groundhogs prefer leafy vegetable crops, but will utilize any crop throughout the growing season Seasonal or cyclic reproductive patterns may influence population numbers 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 used and the size of the area to be protected. An electric wire placed 3-4" above the ground can deter groundhogs from entering a desired area. However, a determined groundhog eventually will dig under the wire and gain access to the protected 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 feet from 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 young emerge. Gas cartridges are a 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. Newly resident animals may recolonize empty burrow systems, so continued vigilance in 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 feet of any occupied building or in areas where gas could escape into areas occupied by animals or humans. Aluminum phosphide is a 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 effectively trap groundhogs. 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 off-site. If the groundhog is 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 is not 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. Growers should verify with the state wildlife agency which weapons that are legal for this purpose in your state.

Bird Damage

Blackbirds refer to a group of 10 species, including common grackle (*Quiscalus quiscula*) and brown-headed cowbird (*Molothrus ater*). The damage these birds inflict most often consists of holes and/or surface blemishes from the pecking of fruits, bulbs, or stems. Proper identification of the bird species doing the damage is relatively easy since it is common to see blackbirds in and around farming operations. European starlings (*Sturnus vulgaris*) 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.

Blackbirds are considered migratory species and thus are granted protection under the federal Migratory Bird Treaty Act. Therefore, 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 to 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 of 1/3 of a tree's crown or a 1/3 of a stand of trees has been successful in reducing or dispersing birds from a roost. Keep in mind, however, that you are also modifying habitat used by other non-destructive bird species. Providing hunting perches for raptors may reduce blackbird numbers as a result of the threat of predation.

Exclusion 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 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.

However, methyl anthranilate remains viable for only approximately 3 days, so it loses maximum 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 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 the remaining birds in the flock, causing them to vacate the area. Dead birds should be collected and disposed of properly. However, use and application of such chemical agents is restricted only to certified applicators (usually representatives of USDA APHIS-WS). Check with your local county extension agent about the 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 are considered to be a non-native species and thus do not have protection under migratory bird laws. Therefore, farmers are allowed to shoot starlings 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.

Bear Damage

The 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 all the corn on a cob before moving on to another. Scat 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. Fences should be baited at approximately 3 feet along the entire perimeter to encourage shock delivery to the muzzle.

Sensory deterrents have been used to deter black bears from crop fields. Pyrotechnics, horns, bright lights, propane cannons, and other such devices provide both visual and auditory stimulation. The success of these techniques is highly variable, and bears usually become habituated to consistent or repetitive disturbance. Sensory deterrents should be switched and relocated often to maximize effectiveness. 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.

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.**

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 requires pollination. Generally as the number of bee visits increases there will be an increase in fruit set, number of seeds per fruit, fruit shape and fruit weight. Pollen transfer between strawberry flowers 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

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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.**

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 requires pollination. Generally as the number of bee visits increases there will be an increase in fruit set, number of seeds per fruit, fruit shape and fruit weight. Pollen transfer between strawberry flowers 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 (eggplant, lima beans, okra, peppers) often benefit from pollen transfer by insects.

Bees are the most important group of insects for crop pollination. European honey bees 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), squash bees (*Peponapis pruinosa*), orchard bees (*Osmia* species), and many species of solitary bees most of which nest in soil. Surveys of wild bees reveals over 80 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 cucumbers, strawberries, and muskmelons 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 (12.8°C). Flights seldom intensify until the temperature reaches 70° F (21.1°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 & 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.

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 (*Apis mellifera*) are the primary managed pollinators because colonies with large populations can be easily moved to the field each year. With the introduction of parasitic honey bee mites (mainly *Varroa destructor*) along with likely impacts of pathogens, insecticides, and fungicides, the viability of European honey bee colonies has decreased. 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 (http://maarec.psu.edu) is a regional group focused on addressing the crisis facing the beekeeping industry. Additional relevant websites are www.beeccdcap.uga.edu and ento.psu.edu/pollinators.

Ideally, colonies should be protected from exposure to sunlight. An east or southeast hive entrance encourages bee flights. The hives should be elevated and the front entrance kept free of grass and weeds. A clean water supply should be available within a quarter mile of the hive. The number of colonies per acre to ensure adequate pollination varies with location, attractiveness of crop, density of flowers, and length of blooming period, colony strength, and competitive plants in the area. In vine crops and strawberries recommendations are one to two 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 with the beekeeper, make initial contact the previous fall. Beekeepers usually assess the survival and strength of their colonies from mid-February to mid-March.
- Any request for hive relocation should be given 48 hours or more in advance.
- 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.
- 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 in the field, such as dandelions, should be eliminated by mowing, cultivation, or herbicides.
- Locate colonies for maximum effect. Place colonies in groups of four to eight 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 sure that rented honey bee colonies 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. See http://agdev.anr.udel.edu/maarec/ for more information.

- Consider the use of bee attractants. Sugar-based attractant sprays are generally ineffective. Bees collect the sugar off the leaves, usually without visiting the 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.

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. Remove extraneous foliage that provides alternative food sources to pollinators. 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. 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 greater than 1 mile from each other. 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 6-12 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 *B.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 disruption habitat.

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. NRCS 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 reproductives 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 are solitary (as opposed to social, 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 a range of 1 to 3 miles from the colony. Most species, however, stay within about 0.5 mile or less of their nest. 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 (Delaware): http://dda.delaware.gov/plantind/forms/publications/FarmManagementforNativeBees-AGuideforDelaware.pdf
- Biology of Squash Bees: http://ohioline.osu.edu/cv-fact/pdf/1003.pdf

Collections of resources are compiled at:

- Tools for Growers – supported by Project ICP (Integrated Crop Pollination) - http://icpbees.org/tools-for-growers/
- 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 www.xerces.org/pollinator-conservation/. Alternative managed pollinators are described in “Managing Alternative Pollinators: A Handbook for Beekeepers, Growers, and Conservationists” (Mader et al.; see Xerces web site).

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 D-6, also 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 48 hours notice, if possible, when you expect to spray 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.
- 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 at least 48 hours notice before spray application to allow for the movement of bees onto or off the crop.

All growers should become familiar with EPA’s new pollinator protection labeling guidelines and new bee advisory box which can be found at the following link: http://www2.epa.gov/pollinator-protection/new-labeling-neonicotinoid-pesticides.

FOOD SAFETY CONCERNS

In recent years, the importance of fruits and vegetables in the diet has received a considerable amount of attention. Fresh or processed products supply vitamins, fiber, and phytochemicals that are known to decrease the risk of several chronic diseases, including heart disease and cancer. Consumers are purchasing more fresh produce than ever before, and between 1970 and 2008, per capita consumption of fresh fruits increased 19 percent, while per capita consumption of fresh vegetables increased 67 percent.

However, reports of foodborne illness attributed to consumption of these products have also 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. The vast majority of 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 Norwalk 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. Many Internet resources on food safety are also available that feature updated information from this guide and other sources. The 1998 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. 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 certification from each participating grower. More recently, in 2011, the Food Safety Modernization Act (FSMA) was signed into law. FSMA (http://www.fda.gov/FSMA/) establishes mandatory practices growers must take to prevent microbial contamination of fresh produce. The final Produce Safety rule (under FSMA) will be released October 31st, 2015, with compliance dates ranging from two to six years. Not all produce farms will be regulated under the final Produce Safety rule (to determine inclusion in the regulation see http://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm 415031.htm). 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) 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. Worker Health and Hygiene, 4. Field Sanitation, 5. Packing Facility Sanitation, 6. Transportation, and 7. Product Trace-back. Each section is summarized below.

1. **Water.** Water is used for irrigation, pesticide application, cooling, transporting, washing, and processing. Water also has the potential to be a source of microbial contamination. Growers and packers, therefore, 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 such as 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 the irrigation water exceeds the agricultural water standards, water treatment with effective disinfectants would be necessary before continuing to use the water source. Application of MicroBiocides, CDG Solution 3000™, SaniDate 5.0 or 12 and calcium hypochlorite tablets have been shown to be efficient on the decontamination of bacterial foodborne pathogens, in irrigation water. Additionally, CDG Solution, SaniDate 5.0 and SaniDate 12.0 are approved by the Organic Materials Review Institute (OMRI) for use in irrigation water. 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 post-harvest operations, only potable water should be used. 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 (for example pH of the water should be monitored for proper chlorine efficacy; 100-150 ppm of free chlorine and a pH in the range of 6.5 to 7.5).

2. **Manure and Municipal Bio-solids.** 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 FSMA Produce Safety Rule regulations have not yet been finalized; therefore, recommendations/guidance/regulations may change. Consequently, growers are encouraged to consult relevant online resources or county extension offices about up to date manure recommendations and regulations.

   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. 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).

   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. Refer to: www.epa.gov/owm/mtb/biosolids/index.htm for an explanation of human health risks. See “Sewage Sludge” in the Plant Nutrient Recommendations section of this manual.

3. **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 use the toilet and handwashing facilities properly. Any worker who shows signs of an illness including diarrhea, coughing, fever, sneezing, sores, or infected wounds should not be allowed to handle produce.

4. **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.

5. **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 un-used pallets, bins, or containers should be kept in a covered location to prevent them from becoming contaminated. 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 should 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.

6. **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.

7. **Trace-back.** Traceability is defined as a procedure which tracks where a food product came from (e.g., 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 GAPS on the farm and in the packinghouse can be obtained from extension offices or the governmental agriculture authority in your state.

POSTHARVEST HANDLING

Vegetables that are fresh and have good flavor bring repeat sales and may bring higher prices. How you handle your produce directly affects freshness and, with some vegetables, how well they retain peak flavor.

For most vegetables, maintaining cool temperatures to slow deterioration and high humidity to prevent moisture loss are the most effective means of preserving quality. Different vegetable commodities, however, respond differently to temperature (Table A-4). Listed below are several ways producers, handlers, and retailers can assure that vegetables going to the market or into storage are of high quality.

Harvesting and handling.

1. Provide gentle harvesting and handling to avoid cuts, abrasions, and bruising damage to produce that allow decay-causing microorganisms to enter the tissue.
2. Harvest produce when consumers will be provided with the peak of quality. This assures greatest value at the time the commodity begins a sales period or storage period for later sale. Vegetables begin to deteriorate at the time of harvest and the highest quality produce will have the greatest shelf life.
3. Harvest during the cool part of the day, if possible. Since temperature controls the rate at which produce deteriorates, harvesting when the vegetables are coolest (usually just after sunrise) will extend their quality as long as possible. This will also reduce energy costs (see "cooling" below).
4. If storage facilities are not available, harvest only as much produce at one time as you can pack or sell while the quality is optimal. This will also allow you to replenish displays at roadside markets with freshly harvested produce throughout the day, ensuring the highest quality is available to your customers.
5. Make successive plantings and use several varieties of varying maturity to spread the harvest season. This allows you to have freshly harvested produce available over an extended period.
6. Use a shade cover on harvest bins, trailers, trucks and market areas. Perform sorting and packing operations in a shaded location. Vegetables exposed to the sun will absorb solar energy and become warmer than those in the shade. This is especially true of dark-colored vegetables, such as zucchini squash, eggplants, peppers, watermelons, green beans, and tomatoes that are often harvested during the middle of summer when solar energy is at a maximum. Workers will be more comfortable and, thus, work more efficiently in a shaded area. Shade may be provided by an open shed, shade cloth over a simple framework, or even by a large tree.
7. Display only good quality vegetables for sale. Those of poor quality will never improve. Frequent sorting to remove poor quality material will present the best display possible to your customers. Shade the sales display from the sun to reduce losses.
8. Remind your customers to keep produce cool (see Table A-4) and prevent moisture loss during transportation and storage at home.
9. For commodities that lose quality rapidly and those to be shipped to market, special postharvest washing, handling, and cooling are required to maintain quality (see Table A-4).

Washing and water treatment. Bacteria and fungi are present on the surface of all freshly harvested vegetables. Where wash water is used, the temperature of the water should be warmer (ideally 10°F warmer) than the pulp temperature of the produce to prevent decay-causing micro-organisms from being drawn into the tissue. Addition of chlorine to the wash water is effective in destroying decay-causing microorganisms on the surface of vegetables and extending shelf life. Chlorine can be added as a liquid sodium hypochlorite concentrate or dry form using calcium hypochlorite. Only labelled products for food use should be considered. The optimum concentration of available chlorine in the wash water depends on the commodity. Chlorination is most effective at pH 6.5 to 7.5. Buffers should be added to wash water to keep the pH in the desired range. Monitor dump/wash tanks and spray wash with commercially available test kits to verify that the correct pH and concentration of available chlorine are present. Consult the label for information on adjusting chlorine levels.

Note: pH (acidity and alkalinity) is best controlled using automated machinery and not manually. Consult with a water treatment specialist about availability, installation, and operation of this type of equipment.

Peroxyacetic acid, or peracetic acid is a mixture of hydrogen peroxide and acetic acid. It decomposes into acetic acid, water, and oxygen, all harmless residuals. Tsunami® 100 is an EPA registered antimicrobial agent for pathogen reduction that contains 11% hydrogen peroxide and 15% peroxyacetic acid and other components. It can be used on various types of conveyance, washing, and hydrocooling equipment in produce facilities in a solution giving 5-80 ppm peroxyacetic acid depending on the produce type and use. Other peroxyacetic acid products that are registered for produce may also be used for microbial reductions in produce washing.

Cooling. Two types of heat are present in vegetables. *Field heat* is the heat content of the vegetable that is due primarily to heat energy absorbed from the surrounding environment. *Heat of respiration* is the heat produced in the cells of the vegetable when sugars, fats, and proteins are oxidized to produce high-energy intermediate compounds, carbon dioxide, water, and **heat**. Quality is reduced more quickly by vegetables with high respiration rates and heat production. High produce temperatures also increase evaporation and transpiration of moisture for fruits and vegetables resulting in more rapid wilting and loss of quality. Cooling vegetables removes field heat, slows respiration, metabolic rates, and heat production. Slowing respiration and metabolic rates of the vegetable slows the rate of development, senescence, ripening, and tissue breakdown. Lowering the temperature also slows the growth rate of microorganisms, thus decreasing and delaying decay.

Methods for Cooling Produce (from Precooling Fruits and Vegetables in Georgia by Changying "Charlie" Li, Extension Agriculture Engineer, University of Georgia).

Room Cooling - Room cooling is a common and simple precooling method that exposes produce to cold air in a refrigerated room. Room cooling is usually used for products that have a relatively long storage life. These products are cooled and stored in the same room. In general, a simple and effective arrangement is to discharge cold air into a cooling room horizontally just below the ceiling. The air sweeps the ceiling and returns to the cooling coils after circulating through the produce on the floor. There should be enough refrigerated air volume to provide adequate cooling. The air velocity should be kept between 200 and 400 feet per minute around and between cooling containers. When cooling is complete, air velocity should be reduced to the lowest level that will keep produce cool – usually 10 to 20 feet per minute. One benefit of room cooling is that both the cooling and storage can be done in the same room and the produce does not need to be re-handled. In addition, room cooling requires a lower refrigeration load than other, faster cooling methods.

Forced-air cooling – Forced-air cooling is the most widely used precooling method in commercial practice. It is particularly popular among small operations because of its ability to handle a wide variety of products. It can rapidly aircool produce by creating an air pressure difference on opposite faces of stacks of vented containers. This pressure difference forces air through the stacks and carries heat away. Forced-air cooling has several advantages over room cooling. Forced-air cooling is much faster than room cooling because the cold air generally cools the produce by flowing around the individual fruits or vegetables in the containers. Forced-air cooling usually cools fresh produce in one to ten hours, which is one-tenth the time needed for room cooling. Rapid cooling can be accomplished with adequate refrigeration and a large volume of airflow per unit of produce. An existing room cooling system can be converted to forced-air.

Hydrocooling - Hydrocooling is one of the fastest precooling methods. Fruits and vegetables can be cooled rapidly by bringing them in contact with cold moving water. One main advantage of hydrocooling is that it does not remove water from the produce and may even revive slightly wilted produce. For efficient hydrocooling, water should come in contact with as much of the surface of each fruit or vegetable as possible. Water also must be kept as cold as possible without endangering produce. In commercial practices, water temperature is usually kept around 31°F except for chilling sensitive commodities. Conveyor hydrocoolers are the most common. Produce in bulk or in containers is carried on a conveyor through a shower of water. To avoid "channeling" (water pouring through larger openings where there is less resistance), it is necessary to either use a heavy shower over a shallow depth of produce or proportion the shower and the drainage from the bottom of containers so that the containers fill partly or entirely with water. Drainage must be sufficient to keep the water in the containers moving and to remove all water before containers leave the hydrocooler. To achieve optimal cooling and save energy, hydrocoolers should be insulated.

Package-icing - Packing crushed ice in containers with produce is one of the oldest and fastest cooling methods, and is particularly useful for cooling field-packed vegetables such as broccoli. It offers the advantage of fast cooling when the product directly contacts the ice, although the cooling rate could be significantly reduced when the ice melts. Another advantage is that the excess ice on the top of the product provides cooling during and after transportation. The product must be tolerant of the wet condition at 32°F for a prolonged time. The package-iced container should also be able to withstand wet conditions.

Vacuum cooling - Vacuum cooling cools fresh produce based on the principle of evaporation cooling: The moisture evaporates and takes heat away from the fresh produce when the atmospheric pressure is reduced below the boiling temperature of water. Leafy vegetables with a large surface area to mass ratio (such as iceberg lettuce) are well suited for this cooling method and can be cooled on a large scale by putting them in air-tight chambers and pumping out air and water vapor using steam-jet pumps. This method can cool packed produce quickly and uniformly in large loads (usually in 20 minutes to two hours), but container walls or other barriers that slow down evaporation can seriously inhibit cooling.

Choosing your ideal method for cooling vegetable products depends on the size of your operation and the commodities you handle. Products that are the most sensitive to heat damage are lettuce and greens, cole crops and legumes. Curcurbit fruits also benefit greatly from rapid heat removal. Root crops such as carrots, parsnips, radish, daikon, turnip, rutabaga, etc. benefit from hydrocooling to maintain tissue turgidity. Solanaceous fruits such as bell pepper and eggplant are less susceptible to heat, and maybe cooled by room or forced air. Care must be exercised when removing field heat from tomatoes. The internal temperature should not be less than 50°F. Vacuum cooling or hydro-vac is generally the most expensive, followed by hydrocooling, forced air, and top-icing. Room cooling is the most inexpensive method.

The length of time required to cool produce depends on method (air-, hydro-,or vacuum-cooled) and temperature of the medium used, initial temperature of the produce, final desired temperature, type of vegetable (i.e., fruit, leaf, or root), use and design of boxes or containers, and flow of cooling medium around the produce or containers. Thus, specific recommendations for cooling times for individual vegetables cannot be made. Determine the cooling time required in your operation by measuring the initial product temperature and the temperature during and after cooling. Temperatures of produce (head, cob, or pulp) must be measured because the temperature of air in cartons or the cooling/storage room does not accurately indicate the internal temperature of the produce.

The term *half-cooling time* is the time required to cool produce to one-half the difference between initial and final (or cooling medium) temperature. Half-cooling time will vary according to the crop, temperatures, and cooling method used. For example, if muskmelons with a pulp temperature of 80°F (26.7°C) are to be cooled to 40°F (4.4°C), the half-cooling time (t minutes) is the time required to cool the melons from 80°F (26.7°C) to 60°F (15.6°C). The time required to cool the melons from 60°F (15.6°C) to 50°F (10°C) is also equal to the half-cooling time of t minutes. This principal is illustrated in the Table A-3 and Figure A-1.

Table A-3 The Concept of Half Cooling Time

Produce Temperature, °F (°C)	Proportion of Cooling Completed	Relative Time to Cool to Indicated Temperature
80.0 (26.7)	--	--
60.0 (15.6)	1/2	t min
50.0 (10)	3/4	t min
45.0 (7.2)	7/8	t min
42.5 (5.8)	15/16	t min
		4t min

It can be seen from Figure A-1 that rate of cooling is most rapid during the early stages of cooling, and declines as temperature of the vegetable approaches the desired temperature or the temperature of the cooling medium. Cooling for a time equal to 4 times the half-cooling time or 15/16 of the desired cooling is sufficient for short-term holding and transit and when additional cooling will take place in transit or storage. For example, if you wish to use hydrocooling (chilled water) to reduce the temperature of carrots from 80º to 34ºF, the time necessary to reach 57ºF would be determined (e.g. 15 minutes), then the cooling would continue for at least 4 times longer (e.g. 60 minutes). Some vegetative tissues and many fruits of vegetable crops are sensitive to chilling temperatures [between 35^{o}F (1.7^{o}C) and 55^{o}F (12.8^{o}C)]. Avoid holding chilling-sensitive crops at these temperatures. See Table A-3 for information on chilling sensitivity of vegetable crops. Monitor temperatures during transit and storage to determine if optimum temperatures are being maintained.

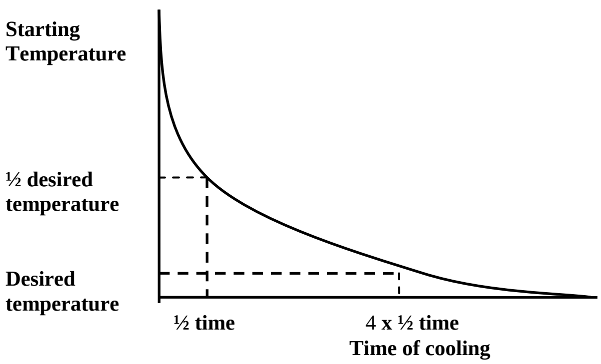

Figure A-1: Relationship of Half Cooling Time and Desired Temperature

Ethylene gas effects. Many vegetable crops lose quality, have reduced shelf life, and show specific symptoms of injury when exposed to ethylene at concentrations of 1 to 100 ppm after harvest. Some examples of ethylene effects include: russet spotting of lettuce along the mid-rib of the leaves, loss of green color in snap beans, increased toughness in turnips and asparagus spears, and development of bitterness in carrots and parsnips. Ethylene also causes yellowing and abscission of leaves of broccoli, cabbage, Chinese cabbage, and cauliflower; more rapid softening and yellowing of cucumbers, acorn and summer squash; and softening and development of off-flavor in watermelons. Ethylene increases browning and discoloration in eggplant pulp and seed and discoloration and off-flavor development in sweet potatoes. Ethylene can also cause sprouting of potatoes and increase ripening and softening of mature green tomatoes.

To avoid the detrimental effects of ethylene on vegetable quality and shelf life:

1. Do not store or transport ethylene-sensitive crops indicated above with ripening fruits such as apples, pears, peaches, plums, melons, avocadoes, bananas, and tomatoes that produce ethylene naturally.
2. Use electric forklifts in storage and transport areas because internal combustion engines may emit ethylene in the exhaust fumes.
3. Vent storage areas (one air exchange per hour) to reduce ethylene levels, or install ethylene absorbers in storage areas.
4. Consider the installation of equipment that selectively removes, absorbs or inhibits ethylene from your storage facility.

Table A-4. Handling Produce for Higher Quality and Longer Market Life[1]

Vegetable Crop	Recommended Cooling Methods[2]: Forced Air or Room Cooling	Hydrocooling	Package Ice or Liquid Icing	Vacuum Cooling	Important Handling Factors: Transit Icing[3]	Recommended Transit and Storage Temperature, °F	Recommended Transit and Storage Relative Humidity, %	Expected Marketable Life Under Best Conditions	Sensitivity to Chilling Injury[4]
Asparagus		+		+	N	32-36	95	1-2 weeks	L
Basil	+				N	46-50	90-95	4-7 days	H
Beans, lima & pod	+	+			N	38-42	90-95	7-10 days	M
Beans, snap	+	+			N	40-45	90-95	7-10 days	M
Beets, bunched		+			R	32	95	1-2 weeks	I
Broccoli			+		E	32	90-95	1-2 weeks	I
Brussels sprouts	+	+	+	+	R	32	90-95	3-5 weeks	I
Cabbage	+				N	32	90-95	3-6 weeks	I
Cabbage, Chinese	+		+	+	R	32	90-95	4-8 weeks	I
Carrots, bunched	+		+		E	32	90-95	1 month	I
Cauliflower	+		+	+	R	32	90-95	2-4 weeks	I
Celery		+			R	32	90-95	2-3 weeks	I
Collards & kale		+	+		R	32	90-95	1-2 weeks	I
Cucumbers	+	+			N	50	90-95	1-2 weeks	H
Eggplant	+				N	50	90-95	1 week	H
Endive & escarole				+	R	32	90-95	2-3 weeks	I
Horseradish	+				N	30-32	90-95	1 year	I
Kohlrabi	+	+	+		R	32	90-95	2-4 weeks	I
Leeks		+	+	+	R	32	90-95	1-3 months	I
Lettuce, crisphead				+	N	32-36	95	2-3 weeks	I
Lettuce, leaf & bibb			+	+	R	32-36	95	1 week	I
Lettuce, romaine				+	R	32-36	95	1-2 weeks	I
Muskmelon, 3/4 slip	+		+		R	36-40	85-90	1-2 weeks	M
Muskmelon, full slip	+		+		R	32-36	85-90	4-7 days	M
Okra		+			N	45-50	95	1 week	VH
Onions, dry					N	32	65-70	1-8 weeks	I
Onions, green		+	+		N	32	90-95	7-10 days	I
Parsley		+	+		E	32	95	1-2 months	I
Parsnips	+				N	32	90-95	2-6 months	I
Peas		+	+		E	32	90-95	1-2 weeks	I
Peppers	+			+	N	45-50	90-95	2-3 weeks	M
Potatoes, early	+				N	40	90	2-4 months	L
Potatoes, late	+				N	40-45	90	5-8 months	L
Pumpkins					N	50-55	70-75	2-3 months	H
Radishes, bunched		+	+		E	32	95	1-2 weeks	I
Rhubarb		+	+		R	32	95	3-4 weeks	I
Rutabagas	+				N	32	95	2-4 months	I
Spinach		+	+	+	E	32	90-95	7-10 days	I
Squash, summer	+	+			N	50	90-95	4-7 days	H
Squash, winter	+				N	50-55	50-75	2-6 months	M
Strawberries	+				N	32	95	1 week	L
Sweet potatoes	+				N	55-60	85-90	3-5 months	VH
Sweet corn	+	+	+		E	32	90-95	5-7 days	I
Tomatoes, green	+				N	60-70	85-90	1-3 weeks	H
Tomatoes, pink	+				N	55-65	85-90	5-10 days	M
Tomatoes, ripe	+				N	55-60	85-90	4-7 days	M
Turnips	+				N	32	95	4-5 months	I
Turnip & mustard tops		+	+	+	E	32	90-95	1-2 weeks	I
Watermelons		+			N	45-50	85-90	3-4 weeks	M

1 Information on optimum temperatures, relative humidity, and storage life was adopted from USDA Handbook 66 and modified by experience under eastern conditions.

2 *Cooling Method*: + = cooling method is suitable for the crop.

3 *Transit Icing*: The importance of transit icing depends on time in transit, transit conditions, and outside temperature. N - not recommended, R = recommended, and E = essential.

4 *Sensitivity to Chilling Injury*: I = insensitive, L = low sensitivity, M = medium sensitivity, H = high sensitivity, and VH - very high sensitivity.

TROUBLESHOOTING: DIAGNOSING VEGETABLE CROP PROBLEMS

When visiting a vegetable field, follow the steps outlined below to help solve any potential problems.

1. Determine whether there is a pattern to the symptoms.
   a. Does the pattern correlate with a certain area in the field, such as a low spot, poor-drainage area, edge of field or sheltered area? Does the pattern correlate with concurrent field operations, such as time of planting, pesticide application, method of fertilization, and rate of fertilization?

2. Try to trace the history of the problem.
   a. On what date were the symptoms first noticed?
   b. What fertilizer and liming practices have been used?
   c. What pest-management practices have been used to suppress or control diseases and undesirable insects and weeds--what chemicals (if any), when applied, and what application rates?
   d. What were the temperatures, moisture conditions, and level of sunlight?

3. Examine the plants affected to determine whether the problem is related to insects, diseases, or cultural practices.
   a. Do the symptoms point to **insect** problems? (A hand lens is usually essential to determine this.)
      (1) Look for the presence of insects on foliage, stems, and roots.
      (2) Look for feeding signs such as chewing, sucking, or boring.
   b. Do the symptoms suggest **disease** problems? These symptoms are usually not uniform; rather, they are specific for certain crops.
      (1) Look for necrotic (dead) areas on the roots, stems, leaves, and flowers.
      (2) Look for discoloration of the vascular tissue (plant veins).
      (3) Look for fungal or bacterial growth.
      (4) Look for virus patterns; often these are similar to injury from 2,4-D or other hormones.
   c. Do the symptoms point to **cultural** problems? Look for the following general characteristics; they may be different on specific crops:
      (1) Nutrient deficiencies.
         - Nitrogen--light green or yellow foliage. Nitrogen deficiencies are more acute on lower leaves.
         - Phosphorus--purple coloration of leaves; plants are stunted.
         - Potassium--brown leaf margins and leaf curling
         - Magnesium--interveinal chlorosis (yellowing between veins of older/lower leaves).
         - Boron--development of lateral growth; hollow, brownish stems; cracked petioles.
         - Iron--light green or yellow foliage occurs first and is more acute on young leaves.
         - Molybdenum--whiptail leaf symptoms on cauliflower and other crops in the cabbage family.
      (2) Nutrient toxicities. (Perform leaf tissue analysis and soluble salt test of soil)
         - Toxicity of minor elements--boron, zinc, manganese.
         - Soluble salt injury--wilting of the plant when wet; death, usually from excessive fertilizer application or salts in the irrigation water.
      (3) Soil problems. (Take soil tests of good and poor areas.)
         - Poor drainage.
         - Poor soil structure, compaction, etc.
      (4) Pesticide injury. (Usually uniform in the area or shows definite patterns.)
         - Insecticide burning or stunting.
         - Weed-killer (herbicide) burning stunting or abnormal growth.
      (5) Climatic damage.
         - High-temperature injury.
         - Low-temperature (chilling) injury.
         - Lack of water.
         - Excessive moisture (lack of soil oxygen excessive water and fruit cracking, edema).
         - Frost or freeze damage.
         - . Low light to high light intensity damage.
         - . Sunscald and leaf scorch
      (6) Other Physiological damage.
         - Physiological leaf curl.
         - Air-pollution injury.
      (7) Poor fruit or seed set due to inadequate pollination

In summary, when trying to solve a vegetable crop problem, look for a pattern in the symptoms, trace the history of the problem, and examine the plants and soil closely. Publications and bulletins designed to help the grower identify vegetable problems are available from your county Extension Agent.