

GENERAL PRODUCTION RECOMMENDATIONS

VARIETIES

New varieties and strains of vegetables are constantly being developed throughout the world. Since it is impossible to list and describe all of them, only some of the better performing commercial types are listed. Varieties are listed in the specific crop in Section F, either alphabetically or in order of relative time to maturity from early to late (see table footnotes). These varieties are believed to be suitable for commercial production under most conditions common to the mid-atlantic U.S. production region. The variety tables in Section F also indicate if these are geographical differences in varietal performance within the Mid-Atlantic Region. The ultimate value of a variety for a particular purpose is determined by the grower, the variety's performance under his or her management, and environmental conditions. Strains of a particular variety may perform better than the standard variety under certain conditions. A small trial planting for several years is suggested for any variety or strain not previously grown. For a true comparison, always include a standard variety in the same field or planting.

Plant Resistance or Tolerance

Vegetable crops are naturally resistant to many pathogens. In cases where diseases are a serious threat, genetic resistance is an effective and low cost strategy of avoidance. Pathogens are highly changeable, and a resistant variety that performs well in one year may not necessarily continue to do so.

Predicted resistance to pathogens some times 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. Letters in parentheses () appearing after the listed variety names refer in Section F to the genes for disease resistance or tolerance they contain and are coded in the "Abbreviations" section in the front of this book.

SEED STORAGE AND HANDLING

Both high temperature and relative humidity will reduce seed germination and vigor. Do not store seed in areas that have a combined temperature and humidity value greater than 110 (i.e., 50°F [12.8°C] + 60 percent relative humidity). Ideal storage conditions for most seed are at a temperature of 32°F (0°C) and less than 40 percent relative humidity. In addition, primed seeds pretreated with salt water do not store well after shipment to the buyer. Seed pelleting may or may not affect germination. Therefore, if you do not use all the pelleted seed ordered in the same season, 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 dropped or thrown since the

seed coats and embryos can crack, resulting in a nonviable seed. If you plan to treat these seed with a fungicide, inoculum, or other chemical application, apply gently to avoid seed damage.

SPECIALTY VEGETABLES

Highly perishable specialty or "gourmet" vegetables offer promise for increased net profits. Before planting the crop, however, **growers must determine that specific retail, wholesale, restaurant, or processing markets exist.** Specialty vegetables often require investment in specific types of equipment, and new field preparation or management techniques.

Growers should also be aware that fewer pesticides are registered for many specialty vegetables and herbs. Successful pest control in these crops is more dependent on sanitation, seed treatment, crop rotation, planting site, mechanical cultivation, and the use of resistant varieties than pesticides. Other methods include the release of biological control agents, conservation of natural and introduced biological control agents through strip cropping, intercropping, and borders with habitats, physical exclusion or repulsion of pests, trap crops, and mechanical cultivation.

Promising perishable specialty crops are asparagus, Belgium endive, dandelion (blanched), greens (collard, kale, mustard, turnip, and tyfon), herbs, oriental vegetables, red leaf lettuce types, romaine lettuce (red and green types), scallions, snap beans (small sieve, harvested less mature), snap peas, snow peas, edamame, Asian and Hispanic cucurbits, and sweet corn types with enhanced sugar and high quality.

Less perishable types that offer promise are bok choy, Chinese cabbage, endive and escarole (blanched), garlic (pink skin), leeks, pak choi, red radicchio, rhubarb, sweet onions, and sweet potatoes (moist types with unusual color).

Miniature or baby vegetables that can be grown are beets, cucumbers (harvested less mature), eggplant "little fingers" type, pickling corn ears, snap beans (small sieve harvested less mature), and summer and acorn squash (immature with blossom attached).

Market demand for vegetables and types of commodities that cater to the special needs and preferences of ethnic groups has also expanded.

ORGANIC PRODUCTION

Vegetable growers may wish to consider organic production. Initial investment is high, partially related to certification costs and increased time and labor for management. However, returns can be higher than conventionally produced products, provided that sufficiently higher wholesale prices can be obtained. The USDA regulates the term 'organic' to protect the sector from profiteers. To become certified organic, growers 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 Northeast Organic Farmers Association (NOFA). 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 adapt 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. Organic farming is replete with products and methods that do not necessarily work. Care should be exercised while incorporating new technologies into your overall system

Growers may wish to 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.

Growers who are beginning the transition phase from non-organic to organic production may wish to 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.

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. 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 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
Eggplants	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
Melons ¹	70-75	65	2-3	6	24
Onions	65-70	60	9-12	--	--
Peppers	70-75	60	8-9	4-6	36
Summer squash ¹	70-75	65	2-3	4	36
Sweet potatoes	75-85		4-5	in bed	in bed
Tomatoes	65-75	60	5-6	6-9	24

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

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. The formula for a very simple mix is given in Table A-2, but a preferred formulation is shown in Table A-3. If plants are to be grown in mix longer than 8 weeks, use the formula in Table A-3.

Table A-2. Simple Plant-Growing Mix

Materials	Cubic Yard (22 Bushels)	2 Bushels
Shredded sphagnum peat moss	11 bu	1 bu (10 gal)
No. 2, 3, or 4 domestic or African vermiculite ¹ or horticultural grade (dust-screened)	11 bu	1 bu (10 gal)
Pulverized limestone		
use <i>dolomitic</i> lime for mixes made with <i>domestic</i> vermiculite	10 lb	1 lb (1¼ cups)
<i>or</i>		
use <i>calcitic</i> lime mixes made with <i>African</i> vermiculite	6 lb	9 oz (¾ cup)
Superphosphate (20% P ₂ O ₅) or Triple superphosphate (46% P ₂ O ₅)	2½ lb	4 oz (½ cup)
	1¼ lb	2 oz (¼ cup)
Fertilizer (5-10-10)	5 lb	8 oz (1 cup)

¹ Vermiculite should be pea-sized and relatively free of fines and dust. Final mix should have a pH of 6.0-6.5.

Notes. Good results for growing lettuce and cabbage transplants have been obtained by diluting this mix with an equal part of sand.

This mix will only get the seedlings up. Supplemental fertilizing will be needed to grow plants to transplant size. About 3 weeks after seeding, begin liquid fertilizing the plants with a soluble fertilizer, such as a 20-20-20, at the rate of 2-3 teaspoons per gallon of water. This rate should be applied at least weekly. More frequent applications may be desirable.

Table A-3. Preferred Plant-Growing Mix

Materials	Cubic Yard	
	(22 Bushels)	2 Bushels
Shredded sphagnum peat moss	11 bu	1 bu (10 gal)
No. 2, 3, or 4 domestic vermiculite ¹ or horticultural grade (dust-screened) <i>or</i>	11 bu	1 bu (10 gal)
African vermiculite ¹ Pulverized limestone use <i>dolomitic</i> lime for mixes made with <i>domestic</i> vermiculite <i>or</i> use <i>calciitic</i> lime mixes made with <i>African</i> vermiculite	11 bu	1 bu (10 gal)
Superphosphate (20% P ₂ O ₅) or Triple superphosphate (46% P ₂ O ₅)	10 lb	1 lb (1¼ cups)
Sulfate or muriate of potash (50%-60% K ₂ O)	6 lb	9 oz (¾ cup)
Osmocote ² (18-6-12)	2½ lb	4 oz (½ cup)
Tomatoes	1¼ lb	2 oz (¼ cup)
Eggplants	½ lb	1 oz (2 tbs)
Peppers	½ lb	1 oz (2 tbs)
Micronutrient mix	Use according to mfr.'s recommendations	
Wetting agent (such as Aqua-Gro granular)	1½ pt	1 oz (4 tbs)

¹ Vermiculite should be approximately pea-sized and relatively free of fines and dust. Final mix should have a pH of 6.0-6.5.

² Osmocote is a slow-release fertilizer. Use a formula that will release nutrients over a period of 8 to 9 months. Therefore, mixes should be made just prior to seeding. Plants grown in mixes containing Osmocote must be carefully watered and the temperature carefully controlled prior to field planting. Reduced rates are suggested to control plant height when using small cells.

Regardless of which formula is chosen, unless good mixing procedures are used, the results will be less than optimal. For best mixing, use a horizontal-type paddle mixer that folds or blends the components, such as lime and fertilizer, evenly throughout the mix. With tilted or other types of mixers, the components tend to segregate or separate out, resulting in erratic performance of the mix.

Good procedures to follow when preparing a mix are:

1. **Use a respirator to prevent inhalation of dust when mixing peat, vermiculite and additives.**
2. For small quantities of mix preparation--1 cubic yard or less--place 4 to 5 inches of vermiculite in the bottom of a 5-gallon pail. Add all the additives (lime, fertilizer, micronutrient, etc.) to the vermiculite in the pail and mix thoroughly.
3. Fluff the recommended amount of peat. Start mixer and begin blending the peat.
4. While blending, add water according to the dampness of the peat. You will need approximately 1 gallon of water per bushel of peat in the mix.
5. While blending, slowly pour the additives, which you have already mixed thoroughly with a small amount of vermiculite, into the mixer and blend for 3 to 5 minutes.
6. Add the recommended amount of vermiculite after the other ingredients and blend for 1 minute or less, depending on the consistency of the vermiculite. It should be mixed thoroughly

without breaking down. Soon after mixing, use the mix for growing your plants. It is not a good practice to stockpile the mix in large piles for long periods of time.

7. Read all labels of the ingredients used, and heed all warnings that may be marked on the labels or bags.

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. Avoid formulations having fine particles, which may hold excessive water and have poor aeration. **Have media formulations tested by your state soil test laboratory to determine the pH and nutrient levels in the media before planting.**

If plants are yellow, growing slowly, or stunted due to high pH (7.0 or higher) in the growing medium, drench seedlings in trays with a solution containing 1 to 1.5 pounds iron sulfate (FeSO₄) per 100 gallons of water. Rinse seedlings after drenching.

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 to be 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:

Chlorine bleach. Dip in the chlorine bleach solution several times. Cover treated flats and trays with a tarp to keep them wet overnight. Wash flats and trays with clean water or a Q-salt to eliminate the chlorine. It is important that the bleach solution remains below pH 6.8 and that new solutions be made up every 2 hours or whenever it becomes dirty. Organic matter will remove the active 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.

Plant Containers. Individual plant-growing containers should 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. Seed that is sown in flats to be "pricked out" at a later date should be germinated in straight 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. 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 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 or in a floor-heated greenhouse. If floor heat or benches are not available, seed the trays, water, and stack them off the floor during germination. **Caution:** be sure to unstack trays before seedlings emerge from the soil surface.

Plant Growing Facilities. Good plant-growing facilities (greenhouses) provide maximum light to the seedling crop. The glass or plastic glazing should be clean, clear, and in good repair. The ideal greenhouse will also have soil-heating capabilities, either on the benches or on the floor, and provide good heating and ventilation systems for effective environmental control. Proper soil temperature ensures uniformity of crop throughout the greenhouse by moderating normal temperature variations experienced with hot air heating systems. Soil heating and growing the crops on the floor provide for a significant energy savings because the greenhouse does not have to be operated 10°F higher than the required soil temperatures for good germination and seedling growth. Heating units are best located in sheds or a headhouse outside the growing area to minimize the chance for aerial pollution adversely affecting the seedlings. Units located inside the greenhouse must be vented and have an outside fresh-air intake to provide air to the heater. The heating and ventilation thermostats must have a wide difference in temperature setting to insure that the exhaust fans do not operate when the heating units are running. Improperly designed ventilation systems that draw in exhaust gases from internal combustion engines can cause yellowing, stunting, and death of the seedlings. 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. Consult Chapter B "Nutrient Management" for an explanation of commercial fertilizer formulations and plant nutritional requirements. If nutrients are needed, the following materials dissolved in 5 gallons of water and used over an area of 20 square feet are recommended for use on the transplants:

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

15-15-15---2 oz/5 gal water

15-30-15---2 oz/5 gal water

Rinse leaves after liquid feeding. Fertilizers used for liquid feeding should be 100 percent water soluble.

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.

Hardening. 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 increases early bolting. Avoid overhardening or underhardening.

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-borne diseases Fusarium and Verticillium wilt, bacterial wilt and nematodes. Grafting may reduce or eliminate the use of certain pesticides (especially fumigants) because the rootstocks will provide tolerance to many soil insect and disease pests. 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 benefit. For example, disease resistance in infested soil. Any grower seeking to perform large-scale grafting should first consult technical resources. Upgraded facilities and employee training will likely be necessary.

NO-TILL CROP PRODUCTION

No-till crop production practices are beneficial for a variety of reasons. Soil compaction is reduced. Water infiltration is improved, and soil erosion from wind and water run-off is reduced. Contamination of waterways with nutrients and pesticide residues is reduced by eliminating or curtailing water run-off and soil erosion. Crop and cover crop residue on the soil surface can provide mulch that moderates soil temperature, reduces soil moisture loss, and may suppress weeds; however, no-till crop production systems do not necessarily make weed control easier or simpler.

Weeds are controlled using biological, cultural, mechanical, or chemical practices.

No-till weed crop production systems eliminate the mechanical weed control option for managing unwanted vegetation in a field. This places greater reliance on the other methods of weed control, especially cultural and chemical control methods. Chemical control methods are often relied on more heavily in no-till systems, and are usually the only control measure available after the crop has emerged if pre-plant cultural control measures fail. Heavy reliance on chemical weed control options in no-till systems increases the possibility that herbicide resistance will develop within existing weed populations. Consequently, the grower should expect to exert more time and energy, and to spend more money controlling weeds in no-till crop production systems than in conventional systems that can utilize mechanical tillage options.

MULCHES AND ROW COVERS

An ideal 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 at 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.

Mulches. The most popular mulches are clear and black polyethylene film (1 to 1¼ mil). Clear polyethylene is used primarily on cucumbers, melons, eggplants, and sweet corn. With the exception of sweet corn, soil fumigation is used in conjunction with clear plastic for weed, disease, and insect control. This increases the cost of using clear plastic when compared with black plastic. However, clear plastic will result in higher soil temperatures, which usually results in greater yields. Different colors and compositions impart new functional properties to mulch. Green 'IRT' types of plastic mulch increase soil temperatures more than black plastic and also suppress most weed growth. The greatest advantage in using green and clear plastic is generally with the earliest plantings. Silver mylar or aluminized mulches exert repellent properties on certain insect pests (aphids, thrips). To obtain the maximum increase in soil temperature, apply mulch films 10-30 days before planting. Allow 21 days for fumigants to dissipate before planting.

For later plantings, black plastic mulch may result in greater net returns than clear plastic. Black polyethylene is used on melons, eggplants, peppers, and tomatoes. Specific crops may respond to specific mulch colors. Tomatoes often yield more on red compared to black plastic, whereas cucumbers may yield more on blue than black. Cantaloupes may produce higher yields on blue or IRT than black plastic, and late-planted peppers may yield more on silver than black plastic. June plantings of tomato may benefit from the use of white plastic to moderate root zone temperatures. Aluminized plastic mulch is used on fall squash and Chinese cabbage because it repels aphids which spread mosaic virus. Yellow mulches attract cucumber beetles and may attract other insect pests. Note that planting date and environmental conditions influence crop responses to color of mulch films.

In a typical operation, a 4-foot-wide mulch and drip irrigation are laid at the same time. Row length varies according to the design of the drip irrigation tubing and field topography. On steep terrain, row lengths may be limited to 300 feet. Under ideal conditions, row lengths of 600 feet or greater are possible. Mulch can be used for either seeded or transplanted crops. Transplanters are available or can be designed to plant through the plastic mulch.

Fertilization. Before considering a fertilization program for mulched crops, the grower should have the soil pH checked. 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, adjust the soil pH to around 6.5. If the pH is outside of this range, nutrients may be present but not available to the plants.

Calculating Fertilizer Rates Applied in Strips Where Plastic Mulch will be Laid. When using plastic mulch **without** trickle irrigation, the total amount of 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 than a broadcast application over the entire field. Growers applying fertilizer in strips where the plastic mulch will be laid should reduce the amount that would be applied on a whole acre by a percentage that is equivalent to the coverage of the plastic. For example, if the plastic is covering 3 feet and are placed on 6-foot centers, then the area covered is 50 percent. (In this example, 4-foot wide plastic was used, but 6 inches of each side are buried. Consequently, the coverage is only 3 foot wide).

Table A-4 below illustrates the reduction in fertilizer that should be calculated for 3 feet of mulch coverage on 5-, 6-, and 8-foot centers when considering applications of fertilizers per unit acre.

Table A-4 Conversion of Pounds of Fertilizer per Acre to Pounds per Mulched Acre at Different Row Spacings.

Pounds Fertilizer per Field Acre	Pounds per Mulched Acre		
	5-foot Centers (60% of total)	6-foot Centers (50% of total)	8-foot Centers (37.5% of total)
100	60	50	37.5
150	90	75	56
200	120	100	75
250	150	125	94
300	180	150	113
350	210	175	131
400	240	200	150
450	270	225	169
500	300	250	188
550	330	275	206
600	360	300	225
700	420	350	263

All essential plant nutrients, including major nutrients (N, P, K) as well as secondary and micronutrients, should be applied according to soil test results 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 determined to be an inefficient use of applied N. When trickle irrigation is used, see "Drip/Trickle Fertilization" in the specific crops sections (i.e., eggplants, muskmelons, peppers, tomatoes, and watermelons) of Section F.

Before any mulch is applied, it is extremely important that the soil moisture level be 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.

Degradable mulches. Photodegradable and biodegradable plastic mulches are available, but usually cost more than conventional films. This additional expense is offset to an extent by reduced disposal costs. They have many of the properties and provide the usual benefits of standard polyethylene mulches.

Photodegradable mulches begin to break down after the film has received a predetermined amount of sunlight. When a photodegradable film has received sufficient light, it becomes brittle and develops cracks, tears, and holes. Small sections of film may tear off and be blown around by the wind. Finally, the film breaks down into small flakes and disappears into the soil. **The edges covered by the soil retain their strength and break down very slowly.**

Biodegradable plastic mulches are weakened by exposure to sunlight and they continue to degrade in the soil by microorganisms when soil moisture and temperatures are favorable for biological activity. Biodegradable film will usually be retained on the surface of the soil rather than be blown away from the application site. In addition, all of the biodegradable film will eventually decompose, including the tucks buried in the soil. It is recommended that biodegradable mulch be incorporated into the soil at the end of the harvest or growing season.

Row covers. These are being used for frost protection, to hasten the maturity of the crop and also to effectively exclude certain insect pests. Currently, vented clear and translucent plastic covers are being used. Row covers are supported by wire hoops placed at 5- to 6-foot intervals in the row. Porous floating row covers are made of lightweight spun fibers or plastic placed loosely over the plants without wire supports. Floating covers are more applicable to the low-growing vine crops than upright plants like tomatoes and peppers. Upright plants have been injured by abrasion when the floating row cover rubs 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 put out over plastic mulch using a combination of mechanical application and hand labor. Research and development is under way on equipment that will cover the rows in one operation. However, farmer-made equipment in conjunction with hand labor is currently the most prevalent method.

Each grower considering mulches, drip irrigation, and/or row covers must weigh the economics involved. Does the potential increase in return justify the additional costs? Are the odds in the grower's favor of getting the most benefit in terms of earliness and yield from the mulch, drip irrigation, or row covers? Does the market usually offer price incentives for early produce or, as a result of harvesting early? Are you competing against produce from other regions? Polyethylene films, used for mulch have risen dramatically in cost because they originate from petroleum. Consult your dealer for current prices. Each grower must obtain the costs for his situation, calculate the potential return, and come to a decision as to whether these techniques are desirable.

Mulch removal. Several methods of removing the plastic have been tried, but on small acreages it is removed by hand by running a coultter 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, pores are open when carefully removed and stored indoors.

Crop foliage and weeds may increase the difficulty of mulch removal. Eliminate vegetation prior to replanting or removing mulch. Broadcast Gramoxone with nonionic surfactant according to labeled direction to desiccate weeds and crop foliage, or delay removal until after frost.

Disposal. Dispose of used plastic in an environmentally responsible manner. Regulations on disposal vary. Contact your local solid waste authority for recommended methods of disposal in your area.

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. Each grower must assess his/her 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 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. Where wooden stakes are used, 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 disinfection is heat treatment. Pathogens are completely eliminated from wooden stakes with exposure to $\geq 220^{\circ}\text{F}$ 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 bleach (sodium hypochlorite) or Oxidate® (hydrogen dioxide; see below). Research has shown that a 20-minute soak in a 5% solution of $\geq 5.25\%$ hypochlorite commercial bleach (equivalent to 0.026% hypochlorite) 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 $\geq 1/16^{\text{th}}$ inch. Pathogens embedded deep within the stake may be able to migrate back to the surface and re-infest fields, although this possibility has not yet been demonstrated. Adding a non-ionic surfactant to the disinfecting solution, increasing the soaking time to ≥ 1 hour, applying a vacuum during the stake soak, using a higher concentration or more potent source of hypochlorite (such as “heavy duty” or swimming pool grade chlorine), or using stakes comprised of non-absorbent stake materials (such as plastic or metal) will help to ensure the elimination of pathogens from the potentially infested stake. Many growers have successfully used the commercial product Oxidate® to disinfect stakes, but there is no research to establish the efficacy of this disinfecting agent as compared to heat or commercial bleach.

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. 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 96 feet 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 several feet to facilitate snow removal. The distance between tunnels should be large enough to allow for adequate (cross) ventilation in all of them. 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 have removable framing (Penn State design) 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 tunnel is covered, prepare the soil, apply and incorporate lime and preplant fertilizer as recommended for the intended crop or crops (See section F). 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 build up 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. When planting high tunnel crops in the spring, it is generally recommended to transplant the vegetable crop about two to three 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, 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 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 is conducive to powdery mildew development on crops such as cucurbits and tomatoes. Plan and execute a prophylactic fungicide program according to crop recommendations in Section F. 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.

WILDLIFE DAMAGE PREVENTION

Farms provide food and shelter for a variety of wildlife species in New Jersey. While many wildlife species do not cause damage to agricultural crops, certain types of wildlife can cost growers money in terms of loss of saleable vegetables. Additionally, surrounding areas, including private lands and suburban neighborhoods, can serve as refuges for some wildlife species that may be found causing damage on farms.

A wildlife damage management plan to proactively deploy prevention or control techniques is recommended. Within your plan, certain areas on your property are delineated for zero wildlife damage tolerance and other areas where some damage may be tolerated. The plan also specifies what types of control techniques you want to utilize. Wildlife damage management practices can be divided into lethal versus non-lethal categories. Different practices (e.g. hunting vs. trapping) may have varying levels of effectiveness and acceptable risk depending on location. Generally, an integrated wildlife damage management approach that employs numerous wildlife damage management techniques over a long-term period is more effective than a reactive strategy or an approach that uses only one or a few management practices.

A wide variety of non-lethal and lethal wildlife management options are currently available. Some options are more effective than others; some are temporary and intended for short-term, localized use, while others are permanent, long-term strategies that may be applicable on a regional or statewide scale. Purchase and implementation costs associated with each management option vary. Each situation where unwanted interactions between wildlife and people are occurring is unique, and management options are most effective when a comprehensive wildlife damage management plan is tailored for a specific site.

There are a wide range of costs associated prevention and control techniques. Before making any decisions as to

what type of prevention or control technique to employ, it is helpful to take some time to estimate your direct and indirect annual losses from wildlife damage. An example of a direct cost would be the yield loss consumption of the crop by wildlife. An indirect cost may be the amount of time you spend, over the course of a year, trying to reduce or eliminate wildlife damage. An estimated total annual cost, in terms of economic loss due to wildlife, helps you decide which strategies are the most cost-effective. In some instances, it may be more practical to tolerate a level of wildlife damage than to attempt to manage it.

Prior to employing any management practice to reduce or eliminate wildlife damage, it is essential that you correctly identify the species doing the damage. Do not assume that because you see an animal on your farm that it is causing damage. Many damage management practices (i.e. trapping, habitat modification) are designed to work with a specific animal's behavior, habits, and ecology in mind. Therefore, if you mistakenly identify the type of wildlife causing the damage, the type of management practice you employ to reduce or eliminate the damage may not be effective. Furthermore, to determine the need for control, the most appropriate control technique, and to evaluate the techniques' effectiveness, pre- and post-treatment surveys should be conducted.

Even though wild animals may be present on your private property, wildlife is legislated as a public resource. As such, many of the wildlife species that may be causing damage on your farm are protected by state and federal laws. Therefore, before conducting any lethal management practices, check with your county extension agent, local conservation officer, or your state Fish and Wildlife office to determine depredation permit requirements and/or legal hunting seasons. The publication FS1017: "Regulations Governing the Management of New Jersey Wildlife," is an additional source of information available at www.rce.rutgers.edu/pubs/. While it pertains specifically to New Jersey regulatory environment, the general information is very pertinent to residents of other Mid-Atlantic states as well.

DEER DAMAGE

Changing public attitudes and land use patterns in the Mid-Atlantic region of the U.S., especially decreased hunting pressure, public and private lands that act as deer refuges and the adaptability of white-tailed deer to human development, have led to highly abundant historical deer population levels. An overabundance of deer has negative impacts on agricultural crops, landscape plants, and deer-vehicle collisions. It also must be appreciated that white-tailed deer can provide recreational, ecological, economic, and aesthetic benefits for the citizens of the region.

There are a wide variety of non-lethal and lethal options available to manage white-tailed deer. All options have advantages, disadvantages, and costs, and each varies in effectiveness. The following will briefly outline options that are currently available as part of a comprehensive deer management program. Additionally, options such as reproductive controls that are still in the research phase and not yet available for managing a free-ranging deer population.

Deer damage may occur in the form of feeding, buck rubs, and/or trampling of crops. Browse (feeding) damage from deer can be recognized by a torn, jagged appearance on

vegetation or a square, ragged break on woody material. Most browse damage occurs from ground level up to 6-feet above ground level. Buck rubs can be identified by scarred saplings, broken limbs, bruised bark, and/or exposed wood. Rubs will usually be located on the trunk of trees up to 3 feet above ground level. Residual damage may occur from the trampling or matting down of vegetation as deer travel or bed down to rest.

Trap and translocation involves trapping deer and physically moving them from the location of capture to another area. 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. Once an animal is captured, it must be released at a suitable site. A prerequisite for such a site is low population of deer, which is often difficult to identify in the Mid-Atlantic region of the U.S. Studies have shown this method of deer management to be effective but often lethal to the relocated animal.

Habitat Modification involves changes within areas where deer reside that alter patterns of deer movement or feeding. White-tailed deer is an edge species, preferring habitats where two or more vegetation types or age classes meet. Habitat modification usually involves the elimination of vegetation, the planting of non-palatable (“deer-resistant”) species, or creating cover or foraging areas to attract deer away from areas targeted for management. This strategy has been used effectively to reduce incidences of deer-vehicle collisions and also browsing on residential vegetation and commercial landscaping.

Harassment or scaring options are intended to encourage deer to leave the area targeted for management. Examples include dogs and devices that make loud noises, such as propane cannons and sonic devices, and visual deterrents like bright lights. Audio and visual deterrents are most often used on farms and airports, and in certain suburban areas. Other devices, such as headlight reflectors and mirrors, and warning whistles are intended to scare deer away from roadways.

Repellents are both taste- and odor-based and are intended to encourage deer to avoid the area targeted for management. There are two types of repellents: contact or area. Contact repellents repel by taste, and are applied directly to the vegetation to be protected either by spraying or using a brush. Area repellents are applied in the vicinity of the vegetation to be protected and repel by odor. Repellents are relatively expensive and have variable effectiveness depending upon, among other factors, incident weather. Rain can wash repellent off of protected vegetation even if a “sticker” is used. Most repellents are recommended for use on dormant vegetation. If repellents are used during the growing season, they must be applied to new plant growth for maximum effectiveness. There are a host of commercial repellents available. Be aware, however, that most repellents are not labeled for food crops. Be sure to follow the manufacturer’s instructions. While contact repellents are usually more effective than area repellents, all repellents are intended to reduce, rather than eliminate, deer damage.

Fencing is a highly effective management option for eliminating or reducing white-tailed deer damage to landscaping, agricultural crops, and forested areas. Fencing varies greatly in unit (lineal foot) cost and design. Options range from temporary to permanent, barrier-type fences

consisting of high-tensile woven wire, heavy plastic, or electricity-conducting metal. While a single-strand electric fence can be very effective on a short-term basis; this type of fence may lose its effectiveness over time. A permanent 8-foot high tensile woven-wire fence, on the other hand, can provide both short- and long-term effectiveness. If deer pressure is very high, fencing may be the only permanent damage aversion solution. The grower should carefully consider historic patterns of deer damage and return on investment (damage abatement) in deciding whether to erect fencing, and which fence design will be the most cost-effective.

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 or gunshot is also approved if the animal is restrained to allow for accuracy. Deer meat from animals euthanized chemically may not be consumed by humans.

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, controlled hunting, live capture-euthanasia, and live capture-relocation. Some state authorities have issued depredation 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.

Permit to Shoot, commonly referred to as a “Depredation Permit”, can be issued by the state Fish and Wildlife authority to owners or lessees of land experiencing crop damage. In addition to regular deer hunting seasons, farmers may apply for a free (no time limitation) depredation permit if they are experiencing deer damage or anticipate deer damage during the growing season. For more information or to apply for a depredation permit, contact the state Fish and Wildlife authority.

Controlled hunting combines 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, in order to reduce potential conflicts with the public or other hunters. Specific restrictions and controls applied to hunting activities will depend on the needs and concerns of landowners, elected officials, and other stakeholders, but usually involve measures similar to hunting regulations during normal deer hunting seasons.

Regulated hunting involves hunters harvesting deer in accordance with defined seasons, bag limits, and population objectives. Hunting may legally take place during any of the

deer hunting seasons established by the state Fish and Wildlife authority. Regulated hunting is the most cost-effective and efficient method for managing deer, and is the only available management option for affecting deer population densities on a statewide level.

PINE AND MEADOW VOLE DAMAGE

It is important to determine which species of vole occurs in your crop production sites. The two most common types of voles found in the Mid-Atlantic U.S. region are the meadow vole (*Microtus pennsylvanicus*) and the pine vole (*Microtus pinetorum*). Meadow voles, also called meadow mice, are about 5 ½ to 7 ½ inches long, have variable colored fur ranging from gray to yellow-brown with black-tipped hairs, and have a bi-colored tail. Pine voles, also called woodland voles, are about 4 to 6 inches in length, have reddish-brown fur, and their relatively short tail is about the same length as the hind foot.

Meadow vole damage is usually in the form of gnawing on the base of woody perennial plants. Sprouts and suckers emerging from the base is evidence of this type of damage. Meadow voles construct surface runways that are 1 ½ to 2 inches wide. These runways can occur throughout the farm. In contrast, pine vole damage is in the form of root girdling, which often goes unnoticed until severe damage has already occurred and the tree is in rapid decline. Pine voles construct burrows that run 1 to 2 inches below ground surface within the trickle irrigation line.

Cultural Practices and Habitat Modification. Control of ground vegetation with herbicides, mowers, or disking helps limit voles by reducing potential cover. Overall, herbicides are the preferred method to eliminate sod. Cultural practices have definite limitations and should not be relied upon as a comprehensive control method for voles. The area should be kept clear of debris such as bags, boxes, and pruned branches since these items provide protection to voles and can hinder mowing and proper bait placement. A final close mowing of the row middles, after harvest, should be utilized annually to further reduce habitat and cover for rodents.

Toxicants. One of the most commonly used single-dose toxicants for vole control is zinc phosphide. Zinc phosphide is a Registered Use Pesticide available as a concentrate, or in pelleted or grain bait applications. As a Registered Use Pesticide, application must be done by a certified pesticide applicator. Zinc phosphide is marketed under many different trade names and is available at farm supply stores. 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, broadcasting bait across the area is not recommended, and may not be permitted, for vole control. Tamper-resistant bait stations may be required by state statutes. 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.

Hand placement of baits directly in runways and burrow openings within the tree drip line is more effective for pine vole control since they are largely confined to their subterranean burrows. Since pine voles store food and meadow voles do not, pine voles can be more susceptible to

bait that require repeated intake, such as anticoagulants. Meadow voles will feed on dry baits such as corn and oats, whereas pine voles prefer fleshy baits such as apples.

To ensure the legality of a particular toxicant in your state, information can be obtained by calling your Pesticide Control Program. As with all toxicants, follow the manufacturers suggested 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. Vegetation that has been clipped by rabbits is characterized by a cleanly snipped, 45-degree angle cut where the damage has occurred.

Cultural Practices and Habitat Modification. Maintaining a well-groomed farm and eliminating brush piles, heavy vegetation, and other types of cover in and adjacent to crop production sites should eliminate nesting sites and help to reduce the rabbit population. However, habitat modification such as removal of cover may have a detrimental effect on other wildlife species that also depend on brush piles for protection or shelter. In addition to habitat modification to control rabbit populations, habitat improvements to attract predators of rabbits (i.e. fox, coyote, and raptors) will help to eliminate the animals.

Exclusion. Fencing off your farm can be a very effective control technique to combat rabbits. A 2-foot high fence consisting of 1-inch or smaller mesh and constructed of any metal (rabbits will gnaw through plastic) material has proven successful in eliminating rabbit damage. The bottom of the fence should be tightly anchored to the ground or even buried 12 inches in the ground and bent outward away from the crops at a 90-degree angle.

Rabbit guards made of metal wire with 0.25- to 0.75-inch mesh are effective. Hardware cloth can also be used. Rabbit guards should be placed about 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.

All guards should be anchored at ground level. A good way to do this is with several shovels of pea-sized gravel placed inside and outside the guard. The gravel will also prevent mice from injuring plants.

Miscellaneous Methods. Rabbits are classified as a game species and, as such, can be hunted during open rabbit seasons. Contact (i.e. Thiram-based) and area (i.e. mothballs) repellents have also been used for rabbit control with variable effectiveness. Finally, trapping rabbits using either homemade or commercial live-traps may be a viable option if damage is not too extensive.

GROUNDHOG DAMAGE

The most obvious sign of groundhog presence, aside from actually seeing the animal, are the entrances to a groundhog burrow system. Groundhog burrows are noticeable due to a large mound of excavated earth at the burrow's main entrance. The diameter of the main entrance may measure 10 to 12 inches. There are usually 2 or more entrances to a burrow system, although some secondary entrances may not have mounds of earth in front of them and may be well hidden. Groundhogs can devastate vegetable crops of all kinds, and at all times of the year. They are not particular eaters, and will consume virtually any type of vegetable, and

any portion of the plant. They do exhibit seasonal behaviors with regard to reproduction and re-population, however, affecting the incidence and extent of damage.

Fumigants (Gas Cartridges and Aluminum Phosphide). Commercial gas cartridges (carbon monoxide) are the most common form of groundhog control. Ignited gas cartridges are placed in the burrow system with all entrances sealed. As the cartridge burns, carbon monoxide and other gases lethal to groundhogs are emitted. 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 General Use Pesticide 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.

Aluminum phosphide tablets, placed deep inside the main burrow entrance, are another type of fumigant that can provide effective groundhog control. The aluminum phosphide tablets react with the moisture in the soil, creating hydrogen phosphide gas. Soil moisture and tightly sealed burrow entrances are important for this type of 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 Registered Use Pesticide and can be applied only by a certified pesticide applicator.

Exclusion. Fencing can be an effective short- or long-term strategy depending on the type of fence used. An electric wire placed about 4 to 6 inches off the ground can deter groundhogs from a desired area in the relative short-term. However, a determined groundhog will eventually dig under the wire and gain access to the protected area.

A more permanent solution involves chicken wire or woven-wire fencing with mesh openings no larger than 2.5 inches. Fences should be at least 3 feet high. To prevent groundhogs from digging under the fence, the bottom edge of the fence should be buried at least 10 inches beneath the ground. In addition, the lower edge should have an L-shaped bend in it extending outward, and the top 15-inches of the fence above the ground should also be bent outward to prevent groundhogs from climbing over the fence.

Trapping. Steel, leghold traps are illegal in most states. However, a medium-sized live trap baited with a variety of baits (e.g. lettuce, apples or plum tomatoes) can provide effective groundhog control, especially in areas where gas cartridges or aluminum phosphide may create a fire or health hazard. 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.

Shooting. Groundhogs that are damaging crops or farmland can be shot at any time of the year by the farmer, those leasing farmland, their immediate relatives, and farm employees. Although groundhogs are considered a game species, farmers do not need a valid hunting license to

shoot nuisance groundhogs. Legal means available to shoot nuisance groundhogs include shotguns (10 ga. or smaller), bow and arrow, muzzleloading shotgun, centerfire and rimfire rifle, and muzzleloading rifles.

BIRD DAMAGE

Blackbirds can damage vegetable crops in the field. Damage most often occurs in the form of holes in fruit, bulbs, or stems from the birds pecking through the skin to eat the flesh or seeds. Blemishes may also occur from birds pecking at fruit or other plant organs. Proper identification of the bird species doing the damage is relatively easy since it is common to see blackbirds in and around farming operations.

Starlings and pigeons inhabit the rafters of barns, warehouses, and other structures. Birds inside packinghouses could be an issue, since fecal contamination may violate USDA food standard guidelines. Fecal contamination of fruit in the field may occur if a bird roost is nearby where large numbers of birds congregate.

Control of Blackbird Damage. Blackbirds are considered a migratory species, and as such, are granted federal protection under the Federal Migratory Bird Treaty Act. Prior to employing methods to control blackbirds, check with the state Fish and Wildlife authority at regarding state and federal wildlife laws.

Exclusion. For high-value crops like sweet corn, legumes, or solanaceous and cucurbit fruit, netting may be an option to exclude birds. Lightweight netting has been used successfully to prevent bird damage by either draping it over individual plants, or by constructing a frame where netting is stretched over entire blocks of plants. To prevent birds from entering packinghouses, netting, or some other type of barrier, should be placed over openings larger than 1-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.

Cultural Practices and Habitat Modification. Most blackbird damage that causes severe yield loss occurs within 5 miles of roosts. By planting crops attractive to blackbirds like field corn or sunflowers near a roost, you may be able to lure blackbirds away from your vegetable crops. The potential risk of this strategy is that you may attract even more birds to the area, and potentially to your farm. Reducing roost areas may also reduce the number of birds in the area. This may be done either by thinning the number of available branches, if a small number of trees are being used as a roost, or by thinning a stand of trees if a woodlot or grove of trees is being used as a roost. Removal of about one-third of either a tree's crown or 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 wildlife bird species.

Frightening. The employment of frightening devices has been effective in relatively short-term protection of vegetable crops. Frightening devices include pyrotechnics like propane cannons and shotguns, mylar balloons and tape, scarecrows, and tape-recorded bird-distress calls. Birds can quickly become habituated to any of these devices. 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 appropriate situations. Birds that ingest the treated bait fly in an erratic fashion, produce distress calls, and usually die. This unusual behavior often alarms the remaining birds, causing them to leave the area. Dead birds should be collected and properly and disposed of. Check with your local county extension agent prior to employing any chemical frightening agent to ensure the legal and safe use of chemical agents on your farm.

POLLINATION

Honeybees and pollinating wild bees visit the flower of several flowering vegetables and strawberries. They may improve the yield and quality of fruit in beans, eggplants, peas, and peppers and they are essential for commercial production of all vine crops and most strawberry varieties. Vine crops require bee pollination since two types of flowers are found on the vines and the pollen is dense and sticky. Cucumbers, squash, pumpkins, and watermelons have separate male and female flowers, while muskmelons have male and hermaphroditic (perfect or bisexual) flowers. The sticky pollen of the male flowers must be transferred to the female flowers to achieve fruit set. Lack of adequate pollination usually results in small or misshapen fruit in addition to low yields. The size and shape of the mature fruit is usually related to the number of seed produced by pollination; each seed requires one or more pollen grains.

Even though bumblebees and some species of wild bees are excellent pollinators, populations of these native pollinators usually are not adequate for large acreages grown for commercial production. The best way to ensure adequate pollination is to own colonies or rent strong colonies of European honeybees from a reliable beekeeper. Commercial bee attractants, such as Bee Scent or Bee Here, have not proven to be effective in enhancing pollination in the Mid-Atlantic states. Growers are advised to increase numbers of rented bee colonies and not rely on such attractants.

The North American beekeeping industry is currently in crisis. European honeybees are afflicted with diseases and parasitic mites that have greatly reduced hive availability and vitality, and the pollinating effectiveness of existing stock. It may be wise to consider the use of alternative pollinators, such as bumblebees, mason bees, and leafcutter bees. Organizations have sprung up that specialize in the rearing and distribution of such alternative pollinators. A good resource to locate these organizations may be found on the web at www.pollinator.com/alt_polvendors.htm.

Movement of bees into the crop at the correct time will greatly enhance pollination. Individual cucurbit and strawberry flowers are usually open and attractive to bees for only a day or less. The opening of the flower, release of pollen, and commencement of nectar secretion normally precede bee activity. 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 must take place on the day the flowers open, since pollen viability,

stigmatic receptivity, and attractiveness to bees last only that day.

Bee activity is determined, to a great extent, by weather and conditions within the hive. Honeybees rarely fly when the temperature is below 55°F (12.8°C). Flight seldom intensifies until the temperature reaches 70°F (21.1°C). Wind speed beyond 15 mph seriously impedes bee activity. Cool, cloudy weather and threatening storms greatly reduce bee flights. In poor weather, bees foraging at more distant locations will remain in their hive, and only those that have been foraging nearby will be active. Ideally, colonies should be protected from wind and be exposed to the sun from early morning until evening. Colony entrances facing east or southeast encourage bee flight. The hives should be off the ground and the front entrances kept free of grass and weeds. A clean water supply should be available within a quarter mile of the hive.

The number of colonies needed for adequate pollination varies with location, attractiveness of crop, density of flowers, length of blooming period, colony strength, and competitive plants in the area. In vine crops and strawberries, recommendations are one to two colonies per 1 acre, with the higher number on higher density plantings. Each hive or colony should contain at least 1,200 square inches of brood and enough adult bees to care for the brood, regardless of weather conditions. Multiple bee visits of eight or more visits per flower are required to produce marketable fruit. When hybrid cucumbers are grown at high plant populations for machine harvesting, flowers should receive 15 to 20 visits for maximum fruit set. Strawberries require multiple pollination for perfect fruit formation. Generally, as the number of visits increases, there will be an increase in fruit set, number of seed per fruit, fruit shape and fruit weight. Insecticides applied during bloom are a serious threat to bees visiting flowers. If insecticides must be applied to any of these crops, select one that will give effective control but pose the least danger to bees (see Table D-6). **Apply these chemicals near evening when the bees are not actively foraging and avoid spraying adjacent crops.** Give the beekeeper 48 hours notice, if possible, when you expect to spray so that necessary precautions can be taken.

A written contract between the grower and beekeeper can prevent misunderstandings and, thus, ensure better pollination service. Such a contract should specify the number and strength of colonies, the rental fee, time of delivery, and distribution of bees in the field. Recommendations for pollinators on specific crops may be obtained from your local Extension agent or beekeeper.

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, or sheltered area? Does the pattern correlate with concurrent field operations, such as time of planting, 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:
 - (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 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.
 - 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 or abnormal growth.
 - (5) Climatic damage.
 - High-temperature injury.

- Low-temperature (chilling) injury.
 - Lack of water.
 - Excessive moisture (lack of soil oxygen).
 - Frost or freeze damage.
- (6) Physiological damage.
- Physiological damage.
 - Air-pollution injury.

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.

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 product than ever before and per capita consumption of fresh fruits and vegetables increased 26 percent between 1970 and 1997.

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 product 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 fruits and vegetables that have been washed, peeled, and cut into convenient ready-to-eat products. Because 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 causing foodborne illness. The vast majority of fresh fruits and vegetables are grown, harvested, and packed under safe and sanitary conditions. However, several highly published cases of foodborne illness have been associated with consumption of lettuce, salad mixes, green onions, tomatoes, sprouts, cantaloupe, cabbage, and carrots. Implicated in most of these outbreaks have been the human pathogens *Salmonella*, *E. coli* O157:H7, *Listeria*, 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 published in 1998, *The Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables*. Many internet resources on food safety are also available that feature updated information from this guide and other sources (e.g. www.foodsafety.gov). See resource section of this publication. The 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 these hazards.

In response to recent outbreaks of foodborne pathogens on fresh produce, an increasing number of distribution networks are mandating an approved plan of “Good Agricultural Practices” (GAP) from each participating grower. Third party audits are often imposed to ensure compliance with GAPs. Increased record-keeping and adherence to strict procedures of human hygiene are inevitable. Although this document provides only voluntary guidelines, many produce distributors, major retail grocery and food service chains, and other whole buyers of fresh produce are relying on the standards as the basis for mandating sanitation specifications for growing and packing. The guide specifically addresses potential hazards and possible methods for their control in seven areas: 1. Water, 2. Manure and Municipal Biosolids, 3. Worker Health and Hygiene, 4. Field Sanitation, 5. Packing Facility Sanitation, 6. Transportation, and 7. Product Traceback. Each section is summarized below.

1. **Water.** Water is used for irrigation, pesticide application, cooling, transporting, washing, and processing. It 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 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, furrow, underground, or low volume spray irrigation techniques are ways to minimize contact with edible portions of the crop. Groundwater is less likely to become contaminated, although wells should be maintained in good working condition and be constructed and protected so that surface water or runoff from manure storage areas cannot enter the system.

In packing operations, periodic testing for microbial contamination, changing dump tank and flume water regularly, and cleaning and sanitizing water contact surfaces will help to prevent contamination. Antimicrobial chemicals such as chlorine may be added to water, but should be routinely monitored and recorded to ensure they are maintained at appropriate levels.

2. **Manure and Municipal Biosolids.** Manure may be contaminated with human pathogens and should be properly treated and stored before field application. Composting or aging will reduce the level of pathogens in manure but cannot guarantee that it is safe to use. Current recommendations are to maximize the time between application of manure to production areas and harvesting. In the spring, manure should be incorporated into the soil at least two weeks prior to planting. Harvesting should not take place within 120 days after manure application. Store manure or compost away from fresh produce fields or packinghouses to protect crop from seepage and runoff. Physical barriers such as ditches, mounds, grass/sod waterways, diversion berms, and vegetative buffer areas help to prevent runoff. Domestic animals are another source of contamination and should be excluded from fields during the growing and harvesting season. Wild animals, though more

difficult to control, should be discouraged from entering where crops are destined for fresh produce markets.

Municipal biosolids (sewage sludge) approved for certain agricultural uses, is 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 vegetables by workers who harvest or pack fresh produce. Growers should provide sanitary facilities that are well equipped, accessible and clean. Also train employees to use toilet facilities and wash their hands properly. Workers at distribution centers, farm stands, or farmers' markets who handle produce should also follow good hygiene practices. Any worker who shows signs of an infectious disease such as diarrhea, boils, 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 harvest equipment and containers or bins prior to use and keep harvesting and packing equipment as clean as practical.
5. **Packing Facility Sanitation.** In packing facilities, clean pallets, containers, or bins before use and discard damaged containers. Keep packing equipment, packing areas, and storage areas clean and store empty containers in a covered location to prevent becoming contaminated. Use an antimicrobial product, such as a chlorine, to prevent contamination of produce during washing or transporting in water flumes and change the water when it becomes excessively soiled. Clean and sanitize food contact surfaces at the end of each day.
Establish a pest control program that prevents rodents, birds, and insects from entering packing and storage facilities, and safely exterminate or remove them once they have entered the facility.
6. **Transportation.** Fresh produce can become contaminated during loading, unloading, and shipping. Inspect transportation vehicles for cleanliness, insects, other 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 refuse. Refrigeration units in trucks should be turned on before loading to insure that proper temperatures are maintained during transit.
7. **Traceback.** The ability to trace the distribution history of food items from grower to consumer will not prevent a foodborne illness outbreak from occurring. However, being able to quickly trace a food back to its source can limit the public health and economic impacts of an outbreak. Growers should be able to trace each packing with the date of harvest, farm identification, and who handled the produce from grower to receiver.

Additional information to help vegetable growers practice GAPS on the farm and in the packinghouse can be obtained from county extension offices.

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-6). Listed below are several things producers, handlers, and retailers can do to assure that vegetables going to the market or into storage are high quality.

Harvesting and handling.

1. Provide gentle harvesting and handling to avoid cuts, abrasions, and bruising damage 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. Since most vegetables begin to deteriorate at the time of harvest, 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.
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, which ensures highest quality available to your customers.
5. Make successive planting and use several varieties of varying maturity to spread the harvest season. This allows you to have freshly picked material available over an extended period.
6. Use a shade cover on field wagons, 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-6) and prevent moisture loss during transportation and storage at home.
9. For commodities that loose quality rapidly and those to be shipped to market, special postharvest washing, handling, and cooling are required to maintain quality (see Table A-6).

Washing, and chlorination. 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 microorganisms 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 concentrate in the form of sodium hypochlorite (commercial bleach) or as a dry powder in the form of calcium hypochlorite. The optimum concentration of available chlorine in the wash water depends on the kind of vegetable. Chlorination is most effective at pH 6.5 to 7.5. Buffers should be added 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 label for information on adjusting chlorine levels. **Note: Acidity and alkalinity are best controlled using automated machinery and not manually. Consult with a water treatment specialist about availability, installation, and operation of this type of equipment.**

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 lost faster by vegetables with high respiration rates and heat production. High produce temperatures also increase evaporation and transpiration of moisture for fruits and vegetables which result in more rapid wilting and loss of quality. Cooling vegetables removes field heat, lowers the temperature of the vegetable, and thus 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.

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. Growers can determine the cooling time required in their own operations 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 cooling/storage room does not accurately indicate product temperature.

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-5 and Figure A-1. Table

Table A-5 The Concept of Half Cooling Time

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

It can be seen 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 a grower wishes to use hydrocooling (chilled water) to reduce the temperature of carrots from 80° to 34°F, the time necessary to reach 57°F 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°F (1.7°C) and 55°F (12.8°C)]. Avoid holding chilling-sensitive crops at these temperatures. See Table A-6 for information on chilling sensitivity of vegetable crops. Monitor temperatures during transit and storage to determine if optimum temperatures are being maintained.

Ethylene 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, avocados, bananas, and tomatoes that produce ethylene naturally.
2. Use electric forklifts in storage and transport areas because internal combustion engines may emit ethylene.
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. This website contains information and links to potential vendors of such equipment: www.postharvest.ifas.ufl.edu/postharvest%20resources/ethylene.htm

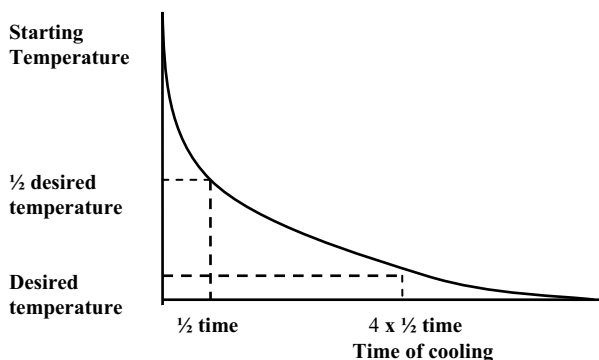


Figure A-1: Relationship of Half Cooling Time and Desired Temperature

Table A-6. Handling Produce for Higher Quality and Longer Market Life¹

Vegetable Crop	Recommended Cooling Methods ²				Important Handling Factors				
	Forced Air or Room Cooling	Hydrocooling	Package Ice or Liquid Icing	Vacuum Cooling	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.