2008-09 Vegetable Production Guide for Commercial Growers

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Trade names are used to simplify information in this publication. No endorsement is intended, nor is criticism implied of similar products that are not named. This guide is for reference only; the most recent product label is the final authority concerning application rates, precautions, harvest intervals, and other relevant information. Contact your county Cooperative Extension Service agent if you need assistance.

Editors' Note to Organic Growers

While the *2006-07 Vegetable Production Guide for Commercial Growers* addresses the needs of conventional vegetable growers, it also contains a great deal of general information of interest to organic producers. Marketing drives production whether it be conventional or organic, and the discussion titled **Consider Your Marketing Options** describes marketing channels available to all types of growers. Introductory chapters on **Insect Management** and **Disease Management** provide information on cultural controls that do not always involve pesticides. **Disease Management** reviews essential principles of disease control and describes cultural controls such as crop rotation that are critically important to all growers. This section also provides brief descriptions of new natural products and "biopesticides" as well as descriptions of more traditional organically approved control materials such as Bordeaux mixture and certain formulations of sulfur and copper. Cultural controls are also found under "Common Diseases and Management" sections in each of the separate crop chapters.

Two UK publications, *Bt Basics for Vegetable Integrated Pest Management* (Publication ID-156) and *Growers' Guide to Bt* (Publication ID-156a) describe in detail the control of caterpillar pests of cole crops and other vegetables using the microbial insecticide *Bacillus thuringiensis*. These publications are available on the web at www.ca.uky.edu/agc/pubs/pubs.htm. To download, search under "Author" for "Rowell" or "Bessin" and click on the publication title.

Variety selection is undoubtedly one of the most important management decisions for both conventional and organic vegetable producers. Disease-resistant varieties often provide the first line of defense in organic production. Notes on disease resistance can be found in the "Varieties" tables under the individual crop chapters and in some cases under "Common Diseases and Management" sections as well.

Fertilizer recommendations are found in tables under each crop. Suggested application rates are expressed as pounds per acre of the elemental or oxide forms of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). These are the amounts of nutrients that can be supplied by using either organic or inorganic sources. These recommendations are easily converted to application rates for various organic fertilizer materials using information provided in Appendix G: **Organic Manures and Fertilizers**.

While detailed organic vegetable production recommendations are beyond the scope of this publication, it is hoped that *some* of the information provided will be helpful to organic producers in Kentucky. Growers should also consult the extensive body of organic vegetable production information available on the Web including Kentucky certification requirements (see Appendix A: **Commercial Vegetable Information Online**).

Cover photo:
Steve Patton, Agricultural Communications Services, Kentucky Cooperative Extension.

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Introduction

Fruit and Vegetable Production and Marketing

With tobacco production declining in Kentucky in recent years, many tobacco growers are taking a closer look at commercial vegetable production as a way to increase farm income. However, there are important differences between vegetable crop and tobacco production. Typically the initial investment in both time and money is much higher for vegetable crops than for tobacco. Successful vegetable production generally requires the grower to make daily decisions regarding pest management, irrigation, and cultural practices. Would-be growers unwilling to make serious investments of time (and money) should not attempt to expand beyond a space at the farmer's market. All too often, vegetable crops are neglected or abandoned for tobacco harvesting or other urgent concerns on the farm.

It is important for vegetable growers to have a market outlet for their product before they choose to start production. Good marketing plans start with the customer and work backwards to production. Potential growers should first determine exactly what buyers want, how they want it, and when they want it. They then must determine how these crops should be grown. Even selecting varieties and determining planting times are basic marketing decisions. To help current and prospective growers evaluate their opportunities, the characteristics of several different marketing channels are compared in the "Marketing Options" section that follows. Kentucky growers should pay particular attention to comparisons of marketing time required, compatibility with off-farm employment, and compatibility with tobacco production. Individual situations vary, and producers must often learn about their particular markets by starting small and getting a foot in the door.

Marketing Options

Direct marketing. Marketing directly to consumers includes sales at local farmers' markets, on-farm markets, roadside stands, farm festival markets, pick-your-own sites, or any combination of these methods. Direct marketing of vegetables has expanded considerably in Kentucky in recent years. Growers have gravitated to direct marketing because they have the flexibility to determine how much or little they wish to grow and because they can often charge retail prices for their product their per-acre revenue may be higher. All forms of direct marketing, with the exception of pick your own, are expanding in Kentucky as well as other states in the region.

On-Farm or Roadside (Tailgate) Markets. These markets need not be elaborate but do need to be highly visible and located close to high traffic areas for success. Direct marketing can also succeed in more remote locations but will require more advertising and promotion.

Many consumers in urban centers now consider visits to on-farm or farmer's markets recreational activities because people enjoy seeing farms and talking with farmers. Some growers have developed seasonal festival days and markets to satisfy this demand. Such "entertainment farming" and some other forms of direct marketing require liability insurance coverage, large time commitments, and employees with friendly, courteous attitudes.

Pick Your Own, or "U-Pick," Sales. This type of direct marketing appears to be declining nationally because consumers have less time and energy available for harvesting produce. U-picks eliminate some of the harvesting, transportation, and marketing costs for growers but may require additional management, supervision, and liability insurance coverage.

Local Town, County, or Community Farmers Markets. The number of registered farmers' markets has continued to grow in Kentucky. According to the Kentucky Department of Agriculture, 115 markets will operate in Kentucky in 2008, representing over 2,015 different vendors. Markets located in larger metropolitan areas tend to generate greater overall sales as well as greater per-vendor sales. The Lexington farmers' market represented the largest market in terms of sales, generating over $1.8 million in gross sales for 2006. These markets are probably the easiest way for new growers to sell small volumes of produce. Less marketing time is required and individual growers do not usually bear all advertising and promotion costs. Farmers should check with their local county agents to determine what rules and regulations each market may have. Those producers wanting to market a processed food product should also check with the Departments of Agriculture and Health about the regulations governing the sale of processed food. In addition, the Kentucky Department of Agriculture printed a State Farmers' Market Manual. An electronic version of this manual can be found at http://www.kyagr.com/marketing/farmmarket/marketmanual.htm.

Community Supported Agriculture (CSA). Though the concept of community supported agriculture (CSA) began in Europe as early as the 1960s it is still relatively new to many regions of the US. Basically a CSA consists of "shareholders" who pay a set fee to a grower or group of growers for a weekly supply of fresh vegetables during the growing season. Because the members of a CSA pay for their "subscription" at the beginning of a growing season they share some of the risk with the farmer. As part of their agreement with the grower, members acknowledge that a poor harvest due to unfavorable weather or pests means that their shares may be smaller than usual. By direct sales to community members, growers receive better prices for their crops and can gain some financial security. Shareholders often have a greater sense of community involvement, knowing that they are helping support local agriculture.

Produce Auctions. Produce auctions have been popular for small growers in some parts of Kentucky. Growers bring produce to the auction facility, where it is sold to the highest bidder. The auction company (sometimes a growers' organization) charges a flat commission of about 10 percent. Both large and small lots are accommodated at some auctions. At the large auctions some of the bidders are operators of medium to large retail produce markets and stands.

A group of Kentucky growers began a produce auction near Hopkinsville in 1996 and built an auction structure by selling $1,000 shares to growers and others in the community. The group is now selling an increasing volume of produce to buyers from as far away as Lexington and Nashville, Tennessee. Produce auctions are also located in Lincoln, Bath, and Mason counties.

Marketing Cooperatives

A marketing cooperative is just one form of indirect marketing in which the producer deals with an intermediary rather than the final consumer. Although most forms of indirect marketing require less time of individual growers, they usually demand more product uniformity, quality, and post-harvest care.

Grower-owned cooperatives or marketing associations are able to assemble truckloads of produce required by large customers, which would not be possible for small growers acting individually. Formally organized cooperatives may also provide technical assistance to growers and help secure seed, boxes, and other needed supplies. In some cases, specialized equipment is shared by growers.

Co-ops usually own and operate facilities with some combination of grading, packing, cooling, and storage equipment for their members. Members typically employ a manager to oversee the co-op's daily operations. There are several small growers' cooperatives with grading, packing, and cooling facilities in Kentucky. Co-ops can offer good marketing opportunities for new growers in counties near the co-op facilities. For long-term success it is advisable that rules requiring minimal standards for quality be set. Poor quality produce that is allowed into the co-op can depress profits for all those involved.

Local Wholesalers, Grocers, and Restaurants

Many potential buyers can be found among local wholesalers, grocery stores, and restaurants. Most metropolitan areas have produce wholesalers who can be dependable buyers of moderate volumes. Local grocery stores (and some chain stores) are sometimes willing to buy directly from growers through direct store deliveries (DSDs). DSDs are often possible with smaller grocery stores or chains but are discouraged by many larger chains.

Many restaurants buy from local or regional wholesalers. However, more and more of them (usually upscale establishments) are promoting locally grown and seasonal items on their menus, so individual growers may be able to sell to them. Like most other forms of produce marketing, restaurant sales are based on good relationships developed over time.

Regional Wholesalers, Chain Store Distribution Centers, and Brokers

Marketing to regional wholesalers or large chain store distribution centers requires consistent quality, often significant volumes, and in some cases, year-round supplies. These buyers often have specific and demanding requirements for product uniformity, types of containers, cooling, transportation, and delivery of fresh produce. In some cases, especially when supplies are plentiful, produce quality must exceed USDA grading standards. Increasingly, grower-shippers are also being asked to supply produce to their supermarket chain buyers with price look-up (PLU) stickers already applied.

Vegetable marketing and production plans need to be developed simultaneously; the most successful growers put equal emphasis on growing and marketing their products.

Larger buyers look for quality and consistency. They need good incentives to interrupt year-round supplies from other parts of the country to buy more local produce. Some chain store buyers will pay a premium for top-quality local produce.

Some growers use brokers to market produce. They negotiate either purchases or sales of produce on behalf of a buyer or seller. Unlike wholesalers, brokers do not take delivery nor assume ownership (title) of the produce. Brokers usually never see what they are quoting for sale or negotiating to buy. Brokers charge a percentage commission on all sales or a flat rate for each carton of produce sold.

Processors

Nationwide consumption and demand for most canned and frozen vegetable products have been flat or declining. Much consolidation of production and processing vegetables has occurred in recent years, with most of the industry now located in California and a handful of northern states. No traditional vegetable processing companies are left in Kentucky, and only one out-of-state processor still contracts for peppers grown in the state.

Several fresh-cut processors exist in the state and have indicated a desire to buy more products from within Kentucky. It is unlikely, however, that fresh-cut and other forms of processing will represent a significant market for Kentucky produce in the near future.

Getting Help

A number of organizations are currently working to create new marketing opportunities for Kentucky vegetable growers:

Cooperative Extension Service. Many county Extension agents know the production and marketing opportunities in their counties. They can provide vegetable production information and access to marketing and production specialists. In addition, county Extension offices can obtain information from produce industry directories such as "The Red Book" or "The Blue Book." These publications list produce buyers by city and state and also include ratings for promptness of payment and other pertinent information.

The Kentucky Vegetable Growers Association. This organization sponsors annual educational meetings (usually during the first week of January) that include special sessions on produce marketing. Ask your county Extension agent to put you on the mailing list for the annual meeting program and registration form. The KVGA web site is kyvga.org.

The Kentucky Department of Agriculture (KDA). The Kentucky Department of Agriculture Division for Value-Added Horticulture and Aquaculture maintains a directory of Kentucky vegetable growers, marketing cooperatives, and produce markets and is working to develop several new programs linking vegetable producers and buyers. The department also supplies the "Kentucky Proud" logo to qualified growers and marketers and administers the Kentucky organic certification program. See Appendix A for KDA Web site addresses.

The Kentucky Department of Agriculture Division for Value-Added Horticulture and Aquaculture supplies this logo to qualified growers and marketers.

The Kentucky Farm Bureau. The Kentucky Farm Bureau's Certified Roadside/Farm Market Program literally can put your farm market on the map. Attractive brochures with your market location, featured products, and other details are made available at the state's welcome centers, at some state tourist attractions, and on the Internet. Contact your local Kentucky Farm Bureau office or see Appendix A for Web site address.

The Internet. A wide variety of information on vegetable production and marketing is available on the Internet. Internet resources include Extension publications on how best to grow, harvest, cool, grade, and pack vegetable crops. Wholesale prices are also posted from markets around the country along with situation reports for certain crops. For some of the best Web sites for commercial vegetable growers, see Appendix A.

COMPARING MARKETING OPTIONS FOR KENTUCKY VEGETABLES

	Available Sales Opportunities					
Things to Consider	**Direct: On-Farm, U-Pick, Farmer's Markets, CSAs[1]**	**Produce Auctions**	**Marketing Cooperatives**	**Local Wholesalers, Local Grocers, DSDs[2], or Restaurants**	**Regional Wholesalers, Chain Store Distribution Centers, Terminal Markets, or Brokers**	**Processors or Fresh-Cut**
Production and Marketing Challenges						
Difficulty getting into the market	low	low	low-medium	medium	high	medium-high
Marketing time required	high	low	low	medium-high	medium	low
Compatible with off-farm employment	yes	yes	somewhat	somewhat	difficult	yes
Compatible with tobacco production	yes	yes	somewhat	somewhat	not in fall	yes
Importance of product quality (especially shelf life)	medium	medium-high	high	medium-high	high	medium
Investments: Time and Money						
Initial commitment level required	low	low	medium-high	high	high	low-medium
Management level required	low	low	medium	high	high	low
Level of service buyers expect from individual growers	low-high	low	low	high	high	low
Initial capital investments required	low	low	medium	medium-high	high	variable
Post-harvest equipment and facilities investment required	low	low	low	medium	high	variable
Income and Potential						
Prices	high	variable	medium	medium-high	medium	low
Price stability	high	medium	medium	medium	medium	high
Product volume required	low	low	medium	medium	high	medium
Market/sales volume potential	low-medium	low-medium	high	medium	high	low
Likely further development potential in Kentucky	excellent	good	good	good	fair-good	low-fair

[1] *CSA = Community-supported agriculture or marketing by subscription (see text).*
[2] *DSD = Direct store deliveries; growers supply supermarkets directly (see text).*

General Production Considerations

Organic Fruit and Vegetable Production

Although the vast majority of vegetables grown in Kentucky are produced using conventional methods, there is a growing demand from consumers for locally grown, organically produced vegetables. According to the National Organic Standards Board, organic agriculture is defined as "an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony." Practically speaking, however, if a grower wishes to sell produce as organically certified they must undergo the certification process administered by the Kentucky Department of Agriculture.

To obtain certification, growers must first complete an application, which can be obtained from the Kentucky Department of Agriculture or downloaded from their Web site. The application requires the applicant to develop an Organic System Plan (OSP) that will be used to ensure compliance with National Organic Program standards. A detailed field history for the previous 36 months must be discussed in the OSP, as well as information regarding proposed plans for weed and pest management for the upcoming seasons.

After the application is reviewed, an on-farm inspection will be performed by a representative from the Kentucky Department of Agriculture to determine if certification can be granted. As of 2007, the (non-refundable) certification fee for organic crop production was $125. As of 2007, however, the State of Kentucky had a cost sharing program for organic certification reducing the real cost of certification from $125 to $35. If certification is granted it is continuous but it does have to be renewed. However, it can be voluntarily surrendered or revoked for violating National Organic Standards.

Small growers who would generate less than $5,000 annually from the sale of organic products are exempt from the certification procedure. Currently these growers have to fill out an exemption/registration form and pay a $25 registration fee.

Organic vegetable production presents many unique challenges, not the least of which is a lack of detailed crop production information. Nonetheless organic vegetable production has increased significantly in all areas of the US and will continue to grow in the future. As is the case with most things, it is suggested that growers moving from conventional to organic production start small, allocating a portion of their farm to organic production at first while they learn to adapt to a new production system.

Alternatively, many growers selling at farmers markets follow many of the organic guidelines but also use some pesticides. They market their produce as sustainably produced with minimal pesticide use or use a variation of this terminology.

Drip Irrigation for Vegetable Crops

A good rule of thumb for commercial vegetable production is "if you can't irrigate it, don't plant it." Droughts are not uncommon in Kentucky; the drought of 1999 was worse than severe droughts that occurred in 1988, 1954, and 1930. The high temperatures and dry conditions during the summer of 2007 meant that the entire state was considered to be under "severe or extreme" drought conditions. No one should consider commercial vegetable production without 1) access to water for irrigation and 2) access to a good high-pressure sprayer for disease control (see the "Disease Management" section). Drip irrigation makes sense for many vegetable crops grown in Kentucky. *Growers unprepared to pay the up-front costs of irrigation will not be successful.*

The best Kentucky growers have used drip with plastic mulch on staked tomatoes for over a decade. It has become standard practice for growers wanting to participate in wholesale vegetable markets and cooperatives. High yields from drip irrigation help keep growers in business during years when produce supplies are plentiful and margins are lower than usual. Those able to increase yields with drip can often achieve good returns in spite of

lower prices. Results from numerous UK and KSU on-farm demonstrations have shown that *yields are usually doubled (sometimes tripled) with drip compared to non-irrigated, rain-fed production.*

Some of the advantages of drip and plastic mulch include:

- Earlier crops (especially in the spring with black plastic mulch)
- Increased crop uniformity
- Reduced water losses from evaporation
- Reduced weed problems
- Reduced fertilizer leaching
- Reduced foliar diseases
- Cleaner products with reduced post-harvest losses
- Cultivation, spraying, harvesting, etc., can continue during irrigation

Some of the principal disadvantages:

- Higher level of management required
- Higher startup costs (need for capital)
- Removal and disposal of plastic mulch

Although drip is best used together with plastic mulch on crops such as tomatoes, peppers, melons, and squash, even bare-ground plantings can benefit from it. Some Kentucky growers have rolled out drip tube on bare-ground plantings of cabbage, sweet corn, and pumpkins. This practice has often made the difference between having a crop and not.

Water Resources

Water savings with drip are substantial—roughly half as much water can do the same or better job than a sprinkler system. A constant water source is essential. Even with water-saving drip, there are still cases of water supplies drying up or being cut off in a drought year. City water has been used successfully by a number of growers in the state; it has been profitable in nearly all cases where it has been used. Other growers use streams, lakes, springs, or farm ponds. Several growers have constructed large farm ponds specifically for drip irrigation on vegetables. The size of the pond is critical because some vegetable crops use enormous volumes of water (see "Tomato Crop Water Usage" graphic).

Installation and Equipment Costs

Contrary to popular opinion, drip irrigation is a relatively cheap and easy technology. It does not require an engineering degree or years of experience to install and operate a typical small farm system. Costs for reusable equipment and components, together with annual disposable supplies, are about $1,400 (see box above) for a one-acre system with an additional $350 per-acre expense for each additional acre for systems up to about 10 acres in size. The $350 per-acre annual costs are for disposable drip irrigation tube (often called drip "tape") and embossed black plastic mulch.

DRIP IRRIGATION COSTS:
(for up to 5-acre system)

Item	***Cost (2005)***
2 in. centrifugal pump on 6.5 HP engine	*$595*
Filter, disc cannister (2")	*190**
Fertilizer Injector	*160*
2 tensiometers: 12" & 18" and service kit	*147*
Layflat, 2" (300 ft. roll)	*105*
Suction hose and strainer	*55*
Fittings, valves, gauges, etc.	*75*
Total (5-7 yrs. reusable)	***$1,327***

Annual per-acre expenses

- *8-10 mil drip tape and black plastic mulch (1 mil, 4 ft wide): $0.05/ft x 7260 linear ft $363*
- *depreciation/rental costs on mulch layer and waterwheel setter*

**Substitute sand filter with flush manifold for disc filter where required (adds $290 to total).*

The most costly piece of farm equipment required is the plastic layer/bed shaper; this machine costs from around $1,350 for a flatbed layer to about $3,500 for a plastic layer plus bed shaper with hydraulic counter-sway. Plastic layers are now also available for walk-behind tillers. The waterwheel setter that is commonly used for transplanting through plastic mulch costs about $1,800-2,200. *Mulch layers that also form raised beds will require considerably more tractor horsepower.* Raised beds may not be necessary on well-drained ground where standing water does not occur.

To help introduce the technology and reduce costs, many counties have bought machinery to rent or loan to local farmers. In addition, UK Horticulture Department Extension associates and county Extension offices conduct annual on-farm demonstrations that help new growers install small farm drip systems.

Setting up a small, low-pressure drip system involves more plumbing than engineering. Although most growers will need some experienced help with the initial layout and design specifications (pump sizes, filter, delivery line size, field zoning, etc.), actual installation and maintenance are very easy.

System Components

A small drip system consists of:

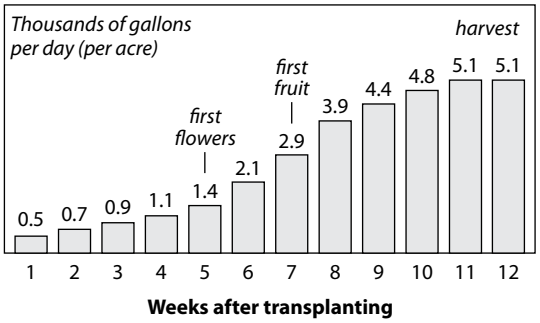
- Water source
- Pump at the water source
- Check valve and/or backflow prevention valve[1] (for city water)
- Fertilizer injector
- Filter
- Pressure regulator and gauge
- Intake and delivery lines
- Drip tubes (drip tape)

Fertigation

Fertigation is the application of water-soluble fertilizer through the drip system using an injector that feeds the solution into the drip lines. Our fertigation recommendations are relatively simple and are found under the individual crops in this publication. We recommend not fertigating phosphorus and potassium on medium-textured soils in Kentucky. All the soil test-recommended potassium should be applied prior to planting on some soils, but additional potassium applied through the fertigation system may help reduce blotchy ripening in tomatoes (see the tomato chapter for details). These two nutrients should be broadcast prior to laying plastic with rates determined by soil test results.

Although all of the crop's nitrogen (N) requirement can be applied prior to laying plastic, most growers prefer to split N applications between a preplant dose and sidedressings applied at intervals through the drip system. We recommend applying about half of the N requirement preplant and dividing the remaining amount into weekly fertigations. Most growers use ammonium, calcium, or potassium nitrate, which is usually dissolved in water prior to fertigating. Although many fertilizers are

TOMATO CROP WATER USAGE



[1]*Growers using city water are required by law to install a more sophisticated backflow prevention device rather than a simple check valve. Most of the items listed are available from dealers in Kentucky. See your county Extension agent for a list of irrigation dealers in the state.*

easily soluble together, care must be taken not to mix fertilizers that may precipitate when together. This can lead to clogs at emitters, resulting in inadequate irrigation. Often high phosphorous fertilizers can precipitate when mixed with sufficient concentrations of calcium.

Insect Management

Proper early identification of insect problems is essential in achieving satisfactory control. The following guidelines should aid in avoiding economic damage to vegetable crops from insect pests.

Although insecticides are important tools, successful management of insect and mite pests relies primarily on cultural practices. Proper cultural practices can minimize the chance for initiation and buildup of infestations. Early detection and diagnosis are key to pest management, as are the proper choice and application of pesticides, when required. Vegetable producers should recognize and understand which pests have caused problems on their farms in the past and use nonchemical, preventive methods to help manage these pests when possible. Producers should regularly monitor insect and mite pests known to be problems in their areas and on the crops they are growing. Integrated Pest Management (IPM) guidelines for several commercial vegetable crops (cabbage, sweet corn, peppers, pumpkins) have been published by the University of Kentucky and are available through your county Extension office or on the Internet (see Appendix A).

Use crop rotation as a means of controlling certain insects such as corn rootworms in sweet corn. Grow varieties that are resistant to insects and disease when possible. Destroy or plow under crop residues immediately after the crop is harvested to reduce overwintering pest populations. Stimulate plant growth by proper irrigation and fertilization. Control weeds in and around crop fields. Weeds can be attractive to pest insects and may serve as hosts to insect-vectored diseases.

These suggestions are primarily preventive methods rather than controls, and most should be done far in advance of the insect's appearance:

- Always properly identify and evaluate your insect problem.
- Learn to identify and conserve beneficial and harmless insects.
- Scout your fields on a regular basis to monitor insect activity and possible damage.
- Use IPM guidelines and treatment thresholds—available for most vegetable crops—to help you determine what level of damage can be tolerated before economic losses occur and treatment is required.
- If an insecticide is needed, select one that best fits your situation.
- Select an insecticide that is labeled for a wide variety of crops; this will minimize the chance of accidentally treating a crop that should not be treated with that insecticide and will reduce the number of products that must be purchased and stored.
- If possible, buy pesticides in quantities small enough to use up during the growing season.
- Select insecticides that do not require a long waiting period from application to harvest so you are not hampered in harvesting when the crop is ready.

Insecticides used to control vegetable insect pests come in several different forms. Dusts, baits, and granules are dry forms used as purchased. Baits are formulated with a pest attractant; dusts and granules include an inert carrier. Dry flowables (DF), emulsifiable concentrates (EC), flowables (F), liquids (L), soluble powders (SP), suspension concentrates (SC), water-dispersable granules (WDG), and wettable powders (WP) are formulations of insecticides that disperse when mixed in water. The latter are all used as sprays. For best results when applying dusts and sprays, thoroughly cover surfaces of infested plants.

Greenhouse Insect and Mite Management

The warm, humid conditions and abundant food in the greenhouse are ideal for pest buildup. Problems can be chronic unless recognized and corrected. Insecticides are important tools, but successful control of greenhouse vegetable pests relies primarily on cultural practices. Proper cultural practices can minimize the chance for initiation and buildup of infestations. Early detection and diagnosis as well as the proper choice and application of pesticides when pest outbreaks occur are key to greenhouse pest management.

Cultural Controls

Pests may enter the greenhouse in the summer when the ventilators are open. Others may be brought into the greenhouse on new plant material or in soil. Many are able to survive short periods of time between harvest or plant removal and production of the next crop. Cultural controls are the primary defense against infestation.

Following are proper cultural practices that will help prevent pest infestations:

- Maintain a clean, closely mowed area around the greenhouse to reduce pests that develop in rank growth.
- Remove all plants or any plant debris and clean the greenhouse thoroughly after each production cycle.
- Keep doors, screens, and ventilators in good repair; use insect-proof netting when possible. (The extremely fine netting for thrip exclusion has been shown to limit air movement and may negatively impact disease management.)
- Use clean or sterile soils or ground media, tools, flats, and other equipment.
- Inspect new plants thoroughly to prevent introduction of insect or disease-infested material into the greenhouse.
- Watch for leaks or pooled water that can lead to fungus gnat infestations.
- If possible, allow the greenhouse to freeze in winter to eliminate tender insects such as whiteflies.
- Avoid wearing yellow clothing, which is attractive to many insect pests.
- Eliminate infestations by discarding or removing heavily infested material.

Monitoring

Early detection and diagnosis of pest infestations will allow you to make pest control decisions before the problem gets out of hand. It is good practice, therefore, to make weekly inspections of plants in all sections of the greenhouse.

Insect monitoring devices are also available. Yellow sticky cards (PT Insect Monitoring Cards, Whitmire Micro-Gen <www.wmmg.com>, or Gempler's <www.gemplers.com>) are highly attractive to winged aphids, leafminer adults, whiteflies, leafhoppers, thrips (blue cards can also be used with thrips), various flies, and other insects. These can be used to alert you to the presence of a pest and identify hot spots in the greenhouse. One to three cards per 1,000 square feet in the greenhouse is recommended and should be changed weekly. If you cannot identify a trapped insect, contact your county Extension agent for assistance. Mass trapping products such as sticky tapes are also available for thrips, whitefly, leafminer, and fungus gnat detection and management.

Protecting Honey Bees from Pesticides

Many valuable crops cannot be economically produced unless adequate numbers of honey bees are present to pollinate them. In addition, honey bees produce more than $50 million in honey and beeswax annually. Many pesticides are extremely hazardous to honey bees, but

CHEMICAL AND BIOLOGICAL PRODUCTS AVAILABLE FOR INSECT CONTROL IN COMMERCIAL GREENHOUSES

Insecticide or Biological Control	Registered Greenhouse Crops[1,2]	Insects and Mites Controlled	Comments
Admire 2 F	Cucumbers, Tomatoes	Aphids, whiteflies	A single soil-application is allowed.
Bacillus thuringiensis	All crops	Armyworms, cabbage loopers, hornworms, cutworms, green cloverworms, tomato fruitworms, salt marsh caterpillars	A microbial insecticide effective against several species of caterpillars. This must be ingested by the insect to be effective. After eating a lethal dose, larvae stop feeding within the hour and will die within several days.
Encarsia formosa	All crops	Whitefly management	A tiny parasitic wasp that attacks whiteflies in greenhouses. While they are not useful in controlling heavy whitefly infestations, they can be used successfully against limited infestations under conditions that favor their development over development of whiteflies (64º to 80ºF). Parasitized larvae die and turn black; a parasite wasp will emerge and continue the beneficial process. Do not throw pruned leaves away without checking them for black parasite scales. Leave these under plants for about one week until wasps have emerged. Very susceptible to insecticides. More effective in controlling greenhouse whitefly than sweetpotato whitefly.
Endosulfan	Tomatoes only (2 day PHI[1])	Aphids, armyworms, blister beetles, cabbage loopers, Colorado potato beetles, flea beetles, tomato fruitworms, and whiteflies	Wear a mask or respirator approved by MSA or OSHA for protection against endosulfan. A foliar insecticide that is effective at higher greenhouse temperatures.
Insecticidal soap	All crops	Aphids, leafhoppers, plant bugs, spider mites, thrips, and whiteflies	Apply when insects first appear. Contains potassium salts of fatty acids. Kills on contact and is neither a stomach nor a residual poison. Exempt from tolerances, can be applied just before harvest.
Malathion	Beans, cucumbers, eggplant, endive lettuce, onions, peppers, sweet corn, tomatoes	Aphids, cucumber beetles, cutworms, leafhoppers, spider mites, and thrips	Apply when insects first appear. May require two to three applications, as some stages of some pests are not controlled with these foliar sprays.
Metaldehyde	On and beneath greenhouse benches	Snails and slugs	Pellets containing 2.75% metaldehyde (HACO, Inc.). Do not allow pellets to come in contact with plants. Thoroughly wet area before and after pellets are spread.
Pyrethrin + Piperonyl Butoxide (Pyrenone Crop Spray, Pyronyl Crop Spray)	All crops	Aphids, armyworms, cabbage loopers, caterpillars, Colorado potato beetles, cucumber beetles, flea beetles, fruit flies, leafhoppers, mealy-bugs, thrips, spider mites, tomato fruitworms, and whiteflies	Apply when insects first appear. A botanical insecticide that is especially effective against whiteflies. For best results, apply during the early evening when foliage is dry and air temperature is between 60º to 80°F. Effectiveness is enhanced when in combination with the synergist Piperonyl Butoxide. Available as sprays and total release aerosols.
Bacillus thuringiensis israelensis (Gnatrol)	Tomatoes, leafy and cole crops, cucumbers, peppers, eggplants	Fungus gnat larvae	Must be timed for a stage of development when larvae are present in the soil.

[1] *PHI = Mandatory pre-harvest interval.*
[2] *Assail, Diazinon, Dimethoate, Dimilin, Di-syston, Intrepid, Kelthane, Platinum, Proclaim, and Trigard are prohibited in the greenhouse.*

damage can be minimized if the pesticide user and the beekeeper cooperate and each takes the proper precautions.

Crops Pollinated by Honey Bees

Some of the crops that require bee pollination are cucumber, squash, pumpkin, watermelon, and muskmelon. Honey bee colonies can be rented in many areas. One or two good hives of bees per acre is suggested to ensure a good yield of high quality fruit, particularly now that parasitic mites are killing many of the wild honey bees.

The Pesticide User's Role

- Use pesticides only when needed and only at the rates recommended on the label.
- If possible, select one of the least hazardous pesticides from the following list, especially when used on flowering plants that attract bees.
- Use the least hazardous method of application. Granules are generally harmless to honey bees. Sprays result in less drift than dusts and are less likely to kill bees in nearby areas. Ground equipment applications result in less drift than airplane applications.
- Do not apply pesticides when honey bees are active in the field. Applications late in the afternoon or at night are least likely to damage bees. Do not apply pesticides when plants are in flower unless absolutely necessary.
- Avoid pesticide drift into apiaries or areas where crops or wild plants are flowering. Plant crops that require heavy pesticide applications in nonsensitive areas if possible.
- Notify nearby beekeepers several days before you apply a pesticide.

The Beekeeper's Role

- Locate colonies away from areas of heavy pesticide use when practical.
- Post your name, address, and phone number conspicuously at your apiary, and tell neighboring farmers where your colonies are located.
- Know what pesticides are commonly used in your area, and be prepared to confine or remove your bees if notified that a pesticide will be applied. Commonly used pesticides, grouped according to hazard, are listed in this section. A plastic sheet can be used at night or in the early morning to confine bees and protect them from short-residual pesticides. However, heat builds up rapidly once the plastic is exposed to the sun, and it must be removed. Wet burlap can be used for periods of a day or more. This may be impractical for large numbers of hives.
- Relocate colonies that are in danger of repeated contact with pesticides in Group 1.

Weed Management

The use of herbicides suggested in this publication is based on research at the University of Kentucky and elsewhere in the region. We have compiled lists of the most effective herbicides with their rates and times of application with selected information on the use and precautions of each pesticide. It is not possible to include every comment and suggestion in the limited space allowed in this book, and growers are encouraged to obtain a copy of the label and read it carefully. In addition, keep in mind that most herbicides are now manufactured by many companies under different trade names. Only one representative trade name is presented in this book for each active ingredient. Growers

are encouraged to compare costs of different brands that may have the same active ingredient. Herbicide and other pesticide labels may change after the printing of this publication, so growers must always consult the label for the final word on crops covered, precautions, rates, and application methods.

Carefully follow the precautions stated on the bag or container label. The use of herbicides for purposes other than those specified on the approved label is a violation of federal law. Such applications can be hazardous to the environment and to people and can severely injure crops. Use herbicides only on crops for which they are approved and recommended on the label. Use only recommended amounts. In addition to wasting money and violating the law, using too much material may damage the crop and make it unsafe for consumption. The EPA is authorized to seize any raw agricultural commodity moving in interstate commerce that carries a pesticide residue in excess of the established tolerance. Note that residues of unlabeled chemicals detected on fresh produce can be traced back to your farm.

Apply herbicides only at times specified on the label and observe the recommended intervals between the time of treatment and time of planting or harvesting the crop. Guard against possible drift injury to nearby susceptible crops. Finally, the use of herbicides should supplement other good weed management practices.

Types of Herbicide Formulations

Herbicides are formulated as solutions (L), emulsifiable concentrates (EC), microencapsulated (ME), wettable powders (WP), flowables (F), wettable dispersible granules (WDG), and granules (G), to name a few. Most herbicides are added to water and applied as solutions. Most spray mixtures require constant agitation to prevent the herbicides from settling to the bottom of the tank. On the other hand, granular herbicides are applied dry. Do not mix different granular pesticides or mix them with fertilizers. Some herbicides are labeled for application through a center pivot irrigation system, others as fertilizer mixtures.

Method and Time of Treatment

Herbicides are applied in the following ways:

- Preplant incorporated: incorporated into the soil prior to planting the crop
- Preemergence: on the soil after planting but before crop or weeds emerge
- Post-transplant: on the soil after crop is transplanted either before weeds emerge or after clean cultivation

COMMONLY USED PESTICIDES GROUPED ACCORDING TO THEIR RELATIVE HAZARDS TO HONEY BEES

Group 1. Hazardous	**Group 3. Relatively Nonhazardous**
abamectin (Agri-Mek)	azadirachtin (Align, Neem)
acephate (Orthene)	Bacillus thuringiensis
azinphosmethyl (Guthion)	Bordeaux mixture
bifenthrin (Capture)	bromoxynil
carbaryl (Sevin)	cyromazine (Trigard)
chlorethoxyfos (Fortress)	captan
chlorpyrifos (Lorsban)	chloramben
cyfluthrin (Baythroid)	copper oxychloride sulfate
cypermethrin (Ammo)	copper 8-quinlinolate
deltamethrin (Decis)	copper sulfate (Monohydrated)
diazinon	dazomet (Basamid)
dimethoate (Cygon)	dicamba (Banvel D)
emamectin benzoate (Proclaim)	dicofol (Kelthane)
esfenvalerate (Asana)	diflubenzuron (Dimilin)
fenropathrin (Danitol)	dinocap (Karathane)
gamma-cyhalothrin (Proaxis)	diquat
indoxacarb (Avaunt)	dodine (Cyprex)
lambda-cyhalothrin (Warrior)	endothall
lindane	EPTC (Eptam)
malathion	glyodin (Glyoxide)
methomyl (Lannate)	imidacloprid (Admire, Provado)
methylparathion	kaolin (Surround)
naled (Dibrom)[1]	maneb
Penncap M 2 FM	MCPA
permethrin (Ambush, Pounce)	monuron (Telvar)
phosmet (Imidan)	nabam (Parzate)
ztea-cypermethrin (Mustang)	nicotine sulfate
	pyrethrins
Group 2. Moderately Hazardous	rotenone
disulfoton (Di-Syston)	ryania
DSMA	simazine (Princep)
endosulfan (Thiodan)	sulfur
metasystox-R	tetrdifon (Tedion)
MSMA	thiram (Arasan)
oxamyl (Vydate)	Zineb
paraquat (Gramoxone)	Ziram
perthane	2,4-D
phorate (Thimet)	
phosalone (Zolone)	2,4-DB
pyriproxifen (Esteem, Knack)	
spinosad (SpinTor, Tracer)	
thiamethoxam (Actara, Platinum)	
thiodicarb (Larvin)	

[1] *Adapted from E-53, "Protecting Honey Bees from Pesticides," G. Hunt, R. Edwards, R. Foster, Purdue University Cooperative Extension Service.*

INSECTICIDE RESISTANCE ACTION COMMITTEE (IRAC) GROUPINGS

These insecticide groupings now appear on many labels. The groupings are based on mode of action of the insecticides. The codes allow users to determine if different insecticides share the same mode of action. This information should be used by growers to prevent/delay the development of resistance by not over using products with the same mode of action.

Insecticide	**Grouping**		**Insecticide**	**Grouping**
Acramite	25		Fulfill	9B
Actara	4A		Furadan	1A
Admire	4A		Hero	3
Agri-Mek	6		Intrepid	18
Ambush	3		Knack	7C
Ammo	3		Lannate	1A
Asana XL	3		Larvin	1A
Assail	4A		Latitude	4A
Avaunt	22		Lorsban	1B
Aztec	1B, 3		Malathion	1B
Baythroid	3		Mocap	1B
Beleaf	9C		Mustang Max	3
Bt kurstaki	11B2		Novodor	11C
Capture	3		Oberon	23
Clutch	4A		Penncap-M	1B
Concur	4A		Platinum	4A
Confirm	18		Pounce	3
Counter	1B		Proaxis	3
Courier	16		Proclaim	6
Danitol	3		Provado	4A
Decis	3		Renounce	3
Diazinon	1B		Rimon	15
Dibrom	1B		Sevin	1A
Dicofol	20		Spintor	5
Dimethoate	1B		Thimet	1B
Dimilin	15		Trigard	17
Di-Syston	1B		Venom	4A
Endosulfan	2A		Vydate	1A
Force	3		Warrior	3
Fortress	1B			

- Post-emergence: on weeds after both weeds and the crop have emerged
- Directed post-emergence: as a directed or shielded post-emergence on small weeds in rows of taller crops or in row middles. When using a post-emergence herbicide, the entire weed must be covered for maximum control.

Follow specified gallonages and pressures on the label in order to achieve complete coverage.

Tank Mixtures

For broad spectrum weed control, more than one herbicide may be necessary. In this publication, we have included only labeled combinations or tank mixes. Follow mixing directions on the label.

Crop Rotation

Because soil residual activity varies considerably among different herbicides, follow the directions closely for crop rotation on the labels of all products used. See the table in this section for restrictions on planting vegetables after using specific herbicides.

Herbicide Sprayers

Even distribution of herbicides at the proper rate is essential to good weed control. A small variation in the rate of application of some herbicides may result in failure to control weeds or it may cause crop injury. For spray applications of herbicides, a low-pressure sprayer that accurately sprays between 15 to 50 psi is the most suitable either for broadcast or band spraying. Hand sprayers of 3- or 4-gallon capacity are suitable for small areas or for spot spraying. Tractor-mounted sprayers, pump-driven from the power takeoff, are quite satisfactory for field spraying.

A good herbicide sprayer should:

- Have a pump that is easily replaced, be resistant to wear and chemical oxidation, and have a capacity of 8 to 15 gallons per minute.
- Have a boom equipped with nozzles with replaceable tips. Nozzle spacing will depend on many factors, such as your crop situation and your equipment. Many manufacturers recommend 16- to 20-inch spacings between nozzles on the boom for broadcast spraying.
- Have mesh screens for the suction line and nozzles, and a gauge that measures pressure accurately from 0 to 100 pounds per square inch. Mesh screen size may vary with the herbicide used. For most herbicides, a 50-mesh size is quite adequate.
- Have a mechanical or jet agitator to keep the spray solution well mixed and to prevent the herbicide from settling to the bottom of the tank.

Hand Sprayers

To spray herbicides on small areas, the most reliable method of application is the 1- to 3-gallon compressed-air sprayer. These sprayers are simple to operate but require careful calibration to assure even distribution of the herbicide over the sprayed area. A general rule is to use 1 gallon of the herbicide mixture for every 400 square feet of soil surface. This volume should be sprayed evenly over the 400 square feet. Do not guess distances or areas to be sprayed. If you have not used a hand sprayer previously, it is a good idea to practice using the sprayer with water the first time. Accurately measure the amount of herbicide that is to be added to the sprayer. See Appendix B for converting rates per acre to rates for small areas.

Cleaning Sprayers

Herbicide sprayers should be thoroughly washed and cleaned after each use. For many products, the screens and filters should also be taken apart and cleaned. For example, residues of triazine products can adhere to screens and will injure

HERBICIDE LABEL RESTRICTIONS* ON VEGETABLE CROP ROTATIONS

Herbicide	Tomato[1]	Pepper	Snap Bean	Sweet Corn	Pumpkin	Melon[2]	Cole Crops[3]
Soybean or Tobacco Herbicides							
Canopy	18-B	18-B	18-B	18-B	18-B	18-B	18-B
Classic	15-B	B	B	B	B	B	B
Command	9-12[4]	NR	9	9	NR	9	12
Dual	6	0[5]	NR	NR	12	12	12[6]
Sencor	4-10	12	12	12	12	12	12
Prowl	AH	AH	AH	AH	AH	AH	AH
Pursuit	26	16	4	26	26	26	26
Reflex	18	18	18	10	18	18	18
Scepter	18	18	11	18	18	18	18
Spartan	24	24	24	18	24	24	24
Squadron	18	18	11	18	18	18	18
Tri-Scept	18	18	11	18	18	18	18
Blazer or Status	AH	AH	AH	AH	AH	AH	AH
Treflan	NR	NR[7]	NR	5	5	5	NR
Turbo	12	12	12	12	12	12	12
Corn Herbicides							
Aatrex	SY	SY	SY	NR	SY	SY	SY
Accent	10[8]	10[8]	10[8]	10	10[8]	10	10[8]
Beacon	18	18	18	8	18	18	18
Bicep	24	24	24	NR	24	24	24
Callisto	18	18	18	NR	18	18	18
Exceed	18	18	10	3	18	18	10[9]
Liberty	4	4	4	4	4	4	4
Lightning	40	40	9.5	18	40	40	40
Permit	8	10	9	3	9	9	15-18
Princep	SY	SY	SY	NR	SY	SY	SY
Spirit	10	18	10	8	18	18	10[9]

* *Waiting period (number of months after application) before the vegetable crop can be planted.*
1 *Transplanted tomatoes only.*
2 *Muskmelons and watermelons.*
3 *Broccoli, cabbage, and cauliflower.*
4 *Depends on rate applied; consult label.*
5 *A special needs label for peppers is held by the Kentucky Vegetable Growers Assn. (see "Weed Control" in the pepper production chapter).*
6 *Except cabbage, which can be planted next year.*
7 *Read label for additional restrictions due to soil pH, application rate, etc.*
8 *18 months with a soil pH of greater than or equal to 6.5.*
9 *Cabbage only.*

B: *Field or soil bioassay should be conducted before planting the crop; consult label.*
NR: *No rotation restriction exists or herbicide labeled for the crop.*
AH: *After harvest—can be planted in fall or spring following application.*
SY: *The crop cannot be planted until the second year after application (cannot be planted the year following application).*

WARNING: This information is for preliminary planning only! Follow manufacturer's instructions on product labels to determine the most up-to-date rotation restrictions and other special conditions that may apply.

nontarget, sensitive crops. Flushing tanks, lines, booms, and nozzles with water is usually sufficient for sprayers used only with preemergence herbicides. For most other herbicides, the sprayer should first be rinsed with water, then cleaned with one of the following in 50 gallons of water:

- ½ gal of household ammonia (let stand in sprayer overnight)
- 4 lb trisodium phosphate cleaner
- 2 ½ lb Sal soda
- 2 lb activated charcoal (leave in sprayer and lines 10 minutes)

NOTE: To remove traces of oil-based herbicides such as ester formulations of 2,4-D, rinse the sprayer with kerosene before rinsing it with water and the cleaners listed above. For specific cleaning directions, refer to the label.

COMMON AND CORRESPONDING HERBICIDE TRADE NAMES

Common Name	Trade Name
2,4-D amine	Several names
acetochlor	Surpass
alachlor	Micro-Tech, Partner
atrazine	Aatrex
bensulide	Prefar
bentazon	Basagran
bromoxynil	Buctril
carfentrazone	Aim
clethodim	Select
clomazone	Command
clopyralid	Stinger
cycloate	Ro-Neet
DCPA	Dacthal
dicamba	Clarity
dimethenamid-P	Outlook
diquat	Reglone
diuron	Karmex
endothall	Desicate II
EPTC	Eptam, Eradicane
ethalfluralin	Curbit, Sonalan
fluazifop-p	Fusilade DX
flumioxazin	Chateau
fluroxypyr	Starane
fomesafen	Reflex
glufosinate	Rely
glyphosate	Roundup
halosulfuron	Permit, Sandea
imazamox	Raptor
imazethapyr	Pursuit
linuron	Lorox
mesotrione	Callisto
metolachlor	Dual Magnum
metribuzin	Sencor
napropamide	Devrinol
nicosulfuron	Accent
norflurazon	Solicam
oxyfluorfen	Goal
paraquat	Gramoxone
pelargonic acid	Scythe
pendimethalin	Prowl
phenmedipham	Spin-Aid
pronamide	Kerb
quizalofop	Assure II
rimsulfuron	Matrix
sethoxydim	Poast
terbacil	Sinbar
topramezone	Impact
trifluralin	Treflan

WEED SUSCEPTIBILITY OF SELECTED HERBICIDES LABELED FOR USE IN VEGETABLE CROPS

	Weeds Controlled	
Herbicide	**Grasses**	**Broadleaves**
Basagran (bentazon)	yellow nutsedge	Canada thistle, purslane, lambsquarters, ragweed, galinsoga, jimsonweed, smartweed, velvetleaf, wild mustard, cocklebur
Buctril (bromoxynil)		mustard, cocklebur, pennycress, jimsonweed, annual morningglory, nightshade, lambsquarters, smartweed, pigweed
Command (clomazone)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, seedling johnsongrass	purslane, ragweed, jimsonweed, lambsquarters, smartweed, velvetleaf
Curbit (ethalfluralin)	annual bluegrass, crabgrass, barnyardgrass, foxtail, goosegrass, fall panicum, seeding johnsongrass, shattercane, witchgrass	wild buckwheat, carpetweed, chickweed, lambsquarters, pigweed, nightshade, purslane
2,4-D amine		carpetweed, dandelion, dock, galinsoga, pigweed, jimsonweed, lambsquarters, morningglory, plantain, ragweed, smartweed, thistle, wild mustard
Devrinol (napropamide)	barnyardgrass, weedy brome, crabgrass, foxtail, goosegrass, seedling johnsongrass	chickweed, purslane, common groundsel, prostrate knotweed, lambsquarters, pigweed, prickly lettuce
Dual II Magnum (s-metolachlor)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, witchgrass, yellow nutsedge	nightshade, carpetweed, galinsoga, pigweed
Eptam (EPTC)	annual bluegrass, crabgrass, barnyardgrass, foxtail, goosegrass, shattercane, witchgrass	annual morningglory, carpetweed, chickweed, lambsquarters, nightshade, purslane
Fusilade DX (fluazifop-P)	bermudagrass, goosegrass, johnsongrass, wild proso millet, barnyardgrass, fall panicum, foxtail, crabgrass, witchgrass, volunteer cereals	
Goal (oxyfluorfen)		evening primrose, pigweed, common groundsel, purslane, black nightshade, shepherdspurse
Gramoxone Extra (paraquat)	most annual grasses	most annual broadleaves
Karmex, others (diuron)	barnyardgrass, crabgrass, annual bluegrass, foxtail	pigweed, purslane, ragweed, chickweed, mustard, pennycress, velvetleaf
Kerb (pronamide)	barnyardgrass, brome, annual bluegrass, panicum, foxtail, goosegrass, volunteer small grains	carpetweed, chickweed, henbit, knotweed, purslane, lambsquarters, nightshade, morningglory
Sencor (metribuzin)	downy brome, crabgrass, foxtail, seedling johnsongrass	pigweed, purslane, ragweed, chickweed, jimsonweed, lambsquarters, pepperweed, shepherdspurse, smartweed, prickly sida
Lorox (linuron)	barnyardgrass, crabgrass, fall panicum, goosegrass	annual morningglory, carpetweed, groundsel, lambsquarters, mustard, cocklebur, pigweed, prickly sida, purslane, smartweed, velvetleaf
Micro-Tech (alachlor)	barnyardgrass, crabgrass, foxtail, goosegrass, fall panicum, witchgrass	carpetweed, pigweed, galinsoga, nightshade, purslane
Poast (sethoxydim)	bermudagrass, goosegrass, johnsongrass, quackgrass, wild proso millet, barnyardgrass, fall panicum, foxtail, crabgrass, witchgrass, volunteer cereals	
Prefar (bensulide)	crabgrass, foxtail, fall panicum, goosegrass	
Prowl (pendimethalin)	barnyardgrass, crabgrass, fall panicum, foxtail	carpetweed, lambsquarters, pigweed, purslane
Pursuit (imazethapyr)		nightshade, pigweed, kochia, wild mustard
Ro-Neet (cycloate)	annual bluegrass, crabgrass, volunteer barley, foxtail, barnyardgrass	nightshade, henbit, lambsquarters, purslane, red-root pigweed, shepherdspurse
Roundup (glyphosate)	most annual and perennial grasses; see discussion of reduced tillage systems	most annual broadleaves; see discussion of reduced tillage systems
Sandea (halosulfuron)		cocklebur, common lambsquarters, common ragweed, honeyvine milkweed, kochia, morningglory, nutsedge, pigweed, smartweed, velvetweed, wild mustard
Sinbar (terbacil)	crabgrass, foxtail, seedling johnsongrass, barnyardgrass, annual bluegrass	chickweed, lambsquarters, wild mustard, pepperweed, shepherdspurse, dandelion, knotweed, pigweed, purslane, plantain, ragweed, henbit, jimsonweed
Treflan (trifluralin)	annual bluegrass, crabgrass, barnyardgrass, foxtail, seedling johnsongrass, goosegrass	carpetweed, chickweed, knotweed, lambsquarters, pigweed, purslane

Herbicide sprayers should not be used to apply other pesticides on vegetable crops. In addition to the potential hazard to the crop from traces of herbicides left in the system, pressures used in herbicide sprayers are inadequate for spraying insecticides and fungicides. When an enterprise requires two herbicide sprayers, use only growth regulator type herbicides (2,4-D) in one sprayer and use the other for other vegetable herbicides.

Disease Management

All vegetable crops grown in Kentucky are affected by one or more diseases, and these diseases cause economic loss by reducing the quality and quantity of produce harvested. Managing diseases also adds to a grower's input costs, thereby cutting into potential profits. Production methods, aimed at achieving maximum production of quality produce, can either favor or inhibit development of certain diseases. Chemical or cultural control methods can also have both positive and negative impacts and must be carefully considered.

Successful management of diseases in a commercial setting requires careful decision making and judicious execution of strategies. New growers in particular should understand the role that diseases play in the crops they plan to produce, as many will encounter serious problems with diseases early on. Any vegetable grower should focus on prevention of disease and slowing disease development rather than curing diseased plants. The practices and products that we use to manage plant diseases generally work best in a preventative program. The explosive nature of plant diseases makes them difficult, if not impossible, to control once they become established. To develop an effective management strategy for any vegetable crop, it is important to understand the diseases that may affect that crop and also the environmental factors that favor disease development.

General Principles of Plant Disease Management

Modern programs for management of plant diseases are designed around a set of general principles that were described many years ago. Remember that these principles are not absolute. It is impossible to completely control any plant pathogen—that's why we tend to use the term "management" instead of "control." The following is a brief summary of the principles of plant disease management.

GUIDE TO RELATIVE RESPONSE OF WEEDS TO HERBICIDES*

	Cocklebur	Crabgrass	Fall Panicum	Foxtail	Galinsoga	Jimsonweed	Johnsongrass *(seedlings)*	Lambsquarters	Morningglory	Nutsedge, Yellow	Pigweed	Purslane	Ragweed, Common	Ragweed, Giant *(horseweed)*	Smartweed	Velvetleaf	Black Nightshade
Preplant Incorporated																	
Command	P	G	G	G	G	P	F	G	P	N	F	E	G	P	G	G	P
Devrinol	N	G	G	G	P	N	F	F	N	P	F	G	F	N	N	P	P
Eptam	P	G	G	G	F	N	G	P	N	G	F	P	P	P	P	P	N
Prefar	P	G	G	G	P	P	P	G	P	N	G	P	P	P	N	F	P
Treflan	N	G	G	G	P	N	G	F	N	N	G	F	P	N	N	N	N
Pre-emergence																	
Atrazine	G	P	P	F	G	G	N	G	G	P	G	G	G	G	G	G	G
Curbit	N	G	G	G	P	N	G	G	N	N	G	G	N	N	N	N	N
Dual	N	G	G	G	G	N	F	F	N	G	G	G	P	P	F	N	G
Goal	N	F	F	F	G	F	N	F	N	N	G	G	G	G	G	G	G
Micro-Tech	N	G	G	G	G	N	F	F	N	G	G	G	P	P	F	N	G
Sandea	G	N	N	N	P	P	N	F	F	G	G	N	G	G	G	G	N
Sencor	F	P	P	P	G	G	P	G	F	N	G	G	G	F	G	F	P
Lorox	F	F	F	F	G	F	P	G	F	N	G	G	G	F	F	F	P
Prowl	N	G	G	G	F	N	F	F	N	N	G	F	P	P	F	F	P
Post-emergence																	
Basagran	G	N	N	N	G	G	N	G	G	N	F	G	G	F	G	G	G
Fusilade	N	G	G	G	N	N	G	N	N	N	N	N	N	N	N	N	N
Poast	N	G	G	G	N	N	G	N	N	N	N	N	N	N	N	N	N

G = Good F = Fair P = Poor N = None
** This table should be used only as a guide for comparing the relative effectiveness of herbicides to a particular weed. The response listed is based on using the maximum recommended rates for a particular herbicide under adequate and good growing conditions. If growers are getting satisfactory results under their conditions, they should not necessarily change products as a result of the information in this table.*

Avoidance. It is possible to manage certain plant diseases by planting a crop at a time of the season when inoculum (spores or other structures) of a pathogen are not present or in a place where there is no pathogen pressure. Avoidance also applies to planting in areas where the environment will not favor a particular disease.

Exclusion. The goal of exclusion is to prevent pathogens from being introduced, and this can be accomplished through quarantines or by the production and use of pathogen-free seed and transplants. Removal of weeds that can harbor plant pathogens is another way to exclude certain viruses, bacteria, fungi, and nematodes that attack crops. Sanitation is an important means to prevent the introduction of pathogens into pathogen-free areas. Prevent movement of infested soil on equipment, implements, shoes, and clothing. Destroy or sanitize stakes, etc., that come from pathogen-infested fields. Avoid operations such as stringing, suckering, or harvest when plants are wet to avoid spreading disease from infected to healthy plants. Do not grow vegetable transplants in facilities where ornamental plants are produced, as ornamentals may harbor diseases that can spread to certain vegetables.

Eradication. This term refers to the elimination, destruction, or inactivation of plant pathogens in soil and on plant parts. Fumigation, rotation, and flooding of pathogen-infested fields are practices commonly used to eradicate or reduce plant pathogens. Removal and destruction of diseased plants is an effective method of eradicating some plant pathogens. Chemical and heat treatments serve to eliminate pathogens from seed.

Protection. Plant diseases can be managed through the application of chemicals (mainly fungicides or bactericides) to a plant or seed, or by the creation of physical barriers to infection.

Resistance. Planting cultivars that have some level of resistance to one or more pathogens is one of the most important and least expensive tools for disease management. The availability of resistant cultivars, however, varies by crop and disease, and resistant varieties don't exist for many plant diseases. It is also important to remember that "resistant" doesn't necessarily mean "immune."

Therapy. This principle deals with the application of materials or methods to "cure" plants that have existing infections. Heat treatment of infected plants or applica-

tion of "curative" fungicides are examples of therapy.

It's easy to see that effective disease management is not limited to a single practice but involves the coordination of tactics that fall under one or more of the principles described above. We need to remember that some tactics are better than others for an individual disease; it's important to learn as much as possible about the diseases and management tools available for the crop being grown. There are also multiple pathways to success; disease management programs can be tailored to fit an individual grower's crops, land, and production practices. When developing a plan for disease management, consider the following:

- Use disease-resistant varieties whenever possible. Plants of a resistant variety may still develop the disease for which it is resistant; diseases may be present at much lower levels or rates of development in resistant varieties compared to susceptible varieties. The resistance may be more effective at one stage of growth than another. Resistant varieties may not have the horticultural qualities of the best susceptible varieties. Remember also that reducing pesticide use or residues has environmental and social value together with significant market appeal.
- Keep the environment around your crops as unfavorable as possible for pathogens. Environmental factors are huge influences on the development of plant diseases. In fact, a diseased plant is the culmination of an encounter between a susceptible host and a pathogen under a favorable environment. We can't change the weather, but we can implement cultural practices that allow for good air movement (and less leaf wetness) and soil drainage.

  A good example of providing a favorable environment for plant pathogens is the float-bed system of transplant production. Although it offers certain advantages for transplant producers, the system provides an ideal environment for pathogens such as *Pythium* and *Phytophthora.* Couple this with a lack of good fungicide tools for use in greenhouse systems in general, and the stage is set for potential disaster. For these reasons we recommend that float systems not be used for production of vegetable transplants.
- Establish and maintain a high state of sanitation in your vegetable operation. Locate cull piles off the farm or as far as possible from production fields. Keep greenhouses clean and weed-free.
- Delay the onset of disease. This principle is key in disease management. Stopping epidemics early in the season is especially important. Once well established and developing rapidly under favorable weather conditions, many diseases are nearly impossible to control. This is particularly true with bacterial diseases—antibiotics, for the most part, are not available to control bacterial diseases in plants as they are for bacterial diseases in humans and animals.
- Buy or produce disease-free seeds and transplants.
- Control weeds and insects. Manage diseases that are spread by insects and survive in weeds or insects. Timely weed or insect pest control is critical in these cases. Classic examples are bacterial wilt of cucurbits and cucumber beetle control, and mosaic virus of corn and johnsongrass control.

Timely Diagnosis of Plant Diseases

Accurate and timely diagnosis of vegetable diseases and disorders is a critical step in disease management. It is next to impossible to apply the appropriate management practice if the problem has not been identified properly. Application of the wrong fungicide or other tool can result in poor disease control and may cause a serious loss of yield. Yield loss and the expense of the fungicide can eat into profits. Knowledge of specific problems that occur in a given field or on a certain variety allows you to incorporate the appropriate controls into the total plan.

The following guidelines will help in obtaining a timely and accurate diagnosis:

- Scout vegetable plantings frequently and regularly. Watch for changes in plant appearance. Identify the specific problem(s) and note when and where it is occurring. Make a field-by-field record of what was found.
- Pay careful attention to patterns of affected plants in the field or greenhouse. If nearly all plants have the problem, the cause is usually something other than an infectious agent. Infectious diseases usually start with a few plants or as a small cluster and spread over time. This information can be extremely helpful in obtaining a timely and accurate diagnosis.
- Know what pesticides were used and when they were applied. Knowing when things are happening aids diagnosis and the timing of control measures. Previous events are valuable clues to a diagnostician.
- Examine the plant carefully for symptoms (the whole plant, including roots and soil). Collect (by digging, not by pulling) several whole plants representing a range of stages of the disease or disorder. Also collect at least one healthy plant. Why the healthy plant? This plant may not be as healthy as it appears, and poor health can predispose plants to certain other problems.
- Rule out soil nutrient problems—both deficiencies and toxicities. Soil test results and records of fertilizers used should be made available to the person making the diagnosis.
- Know the variety that has been planted.
- Take the plant samples and all the information available to the county Extension office. If the grower has collected carefully but the agents are unable to identify the problem, they will have what they need to submit samples to specialists.

Crop Rotation and Tillage—The Foundation of a Good Disease Management Program

General Considerations. Crop rotation reduces losses from more diseases than any other single cultural practice. When coupled with resistant varieties, fumigants, or fungicides, rotation will usually improve or extend control of most plant diseases.

The idea behind rotation for plant disease control is to force the pathogen population to survive without its host so that future crops encounter lower populations of that pathogen. Decline in the pathogen population occurs because reproduction is stopped and the pathogen's resting stages die as its food reserves are depleted over time. This practice slows the buildup of pathogens in fields routinely used for vegetables, even for those pathogen populations that do not decline during rotation. Another important benefit is that the virulence or aggressiveness of the remaining pathogens is often reduced; fungicide-resistant strains may also be reduced.

Although less than ideal, even short rotational intervals are usually beneficial. Short rotations can be used to reduce disease pressure in fields after a serious disease outbreak, although longer intervals between susceptible crops are usually recommended. Unfortunately, rotation is not effective against all diseases. Where effective, it is an invaluable and environmentally safe disease management tool.

In rotating vegetable crops, avoid planting the same crop species or closely related species in the same place more than once every three years. Crops grouped together below are subject to the same disease and insect problems:

- Corn, sorghum, small grains, grasses
- Chives, garlic, leeks, onions, shallots
- Beets, Swiss chard, spinach
- Cabbage, cauliflower, kale, collards, Brussels sprouts, broccoli, kohlrabi, turnips, rutabaga, Chinese cabbage, mustard
- Peas, snap beans, Lima beans, soybeans, clover, alfalfa
- Carrots, parsley, celery, celeriac, parsnips
- Pumpkins, squash, watermelons, cucumbers, muskmelons
- Endive, salsify, lettuce
- Potatoes, eggplant, tomatoes, peppers, tobacco

Some problems (especially nematodes and Phytophthora root rots) will cross over among these groups. Also, crop rotation will not impact many airborne diseases that come in from outside the field. In addition, root and bulb crops—though often not related botanically—are susceptible to many of the same soil pests; avoid other root crops and botanically related plants in the rotation. Many unrelated vegetable crops can act as hosts to root knot nematodes so that major changes in rotational patterns are needed where nematodes become a problem.

Grasses (cool- or warm-season grasses, cereals, corn, sweet corn, and sorghum) are excellent crops to use in rotation with most vegetables. Because of the crop mix used in Kentucky, the most valuable rotations for disease control will be those that use the grass group most often. Since sweet corn is an important crop in many Kentucky vegetable operations, fields to be planted to corn should be chosen carefully to obtain full benefit from its disease-control value. This is a commonly overlooked tool on many farms. The second most valuable group in rotations is the cole crop group because cole crops release natural fumigants as they decompose.

Some diseases will not be much affected by short to moderate rotational schemes. This happens because the pathogen can maintain its population on a wide host range (including weed hosts), produces very resilient resting stages, or has very rapid rates of secondary reproduction. Also, some pathogens have more than one source; new sources can arrive with transplants or on winds even though local soil-borne or crop residue sources were controlled. Serious examples of this problem in Kentucky are bacterial leaf spots, blights, or cankers of tomatoes, peppers, and cole crops.

Many plant pathogens survive between crops in association with crop residues and are unable to persist once the debris has decomposed. Therefore, the earlier that infested debris can be plowed under to decompose, the more rapid will be the decline in the pathogen population. Disking or chopping crop residues immediately after harvest followed by tillage rapidly reduces many pathogen populations.

Finally, adjust crop rotations accordingly when a particular disease develops in a crop. Realize that there is no perfect rotational scheme; all have their strengths and weaknesses and disease control is just one of many factors that must be considered when developing a rotation plan.

Application of Fungicides

Fungicides are important tools for controlling infectious diseases in commercial vegetable crops. Chemical fungicides work mainly as protectants and only a few are eradicants (curatives). Control is usually achieved by inhibiting subsequent infections of the pathogen rather than by curing the diseased plant. This greatly differs from the activity of most insecticides.

Some newer fungicides, however, do have curative or eradicant action; they can arrest further growth and development of the pathogen or possibly eradicate it inside the plant. Even though these products have curative action, using them in this fashion is not advised. In general, the curative-type chemicals affect specific metabolic processes that are controlled by single genes in a pathogen. This makes it more likely that the target fungi will develop resistance. Waiting until significant infection has taken place before treating a crop exposes a larger proportion of the pathogen population to fungicide than if the treatment is applied before infection takes place (or when it just begins). Thus, the probability of selecting for a resistant individual in that pathogen population is increased by delaying fungicide application.

Timing applications relative to when the disease develops is very important. For protectant fungicides, applications must be made before the disease begins. Why? Because these materials stop the pathogens by preventing spore germination and by preventing subsequent infections and not by eradicating the pathogen after it is already inside the plant.

All fungicides are subject to weathering and must be applied early in the disease cycle and reapplied at regular intervals. This keeps plants adequately covered due to new growth and weathering of the pesticides. Discontinuing applications often results in even more disease than if no sprays were applied. Delaying applications, increasing spray intervals, or stopping applications should be based on the occurrence of environmental conditions that prevent infection or spore production. Several predictive models have been developed for commercial vegetables (such as the Tomcast system for tomatoes) that use monitoring techniques for leaf wetness and temperature to decide when to start and stop sprays.

Follow all label directions concerning alternating and mixing fungicides. The Fungicide Resistance Action Committee (FRAC), has classified the active ingredients found in fungicides by their mode of action (target site) and assigned them a group number, called the "FRAC code" or "FRAC group." Fungicides with the same FRAC group number have the same mode of action, even if they belong to different chemical classes. Fungicides that are at risk for development of resistance will contain the FRAC code (group), along with specific resistance management guidelines.

It is not necessary to memorize modes of action for each fungicide used; use the product's FRAC code to decide how each fits in a season-long spray program. Careful adherence to resistance management guidelines will go a long way toward delaying or preventing the development of resistance. Refer to the table in this section for a complete list of fungicides, their modes of action, FRAC codes, and chemical classes.

A good resistance management practice is to avoid back-to-back applications of fungicides that have very specific modes of action (such as strobilurins or sterol biosynthesis inhibitors), as the likelihood of developing resistance to these types of compounds is much greater than for broad spectrum materials such as chlorothalonil, copper, or mancozeb.

Also, remain alert to label advice concerning the pH of the spray solution. Some products undergo a chemical degradation called alkaline hydrolysis when the pH is above 7. Likewise, there are fungicides that degrade in acid water; these include most copper materials important for the control of bacterial diseases. Spray adjuvants or surfactants should be used if the product label recommends them to ensure uniform coverage. Do not use these materials unless the label indicates that they are needed. Surfactants are most valuable in cole crops and peppers due to waxy leaf surfaces on these crops.

Consideration should be given to the time of day applications are made. When possible, applications should be made when the air is still. With high pressure and tiny droplets, drift can be significant. In some cases, crop damage may result from fungicide applications made during very hot and humid parts of the day.

Spray Systems for Disease Control

A properly equipped and calibrated spray rig is a key element to any disease control program. Accurate delivery translates to good coverage, and good coverage is essential for fungicides to perform to their maximum potential. Most fungicides control disease by stopping germination of the microscopic spore prior to infection. The chemical must therefore be applied precisely to reach and cover all microscopic surfaces of the foliage during spore germination. The fungus cannot move around and contact the chemical as do insects with insecticides. Only with systemic fungicides is coverage sometimes less demanding.

Ground-operated spray equipment should be set to deliver 40 to 150 gallons per acre at 70 to 400 psi to ensure thorough coverage of plant surfaces. For protective fungicide applications, piston pumps and diaphragm pumps are best, although some roller pumps are also suitable. Lower volumes and pressures are not usually as effective.

Hollow-cone or twin-jet nozzles are preferred for fungicide applications. Two-piece cone nozzles (consisting of core and whirl plate-orifice disc) are usually best with high pressures. The core is a fan-shaped insert that shapes the spray pattern; the orifice uses a small hole in a disc to control the volume that passes through at a given pressure. These components come in different sizes that can be used in different combinations to greatly impact delivery and coverage.

Spray nozzles are made from brass, stainless steel, polymers, and ceramic. Brass nozzles are relatively inexpensive but wear out quickly, requiring frequent replacement and re-calibration of the rig. Ceramic nozzles have the longest life but can be expensive. Keep in mind that these nozzles won't need to be replaced as often as brass nozzles and will hold calibration longer because of reduced wear. Stainless steel nozzles are less expensive than ceramic nozzles and provide long service life as well.

The type of spray boom needed varies greatly from crop to crop. Ground crops such as melons and most crops early in the season can be sprayed effectively with a broadcast boom sprayer. Sprayers used on upright crops such as staked tomatoes and peppers, however, should be modified with drops and multiple nozzles to achieve success. During application, nozzles should be turned about 15 to 20 degrees towards the direction of travel (front) to achieve a more vigorous spray action and improve coverage. The change in angle reduces immediate contact with leaves (which block delivery) and increases the stirring of leaves/foliage (at high pressure). This aids in the coverage of the undersides of leaves and areas of leaf overlap.

Air-blast sprayers and motorized backpack sprayers can be used successfully for many vegetable crops. They are usually not as effective as properly equipped broadcast boom sprayers for most commercial vegetables, except where each row is being sprayed from both sides.

Finally, all types of sprayers should be properly calibrated. Because of nozzle wear, this needs to be done often when fungicides are used (see Appendix F).

Vegetable Seed Treatments

Quality of seed is very important to a vegetable grower's success. Planting high-quality seeds that have been treated with fungicides will help achieve the best control of seedling diseases. This is truly the first step in producing quality, disease-free transplants for the field. Seed should not be saved from a previous crop. Purchase fresh seed from reputable dealers. A reputable dealer should be able to share specific information on the geographic areas of seed production and the steps taken to ensure that the seed are pathogen-free.

Be specific in your requirements for seed treatments when purchasing seed. Ask about the source of the seed. Have they been tested for seed-borne diseases and found to be negative? Have they received heat, acid, or bleach treatments? What fungicide treatments have been applied? These questions are much more important now because, in most cases, growers are not equipped to apply fungicide seed treatments on the farm. Most commercially available vegetable seeds come treated with one or more fungicides and possibly an insecticide. Check the product packaging or check with the seed dealer to find out what treatments have been applied. Most seed companies also sell untreated seed for use by organic growers or those who wish to apply their own seed treatments.

Types of Seed Treatments. Treatment of vegetable seed is an important tool for control of certain seed-borne diseases. Seed treatment can be broken into two major categories: eradication and protection. Eradicant-type treatments aim at eliminating or reducing pathogens in and on seed; protectants form a barrier that inactivates pathogens as they emerge or prevents soilborne pathogens from attacking the emerging seedling. The following are examples of these types of seed treatments:

Eradicant Seed Treatments
Fermentation
Heat (hot water)
Chemical (chlorine bleach, acid, trisodium phosphate)
Systemic fungicides
Protectant Seed Treatments
Fungicides
Bactericides

See Appendix I for specific information on disinfestation of vegetable seeds. In the case of fungicide seed treatments, many registrations have been cancelled over the years, although some have been restored, so check and follow labels carefully. The majority of labeled seed treatments are restricted to commercial treatment only. This is due in part to concerns about applicator exposure during seed treatment and handling. Many vegetable seeds are treated prior to sale with both fungicides and insecticides. Be sure to check seed package labels to avoid double treatment and to ensure your own safety. If in doubt about how seed has been treated, ask for specifics from your seed company representative or from company headquarters. Never use chemically treated seed for food or feed.

Nematode Control

Historically, Kentucky's vegetable producers have had few problems with nematodes because they have practiced crop rotation. When problems have developed, they have mostly occurred in sandy or rocky soils. Problems have been mainly with the root-knot nematode in warm and dry summers, with a few cases involving lesion nematodes. Soybean cyst nematode can be a problem with bean crops, and special consideration is needed where soybeans and other bean crops are grown on the same farm. Problems with nematodes are increasing to some degree on vegetable and other host crops as vegetable production increases and rotations with grasses decline in Kentucky.

What are nematodes? Nematodes are microscopic roundworms that feed mainly on plant roots. They cause damage by reducing root health, reducing the quality of root crops, and increasing susceptibility to other diseases—especially the vascular

FUNGICIDE RESISTANCE ACTION COMMITTEE CODES			
Product	**FRAC Code**	**Active Ingredient**	**Chemical Group**
Acrobat 50 WP	15	dimethomorph	cinnamic acid
Actigard	P	acibenzolar-S-methyl	SAR inducer
Agri-Mycin 17	25	streptomycin	antibiotic
Aliette WDG	33	fosetyl-Al	phosphonate
Amistar	11	azoxystrobin	QoI fungicide
Badge SC	M	copper hydroxide + copper oxychloride	inorganic
Basic Copper 53	M	basic copper sulfate	inorganic
Botran 75 W	14	dicloran	aromatic hydrocarbon
Bravo Ultrex	M	chlorothalonil	chloronitrile
Bravo WeatherStik	M	chlorothalonil	chloronitrile
Bravo ZN	M	chlorothalonil + zinc	chloronitrile
Bumper 41.8 EC	3	propiconazole	DMI fungicide
Cabrio	11	pyraclostrobin	QoI fungicide
Champ DP	M	copper hydroxide	inorganic
Champ Formula 2 FL	M	copper hydroxide	inorganic
Champion WP	M	copper hydroxide	inorganic
COC DF	M	copper oxychloride	inorganic
COC WP	M	copper oxychloride	inorganic
C-O-C-S WDG	M	copper oxychloride + basic copper sulfate	inorganic
Copper-Count-N	M	copper-ammonium complex	inorganic
Cuprofix Disperss	M	basic copper sulfate	inorganic
Cuprofix Ultra 40 Disperss	M	basic copper sulfate	inorganic
Cuprofix MZ Disperss	M	basic copper sulfate + mancozeb	inorganic + dithiocarbamate
Curzate 60 DF	27	cymoxanil	cyanoacetamide-oxime
Dithane DF Rainshield	M	mancozeb	dithiocarbamate
Dithane F-45 Rainshield	M	mancozeb	dithiocarbamate
Dithane M-45	M	mancozeb	dithiocarbamate
Echo 720	M	chlorothalonil	chloronitrile
Echo 90 DF	M	chlorothalonil	chloronitrile
Endura	7	boscalid	carboxamide
Equus 720 SST	M	chlorothalonil	chloronitrile
Equus DF	M	chlorothalonil	chloronitrile
Evito 480 SC	11	fluoxastrobin	QoI fungicide
Flint	11	trifloxystrobin	DMI fungicide
Flouronil	4/M	mefenoxam + chlorothalonil	phenylamide + chloronitrile
Forum SC	15	dimethomorph	cinnamic acid
Gavel 75 DF	22/M	zoxamide + mancozeb	benzamide + dithiocarbamate
Gem	11	trifloxystrobin	QoI fungicide
Headline	11	pyraclostrobin	QoI fungicide
Heritage	11	azoxystrobin	QoI fungicide
Iprodione 4L AG	2	iprodione	dicarboximide
Kocide 101	M	copper hydroxide	inorganic
Kocide 2000	M	copper hydroxide	inorganic
Kocide 3000	M	copper hydroxide	inorganic
Kocide 4.5 LF	M	copper hydroxide	inorganic
Kocide DF	M	copper hydroxide	inorganic
Maneb 75 DF	M	maneb	dithiocarbamate
Maneb 80 WP	M	maneb	dithiocarbamate
Manex	M	maneb	dithiocarbamate
ManKocide	M	copper hydroxide + mancozeb	inorganic + dithiocarbamate
Manzate 75 DF	M	mancozeb	dithiocarbamate
Manzate Flowable	M	mancozeb	dithiocarbamate
Manzate Pro-Stick	M	mancozeb	dithiocarbamate
Maxim 4 FS	12	fludioxonil	phenylpyrrole

FUNGICIDE RESISTANCE ACTION COMMITTEE CODES			
Product	**FRAC Code**	**Active Ingredient**	**Chemical Group**
Maxim MZ	12/M	fludioxonil	phenylpyrrole + dithiocarbamate
Maxim Potato Seed Protectant	12	fludioxonil	phenylpyrrole
Mertect 340 F	1	thiabendazole	benzimidazole
Moncut 70 DF	7	flutolanil	carboxamide
Nova 40 W	3	myclobutanil	DMI fungicide
Nu-Cop 3 L	M	copper hydroxide	inorganic
Nu-Cop 50 DF	M	copper hydroxide	inorganic
Nu-Cop 50 WP	M	copper hydroxide	inorganic
PCNB 2E	14	PCNB	aromatic hydrocarbon
Penncozeb 4 FL	M	mancozeb	dithiocarbamate
Penncozeb 75 DF	M	mancozeb	dithiocarbamate
Penncozeb 80 WP	M	mancozeb	dithiocarbamate
Polyram 80 DF	M	metiram	dithiocarbamate
Previcur Flex	28	propamocarb	carbamate
Pristine	7/11	pyraclostrobin + boscalid	QoI fungicide + carboxamide
Proline 480 SC	3	prothioconazole	DMI fungicide
Propimax EC	3	propiconazole	DMI fungicide
Quadris	11	azoxystrobin	QoI fungicide
Quadris Opti	11/M	azoxystrobin + chlorothalonil	QoI fungicide + chloronitrile
Quilt	3/11	azoxystrobin + propiconazole	QoI fungicide + DMI fungicide
Quintec	13	quinoxyfen	quinolene
Ranman SC	21	cyazofamid	QiI fungicide
Reason 500 SC	11	fenamidone	QoI fungicide
Ridomil Gold Bravo	4/M	mefenoxam + chlorothalonil	phenylamide + chloronitrile
Ridomil Gold Bravo SC	4/M	mefenoxam + chlorothalonil	phenylamide + chloronitrile
Ridomil Gold Copper	4/M	mefenoxam + copper hydroxide	phenylamide + inorganic
Ridomil Gold EC	4	mefenoxam	phenylamide
Ridomil Gold GR	4	mefenoxam	phenylamide
Ridomil Gold MZ	4/M	mefenoxam + mancozeb	phenylamide + dithiocarbamate
Ridomil Gold PC GR	38456	mefenoxam + PCNB	phenylamide + aromatic hydrocarbon
Ridomil Gold SL	4	mefenoxam	phenylamide
Rovral 4 Flowable	2	iprodione	dicarboximide
Scala	9	pyrimethanil	anilinopyrimidine
Sovran	11	kresoxim-methyl	QoI fungicide
Sulfur	M	sulfur	inorganic
Super Tin 80 WP	30	triphenyltin	organo-tin
Switch	9/12	fludioxonil + cyprodinil	phenylpyrrole + anilinopyrimidine
Tanos	11/27	cymoxanil + famoxadone	cyanoacetamide-oxime + QoI fungicide
Tenn-Cop 5 E	M	copper tallate	inorganic
Terraclor 15G	14	PCNB	aromatic hydrocarbon
Terraclor 2E	14	PCNB	aromatic hydrocarbon
Terraclor 75 WP	14	PCNB	aromatic hydrocarbon
Terraclor Flowable	14	PCNB	aromatic hydrocarbon
T-Methyl W 70 WSB	1	thiophanate-methyl	thiophanate
Thiophanate-Methyl 85 WDG	1	thiophanate-methyl	thiophanate
Tilt	3	propiconazole	DMI fungicide
Topsin 4.5 FL	1	thiophanate-methyl	thiophanate
Topsin M 70 WP	1	thiophanate-methyl	thiophanate
Topsin M WSB	1	thiophanate-methyl	thiophanate
Turfcide 10G	14	PCNB	aromatic hydrocarbon
Ultra Flourish	4	mefenoxam	phenylamide
Ziram	M	ziram	dithiocarbamate

wilts. Poor uptake of nutrients and water usually contribute to the most common symptoms. Unthrifty, stunted, or wilting plants should be examined for nematodes when symptoms are noticed. Root galling and irregular root enlargement are usually present if root knot nematode is involved, although these symptoms may not be obvious with all crops.

Management of plant parasitic nematodes hinges on correct diagnosis of the problem and knowledge about the population level of the nematode(s). Samples should be collected during the growing season while symptoms are present. The sample of affected plants should include tops with roots attached plus a composite soil sample collected from 10 areas of the field. In addition, healthy plants and a separate soil sample from areas of the field not affected should be included. A number of

nonchemical and chemical tools are available for management of nematodes.

The key to nematode control is to keep the populations low and below damaging levels (especially early in the season). Crop rotation to a non-host or poor host plants, such as grasses or small grains, is the key to keeping populations low once they are present. Yield losses can usually be minimized in most Kentucky soils through proper nutrition, irrigation, and reduction of plant stress where populations are low. This approach still allows nematode numbers to build; other controls will be needed to avoid serious damage to later plantings. Plants can tolerate much higher nematode levels in our heavier and cooler soils than they can in the lighter and warmer soils to the south, especially when irrigation is being used.

Spread of nematodes must be prevented. Nematodes move only short distances on their own but are easily moved on infested soil or on infested plant material through human activities. Take steps to limit field-to-field spread of nematode-infested soil; clean equipment, vehicles, and shoes thoroughly after working infested fields.

Prompt and proper crop destruction after harvest followed by replanting with a non-host cover crop prevents further increases in the nematode population and traps some nematodes in the middle of their reproductive cycle. Non-host cover crops suppress nematodes by starving them and preventing reproduction. Antagonistic crops (French marigolds or certain rapeseed crops) suppress through direct toxic effects to nematodes.

Cover crops that are nematode hosts can be used to trap and reduce nematode populations by destroying the host plant (cover crops) before the nematode can reach a reproductive life stage (from which it can survive to the next crop). Timing with trap crops is critical because even more serious problems exist when crop destruction is delayed until after nematodes have reproduced.

The introduction of large amounts of organic matter in the soil is suppressive to plant parasitic nematodes. Maximum benefit is achieved when large amounts of organic matter are incorporated as green manure; however, sufficient time must be allowed for adequate decomposition to avoid crop damage from organic matter toxicity and other problems.

Nematode resistant varieties are available in only a few crops. For example, the N in 'VFN'-resistant tomato variety descriptions indicates resistance to root knot nematode. Resistance does not solve all root knot nematode problems on tomatoes in Kentucky, however. The gene involved confers resistance to most, but not all, species of root knot nematode. The northern root knot nematode *(Meloidogyne hapla)* is not controlled by this gene. Since the northern root knot nematode is native to Kentucky soils, problems can still occur with commercial tomato varieties labeled VFN on sites where rotation is not practiced.

FUMIGANTS FOR VEGETABLE CROPS

Trade Name	Common Name	Rate/A	Timing *(Plant-back)*
Telone II	1,3-dichloropropene (97.5%)	9-12 gal	3-4 weeks before planting
Telone C-17	1,3-dichloropropene (81.2%) + chloropicrin (16.5%)	10.8-17.1 gal	3-4 weeks before planting
Telone C-35	1,3-dichloropropene (63.4%) +chloropicrin (34.7%)	13-20.5 gal	3-4 weeks before planting
Chloropicrin	chloropicrin (99.5%)	22-36.5 gal	> 2 weeks before planting
Vapam HL or Sectagon	metam sodium (42%)	37.5-75 gal	3-4 weeks before planting

Soil Fumigants for Control of Nematodes and Soilborne Diseases

When proper rotation is not an option, or when populations of soilborne fungi and nematodes have reached damaging levels, soil fumigants should be considered. These materials have a broad spectrum of activity and can be relatively expensive. Their use tends to be limited to high-value crops such as staked tomatoes. Fumigation of soils will, if properly done, reduce soil pathogen populations early in the season, alleviating plants from pathogen stress and allowing for increased productivity. However, pest populations at the end of the season may be equal to or greater than that prior to fumigation. The reason for this is that natural competitors and parasites of soil pathogens are reduced by fumigants, so pathogen populations tend to explode once they move into fumigated areas from adjacent, non-fumigated soils. Thus, in the absence of rotation, fumigants may need to be applied yearly to maintain acceptable disease control and yields.

Materials available for general fumigation and nematode control on most vegetable crops are described in this section. Follow labels carefully concerning application methods, waiting intervals before planting, and all safety precautions. Most soil fumigants are extremely dangerous to people and animals; specialized equipment is required to apply these materials properly. In many cases, growers should consider hiring a licensed applicator to put out soil fumigants.

Fumigants must be applied correctly. Sites to receive soil fumigation need to be prepared properly. Debris from the previous crop should be removed, the soil should be free of clods and stones, and soil moisture must be adequate to permit activation and movement of fumigant materials. If the soil is inadequately prepared, fumigation will not be effective because the fumigant will not penetrate the clods and large debris—it will flow around them, following the path of least resistance. If soil moisture is inadequate, microbes may not be actively growing and will thus be less affected by fumigants. Irrigate the site, if necessary, several days in advance to revive dormant soil organisms. If the site is too wet, however, soil pores will be filled with water and fumigant movement in soil will be reduced (along with efficacy). Soil temperature at the 4- to 6-inch depth should be between 50°F and 80°F; cooler temperatures slow fumigant movement in soil, and higher temperatures allow for the gases to escape too rapidly.

Fumigant trapped in soil can cause phytotoxicity when crops are transplanted. Following fumigation, soil must be sealed by irrigation or tarping to maximize pathogen kill. Allow sufficient time for residues to dissipate so as to avoid crop injury; the plant-back period for these materials varies by product, soil temperature, and moisture.

Nematicides. Telone II and Telone EC (1,3-dichloropropene) are fumigant nematicides labeled for most vegetables. These products can be applied broadcast or in beds, using chisels (shanks) spaced up to 12 inches apart and set to a 8-10 inch depth. 1,3-dichloropropene is strictly a nematicide and has little effect on fungi or weeds.

Multipurpose Fumigants. A mixture of methyl bromide plus chloropicrin (67/33%) is a biocidal mixture that will reduce nematodes, weeds, and soilborne fungi. This material is labeled for most vegetable crops and must be tarped after application. The production of methyl bromide was significantly reduced in the U.S. in compliance with the Montreal Protocol, with only specific critical uses being permitted. Existing stocks, however, can be used.

Metam sodium, chloropicrin, and mixtures of 1,3-dichloropropene plus chloropicrin (Telone C-17, Telone C-25, InLine) are multipurpose soil fumigants that are labeled on many vegetables for controlling nematode and fungal diseases. All can be injected into soil as fumigants, and metam

NON-FUMIGANT NEMATICIDES

Product	Product Amt/A	Application Method/Timing	Crops
Mocap 15G	13-80 lb	pre-plant broadcast or banded at-plant	beans (succulent), cabbage, cucumber, irish potato, sweet corn, sweetpotato
Mocap EC	3.33-8 qt	pre-plant broadcast or banded at-plant	same as for Mocap 15G
Nemacur 3	2.33 qt	at-plant banded	eggplant
Vydate L	2-8 pt	pre-plant in-furrow, post-emergence (drip irrigation and foliar)	carrot, cucurbits, eggplant, pepper, irish potato, sweetpotato, tomato

sodium, chloropicrin, and InLine can be applied through irrigation systems. Metam sodium can also be sprayed onto soil surfaces and incorporated. The plant-back period ranges from 3-4 weeks or longer, which requires careful planning. Where erosion controls will allow, fall applications are an option, especially for early plantings. The table "Fumigants for Vegetable Crops" on the previous page summarizes fumigant materials that can be used on many vegetable crops grown in Kentucky. Check product labels for specific crop listings, application instructions, and safety precautions.

Non-fumigant Nematicides. Several non-fumigant materials can be applied pre- and post-planting to suppress nematodes in a number of vegetable crops. Most are insecticidal as well, and all are extremely dangerous. The table "Non-fumigant Nematicides" above lists products registered in Kentucky. Consult product labels for rates on specific crops and for application types permitted on each crop.

Air Pollution Injury in Vegetables

Vegetable crops in Kentucky are damaged every year from air pollution. The extent of damage varies greatly by location and year. Meteorological developments greatly affect air pollution episodes in the Ohio River Valley. These developments directly determine air stagnation events, presence or absence of pollution, and crop susceptibility at the time of the episode.

Ozone injury is the most common air pollution problem diagnosed in Kentucky vegetable crops. It results from high ozone levels during midsummer stagnation events. It appears as small stipple- to fleck-like lesions visible on upper leaf surfaces. Lesion color varies with the crop, ranging from white to dark. The most susceptible tissues are those leaves that recently matured at the time of the pollution episode; very young and very old foliage are normally resistant. In some crops the lesions are more common toward the tips and margins of the leaf. These lesions can be confused with those resulting from small insects (mites, thrips, leafhoppers), but with careful observation, insects can be found if they are the cause. Also, when ozone is involved, many plant species in the area will have been affected. The most sensitive crops to ozone include beans, cucurbits, potatoes, and tomatoes. Much less ozone damage occurs in some of these crops if mancozeb was in the spray program before the air pollution event occurred.

Injury from PAN (peroxyacetyl nitrate) also occurs, although much less frequently than ozone injury in Kentucky. It too affects mainly the newly matured leaves. Symptoms include bronzing or glazing of the leaf undersides, with some areas of complete tissue collapse appearing in diffuse bands across the width of the leaf (tissues of the same age are affected). The most sensitive plants are lettuce, mustard, Swiss chard, beets, and cantaloupes.

Damage from other localized air pollution events is occasionally observed in Kentucky. These include sulfur dioxide damage following scrubbing operations at power plants and damage from ammonia and chlorine associated with local spills.

Biopesticides

A number of products derived from plants, microorganisms, or from GRAS (Generally Recognized As Safe) chemistries are labeled for disease control in vegetable crops (see table). Some of these products are effective under certain conditions, and others have very limited disease-control potential. Most are not as effective as the recommended conventional pesticide labeled for the disease in question. The EPA looks only at safety issues during the labeling process and does not test the efficacy of the product. It assumes the marketplace will sort out what is effective and what is not. Some of these "soft" chemicals are also not EPA-registered because they do not specifically claim to be pesticidal. These alternative products include living microorganisms (bacteria, viruses, fungi, nematodes, and protozoa), "natural chemicals," plant extracts, etc. Their aim is to achieve good disease control with less impact on human safety and the environment compared to traditional pesticides. These products will be carefully considered for recommendation in our crop guidelines as university research data become available to justify their inclusion.

Our goal is to help commercial growers integrate all available tools in a manner that provides effective disease control with minimal risk to producers, consumers, and the environment. The table "Biopesticides for Plant Disease Management" on the next page lists alternative products and provides some general information on these new materials but does not constitute a recommendation. Growers interested in these products should first test them in small-scale trials before dropping or changing from a recommended spray program. Many are approved for greenhouse use; check product labels.

Post-Harvest Decays

Vegetable crops are subject to great losses after harvest because of environmental conditions and microbes. Bacteria and fungi are present in wounds and on surfaces of fresh produce. Many post-harvest pathogens cannot invade the plant unless a wound is present. Significant losses occur as these pathogens spread and increase due to improper harvesting, poor handling, and improper cooling. Proper post-harvest handling, precooling, storage, and packaging procedures are all disease control practices that are essential to successful commercial vegetable production.

Chlorination of water bath washes or sprays is an important practice to reduce pathogen numbers and spread and to improve shelf life. The wash water temperature should be about 10°F warmer than the internal temperature of the product being washed. This avoids microbes being drawn into the tissues, which occurs when colder water is used.

Although chlorine can be added to wash water in several forms, the water pH must be adjusted so that chlorine remains available and active. Wash water pH should always be between 6.5-7.5 to ensure that adequate chlorine is available. The following forms of chlorine are used in post-harvest water baths:

- Sodium Hypochlorite 5.25 percent (household bleach)—use 13 to 17 fluid ounces per 100 gallons of water. The label covers most vegetables as a dip and rinse.
- Calcium Hypochlorite (Magnum 65%)—use 1 ounce per 100 gallons of water; labeled for most vegetables as a dip and rinse.

BIOPESTICIDES FOR PLANT DISEASE MANAGEMENT

Active Ingredient	Product	Crops	Target Diseases/Pests
Acibenzolar-S-methyl	Actigard	tomato	bacterial spot & Speck
Bacillus pumilus QST2808	Ballad, Sonata	brassicas, cucurbits, legumes, bulb vegetables, root crops, pepper, tomato, sweet corn	early blight, late blight, downy mildew, powdery mildew, leaf blights, rust
Bacillus subtilis GB03	Companion	greenhouse	root diseases
Bacillus subtilis MBI600	SubtilexProMix with Biofungicide	sweet corngreenhouse	root diseasesroot diseases
Bacillus subtilis QST713	Serenade	legumes, cucurbits, pepper, tomato	downy mildew, powdery mildew, leaf blights
	Rhapsody	greenhouse	root diseasese, leaf blights
Coniothyrium minitans	Contans	leafy vegetables	Sclerotinia blight
Gliocladium cantenulatum	Primastop Biofungicide	vegetables	seed rots, root diseases
Gliocladium virens G-21	SoilGard	vegetables	seed rots, root diseases
Harpin protein	ProAct, Messenger	vegetables	foliar diseases
Hydrogen peroxide	Oxidate, Terracide	vegetables	root diseases, leaf blights
Myrothecium verrucaria	DiTera DF	leafy vegetables, cole crops	nematodes
Neem oil	Trilogy	vegetables	foliar diseases
Phage	AgriPhage	peppers, tomatoes	bacterial spot, speck
Phosphorous compounds	Phostrol, Lexx-A-Phos, Agri-Fos, ProPhyt, Fosphite	vegetables	downy mildew, powdery mildew, leaf blights
Potassium bicarbonate	Armicarb, Kaligreen	vegetables	powdery mildew, Botrytis
Pseudomonas chlororaphis	Ateze	vegetables	stem, root diseases
Pseudozyma flocculosa	Sporodex L	greenhouse cucumbers	powdery mildew
Rhamnolipid biosurfactant	Zonix	vegetables	Pythium, Phytophthora
Streptomyces griseoviridis	Mycostop	vegetables	seedling, root, stem rots
Trichoderma harzianum	T-22, RootShield, PlantShield	vegetables	seedling, root, stem rots
Trichoderma viride	Binab	vegetables	seedling, root, stem rots

For detailed information regarding post-harvest handling, storage, and care of fresh produce, including chlorination procedures, see the "Post-harvest" section of Appendix A.

Disease Control in Greenhouse Vegetable Crops

Sanitation and moisture control are two very important strategies for disease control in the greenhouse. Few fungicides are labeled for use in greenhouses, and a limited number of resistant varieties is available. Excluding pathogens and reducing disease-favorable environments are the most important control measures in greenhouses.

Sanitation is extremely important. Everything that goes in the greenhouse should be new or sanitized to a like-new condition to prevent problems with damping-off and root and stem diseases. The wetter the production system, the more critical is the sanitation program.

Solarize the greenhouse by closing it tightly for several weeks during the hot and sunny parts of summer so that air temperatures reach 140°F. This will reduce populations of many pathogens. This treatment will not penetrate soil much more than ½ inch, nor will it control tobacco mosaic virus. Deeper penetration can be obtained in areas covered with clear plastic near the soil. Remove all heat-sensitive materials and clean out all debris before solarizing. Keep the system moist to encourage microbe activity during this solarization period; this will make microbes more sensitive to being killed by heat.

Steam at 180°F for 30 minutes is an effective sanitizer on any material that can tolerate it. Lower temperatures are helpful but not as effective. Metam sodium and chloropicrin are options for fumigating soil beds and soils where nematodes and soilborne fungi are present. Read and follow the labels for all products carefully, as these are extremely poisonous materials, especially in enclosed areas.

Foliar diseases in most greenhouse crops can be suppressed if relative humidity is kept below 90 percent. Manage the heat and temperature and keep the air circulating with fans and tubes. Consult a greenhouse specialist for more information on how to best manage the greenhouse environment. To avoid virus disease problems, do not produce vegetable transplants in greenhouses together with ornamental plants.

The following table summarizes the fungicides and bactericides registered for use on greenhouse-grown vegetables (including transplants). Exotherm Termil is no longer labeled for use on greenhouse-grown tomatoes. Consult product labels for crops covered by each material and for application instructions.

FUNGICIDES AND BACTERICIDES FOR GREENHOUSE-GROWN VEGETABLES

Product	Rate	Target Diseases	Comments
Armicarb	2.5-5 lb/100 gal water	powdery mildew, Botrytis	Apply on 5-14 day schedule.
Agri-Mycin 17	1 lb/100 gal water	Bacterial leaf spot	Apply beginning at two-leaf stage & continue on a 4-5 day schedule until transplanting (tomatoes & peppers only)
Botran 75 W	1 lb/100 gal water	Botrytis	Direct spray at stems; limit 4 applications per crop.
Kocide 101	4-8 tbsp/1000 sq. ft	bacterial diseases, early blight, leaf spots	Apply on a 7-14 day schedule. Other fixed coppers are registered; check product labels.
Dithane DF	1-3 lb/100 gal water	early blight, leaf spots, bacterial diseases (+ Kocide 101)	Apply on a 7-day schedule. Other formulations of mancozeb are registered; check product labels.
Maneb 75 DF	1-3 lb/100 gal water	early blight, leaf spots, bacterial diseases (+ Kocide 101)	Apply on a 7-day schedule.
Previcur Flex	Varies by application method—see label	Damping-off & root rot (*Pythium* spp. & *Phytophthora* spp.)	Can be applied to seedlings (transplant production) or greenhouse-grown crops. For use on cucurbits, leaf lettuce, peppers, and tomato.
Scala SC	7 fl oz/A	Early blight & Botrytis gray mold	For tomatoes grown in greenhouses & plastic tunnels.
Sulfur	Varies by product—see label	Powdery mildew & fungal leaf spots	Apply on a 7-14 day schedule.
Turfcide 10G	1-1.5 lb/ cubic yard of growth medium	root/stem rot; damping-off (Rhizoctonia)	For use on cabbage, cauliflower, broccoli, Brussels sprouts, pepper, and tomato plants grown in containers.