UTAH VEGETABLE PRODUCTION & PEST MANAGEMENT GUIDE

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2016 UTAH VEGETABLE PRODUCTION & PEST MANAGEMENT GUIDE

Publication Coordinator and Editors

Cami Cannon (Vegetable IPM Associate)
Editing assistance by: Marion Murray (IPM Project Leader), Diane Alston (Entomologist), and Dan Drost (Vegetable Specialist)

Chapter Authors

General Vegetable Production Recommendations
Dan Drost

Soils, Nutrients, and Water Management
Dan Drost

Vegetable IPM Practices
Diane Alston, Marion Murray

Brassica Production
Production: Dan Drost
Insects: Cami Cannon, Diane Alston, Marion Murray
Diseases: Claudia Nischwitz (Plant Pathologist)

Cucumber, Pumpkin, and Squash Production
Production: Dan Drost
Insects: Cami Cannon, Diane Alston, Marion Murray
Diseases: Claudia Nischwitz

Melon Production
Production: Dan Drost
Insects: Cami Cannon, Diane Alston, Marion Murray
Diseases: Claudia Nischwitz

Onion Production
Production: Dan Drost, Michael Pace (Agriculture Agent and Director of Box Elder County Extension)
Insects: Diane Alston, Bonnie Bunn (prior Vegetable IPM Associate)
Diseases: Claudia Nischwitz

Potato Production
Production: Dan Drost
Insects: Cami Cannon, Diane Alston, Marion Murray
Diseases: Claudia Nischwitz

Tomato, Pepper, and Eggplant Production
Production: Dan Drost, Britney Hunter (Horticulture Agent, Davis County)
Insects: Diane Alston, Bonnie Bunn
Diseases: Claudia Nischwitz

Sweet Corn Production
Production: Dan Drost, Taun Beddes (Agriculture Agent, Utah County)
Insects: Diane Alston, Bonnie Bunn
Diseases: Claudia Nischwitz

Pesticide Information
Marion Murray

Image Credits

Contact Information

Utah State University IPM Program
Dept. of Biology
5305 Old Main Hill
Logan, UT 84322
(435) 797-0776
utahpests.usu.edu/IPM

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CHAPTER 1 VEGETABLE PRODUCTION RECOMMENDATIONS

Varietal Selection

New varieties of vegetables are constantly being developed. Each vegetable crop (tomatoes, sweet corn, pumpkins, etc.) may have hundreds of named varieties, thus it is impossible to list and describe all of them. Therefore, it is important to regularly talk to knowledgeable individuals to learn about new varieties. The recommendations given in this production guide for each specific crop are based on limited testing. They have been selected to provide some reference and most are suitable for the primary production areas of the Intermountain West region. A particular variety may perform better than the prevailing standard variety under certain conditions.

Keep the following in mind if you are considering changing to a new variety:

1. Use seed catalogs or other sources to identify a variety that has similar production characteristics. These characteristics may include maturity times, growth habits, fruit size, cold/heat tolerance, or pest resistance. Visit SeedQuest for a listing of the major seed producers (www.seedquest.com/).
2. Grow the new variety on a small scale for 1 or 2 years. Compare the new variety to your farm's standard variety so you can see if the performance is the same or better under your conditions and management practices.
3. Evaluate the new variety's performance in the marketplace, noting customer comments.
4. Use this information to adopt or reject the new variety.

Ideally, your selected varieties should have good resistance or tolerance to many of the pathogens found on your farm. Keep in mind that varietal resistance to disease may break down due to different pathogen strains, when environmental conditions favor the organism, or when there is reduced natural plant resistance. If crop-threatening diseases occur on your farm, genetic resistance is an effective and low cost strategy to minimize disease outbreaks.

Vegetable variety types may be labeled as heirloom, open-pollinated, hybrid, genetically modified, or organic. Heirlooms are “old” varieties that have been selected and preserved from historic seed lines over many generations. There is some debate over how old a variety needs to be before it can be considered an heirloom. They are generally open-pollinated, but not all open-pollinated varieties are heirlooms.

Open-pollinated varieties are cross- or self-pollinated crops where plants are allowed to intercross freely with other plants in the field. Plants that are open-pollinated are more genetically diverse, but as long as no new pollen is introduced to the population, the resulting seeds (and plants) are relatively true to type (similar to the parent plants). Hybrid varieties come from crossing specific individuals where pollination is carefully controlled. The goal of hybridization is to isolate unique traits from plants through classical breeding techniques. Once these traits are isolated, specific crosses are made so that the traits are expressed within the offspring. To continually breed this hybrid, the specific parents are maintained so that the resulting crossed plants will always be the same. Hybrid seeds tend to be unstable and if you save seeds from them, the resulting plants are often different (not true to type) from the hybrid plants and may be less vigorous and productive.

Genetically modified (GM) varieties are developed when genetic material from different plants, animals, or organisms is inserted into the desired crop. These new GM varieties have new traits which do not occur naturally in the crop. These traits may include improved disease or insect tolerance, resistance to specific chemicals like herbicides, or tolerance to adverse environments.

Organic varieties can be heirlooms, open-pollinated, or hybrids, but they cannot be GM crops because to be organic, seeds must be harvested from plants that were grown following organic production practices.

Seed Storage and Handling

Proper storage and handling is important to seed viability. Large vegetable seeds like sweet corn, peas, and beans are susceptible to mechanical damage if

Table 1.1. General recommendations for growing transplants from seed.

Crop	Seeds/ft^2	Seeding Depth (inches)	Optimum Germination (F)	Germination Time (days)	Optimal Growth Temperature		Grow Time** (weeks)
					Day (F)	Night (F)	
Asparagus	36	¼-½	75	8-10	65-70	60	8-12
Broccoli	48	¼	85	4	65-70	60	5-7
Cabbage	48	¼	85	4	65-70	60	5-7
Other Brassicas	48	¼	80-85	4-6	65-70	60	6-8
Cantaloupe	36	½	90	3	75-80	65	3-4
Cucumber	36	½	90	3	70-75	65	3-4
Eggplant	36	¼	85	5-6	75-85	65	6-8
Endive	60	¼	70-75	3	65-70	60	4-6
Lettuce	60-80	¼	70-75	3	60-65	45	4-6
Onions	80-100	¼	75	4-6	65-70	60	8-12
Other Leafy Greens	60-80	¼	70-75	3-5	60-70	45-60	4-6
Peppers	36	¼	85	8	75-80	65	7-9
Summer Squash	36	½	90	3	70-75	65	3-4
Sweet Potato	- - -	¼	- - -	- - -	75-85	65	5-6
Tomato	36	¼	85	5-6	65-75	60	6-8
Watermelon	36	½	90	3	75-80	65	3-4

**Average number of weeks required to grow to transplantable size. Note: temperature, light levels, nutrients and other factors can influence grow times.

handled roughly. When loading or unloading these crops, do not throw or drop the bags since the seed coats and embryos can be damaged. Rough handling has been shown to significantly decrease germination or reduce vigor of germinated seedlings. Minimize seed damage when treating seeds of these crops with a fungicide, inoculum, or other chemicals.

High temperature and high relative humidity will reduce seed germination and vigor. Do not store seed in areas that have high temperatures (greater than 70°F) or where humidity values are greater than 60 percent. The ideal storage temperature for seeds is 35-40°F with a relative humidity of less than 40 percent. Most refrigerators hold a temperature of about 40°F but have high relative humidity. Seeds stored in a refrigerator should be kept in containers that have a good seal to keep the humidity levels low.

If you purchase primed seeds, use them during the present planting year, as primed seeds do not store well. If you plant pelleted seeds, large fluctuations in relative humidity can influence pellet integrity, which makes them difficult to plant. Pelleted seed stored for more than 2 years may have reduced germination percentage, so perform a germination test to assess viability before planting. Refer to Table 1.1 for seed germination and storage information.

Transplant Production Approaches

Growers use transplants to grow long-season crops in short-season areas, improve land use efficiency, save costs when growing expensive hybrid seeds, and get early production for early markets. Using transplants can improve water savings, manage early weed problems more efficiently, ensure more uniform production, and assure better stands.

High quality transplants are almost always grown in heated greenhouses where growing conditions are carefully managed. To grow quality transplants, it is important to optimize inputs like growing media, temperature, fertilization, water, and spacing needs. Table 1.1 provides seed spacing and temperatures for seed germination and plant growing, and the time required to grow the plant to transplantable size. Quality plants are grown by using the appropriate trays and soil media, controlling germination, temperature and nutrients, and properly conditioning the plants for the field.

Flats, Trays, and Pots

Use new flats and liners for transplant production to avoid pathogens that cause damping-off and other diseases. If old trays or liners are used, they should be thoroughly cleaned. Dip them in 10% chlorine bleach several times, then cover with plastic to keep them wet overnight. The bleach solution should remain below pH 6.8 to effectively kill disease pathogens (make a new bleach solution every 2 hours or whenever it becomes contaminated or diluted). Wash the trays with clean water to eliminate the chlorine, and let the flats dry prior to use. Wash exposed surfaces like benches, frames, and walls in the greenhouse to sterilize them as well. If plastic pots are reused, disinfest them as described above.

Seedling performance depends on cell size. Generally, transplants grown in larger cells (50's, 72's) produce earlier yields. Cell size does not affect total yield when growing seasons are long. If earliness is important, use larger cell sizes or bigger pots. While you may grow more plants per unit area of greenhouse in small cells (128's, 256's) and keep costs down, these trays may not be appropriate for some vegetables like melons. Transplant production cost depends on the number of plants grown per unit area and the length of time needed to grow the plant to plantable size.

Plant-Growing Mixes

There are many different pre-mixed growing media available and the best are lightweight, disease-free, and made from peat and vermiculite. Most commercial mixes produce quality transplants when used with good management practices. Commercial mixes can vary in composition, particle size, pH, aeration, nutrient content, and water-holding capacity. Most growers find a mix that works well for them and then continue to use it year after year. Avoid fine particle mixes which may hold excessive water and have poor

Table 1.2. Transplant mixes for pots, flats, or transplants trays.

Tipi Potting Mix Recipe (organic)	Organic Potting Mix
2 bales sphagnum peat moss (3.8 or 4.0 cubic foot bales) 1 bag coarse vermiculite (4.0 cubic foot bags) 1 bag coarse perlite (4.0 cubic foot bags) 6 quarts of a fertilizing mix comprised of: 15 parts steamed bone meal 10 parts kelp meal 10 parts blood meal 5 to 10 parts dolomitic limestone (80 to 90 mesh)	1 part sphagnum peat 1 part peat humus (short fiber) 1 part compost 1 part sharp sand (builder's) To every 80 quarts of this add: 1 cup greensand 1 cup colloidal phosphate 1½ to 2 cups crab meal or blood meal ½ cup lime
Standard Vegetable Transplant Mix	**Organic Soil Blocking Mix**
Equal parts by volume of: • Vermiculite • Peat moss • Perlite (use common liquid feeding program after seedlings emerge)	3 buckets (10-quart bucket) brown peat 1/2 cup lime (mix well) 2 buckets coarse sand or perlite 3 cups base fertilizer (mix equal parts blood meal, colloidal phosphate, and greensand together) 1 bucket good garden soil 2 buckets quality compost Mix all components thoroughly and moisten to point where blocks hold together.

aeration. If switching mixes, have them tested to determine the pH and nutrient levels in the media. Some growers blend their own media to reduce cost and to create a uniform, consistent composition. See Table 1.2 for some simple conventional and organic transplant growing mixes.

Seed Germination

Consult Table 1.1 for the optimum temperatures for seed germination. Since vegetables differ in their temperature needs, it is difficult to grow a wide variety of crops in limited greenhouse space due to the different environmental requirements of each.

Seeds that are planted to be "pricked out and repotted" at a later date should be germinated in 100% vermiculite (horticultural grade, coarse sand size) or a high quality commercial plant growing mix. Add fertilizer after the seed leaves (cotyledons) are fully expanded. Use a half-rate of a liquid formulation (Table 1.3). Seedlings can be held for 3 to 4 weeks if fertilization is withheld until 3 to 4 days before "pricking out."

Seed sown directly into trays or pots can be germinated in a mix containing fertilizer. For fast, uniform seedling emergence, germinate and grow seedlings on benches or in a floor-heated greenhouse at the recommended temperature. Research has shown that germinating the seedlings at higher than recommended temperatures for too long results in etiolated (elongated) hypocotyls (stem under the seed leaves). These seedlings tend to be weak and more prone to problems.

A germination chamber will better control heat when floor or bench heat is not available. Flats, trays or pots are seeded, watered, and then stacked in the chamber for germination. When using this method be sure to remove the trays from the chamber and un-stack them before the seedlings emerge.

Transplants are used to grow long season crops in short season areas, and get early production for early markets.

Greenhouse Management

Good greenhouses provide maximum light, have soil heating capabilities, and provide good heating and ventilation systems for effective environmental control. Proper growing temperatures ensure uniform growth throughout the greenhouse.

Properly maintained heating systems ensure energy savings and creates the environmental conditions required for germination and seedling growth. Invest in good heating and ventilation thermostats so that greenhouse temperatures are properly maintained. Heating or ventilation systems that don't work properly may cause yellowing, stunting, or death of the seedlings.

Transplant Nutrition

There are many different commercial fertilizer formulations available. Supplemental nutrients are needed to augment the fertilizers added to the media. Commercial fertilizers should be 100 percent water soluble and applied 1-2x per week to maintain steady growth. Use additional feeding to accelerate growth. Always rinse the leaves after liquid feeding. Higher amounts of fertilizer added to the irrigation water is not recommended since root "burn" may occur due to fertilizer concentration and salt buildup. When mixing starter solutions for field transplanting, follow recommendation printed on the fertilizer bag.

Table 1.3. Common liquid fertilizer formulations and recommended amounts.

Formulation	Rate
20-20-20	1-2 oz/5 gal water
15-15-15	2 oz/5 gal water
15-30-15	2 oz/5 gal water

Watering

Keep soil mix moist, but not wet. Water in the morning when possible. This allows the leaves to dry before night and reduces disease. Water less in cloudy weather. Water just enough to ensure some drainage as this helps reduce fertilizer salt buildup. Remember that plants grown in small cells may require several

watering each day while plants growing in large pots generally need less frequent irrigations.

Hardening / Conditioning

Special treatments, called hardening/conditioning, are used to slow seedling growth before transplanting. Hardening thickens the cuticle, increases leaf wax, and increases dry matter and carbohydrate levels in the seedlings. Ideally, hardened or conditioned seedlings can take the harsh conditions in the field (temperature extremes, water stress, wind, pests, etc.).

Generally, hardening treatments are imposed about 7 to 10 days before field planting, and include:

- reducing the amount of water provided to the plant
- lowering the growing temperatures
- limiting the amount of fertilizer

When hardening vine crops, tomatoes, peppers, or eggplants, do not lower temperature more than 5°F below the recommended minimum growing temperatures (see Table 1.1). Exposing warm season vegetables to low temperature (<45°F) can cause chilling injury, which delays growth after transplanting. Biennial vegetables (cabbage, onion, endive, chard or celery) should only be water-hardened, as cold treatments may induce vernalization and promote premature flowering. Do not over- or under-harden as plant re-growth may be slowed under field conditions.

Mulches and Row Covers

Mulch is any material (natural or artificial) that is used to cover the surface of the soil and modify the soil environment. Natural mulches include bark, wood chips, straw, manure, compost, or sawdust. Artificial or synthetic mulches include plastics, paper, or foils. Row covers are materials that cover plants and create an altered environment around them.

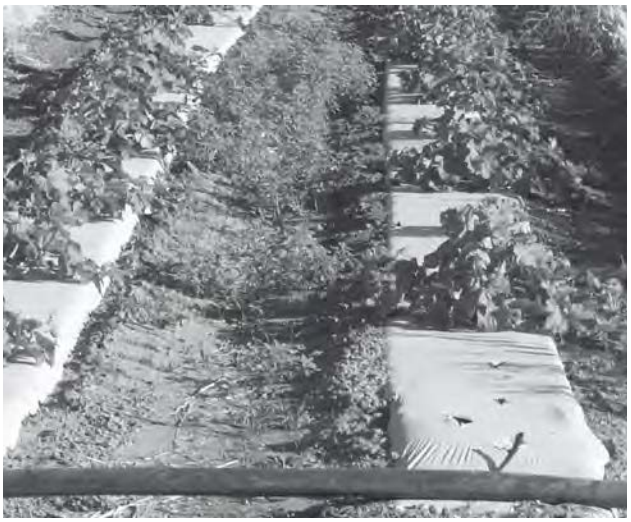
The advantage associated with mulches and row covers is to create conditions that improve the growth of the crop. Some of the more common benefits of mulches and row covers are significant temperature modification, more efficient water use, reduced fertilizer losses, improved weed and insect management, and reduced fruit losses due to rots.

Mulches

The most popular mulches used in agriculture are clear and black polyethylene (plastic) films. Clear plastic is used where higher soil temperatures are needed early in the season for crops like cucumbers, melons, and sweet corn. Soil temperatures are generally 10°F warmer under clear than black plastic and 15-20°F warmer than bare soil. This extra warmth usually results in high yields for early spring planted crops. One disadvantage associated with clear plastic is the need for good weed control under the mulch. Often, soil fumigation is used in conjunction with clear plastic to better manage weeds, diseases, and insects.

There are many different mulch colors and compositions available for use. Black is the most common color, but there are instances where green 'IRT' mulches are used where soil temperatures need to be warmer. Silver or aluminized mulches have been shown to repel certain insect pests (aphids, thrips). In cloudy areas, red mulches reflect more light back into the plants which increases productivity. In the heat of summer, white mulches reflect heat and soils stay cooler. Regardless of the mulch color, to obtain the soil temperature benefits, lay the mulch 3 to 6 days before planting. If you fumigate under clear mulch, allow 21 days for fumigants to dissipate before planting.

In a typical mulching operation, a 3 or 4-foot-wide mulch plus drip irrigation tape are laid at the same time. Mulches will work with furrow irrigation so long as furrows and plants are very close to the plastic edge so young plants can access the water.



Plastic mulches help regulate soil temperatures.

Other options are photodegradable and biodegradable plastic mulches. These usually cost more than regular plastic films but the difference may be offset by reduced disposal costs. Over time, sunlight causes photodegradable mulches to become brittle and break down. One disadvantage of the degradable mulches is that small pieces of film tear off and are blown around by the wind. In addition, they are weakened by soil microorganisms in high soil moisture and temperatures. One advantage is that they can be incorporated into the soil at the end of the growing season.

Plastic mulches are commonly only used once, then are removed from the field and disposed at the end of the growing season. On small farms it is often removed by hand while on larger operations, tractor mounted mulch removal equipment is available. High-quality plastic mulches can be used for two successive crops during the same season if you are careful. Crop foliage and weeds may increase the difficulty of mulch removal. When replanting through or removing the plastic mulch, eliminate as much vegetation as possible. Use glyphosate or paraquat to desiccate both weeds and residual crops or delay plant removal until after a hard frost kills the crop.

After the mulch has been removed from the field, dispose of used plastic in an environmentally appropriate manner. Regulations on disposal vary so contact your local solid waste authority for recommended methods of disposal. Some plastics can be recycled and specific programs for recycling agricultural plastics may be available. Consult with your state authorities to learn the specifics of plastics disposal.

Organic mulches (straw, sawdust, bark, etc.) reduce soil temperatures, improve soil moisture control, and help reduce soil erosion (wind or water). If the organic mulch is applied thickly (>2 inches), good weed control is reported. Organic mulches are often bulky, hard to apply, and may be difficult to source. There have been instances where insect (slugs, cutworms, etc.) and rodents damage occurs when using organic mulches. Organic wind breaks are commonly used to provide plant protection during establishment and can be used with plastic mulches.

Row Covers

Row covers are fabric or plastic materials which cover plants and hasten crop maturity, provide frost or hail protection, and also may exclude certain insect pests from gaining access to the crop. Floating row covers are made of lightweight spun fibers (polyester or polypropylene) that lay loosely on the plants or can be suspended over the plants with wire supports.

Floating row covers are used to cover low growing vine crops or to protect upright plants like tomatoes and peppers. Plants may be injured by abrasion when the floating row cover rubs on the plant in windy conditions. Frost damage can occur with floating row covers, particularly where the covers touch the leaves. Air temperature under the floating row cover is 3-5°F warmer at night, and more than 10°F higher during the day than the outside air temperature.

Clear and translucent plastic row covers (low tunnels) are another option to enhance early season plant growth. Plastic row covers are supported by wire hoops placed at 3 to 6 foot intervals in the row. Air temperatures under the low tunnels on warm sunny days can be 25-30°F warmer than outside, so plants may experience heat injury. Provided the temperatures under the low tunnels do not exceed 90°F, most warm season crops are not damaged. At higher temperatures, crops can be stressed, which inhibits growth, causes flower abortion or bolting.

Fabric and plastic row covers are often used in combination with plastic mulches. Most research shows that plants grown on plastic mulches under

Row covers accelerate plant growth and provide protection from frost, hail, and insect damage.

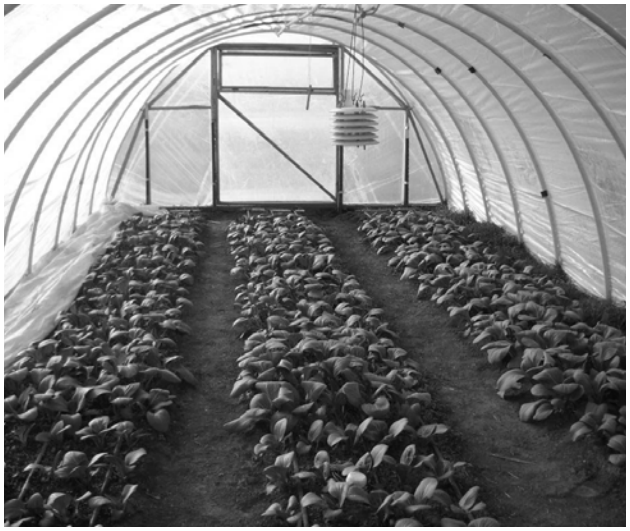
row covers mature earlier and yield more than those grown outside on bare ground. Several different companies make equipment that lay plastic mulch and row covers in one operation. Plastic mulches, fabric, and plastic row covers can be costly, and prices change rapidly because they are manufactured from petroleum. Consult your dealer for current prices.

High Tunnels

High tunnels are structures used to improve the growing conditions during early spring and late fall. They significantly increase earliness, total yield potential, and crop quality.

High tunnels come in a variety of widths (14-30 feet) and lengths (50-150 feet) and are tall enough so that a person can stand up in part of the structure. Some tunnels are tall enough to accommodate tractors and other equipment. High tunnels are not greenhouses since most are not heated and rely on manual ventilation for temperature control.

When considering growing in high tunnels, prior to construction, carefully select the site and location of the structure. Tunnels should be oriented with the ends toward the dominate wind direction. Space them so that they don't shade each other and with room for snow removal. Remove heavy, wet snow from the top of the tunnels. If left, melting snow will drip into the tunnel along the side walls. This cold water can slow plant growth and make it difficult to manage watering inside the tunnel. Finally, the distance between tunnels should allow for adequate (cross) ventilation.



High tunnels are used to improve growing conditions and extend the growing season during early spring and late fall.

The keys to successful production of vegetables in high tunnels are crop scheduling, ventilation, and moisture control. When planting in the spring, transplant cold sensitive crops (tomato, pepper, etc.) 3 to 4 weeks earlier compared to the earliest planting date in the field. If you use low tunnels or row covers inside the high tunnel, you can plant five to six weeks before planting outdoors. Invest in a good max/min thermometer and carefully track tunnel temperatures. If cold night temperatures are forecast, use floating row covers, low tunnels, thermal blankets and/or clean burning propane heaters to increase the air temperature. A modest investment in heat can save the crop and ensure early production. Cold damaged plants often do not recover, or if they do, are very late yielding.

High temperatures are managed by careful ventilation. Ventilation is accomplished by opening the doors or rolling up the sides of the tunnel. The goal of growing in high tunnels is to maintain optimum conditions inside without extreme temperature fluctuations. These conditions guarantee early, high yielding and high quality crops. As described with low tunnels, it only takes one high temperature even of sufficient duration to significantly reduce the crop's performance. It is important to regularly check and adjust conditions in the tunnel to optimize internal temperatures. Remove the plastic from the high tunnel when the weather gets warm, and replace it with 30% shade cloth. Shading has been shown to reduce air temperatures and significantly increase the quality of the crop.

For crops requiring pollination like cucumber or squash, fruit set may be problematic since bees are required to transfer pollen from one flower to another. Bees generally don't like to fly into or under tunnels. In this case, fruit set is good around the edges of the tunnels but very poor near the centers. Hives can be placed in the tunnels but maintaining the bees there is difficult.

High tunnel production minimizes many diseases by improved water management. With proper ventilation, humidity levels in the tunnel stay low, and since rain is excluded due to the plastic cover, disease incidence is minimal. Even in our dry climate, some diseases (powdery mildew, bacterial diseases, and

Bee hives are placed by crops to promote pollination of flowering plants.

root rots) can become problematic, particularly when temperatures outside are cool and tunnels are not adequately ventilated. Fungicides (conventional and/or organic) can be used to manage common tunnel diseases.

For irrigation, use plastic mulches and drip. Most vegetables vary in their seasonal and growth specific water requirements, and these details are included in the individual crop chapters.

Pollination

Managed bees, such as honeybees and bumblebees, and pollinating wild bees are critical for the success of most vegetable operations. Bees improve the yield and quality of many fruiting vegetables including eggplants, peppers, vine crops and strawberries.

Cucumbers, squash, pumpkins, and watermelons require pollination since the plants have separate male and female flowers. Pollen from the male flowers must be transferred to the female flowers to achieve fruit set. Without adequate pollen transfer, vine crops produce small or misshapen fruit. While bumblebees and wild bees are excellent pollinators, their populations may be too low to adequately pollinate large acreages of production. Therefore, colonies of European honeybees may be needed to assist pollination.

For most plants, pollination must take place on the day the flowers open. For many crops, pollen viability, stigmatic receptivity, and attractiveness to bees last only that day. Bee activity is determined by weather and conditions within the hive. Honeybee activity declines at temperatures below 55°F and at wind speed above 20 mph.

The number of colonies needed for adequate pollination varies with crop, flower density, length of bloom period, colony strength, and competitive flowers in the area. For most crops, provide one to two colonies per acre.

Insecticides applied during bloom are a threat to bees. If insecticides must be applied, select one that gives effective insect control but poses the least danger to bees. Also try to apply the sprays when bees are less active. When renting hives, get a written contract and have the contract specify the number and strength of the hives, the rental fee, time of delivery, and distribution of hives in the field.

Postharvest Handling

How you harvest and handle your produce directly affects freshness and flavor. For most vegetables, rapid cooling after harvest slows deterioration, and high humidity prevents moisture loss. Different vegetables respond differently to the cooling method used, storage conditions required, and the temperatures where injury may occur (see Table 1.4). There are several ways to assure that the vegetables grown

Tomatoes and other vegetables have specific criteria for optimal longevity for post-harvest storage.

Table 1.4. Cooling method and handling factors recommended to maintain quality and shelf life.

Crop	Recommend Cooling Methods				Crop Handling-Storage Factors			
	Air	Water	Icing	Vacuum	Temp. (F)	Relative Humidity (%)	Storage Life*	Chilling Injury**
Asparagus		+		+	32-36	95	1-2 w	L
Beans	+	+			40-45	90-95	7-10 d	M
Broccoli			+		32	90-95	1-2 w	I
Cabbage	+				32	90-95	1-3 m	I
Other Brassicas	+	+	+	+	32	90-95	2-5 w	I
Cantaloupe	+		+		36-40	85-90	4-14 d	M
Cucumber	+	+			50	90-95	1-2 w	H
Eggplant	+				50	90-95	1 w	H
Endive				+	32	90-95	2-3 w	I
Lettuce			+	+	32-36	95	1-2 w	I
Onions	+				32	65-70	1-6 m	I
Other Leafy Greens		+	+	+	32-36	95	1-2 w	I
Peppers	+			+	45-50	90-95	2-3 w	M
Potatoes	+				40-45	90	4-8 m	L
Root Crops	+				32-36	90-95	2-6 m	I
Summer Squash	+	+			50	90-95	4-7 d	H
Sweet Corn	+	+	+		32	90-95	5-7 d	I
Sweet Potato	+				55-60	85-90	3-5 m	VH
Tomato	+				55-65	85-90	4-14 d	M-H
Watermelon		+			45-50	95-90	3-4 w	M
Winter Squash	+				50-55	50-70	2-6 m	M

*Storage life are days (d), weeks (w), or months (m) under the best conditions.

**Chilling injury sensitivity: I-insensitive; L-low; M-moderate; H-high; VH-very high. Sensitivity varies with stage of maturity for some vegetables.

Information from USDA Handbook 66 (www.ba.ars.usda.gov/hb66/contents.html).

will maintain their freshness and quality, including cooling, harvesting and handling, washing, and storage conditions.

Cooling

After harvest, vegetable quality is maintained through cooling and by slowing down the rate of respiration. Field heat is the temperature of the vegetable at the time of harvest. The heat of respiration is the heat produced by the crop when sugars, fats, and proteins are broken down after harvest. The by-products of respiration are carbon dioxide, water, and heat. Initially, cooling removes field heat and holding the produce in a cool environment slows respiration. Slowing respiration slows post-harvest growth, delays senescence and/or ripening, and decreases tissue breakdown. Lower temperatures also slow the growth of microorganisms, and thus decrease decay. Vegetable quality is reduced more quickly in high respiration rates and heat production. Produce with high temperatures also have increased rates of evaporation and transpiration, resulting in rapid wilting and loss of quality.

There are several ways to effectively cool produce after harvest, and different crops have different recommended cooling methods (Table 1.4). Besides harvesting when it is cool, produce may be air-, hydro-ice-, or vacuum-cooled. Each method has different advantages and disadvantages.

The length of time required to cool produce depends on:

- cooling method (air-, hydro-, ice-, or vacuum-)
- temperature of the medium used
- initial and final desired temperatures of the produce
- type of crop (fruit, leaf, or root)
- containers used and their size

Specific recommendations for cooling times vary with individual vegetable types. To be successful, measure the initial product temperature at harvest, and monitor the temperature during and after cooling. Don't rely only on the air temperature in the cool room, but track fruit, leaf, or root temperatures. Remember that some leafy greens and many fruits are sensitive to chilling temperatures (between 35°F and 55°F). If possible, monitor temperatures during storage and also during delivery to determine if optimum temperatures are maintained.

Harvesting and Handling

1. Handle fresh produce with care. Avoid cuts, abrasions, and bruising damage to the tissue.
2. Harvest produce at the peak of quality.
3. Harvest during the cool part of the day (if possible). Produce is coolest in the early morning and lower temperatures reduce the rate of deterioration, extends quality, improves shelf-life, and reduces cooling costs.
4. If cold storage is not available, harvest only what you can pack or sell. Replenish roadside stands with freshly harvested produce throughout the day.
5. Spread the harvest season through successive plantings and a mix of varieties.
6. Shade harvest bins, trailers, trucks and market areas. Sort and pack in a shaded location.
7. At fresh market stands, display only quality vegetables. Sort and remove poor quality produce during the day. Shade the sales display from the sun.
8. Explain storage requirements to customers.
9. For vegetables that lose quality rapidly, ensure that washing, handling, and cooling are appropriate to maintain quality.

Washing

1. All fresh produce has some bacteria and fungi present on the surface. When washing, the temperature of the wash water should be warmer than the produce temperature to prevent decay organisms from being drawn into the tissue.
2. Be careful about using recycled wash water. Bacteria levels and dirt build up over time.
3. Add chlorine to the wash water to destroy decay-causing microorganisms on the surface of vegetables. Chlorine concentrations in the wash water depend on the vegetable; chlorination is most effective at pH around 6.5 to 7.5.
4. Monitor chlorinated wash tanks and spray washes with test kits to verify that the correct pH and concentration of available chlorine are present.

Other Factors

Many vegetables lose quality and show specific injury symptoms when exposed to ethylene after harvest. Ethylene damage includes: leaf spotting, green color loss, increased toughness or woodiness, bitterness, leaf yellowing and abscission, rapid softening, and development of off-flavors. While most know that ethylene increases ripening and softening of mature green tomatoes, it can also cause sprouting of potatoes. To avoid the detrimental effects of ethylene on vegetable quality:

1. Do not store or transport ethylene-sensitive crops with ethylene-producing fruits like apples, cantaloupe, bananas, and tomatoes.
2. Use electric forklifts in storage and transport areas. One by-product of internal combustion engines is ethylene in the exhaust fumes.
3. Vent storage areas to reduce ethylene or install ethylene absorbers.

For more information on maintaining produce quality during harvest and post-harvest, visit the Postharvest Technology Center for detailed information on how to reduce postharvest losses and improve the quality, safety, and marketability of fresh horticultural products: postharvest.ucdavis.edu.

Organic Production

To become certified as organic, growers must follow the production practices contained in the National Organic Standards (www.ams.usda.gov/AMSv1.0/NOPOrganicStandards) and be certified by a USDA accredited certifying agency. In Utah, the Utah Department of Agriculture and Food is the official certifying agent. There are other certifying agents listed in the National Organic Standard. Farmers may use any certification agency as long as they are USDA-accredited and authorized to certify operations to the USDA organic standard.

The cost to become certified is quite high since the farm must pay based on farm size, distance the certifying agent must travel, and the time spent conducting the evaluation. Some of the benefits to becoming "certified organic" include the potential for premium prices, better access to local, regional, or international markets, increased protection of natural resources, and access to additional assistance. The USDA carefully regulates the term "organic" and only certified farms can use the USDA organic seal. Not all growers or farms need to be certified to call themselves organic. Growers whose annual gross farm income from organic products is less than $5,000 are exempted from certification. However, even these very small farmers must use production practices that meet the requirements of the National Organic Standards.

To become "A Certified Organic Farm" typically requires a three-year transition period. During the transition, all farm practices must comply with the National Organic Standards. Organic production is a long-term plan. It may take several years for organically managed farms to reach their full productivity potential. Growers wanting to become certified organic must provide a detailed description of the operation, document what was applied to the land, describe the organic products grown, raised, or processed, and create a written Organic Plan describing the practices and substances to be used.

During the certification process, the grower adopts organic practices and submits his/her application and fees to the certifying agent. The certifying agent then reviews the applications to verify compliance with USDA organic regulations and conducts an on-site inspection. Once the certifier verifies compliance, an organic certificate is issued. Each year, the farm must go through the re-certification process. Growers must provide annual updates to the certifying agent, schedule an on-site inspection of the farm, and pay the appropriate fees. From this information, the certifying agent determines if the applicant still complies with the USDA organic regulations and if the organic certificate should be re-issued.

CHAPTER 2 SOIL, NUTRIENT, & WATER MANAGEMENT

SOIL

The best soils for growing vegetables are well-drained, deep, fertile soils, with adequate levels of organic matter. Soil textures like sandy loam or loamy sand are suitable for early market crops since they are accessible to machinery and workers even when wet. Loam and silt loam soils are better suited for growing crops for later fresh-market use. Regardless of the soil type, develop a best management practices (BMP) plan for the farm, which includes a good soil management program, proper fertilization, good tillage practices, suitable crop rotations, strategies to increase organic matter, and managed irrigation. Consider integrating cover crops between vegetable plantings to maintain or improve soil structure and retain topsoil.

Many factors influence the nutrient requirements of a given vegetable. Soil textural classification, cation exchange capacity, organic matter content, and drainage are important properties that influence the nutrient needs of vegetables. Rainfall, irrigation methods and management, and environmental conditions during the growing season can alter the retention, availability, and uptake of nutrients.

Soil Tests

One way to determine the soil type and fertilizer need is to have your soil tested. Soil sample kits and instructions are available in every county Extension office. The local Extension Educator can help with sampling approaches, testing needs, and provide you with the costs of the various soil testing services performed by the USU Analytical Laboratory. Knowledge of the current soil fertility can reduce fertilizer application rates and better match soil fertility level, past cropping history, and soil management practices to the crops grown. To minimize potential soil damage and water pollution, nutrient recommendations are based on the soil test results and past cropping and fertilization practices. For more information on soil testing and interpreting results, visit the Utah State University Analytical Laboratories website (www.usual.usu.edu).

Soil Test Interpretation

A soil test evaluates the nutrient-supplying capabilities of a soil. A common misunderstanding is that the test provides you the total amount of nutrients that are available for plant growth. The soil test only provides a prediction of how much fertilizer is required for optimum plant growth. If fertility levels are below optimum, addition of the nutrient should enhance or increase plant growth and productivity (provided something else is not limited). If the soil test indicates that a nutrient is at adequate or excessive levels, no applications are needed.

The basic soil test determines the soil texture (sand-silt-clay), soil pH, salinity, and phosphorus (P) and potassium (K) levels. A "complete" analysis also tests for nitrates, micronutrients, sulfate, and organic matter. Soil test recommendations are commonly expressed in units of pounds of the particular nutrient per acre (Table 2.1). Reading and understanding the soil test depends on knowing what method was used in the test laboratory and what units are used to express the soil nutrient levels. If the soil test report does not state the method used, call the laboratory to find out. This information is needed before interpreting the soil test results.

Table 2.1. Soil test categories for nutrients.

Test Category	Soil Test Value (mg/Kg)	
	Phosphorus (P)	Potassium (K)
Very Low	0-10	0-70
Low	11-20	70-125
Adequate	21-30	126-300
High	31-60	300+
Very High	60+	-

Nutrient Recommendations

Always base nutrition applications on a current soil test. When soil test results are not available, use recommended amounts of P_2O_5 and K_2O listed under adequate phosphorus and potassium soil test levels for the crop to be grown. This is not as accurate, but is a conservative approach that minimizes the chance of over-application. Refer to Table 2.1 to interpret the

relative levels of phosphorus and potassium in the soil based on the soil test report from the laboratory. When a current soil test is available, use the crop specific recommendations or consult your local county Extension Educator.

Use the fertilizer recommendation from the soil test to determine the rate of fertilizer needed to fulfill these requirements.

EXAMPLE:

If the soil test recommends a 100 pounds of nitrogen (N), 100 pounds of phosphate (P_2O_5), and 100 pounds of potash (K_2O) per acre, you would need a fertilizer with a 1:1:1 ratio, such as a 16-16-16. To determine the quantity of fertilizer to apply:

1. Divide the percentage of N, P_2O_5, or K_2O in the fertilizer into the quantity of nutrient needed per acre.
2. Multiply that value by 100.
3. Total fertilizer required to provide 100 pounds of N per acre would be 625 pounds of the 16-16-16 (100/16=6.25 x 100 = 625).

Nutrient Management

Plants remove nutrients from the soil and air to enable them to grow and reproduce. Some nutrients are needed in larger quantities and are termed macronutrients. Those needed in smaller quantities, the secondary and micronutrients, are just as important for achieving healthy plant growth. Most commercial fertilizers provide macronutrients: nitrogen (N), phosphorus (P), and potassium (K). Secondary and micronutrients may be supplied along with macronutrients or are manufactured in special formulations for plant use.

Nitrogen

Nitrogen is essential for plant growth and photosynthesis. Without N, plants could not produce amino acids which are needed to form proteins, resulting in stunted growth.

Nitrogen (N) is difficult to manage in crop production systems because N is easily leached from soils or can be immobilized by soil microbes, volatilize back to the air, or lost via denitrification in water-saturated soils. Symptoms of N deficiency include slow, stunted growth, pale yellow-green coloration, and premature dying of older leaves (due to N mobility in plants). Nitrogen is not routinely tested by soil testing laboratories for making crop recommendations because of these losses. Instead, N recommendations are based on your experience and the crop's yield potential.

While soil tests provide some information about plant N needs, tissue testing is the better option for deciding if and how much more N is required to meet yield goals. Most private testing laboratories can provide plant tissue N levels quickly to aid in nitrogen application decisions. Labs can test N from leaves, whole petioles, and petiole sap. Consult the testing laboratory for detailed collection instructions.

Phosphorus

Phosphorus (P) is needed by plants for nucleic acids (DNA/RNA) and in energy storage and transfer (ATP). Root formation, early plant growth, crop maturity, and seed production are all stimulated by P. Symptoms of P deficiency include stunted growth, purple coloration to leaves, delayed maturity and poor fruit or seed development.

Crops respond to P when soil tests indicate that levels are very low or low. When tests indicate adequate or high P, crops may respond to P fertilization if the fertilizer is placed near the plant or when soils are cold. Phosphorus may be banded near the seed as a starter fertilizer regardless of soil P levels. Soils that have received regular manure applications often have very high P levels, so knowing the past history of a field is very important in making fertilizer recommendations. Phosphorus is strongly adsorbed to soil particles and very little is lost via leaching.

Potassium

Potassium (K) is essential for the translocation of sugars and starch formation. It is important for plant water use regulation. Potassium encourages root growth, increases disease resistance, improves fruit quality, and boosts winter hardiness. Symptoms of K deficiency include browning on the leaf margins, weak stalks or stems, small fruits and slow growth.

Crops respond to K when soil tests indicates that levels are very low or low. Where levels are adequate or high, crops may respond to K when drought stressed. Most often, K fertilizer should be broadcast rather than

banded or side-dressed unless K levels are low. Most vegetables require larger amounts of K than P during a growing season. Some very coarse sandy soils have low K reserves and may require frequent applications to maintain K at an optimum levels.

Secondary and Micronutrient Management

Calcium (Ca), magnesium (Mg), and sulfur (S) are often called the secondary elements. Calcium levels in Utah soils are quite high but may not be readily available to plants. Calcium is a component of plant cell walls and membranes and does not move around in the plant. Calcium is transported around the plant with water so when crops are drought stressed, young tissue may not receive enough Ca. Symptoms of Ca deficiency include "tip burn" of young leaves in lettuce or cabbage, blossom end rot of tomato, pepper or melons, terminal bud death, premature blossom drop in bean or tomato, or very dark foliage.

Soil Mg levels can be quite high but can still be deficient in vegetable soils. Magnesium is part of the chlorophyll molecule and is needed in photosynthesis. It is very mobile in the plant so deficiency shows up in older leaves. Symptoms of Mg deficiency include:

- interveinal chlorosis of older leaves
- leaf curling
- leaf margin yellowing

Sulfur is an important nutrient for plants. It is an essential component in several amino acids and thus needed for protein synthesis. Symptoms of S deficiency are:

- yellowish colored leaves
- small spindly plants
- slow growth

Sulfur deficiencies can occur when irrigation water is very pure or when high-analysis low-S fertilizers are used regularly. Onions and plants in the cabbage family (cole crops) have high S requirements.

The micronutrients include boron, chlorine, copper, iron, manganese, molybdenum, and zinc. Boron (B) is needed for meristem growth and acts as a binding agent between cell walls. Deficiencies are most common in the young growing points as B is not mobile around the plant. Boron may be deficient in intensively managed vegetable crop soils. Deficiencies are likely to occur in bulb and root crops, cole crops, and tomatoes. Over application of B can be toxic to plant growth, so DO NOT exceed recommendations levels.

Chlorine (Cl) deficiencies are quite rare. Chlorine is required for photosynthetic reaction in plants and deficiency symptoms are:

- wilting
- excessive root branching
- leaf bronzing

Copper (Cu) deficiencies are also rarely observed in Utah. Copper is needed for enzyme activation and plays a role in vitamin A production. Plants deficient in Cu are:

- stunted
- have chlorotic shoot tips
- pale green in color

Iron (Fe) deficiency is a common problem particularly when plants are over-irrigated. Iron is required for chlorophyll formation, photosynthesis and nitrogen fixation. Soils with very high pH or aeration problems often are Fe deficient. Symptoms of Fe deficiency are:

- interveinal chlorosis
- terminal tip dieback
- general leaf discoloration

Manganese (Mn) deficiencies are not that common. Manganese is needed for enzyme activity and works with Fe in chlorophyll formation. Excess Mn may induce Fe deficiency with similar deficiency symptoms.

Molybdenum (Mo) deficiency are quite rare. Plants need Mo to transform nitrate-N into amino acids and N-fixing bacteria cannot use atmospheric N unless it is present. Deficiency symptoms are:

- stunted growth
- cupping of leaves
- yellowing of leaves

Zinc (Zn) is occasionally deficient in Utah soils. Zinc helps regulate enzymes and other growth regulating processes. When plants are Zn deficient they may have:

- a rosette growth form
- fewer flower buds
- mottled leaves

If you suspect a deficiency, it is important to have the affected plants tested.

Foliar Fertilization

Plants commonly obtain nutrients from the soil through their roots. Plants can also absorb a limited amount of some nutrients through leaves. If the soil has been properly managed, soils can supply all the nutrients a crop needs to grow and produce high yields. If a nutrient becomes deficient or unavailable during the development of the crop, foliar nutrient applications may then be beneficial. Foliar feeding is not recommended for the macro-nutrients but is commonly used to correct micro-nutrient deficiencies. Nutrient concentration, application methods, and plant type all influence the effectiveness of foliar feeding. Consult your county Extension Educator for more information on nutrient applications to plants.

Organic Nutrient Sources

For farms with a focus on organic production, nutrient management is critical to maintain high levels of productivity. Depleted soils need to be regenerated and rebuilt so they can sustain crop yield and improve the foundation of the farm. In organic systems, nutrient levels need to be maintained or replaced through nutrient cycling, nutrient uplifting from deeper in the soil, or through the addition of nutrient from outside sources.

One of the keys to success will be creating a program that maintains and increases soil organic matter. Organic matter (OM) is the living component of the soil. It consists of plant and animal residues in various stages of decomposition and is an important storage site for nutrients. By increasing soil OM, you will also

Table 2.2. Cover crops or green manures for vegetable farms.

Crop	Seeding Rate (pounds)	Seeding Dates*	Tolerance to:		
			Cold	Heat	Drought
Non-legumes					
Barley	75-100	Sept. 1 - Oct. 31	G	M	M
Brassica (mustard/rape/kale)	20-40	Aug. 15 - Oct. 31	G-E	P	M
Buckwheat	50-75	May 1 – July 31	P	M	M
Millet (various)	25-40	May 1 – July 31	P	G	P
Rye	75-100	Sept. 1 - Oct. 31	E	M	M
Sudangrass	30-60	May 1 – July 31	P	E	G
Oats	75-100	Sept. 1 - Oct. 1	M	P	P
Wheat	75-100	Sept. 1 - Oct. 31	E	P	M
Crop	**Seeding Rate (pounds)**	**Seeding Dates***	**Tolerance to:**		
			Cold	**Heat**	**Drought**
Legumes					
Alfalfa	20-30	Mar. 1 – Apr. 30	G	G	G
Beans (various)	60-90	May 1 – July 31	P	M	M
Clovers (various)	15-30	Mar. 1 – Apr. 30	G	M	M
Cowpea	60-90	May 1 – July 31	P	G-E	G
Field Pea	75-100	Mar. 1 – Apr. 30	G	P	M
Soybean	75-100	May 1 – July 31	P	G	G
Vetch (various)	50-75	Sept. 1 - Oct. 31	M-G	P	M

* Seeding dates depend on location. Plant later in spring and earlier in fall in colder areas. Plant earlier in spring and later in fall in warmer areas. Dates are suggested ranges only.

P=poor; M=moderate; G=good; E=excellent

Table 2.3. Approximate nutrient values for selected manures, animal products, composts and crop residues. There are many other sources of organic based nutrients. Always check the nutrient analysis to help determine application rates.

Nutrient Source	Total N	P_2O_5	K_2O
Manures	lbs/ton wet weight		
Cattle	18-22	14-18	22-26
Dairy	8-12	4-6	8-12
Horse	14	4	14
Pig	8-10	6-10	6-9
Poultry	35-55	40-50	30-35
Sheep	14-18	8-12	22-26
Compost – Manure Based	1.5-2.0	2	1
Compost – Plant Based	0.5-1.0	1	1
Animal Products	percent (%)		
Dried Blood	12	1	0.5
Bone Meal	3	15	0
Feather Meal	13	0	0
Fish Emulsion	4	2	0
Fish Meal	10	7	0
Crop Residues	lbs/ton (dry weight)		
Alfalfa hay	45-50	11	45-50
Buckwheat	10-15	1-5	45-50
Clovers	50-60	10-20	40-60
Sorghum/Sudan grass	20-30	5-10	10-30
Straws (barley/oat/wheat)	10-15	3-6	20-30
Sweet Corn Stover	30	8	25
Vetches (common/hairy)	40-60	15	45-55

increase soil water storage, decrease runoff, erosion, and leaching as well as improve soil structure and porosity. In the western US, soils are low in OM. Soil OM breaks down quickly, particularly when there is intensive cultivation and frequent irrigation. Cover crops and green manures are good ways to recycle or lift nutrients already existing in the soil. Composts and manures can add new nutrients into the soil. While changing soil OM levels is a slow process, through the careful use of a variety of cover crops, manures (green or animal) and compost, organically managed farms can be highly productive and sustainable.

Cover Crops and Green Manures

Cover crops (CC) and green manures are commonly seeded after harvest, grown over a specific period of time and then incorporated into the soil. The winter-grown cover crops include wheat, barley, oats, rye, some brassicas and various legumes like alfalfa, vetches, clovers, or peas. Summer cover crops include warm-weather grasses like sudangrass, sorghum or millets, broadleaf plants like buckwheat and mustards, and legumes like beans or cowpea. Seeding rates for these crops vary, as do appropriate planting times (Table 2.2).

Most CC are grown for several months before they are clipped or mowed, and then disked back into the soil. With all CC, care should be taken that they do not set seeds as this can lead to the cover crop becoming a weed problem. Sometimes the CC are strip tilled as the strips provide wind protection during the early part of the growing season. With proper management, CC can reduce nutrient loss during the winter and early spring. With all CC, they should be incorporated when the foliage is still green so they decompose rapidly and return the greatest amounts of nutrients to the soil.

Most soils that are not productive due to poor physical properties can be restored and made to produce good crops through the use of a good cover crop rotation program. Also, if soil moisture is a limiting factor, growing CC can seriously deplete soil moisture levels in the spring or summer. Use of CC and GM should be location specific as each has different tolerances to cold, heat, or drought (Table 2.2).

For more information on cover crops and green manures, refer to *Managing Cover Crops Profitably,* one of the many publications available at the Learning Center of the Western Sustainable Agriculture Research and Education (http://www.westernsare.org/Learning-Center) program.

Compost and Manure

Application and incorporation of compost or manure to soils will increase soil organic matter and certain soil nutrient levels. Both compost and manures are widely used in crop production but differ in how they are used (Table 2.3).

Composting is when plant tissue or animal waste is broken down into organic matter through heat and microbial action. Composting reduces bulk, stabilizes soluble nutrients, and hastens the formation of humus. Most organic materials (manures, crop residues, leaves, sawdust, etc.) can be composted. Finished composts provide relatively low amounts of readily available nutrients. They vary in their nutrient content depending on the original source of material. Even though most composts don't supply large amounts of nutrients, they help improve soil fertility by increasing OM and by slowly releasing nutrients. Compost should be tested for nutrient content and for organic certification purposes.

Manure can supply the nutrients required by crops and replenish nutrients removed from soil during harvest. Since manure contains multiple nutrients, applications should consider not only what is needed for the crop, but also how the ratio of nutrients in manure could affect soil test levels. This ensures adequate nutrient supply and reduces potential for over- or under-application and subsequent buildup or depletion of selected nutrients in the soil. Good manure nutrient management should consider short- and long-term impacts on crop nutrient supply and soil resources.

Manure has characteristics that make nutrient management different and sometimes more complicated than using fertilizer including;

- a mix of organic and inorganic nutrient forms
- variation in nutrient concentration and forms
- variation in dry matter and resultant handling as a liquid or solid
- relatively low nutrient concentration requiring large application volumes. Sampling and laboratory analysis are always needed since manure nutrient composition can vary significantly.
- timing of manure application
- if applied far in advance of the crop, manure can be quite useful. When applied closer to when the crop is planted or at very high rates, damage may occur
- regulations associated with organic certification need to be followed

For more information on how to improve soil, refer to *Building Soils for Better Crops: Sustainable Soil Management,* one of the many publications available at the Learning Center of the Western Sustainable Agriculture Research and Education Program (www.westernsare.org/Learning-Center).

Irrigation

Soil water management is critical for the production of high quality vegetables. Even short periods of moisture stress can affect a crop's performance. Irrigation is essential in the Intermountain West due to high temperatures and high rates of evapotranspiration. Moisture deficiencies can occur early in the crop production cycle before local irrigation is available, which may delay or reduce emergence or slow early growth. Shortages later in the season often decrease fruit set, size, or quality. Over-irrigating is as detrimental to the crop as water shortage. Too much water can delay harvest, reduce quality, and shorten postharvest life. Table 2.4 lists the critical periods when water is critical for high quality vegetable production.

A crop's water requirement, termed evapotranspiration (ET), is equal to the quantity of water evaporated (E) from the soil surface and the quantity lost from the plant (transpiration=T). Many

Table 2.4. Effective root depth of selected vegetables. Effective root depth is where the bulk of the root system is located. Some roots do go deeper.

Shallow (6-12 inches)	Moderate (18-24 inches)	Deep (30+ inches)
Radish	Cabbage	Asparagus
Broccoli/Kale/Kohlrabi	Cantaloupe/Cucumber/Summer Squash	Pumpkin/Squash
Salad Crops (Lettuce/Spinach/Chard)	Beet/Carrot/Turnip	Watermelon
Garlic/Onion	Eggplant/Potato/Tomato	
Pepper	Bean/Pea	
	Sweet Corn	

Note: Direct seed crops tend to root deeper than transplanted crops.

factors must be considered when estimating ET. Most weather services provide an estimate of ET based on solar radiation, air temperature, wind speed, and humidity level. Therefore, using ET can improve irrigation management, and taking time to better understand crop water needs can greatly improve yield and quality.

There are many things that affect irrigation requirements. These include crop species and variety, canopy size, plant population, rooting depth, and stage of growth. These all influence transpiration, light absorption, and the rate that water evaporates from the soil. Mature plants use more water than crops which do not have a complete canopy (immature plants, recently transplanted crops). Rooting depths vary with crop species and determines the volume of soil from which the crop can draw water (Table 2.4).

Plant growth stage influences susceptibility to moisture stress (Table 2.5). Irrigation is beneficial for newly seeded or transplanted crops as their root systems are not well established. Irrigation after transplanting significantly increases plant survival, especially when soils are dry and ET is high. Irrigation can also increase seed emergence and uniformity and final plant stand. For seeded crops, crusting can be an issue so the water application rate and volume needs to be carefully regulated. If crusting is common, apply low rates and volumes of irrigation to soften the crust until seedlings emerge.

Cultural practices also influence ET and irrigation requirements. Cultivation, mulching, weed growth, and method of irrigation are factors to consider. Cultivation generally increases soil evaporation. Shallow cultivation helps eliminate soil crusts and may improve water infiltration, but if crop roots are damaged by the cultivator, water uptake may be reduced. Plastic or organic mulches generally reduce water use because they reduce evaporation. Weeds compete with the crop for water. Sprinkler irrigation systems which wet the whole field have greater evaporation loss than drip systems that wet only the area around the plant.

Table 2.5. Critical periods during vegetable plant growth when adequate water is required for a healthy crop.

Crop	Critical Period-Growth Stage
Allium Crops (Garlic/Leeks/Onion)	Bulb sizing
Asparagus	Summer fern growth
Brassica Crops (Broccoli/Cabbage/etc.)	Head formation or sizing
Cucurbits (Cucumber/Melons/Squash/etc.)	Flowering, fruit sizing, and ripening
Legumes (Beans/Peas)	Flowering, fruit set, pod sizing or filling
Potato	Tuber set and enlargement
Root Crops (Beets/Carrots/Radish/Turnips)	Root elongation and enlargement
Salad Crops (Chard/Lettuce/Spinach/etc.)	Leaf enlargement or heading
Solanaceae Vegetables (Eggplant/Pepper/Tomato)	Early flowering, fruit set, and sizing
Sweet Corn	Silking/Tasseling, ear development

Note: Water availability is critical for stand establishment for direct seeded or transplanted crops.

Table 2.6. Water-holding capacity and infiltration rates based on soil texture.

Soil Texture	Water Holding Capacity (inch/foot of soil)	Infiltration Rate (inch/hour)
Sand	0.25-0.75	2.0
Loamy Sand	0.75-1.40	1.8
Sandy Loam	1.30-1.80	1.5
Loam	1.70-2.20	1.0
Clay/Silt Loam	1.60-2.50	0.5
Clay	1.50-2.20	0.2

Soil type and texture has a big influence on water-holding capacity (Table 2.6). Soils with more silt, clay, and organic matter hold more water than sandy or compacted soils. It is the amount of available water (amount of water a plant is able to withdraw from the soil) that is most important. Soils with high available water-holding capacity require less frequent irrigation than soils with low available water-holding capacity. When applying irrigation, consider the soil infiltration rate. Water should not be applied at a rate greater than the rate at which soils can absorb water. If the rate applied is excessive, erosion and runoff can occur.

To accurately schedule irrigations, you need to consider all the above factors. While published ET values are helpful, keep in mind the following points when deciding when and how much to irrigate.

1. Soils vary greatly in water-holding capacity and infiltration rate. Know your soil type and learn how rapidly water infiltrates to minimize runoff.
2. Water loss from soils (Evaporation) and plants (Transpiration) is greater on clear, hot, windy days than on cool, overcast, humid days. When the weather is hot and dry, ET rates may reach 0.35 inch/day or more.
3. Plastic mulches reduce evaporation from the soil but most rainwater flows off and away from the crop. Organic mulches like straw will absorb rain and sprinkler irrigation water.
4. Most plants do better if soil moisture levels stay just below field capacity (75 to 90 percent soil moisture). Small frequent irrigations are better than letting the soil moisture get too dry (40 to 50 percent soil moisture) and then applying a heavy irrigation.
5. Assess the rooting depth of the crop and then apply water to recharge the area to field capacity. This will ensure that water reaches active areas of the root zone.
6. If irrigation water or soil has a high salt content, apply enough water to keep salts from accumulating in the soil.

Surface or Sprinkler Irrigation

Surface irrigation includes flood, furrow, border, and basin. Irrigation this way requires more labor and may not be as efficient as other methods. Design of the system depends on soil type (texture and intake rate), slope, stream size, and length of run. Keep in mind that the distribution of water in coarse textured soils (gravel and sands) will be less uniform than on fine textured soils (loamy to clay). Because surface irrigation requires some runoff or ponding to guarantee adequate infiltration at the lower end of the field, it is not very efficient.

Surface irrigation is the most common method of irrigating agricultural land. For most vegetable production systems, crops are planted on beds and the area between the beds are furrowed out to create channels for the water to move through the field.

Advantages of surface irrigation are:

- limited energy required as water flows via gravity
- relatively low cost to construct
- fairly simple system to operate and manage
- less affected by climate or water quality

Some disadvantages to surface irrigation systems are:

- soil spatial variability affects infiltration and application uniformity
- fields need to be properly graded to aid water movement
- system is more variable
- machinery access and use may be limited for some time
- more difficult to automate
- promotes soil erosion
- lower efficiency due to evaporation

Sprinkler irrigation is any of numerous devices that spray water over the soil surface. They include hand move, wheel move, center pivot, solid set, drag lines, and water cannons. Sprinklers can be a good investment when properly designed, installed, operated, maintained, and managed. Water from a sprinkler head is discharged into the air where it will

fall like rain onto the soil. Water application rates need to match soil infiltration rates so there is little surface ponding and/or run off. The spray patterns from each head must properly overlap and the pressure should not be so great as to create very small droplet size. If improperly designed, evaporation losses, wind drift, and surface crusting become the main causes of water loss. Sprinkler irrigation is a good choice for fields that have varied soils and topography.

Generally with sprinkler systems it is easier to get high uniformity of water distribution in the field. Sprinkler systems can be adapted to all soil types since sprinklers are available with a variety of discharge capacities.

Some of the advantages to sprinkler irrigation are:

- suitable for most soil types
- works well on a wide range of topography
- adaptable to specific needs
- can add fertilizers or pesticides
- useful for crop establishment, frost protection or stress relief in hot weather

Some disadvantages to sprinkler irrigation systems are:

- large investment in equipment
- high energy and labor expenses
- distribution uniformity sensitive to wind
- machinery access and use may be limited for some time
- crops are more prone to disease and weed pressure may increase
- plugging potential increases when low water quality used

Drip/Trickle Irrigation

Drip (also called trickle) irrigation is a method of applying small amounts of water directly to a plant's root zone. Water is often applied frequently (daily or several times per day) to maintain optimal soil moisture conditions. The advantages of drip systems are:

- less water is used
- pesticides, fertilizers, and other materials can be applied uniformly
- can be used on a wide range of crops
- especially effective when used with plastic mulches
- uses significantly less water
- can be automated
- disease and insect damage may be reduced because leaves remain dry
- less weed growth between rows because these areas remain dry
- field operations (spraying, etc.) can continue even during irrigation

Drip systems do have some potential limitations including:

- require a higher level of management
- moisture distribution in the soil is limited
- smaller soil water reserves are available to plants
- equipment can be damaged by insects, rodents, and laborers
- requires a higher initial investment cost
- must have a constant water supply as irrigation may be needed on a daily basis
- sophisticated filtration equipment is needed to clean dirty water sources
- offer little in the way of frost protection.

To use a drip irrigation system effectively, you need to design the system for the specific crop of interest, maintain a constant pressure throughout the system, and manage the system in accordance with crop growth stages and water needs. Since soils vary greatly in their water-holding capacity and infiltration rates, drip system designs need to take this into account. Also, as plants grow, their water needs increase, so the drip system has to have the capacity to meet this increasing water demand. Pressure maintenance is important so that the whole field gets the same amount of water. Growers using drip systems need to be vigilant. If there are leaks, clogged lines or damaged tape, this will affect water distribution and may negatively impact the crop.

Finally, irrigation scheduling is needed to determine how often to irrigate (duration) and how much water to apply. Soil moisture monitoring tools are needed to determine irrigation frequency. These tools include soil moisture blocks, tensiometers, and other sensors that measure water available in the crop root zone. These are commonly placed at various soil depths throughout the field to determine whether or not the irrigation has reached a certain depth and to help determine the depth from which plants draw the most water.

CHAPTER 3 VEGETABLE IPM PRACTICES

Integrated pest management (IPM) combines a host of practices that keep vegetable crops healthy while minimally impacting human health, the environment, or profits. IPM requires a knowledge of the crops and associated pests so that general farm practices may be tailored to minimize them, and that control intervention, when necessary, will integrate the most appropriate methods.

Growers successfully using IPM combine the following factors:

1. Knowledge of host plants and their associated weeds, pests, and beneficial organisms (including identification, biology, and life cycle).
2. Conduct day-to-day practices to minimize pest problems (such as crop rotation, resistant varieties, composting soil, promotion of beneficial predators, and sanitation).
3. Monitor for pests, symptoms, and beneficial organisms.
4. Chemical use only when pest thresholds are reached .
5. Integrate non-chemical control tactics (mechanical, cultural, biological controls).
6. Keep records of monitoring results, treatments applied, and treatment results.

Pest Monitoring Techniques and Supplies

Monitoring for insects and diseases and for plant injury is essential for effective pest management. Knowing which pests are active and when will allow for precise pesticide treatments when needed. Regular monitoring provides information on:

- early warning of potential pest problems
- which life stage is active
- presence or absence of natural enemies
- when to implement control measures
- whether pest control activities are working

Ideally, vegetable crops should be monitored for pests or for unusual symptoms once per week. Scouting should occur on the same day each week and may take 30 minutes to 2 hours, depending on the farm size, to do a thorough job.

How to Monitor

Visual Inspections

Visual inspections may be conducted by examining the plant with a hand lens (at least 20x in magnification), using a sweep net, or by using a "beat cloth" for taller plants. A sweep net is helpful to count insects that are mobile, such as stink bugs or leafhoppers. A beat cloth is a white or light-colored cloth attached to dowels or fitted into a frame, and is placed underneath a vigorously shaken plant to catch insects. Sweep nets and beat cloths will allow you to quickly cover more ground.

For each plant to be inspected, examine all plant parts (leaves, stems, and vegetables). Look for plant injury as well as signs of insects or disease, and record the following:

- Symptoms such as chewed areas, spots or discolorations, wilting, cavities/sunken areas, rot, or reduced growth.
- The number of pest insects per plant, or percentage of plant affected by insect feeding or disease.

Using a hand lens greatly helps in identifying insects. Aphids, for example, look very similar to leafhopper nymphs, and are difficult to tell apart with the naked eye.

- The number of beneficial insects you may encounter.
- Soil moisture conditions (wet or dry) and competition with weeds.

Monitoring with Traps

Insects communicate using chemical substances they produce called pheromones. Pheromones of some vegetable pests have been synthesized and are available to purchase as a "lure" for use in monitoring traps. Pheromone traps are primarily used for moth species including corn earworm, cutworms, armyworms, diamondback moth, cabbage looper, and others.

- "Delta" traps include a triangular, plastic housing with a removable sticky liner. The specific moth's pheromone is imbedded in a separately packaged rubber septum that is placed on the center of the sticky liner.
- "Heliothis" traps are used for corn earworm, and include a fabric and mesh cylinder inside which the lure is hung.
- Traps are hung on small posts above the crop in spring, and spaced at least 20 yards apart.
- Check traps every week and record the counts. The pheromone traps will provide an indication of the timing of adult activity and abundance of the species.

Orange delta traps are easy to use. Label the trap with the insect name and re-use for several years.

Essentials of Pheromone Lures and Traps

Traps are sold as "large plastic delta" or "wing-style." We recommend the delta traps for ease of use (sticky liners easily slide in and out) and durability (reusable for 5 years or more). Do not use white-colored traps, as these attract bees.

Lures run about $1.20 each. Wing-style traps are approximately $2 each and only last one season. Delta traps are approximately $5 each. All traps should be labeled with name of the insect lure used and should not be used it for another insect. Store unopened lures in the freezer (up to 2 years) until use or they will lose effectiveness.

Sources of Monitoring Supplies

Great Lakes IPM
Vestaburg, MI
800-235-0285
greatlakesipm.com

Gemplers
Mt. Horeb, WI
800-382-8473
gemplers.com

Trécé
Salinas, CA
408-758-0205
trece.com

Alpha Scents
West Linn, OR
503-342-8611
alphascents.com

Pest Monitoring Toolkit

- 10-30x hand lens
- orange delta traps for certain moth pests and/or Heliothis trap for corn earworm
- extra sticky liners for traps
- beat cloth
- sweep net
- vials of alcohol, tweezers, a small paintbrush, and plastic containers for collecting unknown specimens.

Field Guides

Cranshaw, Whitney. 2007. Garden Insects of North America: The Ultimate Guide to Backyard Bugs. Princeton University Press. 672 pp.

Bessin, Ric and John Obrycki. 2011. An IPM Scouting Guide for Natural Enemies of Vegetable Pests. U. of KY Extension, Bulletin ENT-67. 24 pp. www2.ca.uky.edu/agc/pubs/ent/ent67/ent67.pdf .

Pest Identification

If you find a pest or plant damage that you are unsure of, there are resources to help you.

1. Send the specimen to the Utah Plant Pest Diagnostic Lab (www.utahpests.usu.edu/uppdl) at 5305 Old Main Hill, Logan, UT 84322. A submission form, which is available online, must accompany the specimen. The fee is $7 and includes identification and management options.
2. Contact your local county extension agent (www.extension.usu.edu).
3. Visit the USU Extension integrated pest management website at utahpests.usu.edu/ipm/ to access image galleries, fact sheets, or to subscribe to the seasonal Vegetable IPM Advisory.

Thresholds for Treatment

Pest monitoring provides information on pest activity and population size. To decide if control is required, pest density and potential crop loss must be weighed against the cost of treatment. If the cost of treatment is more than the potential crop loss, do not treat. Activity of natural enemies must also be considered when determining whether to treat. Some pests like aphids or spider mites can be kept below economic injury levels by a healthy population of predators.

Heliothis traps are used to trap corn earworm. Traps are constructed from a mesh fabric in a funnel shape. The lure is hung from an elastic strap at the bottom with a binder clip. Moths collect in the top "bag" and can be counted and removed

Most threshold levels, where known, are provided for the pests in each crop chapter of this book, but some examples include:

- *asparagus beetle*: treat when 10% of crowns are infested with beetle adults
- *corn earworm*: treatment (if plants are in silking stage) should be implemented if 2 to 5 moths have been captured in Heliothis traps over 3 consecutive nights
- *onion thrips*: treat when there is an average of at least 7 thrips per plant
- *squash bug*: treat when the average number of egg masses is more than 1 per plant
- *striped cucumber beetle*: treat melons when an average of 4 to 5 adults are found per 50 plants

Treatment Options

Cultural Control

Options include tilling debris, crop rotation, cover cropping, application of proper irrigation and nutrition, improving soil health, using resistant varieties, and other similar methods. Often, practicing proper cultural controls throughout the year is enough to keep most pests in check.

Mechanical Control

Options usually involve methods to exclude pests such as applying row covers, discing weeds, and good sanitation practices (keeping tools clean, prompt removal of unhealthy plants, etc.).

Biological Control

For greenhouse or high tunnel crops, biological control using release of organisms works very well for controlling many insects and diseases. Because some insects used for biocontrol tend to disperse after release, they are not suitable for use on crops grown in the field. A better alternative is to enact measures that conserve and promote naturally occurring beneficial

Using genetic resistance is an effective and low cost strategy to minimize insect and disease outbreaks. Resistant varieties tolerate insect and disease injury better and result in more vigorous plants.

organisms through border or edge habitat plantings, applying compost to soil, and reducing pesticide use.

Chemical Control

If it is determined that a pesticide is needed for treatment, be aware that for insects (and many diseases), treatments should be applied only during the time period when the most susceptible life stage is active. For example, leafhopper on potato is most easily treated before the young (nymphs) develop wings. Once they can fly, they can avoid the insecticide application, and they are already producing new offspring to infest the crop. In addition, if symptoms of feeding are found but no causal insect can be identified, a chemical spray is not recommended.

Pesticides are grouped by mode of action (how they kill the target organism), which is usually designated by a group number. Pesticides with similar active ingredients will have the same number. Rotating among pesticides in different group numbers will reduce the likelihood of pest resistance.

For each pest group (insects, diseases, weeds), there are many pesticide options from which to choose. Products that are "broad-spectrum" kill a range of organisms, including beneficial ones, whereas other options target certain species and are less toxic. The EPA's Conventional Reduced Risk Pesticide Program registers certain pesticides as "reduced risk." These are pesticides that pose less risk to human health and the environment than existing conventional alternatives. (Biological and antimicrobial pesticides are all reduced risk, but are handled through separate registration processes.)

Products given the Reduced Risk designation have:

- low impact on human health
- lower toxicity to non-target organisms (birds, fish, plants)
- low potential for groundwater contamination
- low use rates
- low pest resistance potential
- compatibility with Integrated Pest Management (IPM) practices

Pest Sampling Methods

Fig. 3.1. Black light traps are used to trap nocturnal moths.

Fig. 3.2. Cloth placed under a shaken plant will aid pest scouting.

Fig. 3.3. "Heliothis" traps are used to catch corn earworm adults.

Fig. 3.4. A sweep net is helpful to count mobile insects.

Natural Enemies

Fig. 3.5. Assassin bugs have piercing-sucking mouthparts.

Fig. 3.6. Big-eyed bugs are predators that feed on a variety of insects.

Fig. 3.7. Damsel bugs have grasping forelegs used to catch prey.

Fig. 3.8. Green lacewings have pincher-like mouthparts.

Fig. 3.9. Green lacewing larva feeding on aphids.

Fig. 3.10. Green lacewing eggs on an onion leaf.

Fig. 3.11. Lady beetle adults can be carnivores or herbivores.

Fig. 3.12. Lady beetle larva.

Fig. 3.13. Lady beetle eggs.

Fig. 3.14. Minute pirate bugs are often found in litter and grass.

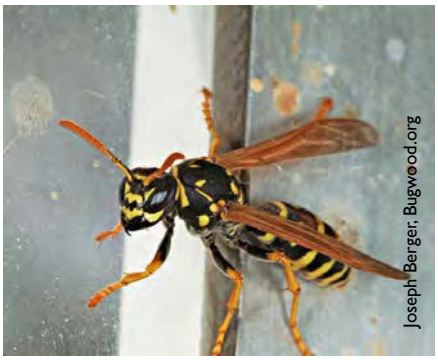


Fig. 3.15. Paper wasps prey on various caterpillars.

Fig. 3.16. Parasitized aphids, called "mummies" (lighter colored aphids).

Fig. 3.17. Rove beetles have short forewings and thrive under rocks.

Fig. 3.18. Syrphid flies resemble bees/wasps but have only two wings.

Fig. 3.19. Syrphid larva feeding on aphids.

CHAPTER 4 BRASSICA PRODUCTION

Varietal Selection

Variety selection can be challenging, given the large number of choices available. Consider the length of the growing season, soil type, climate conditions, and production practices when selecting varieties. For information on variety options, look at some of the different regions where brassica crops are produced and talk to your seed salesperson. Most varieties will grow and produce in Utah but not all may be suited to your location. When selecting a new variety, evaluate it based on earliness, growth habit, market needs, and disease resistance. Heirloom (open-pollinated) varieties generally lack disease resistance and are more prone to cosmetic defects.

We recommend comparing new varieties to what you already grow. On-farm testing is the best way to identify varieties most suited to your farms local and unique conditions. A few suggested varieties are shown in Table 4.1. Exclusion from the table list does not imply that the variety lacks merit.

Table 4.1. Variety Suggestions – Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, and Kohlrabi

Brassica Types	Varieties (limited list)
Broccoli	Emerald Crown, Gypsy, Hallmark, Marathon, Packman, Premium Crop
Brussels Sprouts	Diablo, Dominator, Hestia, Revenge, Royal Marvel
Cabbage	Artost, Caraflex, Bronco, Cairo (red), Quisto, Rendero (red), Surprise
Cauliflower	Amazing, Denali, Freedom, Hermon, Minuteman, Synergy, Whistler
Kale	Red Russian, Redbor, Rogue, Starbor, Winterbor
Kohlrabi	Kolibri (red), Konan, Kongo, Early Purple Vienna

Transplant Production

Start transplants in a greenhouse for the earliest plantings, in a cold frame/high tunnel for slightly later crops, and in outdoor seed-beds or directly in the field when the weather is warm enough for germination and growth (above 50°F). For most brassica crops, the minimum temperature for germination and growth is 40°F, the optimum range is 50-85°F (ideal 75°F), and the maximum greater than 90°F. It takes 6 to 8 weeks for plants to reach transplant size, and 1 oz. of seed will produce about 5000 transplants.

In the greenhouse, seed directly into plug trays or soil blocks. Plants are commonly grown in 128 cell trays. Smaller celled trays (256's) cost less per plant but require more management. A day/night temperature difference of 10°F in the greenhouse tends to grow the best plants (for example: 70d/60n). Temperatures in cold frames/high tunnels or outdoor seed-beds should be similar but are harder to achieve.

For out-door or ground grown seed-beds, plant in well-drained, disease free, sandy soils. Plant enough seed to produce 20-25 plants per row-foot and space rows 10-12 inches apart.

Transplants take 6-8 weeks after seeding (depending on growing temperature) to grow 5 to 7 true leaves (transplant size). Seedlings from a greenhouse require some hardening-off while those from outdoor seed-beds can be moved directly without conditioning. Do not over-harden since buttoning (see other production problems on pg. 34) is more likely to occur. Thoroughly water the outdoor grown plants prior to pulling. Undercut seedbed plants for easy removal and to minimize root breakage. Outdoor or ground grown plants are generally planted bare root. Set transplants slightly deeper in the field (cover root ball), irrigate after planting, and add a starter solution to aid in establishment.

Sometimes, brassicas are direct-seeded in the field. Seedbed conditions should be worked to a fine tilth that is free of surface trash, firm, and level. Precision seeders ensure more uniform seed spacing but these require size graded or pelleted seed. Seed requirement is about 0.5 to 1.5 lbs./acre depending on seed size and row spacing. Under most soil conditions, seed should be plant ⅓ to ½ inches deep. Direct-seeded crops will need to be thinned to the desired plant spacing when they have 3-5 leaves. Direct-seeded plants often mature several weeks earlier than transplants.

Soil

Deep sandy to loamy soil with a pH of 6.5 to 7.5 is ideal for early brassicas and heavier soils, while more productive, should be used for main season production. Most soils in Utah are suitable for the brassicas provided they are well drained, fertile, and do not have a buildup of salt. A well prepared seed bed encourages uniform planting conditions for seeds or transplants. Several weeks before planting, prepare the field for planting. If the site has drainage issues, consider 6-8 inch raised beds.

The brassica crops may be sensitive to residual herbicides from the previous crop, so pay attention to site selection if residual herbicides have been used in the past. Crop rotation is necessary. Remember, brassicas are all closely related to each other and insects and diseases are common to all. Plant residues should be completely buried to facilitate decomposition and reduce disease incidence.

Fertility

Prior to planting, have the soil tested to determine nutrient needs and deficiencies (Table 4.2). Soil sampling approaches and interpretation can be found on the Utah State University Analytical Laboratories website (www.usual.usu.edu). Organic growers should incorporate composted organic matter before planting to improve soil fertility. If you regularly apply compost or manure, periodic soil testing is critical. Regular additions of organic fertilizers can result in the buildup of salt levels and excess levels of other nutrients. An initial application of 5 tons per acre of high quality compost of known nutrient analysis may be helpful. This can be broadcast over the whole field or banded and then incorporated into the soil.

Generally, ¼ to ⅓ of the nitrogen and all the phosphorous and potassium is applied prior to planting. This fertilizer is either broadcast or banded. In soils with high P and K levels, broadcasting all of the fertilizer is acceptable. Banding is a good method to ensure the fertilizer is near the plant. Fertilizer bands should be 3 inches beside and 3 inches below the seed or transplant to minimize salt injury during establishment.

Transplants are "watered in" with a high P starter fertilizer at one quarter to one half pint per plant. The starter fertilizer is applied in addition to the broadcast of banded fertilizer. Most brassicas need additional magnesium and boron for optimal growth. Be sure you soil test for these minor use nutrients and add them prior to planting.

Table 4.2. Phosphorus (P_2O_5) and Potassium (K_2O) based on soil test results.

Phosphorus Test Results	Lb/acre	Potassium Test Results	Lb/acre
0-14	150-200	0-99	150-200
15-29	75-100	100-149	75-150
30-45	40-70	150-199	25-75
46-60+	0-30	200+	none

Use the higher amount when soil test values are in the lower part of the range

Nitrogen (N) – Up to 50 lbs. N/acre can be applied prior to planting. High pre-plant soil N levels cause seed or transplant establishment problems, N leaching, and is wasteful since plants use very little N during the first 4 weeks of field growth. An additional 75-120 lbs. N/acre is often applied in two sidedress applications. Based on the N uptake pattern in brassicas and extensive research, the first side-dressing is at thinning or 4 weeks after transplanting. The second, if needed, is 4-6 weeks later. Research shows that if pre-sidedress soil nitrate-N concentration is below 20 ppm, the brassicas will respond to additional N. Excessive N applications causes loose, soft heads and splitting in cabbage and Brussels sprouts. For broccoli or cauliflower, excess N contributes to non-uniform, rough, leafy heads and hollow stems (see other production problems on pg. 34). Use less N if the soil had additions of manure, compost, or when brassicas are grown after legumes (beans, alfalfa, etc.).

Planting, Spacing and Thinning

Planting dates vary widely in Utah depending on local climate conditions. Planting may begin in February in southern Utah (St. George) and may be as late as early-June in cooler mountain areas of northern Utah. Planting is recommended after danger of hard frost has passed. Local freeze dates can be accessed through the Utah Climate Center (climate.usurf.usu.edu).

Brassica seeds germinate well in cool soils (below 60 °F) and is most rapid around 75 °F. Plants grow best when the mean daily temperatures are 60-70 °F and brassicas easily withstand night temperatures below 40 °F. Transplants can withstand temperatures below freezing for short periods provided they are well conditioned. Large broccoli or cauliflower transplants (6-8 leaves) may prematurely head out (button) if exposed to cold temperatures while cabbage may not form a head (blind) if excessively chilled. Temperatures above 85 °F significantly slows plant growth, alters head shape (more pointed) in cabbage, and decreases head/curd quality in broccoli and cauliflower. Cauliflower curds and broccoli floral buds grow unevenly (rough head appearance), discolor (yellow), and often have small leaves (bracts) growing up through the heads when exposed to high growing temperatures (see other production problems on pg. 34).

Plant and row spacings vary with cultivar grown, plant growth habit, available equipment, irrigation approach, and market requirements. The following spacings are common and only provided as recommendations:

Table 4.3. Brassica Row Spacing

Crop	Between Rows (ft.)	Within Rows (in.)	Plants/ acre
Brussel sprouts	2.5-3.5	18-30	5,000-12,000
Cabbage, Broccoli, Cauliflower	1.5-2.5	8-24	8,700-40,000
Kohlrabi, Mustards, Pak choi, etc.	1-2	6-15	17,500-87,000

If direct seeding brassicas, precision plant at 0.5-1.5 lbs. seed per acre and place seed ⅓ to ½ inches deep (depending on soil moisture, time of year, and irrigation availability). Thin direct seeded plants to final spacing when they have 3-5 leaves.

Irrigation

All of the brassicas require regular, uniform watering during the growing season. Water shortages during establishment can limit seed germination, transplant establishment, and early growth. Inconsistent watering around heading set can cause misshapen, rough broccoli or cauliflower heads, induce splitting or tip burn in cabbage, and affect flavor. Over-watering wastes water and encourages root rots and foliar disease. Sprinklers are regularly used to germinate seed or establish transplants. Then after the first cultivation, you can switch to furrow irrigation. For small production areas it is common to use drip irrigation.

Soil water status should be monitored regularly to maintain consistent, uniform water supply. Use soil moisture monitoring sensors and weather based irrigation scheduling to monitor plant needs. Place sensors at various locations in the field and at several depths in the soil profile to get an accurate measure of soil water content. Start irrigating at 20-25% depletion when irrigating by drip and at 35-45% depletion for furrow or sprinkler systems. Water extraction estimates, using reference evapotranspiration adjusted with a crop coefficient (kc), are closely related to row canopy cover in the brassicas. The kc for a crop with 25% row cover is about 0.3, for 50% cover 0.6, and 85% cover the kc is 1. Note that irrigation also depends on your soil type (Table 4.4). Other low cost tools and methods to monitor soil water can be found at attra.ncat.org/attra-pub/soil_moisture.html.

Table 4.4. Soil tension values for different soil textures for use in scheduling drip irrigation, based on various percentages of depletion of available water holding capacity (Field capacity).

Soil Texture	0%	20-25%	35-45%
	Soil Tension Values (centibars)		
Sand, loamy sand	5-10	17-22	25-30
Sandy loam	10-20	22-27	33-40
Loam, silt loam	15-25	25-30	40-50
Clay loam, clay	20-40	35-45	55-65

Harvest and Handling

Broccoli

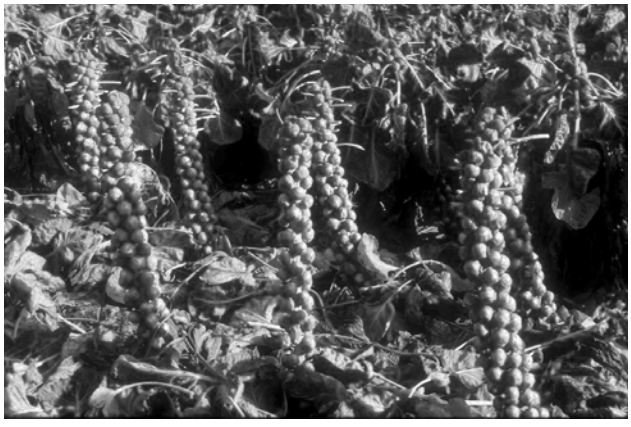
Depending on the variety, it often takes 50-70 days from transplanting till harvest. Mature heads should be compact, uniform in color (no yellowing or flowering), and tight. Cut the center head with 3-4 inches of stem. Side shoots will develop if plants are watered and fertilized. These shoots are harvested as

bunching heads over several weeks. For a continuous supply of the main crowns, seed and/or transplant every 2 to 3 weeks from early spring until mid-July.

Broccoli heads ready for harvest should be compact, tight, and uniform in color.

Brussels Sprouts

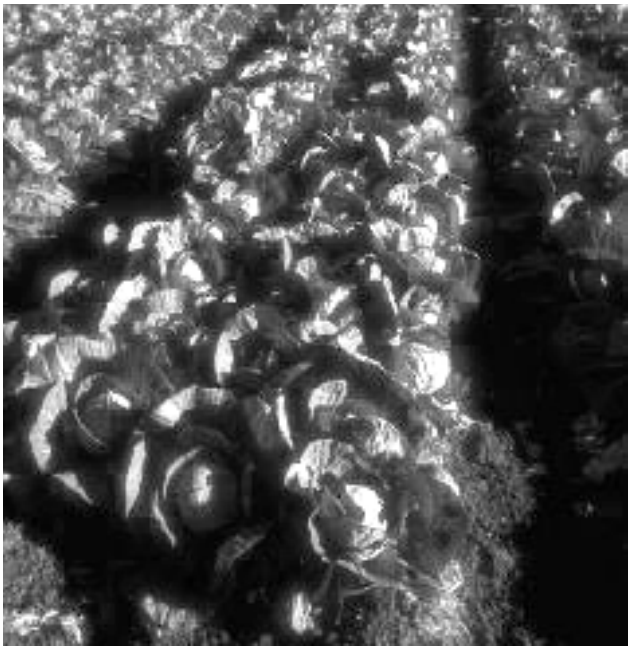
Depending on the variety, it often takes 90-120 days from planting till harvest. Begin harvesting early sprouts for the fresh market as soon as the lower ones on the stalk are appropriately sized (1-1.5 inches). This will allow the upper sprouts to continue enlarging for later harvest. For uniform sprout size and maturity on the stalk, plants are topped (growing point pinched out) when the lower sprouts are beginning to size (mid-August). Whole stalks can be harvested and marketed using this technique. Plants are very frost tolerant and can be left standing in the field till early December.



Brussels sprout stalks.

Cabbage

Depending on the variety, it often takes 80-100 days from planting till harvest. Heads are commonly hand harvested when they are hard. Cut at the base, trim off the outer wrapper leaves, and pack in cardboard boxes or bulk bins. Fields may be harvested three or four times as maturity time may vary.



Cabbage heads ready to harvest.

Cauliflower

Depending on the variety, it often takes 70-90 days from planting till harvest. A bright white color is critical at harvest for a premium cauliflower curd. When exposed to sunlight, the curd yellows so heads must be shaded (known as blanching). Cultivars with large, upright leaves (called self-blanching types) do not generally need tying. However, most growers tie up the leaves to protect the curd during the last 7-14 days prior to harvest. This is done by breaking leaves over the curd or tying the leaves together with elastic bands. The use of different colored elastics is used to indicate which heads are ready to harvest next. Heads should be at least 6 inches in diameter, fully developed, compact, and several of the leaves are left on to protect the head.

Greens (Collards, Kale, Mustards)

Depending on the variety, it often takes 50-70 days from planting till harvest. Leaves are commonly hand harvested. Cut off the whole plant at the base or individually remove older leaves which allows the

plant to continue to grow. Leaves are washed, tied, and packed in cardboard boxes. Fields may be harvested three or four times as maturity time may vary and quality deteriorates with age.

Kohlrabi

Depending on the variety, it often takes 40-60 days from planting till harvest. Harvest by hand when the swollen stem is 2-3 inches in diameter. Pull up the plants, wash, cut off the root and tie several plants (with leaves) to form a bunch. Fields are often harvested three or four times as maturity varies.

Postharvest Handling and Storage

The optimal storage conditions for all brassicas are cold (32-35°F) and moist (+95% relative humidity). Length of storage varies greatly. Under good conditions, cabbage can be stored for more than 6 months, broccoli, Brussels sprouts, and cauliflower for 2-4 weeks, kohlrabi for 1-2 weeks, and the greens for 2-3 weeks. The brassicas are quite sensitive to ethylene gas so do not store with fruit. Ethylene causes leaf or curd color changes, leaf abscission, head yellowing, and increases bitterness.

For more detail on storage and handling of the different brassicas, refer to the specific produce fact sheets available through the UC Davis Postharvest Technology website: http://postharvest.ucdavis.edu . These fact sheets are comprehensive guides to maintaining postharvest quality of the specific crop of interest.

Weed Management

In conventionally managed brassica fields, weed control is achieved with preplant and/or preemergence herbicides. Fields are often cultivated 4-6 weeks after planting and then post-emergence herbicides are applied to control broadleaf and grass weeds. Hand hoeing is done as needed.

In organic production systems, growers manage weeds by encouraging weed emergence with irrigation, then killing these weeds with tillage, flaming, or mulches (straw, cardboard, etc.). There are OMRI approved organic herbicides that can assist in weed management in organic operations. These herbicides are non-selective, contact herbicides, and must be applied to green tissue. Most organic herbicides have limited residual activity and are used with a combination of controls like tillage, hoeing, and mulches. Be sure to consult your certifying agent prior to applying organic herbicides to ensure you stay in compliance.

Pesticide applicators should have a current chemical applicators license, have a copy of the label, and have read it carefully. Many herbicides are manufactured by different companies under different trade names. The use of chemical names (active ingredient) along with one representative trade name is listed in Table 4.5. Herbicide labels change so growers must always consult a current label to determine 1) if the crop is listed for herbicide use; 2) what precautions are required; and 3) what rates and application methods are allowed. It is a violation of federal law to use any herbicides for purposes other than those specified on the approved label. Off-label applications are hazardous to the environment, to people using the product, and can severely injure the crop.

Use the recommended amount of product and apply it as stated. Pay attention to re-entry intervals (REI) and pre-harvest intervals (PHI). Over-application wastes money and violates the law, and may damage the crop and make it unsafe for consumption. Don't spray in high wind conditions. Work with your neighbors as many herbicides are toxic to other crops that are growing nearby. Finally, herbicides are just one tool available for weed control and their use should supplement other good weed-management practices.

Herbicides are applied in the following ways:

- **Pre-plant incorporated:** incorporated into the soil prior to seeding or transplanting the crop.
- **Pre-emergence:** applied to the soil after planting but before the crop or weeds emerge.
- **Post-transplant:** applied to the soil after the crop is transplanted either before weeds emerge or after clean cultivation. In some cases, sprays are directed to row middles and shielded from application to the crop.
- **Post-emergence:** applied to weeds after both weeds and the crop have emerged. In some cases, sprays are directed to row middles and shielded from application to the crop. When using a post-emergence herbicide, the entire weed must be covered for maximum control.

Other Production Problems

Blindness (Broccoli, Cabbage or Cauliflower): Plants fail to form flower head, curd or head. Leaves tend to be large, dark colored, and leathery, the apical bud may divide multiple times. Believed to be induced by cold temperatures after transplanting, injury by insects, or some other post-transplanting stress event.

Bracts (leaves) in Heads (Broccoli or Cauliflower): High temperatures and/or low soil moisture during early head formation can result in the growth of leaves within the heads of broccoli and cauliflower. Maintaining uniform soil water conditions while reducing heat stress, helps minimize the problem.

Brown Bead (Broccoli): Brown beads occurs when individual flower buds abort (die/dry out) under hot, dry conditions. The problem may be associated with calcium distribution in the plant combined with rapid plant growth. Periods of cool, wet followed by hot, dry conditions alter plant growth and calcium uptake which triggers the condition. Varieties vary greatly in their expression of the problem. Maintaining uniform growth conditions helps minimize brown bead.

Internal Browning or Tip-burn (Brussels sprouts and Cabbage): Internal leaves in the head or sprouts discolor, breakdown, and rot. The problem is more severe on large, over-mature heads or sprouts (those near the bottom of the stalk). The disorder is associated with a lack of calcium in the developing head/sprouts brought on by stress (heat, water, nutrients). Crops on sandy soils are more susceptible than those on heavier soils.

Head Splitting (Cabbage and Brussels sprouts): Mature heads split if rain or heavy irrigations follow a dry spell. Rapid influx of water results in pressure buildup in the heads resulting in splitting. Early varieties split if not harvested on time.

Hollow Stem (Broccoli or Cauliflower): Plants with leaf curling or rolling, brown curds or flower buds, and a hollow stem with brown discolorations may be deficient in boron. Use soil and tissue tests to determine boron concentrations. Sometimes stems are hollow without any discoloration. When plants are fertilized excessively (N), they grow rapidly and the stem core splits causing a hollow cavity. More moderate N nutrition or split N applications will maintain uniform growth which minimizes the problem.

Premature Head Formation (Buttoning in Broccoli and Cauliflower): Small heads form before plants grow enough leaves to develop a marketable head. Buttoning occurs when transplants are exposed to stress (heat/cold, water) after planting in the field. Early varieties and older, larger transplants (more than 8 leaves) are more susceptible. Low fertility, micronutrient deficiencies, water stress, warm weather (+85°F day/75°F nights), diseases, and insects can also cause buttoning.

Yellow Beads (Broccoli): Yellowing of floral buds can be a sign of over-maturity in the field. Broccoli heads are true flower tissue so if not harvested at the correct time, the flowers continue to develop and may open. In storage, high temperatures after harvest or ethylene exposure can also induce yellowing or browning of individual flower buds.

Insect and Mite Pest Management

Cabbage Aphid *(Brevicoryne brassicae)*
Order Hemiptera: Family Aphididae

DESCRIPTION:

Adult & nymph: Green-gray in color with a white waxy coating and short cornicles (two "tail-pipes" on the tail-end of the abdomen). Adults may be winged or wingless (Fig. 4.1). Cabbage aphids form dense colonies on undersides of leaves of broccoli, Brussels sprouts, cabbage, cauliflower, kale, and other related cole crops (Figs. 4.2 and 4.3). Aphids prefer to feed on young leaves and flowering structures; they can occur deep inside the heads of Brussels sprouts and cabbage.

LIFE HISTORY:

As aphid densities increase or plant conditions deteriorate, winged adults are produced, and they migrate to alternate hosts including vegetables and weeds during the summer. Winged adults colonize plants by depositing live young on one plant, and then fly to a nearby host plant. Aphids reproduce asexually (parthenogenesis) during the spring and summer, and sexually in the late summer and fall. Many overlapping generations occur each year.

DAMAGE:

Aphids feed by inserting their piercing-sucking mouthparts into plant tissue and removing the sap. Aphid feeding may cause yellow spots, water stress, and reduced plant growth rate. If aphid feeding is prolonged, or heavy infestations occur, reduction of yield may result. Leaf distortions may also occur, though this is more common on primary hosts. Aphids excrete a sticky substance known as honeydew on which sooty mold can grow.

MANAGEMENT:

Cabbage aphids can overwinter as eggs on Brussels sprouts, cabbage, and kale. It is important to thoroughly destroy host plant debris through tillage and/or rouging.

Cultural:

- *Avoid excess fertilization.* Aphid densities tend to be higher on plants that have an excess of nitrogen fertility.
- *Use mulches or row covers.* Metallized/reflective mulches and row covers can help reduce aphid populations on vegetables by interfering with the ability of winged aphids to find plants.
- *Don't plant vegetable crops near overwintering hosts* such as peach or nectarine trees.
- *Remove/destroy plant debris.* Disking fields immediately after harvest will destroy alternate host plants and reduce available aphid and virus sources.
- *Maintain healthy, vigorous plants.* They are more tolerant to attack by aphids.
- *Plant susceptible crops upwind.* Planting upwind from infested plants decreases aphid migration into the crop since aphids are blown downwind.

Chemical:

Many aphids have developed resistance to a number of different insecticides, including some synthetic pyrethroids, carbamates, and organophosphates. Additionally, when selecting insecticides, choose those that are less damaging to natural enemies of aphids and other insects in the crop.

Biological:

Natural enemies include lady beetles, lacewings, syrphid flies, and parasitic wasps. These and other predators play a major role in the natural suppression of aphids.

Cabbage Looper *(Trichoplusia ni)*
Order Lepidoptera: Family Noctuidae

DESCRIPTION:

Adult: Brown-colored moth with a silvery figure-8 (or 'u' shape with a circle beneath) on the front wings (Fig. 4.4).

Egg: Yellowish-white to green in color, dome-shaped with longitudinal ridges, and laid singly or in groups of 6 to 7 on the upper or lower surface of leaves (Fig. 4.5).

Larva: Green caterpillars, about 1½ inches long at maturity, with a white stripe along each side of the body and several narrow lines along the back. Distinguished by their "loop-like" crawling where the mid-section of their body forms a loop as they bring their back legs (prolegs) toward their front legs (Fig. 4.6).

Pupa: About ¾ inch long. The pupa develops inside a thin white cocoon on the underside of foliage, plant debris, or in soil clods.

LIFE HISTORY:

Overwinter as pupae, and adults begin to emerge in late March to April. Most pupae cannot survive the winter in northern Utah due to cold soil temperatures. Moths immigrate from warmer regions in the south. Eggs are laid on the upper and lower surfaces of leaves. Larvae feed on foliage for 2 weeks before pupating. The time from egg to adult is about 30 days. There are 3-4 generations per year in Utah.

DAMAGE:

Damage typically occurs after head formation begins in cole crops, but caterpillars can sometimes attack seedling plants. Loopers chew through leaves creating ragged holes, bore into heads, and contaminate leaves and heads with their bodies and frass (excrement).

MONITORING:

- *Monitor.* Scout weekly for cabbage loopers by randomly checking one out of ten plants (10%) in small fields, and one out of 100 plants (1%) in fields > 1 acre. Look on the undersides of leaves for small larvae and eggs. Look for feeding holes; search for larvae nearby and inside damaged heads.
- *Use pheromone traps.* Mount traps on a stake and place just above crop canopy height at the field edges. Use a pheromone lure specific to cabbage looper to attract male moths to the trap for counting. Moths fly at dusk and into the early nighttime. See pg. 24 for sources of monitoring supplies.

MANAGEMENT:

Loopers are difficult to manage once they get inside head-forming cole crop plants. Thus, timely monitoring and management is crucial.

Cultural:

- *Handpick caterpillars.* Where practical (in smaller fields), physically remove larvae when plants are young or when only a few loopers are present.
- *Use floating row covers.* Apply covers before loopers are present to prevent adult moths from laying eggs on plants. Remove covers during flowering to allow for pollination. This option is only practical for home gardens and small commercial fields.
- *Plant tolerant varieties.* Cabbage varieties with resistance to cabbage looper include 'Green Winter', 'Savor', 'Savoy Chieftain', and most red cabbage varieties.
- *Sanitation.* Clean fields of plant debris after harvest; thus, removing overwintering sites for pupae.
- *Manage weeds to remove overwintering sites for pupae.* Weed hosts for looper caterpillars include wild mustard, pepper grass, and shepherd's purse.

Biological:

Insecticides containing *Bacillus thuringiensis var. kurstaki* (Bt) and spinosad (e.g. Entrust) are effective in suppressing cabbage looper larvae. Bt must be applied when larvae are still young (< ½-inch long), and plant coverage is important as Bt must be ingested by larvae to be effective.

Chemical:

When more than one cabbage looper larva is found in one out of ten monitored plants (10%), treat just before heading or at Brussels sprout formation. Seedlings only require treatment if medium- to large-sized caterpillars are present, and defoliation (loss of plant tissue) exceeds 10%.

SEARCH THE INTERNET FOR MORE INFORMATION:

- UC Davis IPM Cole Crops Cabbage Looper
- Oregon State University Looper Life Cycle and Biology
- USU IPM Advisory Cabbage Caterpillars

Diamondback Moth *(Plutella xylostella)*

Order Lepidoptera: Family Plutellidae

DESCRIPTION:

Adult: Small (1/3 inch), slender, grayish brown moths with folded wings that flare outward and upward at the hind end (Fig. 4.7). Male moths have a row of three yellow diamond-shaped spots down the middle of their back.

Egg: Very small and yellow to white in color; laid singly or in groups of 2-3 on the underside of lower leaves or stalks.

Larva: Mature larvae are about 1/3 inch long with a pale yellow-green body that is pointed at both ends (Fig. 4.8). Diamondback larvae are distinguished by their habit of wriggling vigorously or dropping from a plant on a string of silk when disturbed.

Pupa: Green in color and develop in a loosely spun, lace-like cocoon that is attached to the leaves or plant stems (Fig. 4.9).

LIFE HISTORY:

Diamondback moths overwinter as adults, but don't survive the winter in colder areas of Utah. They are re-introduced to cooler areas on strong winds from warmer, southern locations. Adult flight occurs in the spring; first eggs are laid in the late spring and early summer. Eggs hatch within 4-8 days; larvae initially feed on the undersides of older or outer leaves of older plants. Larvae mature in 10-30 days depending on temperatures; pupation lasts for 10-14 days. Up to 4-6 overlapping generations of diamondback moth may occur each year in Utah.

DAMAGE:

Diamondback moths prefer cabbage and broccoli, but will feed on other cole crops and cruciferous weeds. Immediately after hatching, tiny larvae mine through leaves (leaving the upper side of the leaf intact) creating small depressions called "window panes" that appear as holes (Fig. 4.9). This damage primarily occurs on outer or older leaves of older plants. Larvae will also feed on flower buds and floral stalks. Larvae present in the heads and stems at harvest reduce the marketability of the crop (Fig. 4.10).

MONITORING:

- *Scout for larvae and pupae* on leaves of susceptible plants at the seedling stage, during crop thinning, and just before crop head formation. Select 10 mature, unfolded, leaves (but not old and discolored) from 10 different areas in a field (100 leaves total); inspect the leaves for "window pane" damage, larvae, and pupae.
- *Use pheromone monitoring traps.* Mount traps on a stake and place just above the crop canopy height at the field edges. Use pheromone lures specific for diamondback moth to attract male moths for counting.
- *When monitoring, pay attention to border rows that are next to fields that have had high populations of diamondback moths and high weed populations.* Adults commonly migrate to new areas from fields that have recently been harvested or disked under.

MANAGEMENT:

Cultural and Mechanical:

- *Hand pick and destroy larvae.*
- *Heavy irrigation (or rainfall) can reduce early larval populations.* Crops that are drip or furrow-irrigated may have higher diamondback moth populations.
- *Use row covers on susceptible crops to exclude diamondback moths.* Remove covers during flowering for pollination.

Biological:

Parasitoid wasps that attack diamondback moth include *Diadegma insulare*, *Diadromus subtilicornis*, *Microplitis plutellae*, and *Trichogramma pretiosum* (egg parasitoid). Generalist predators include predaceous arthropods such as ground beetles, syrphid fly larvae, true bugs, lacewing larvae, and spiders.

Chemical:

Worldwide, diamondback moth has developed resistance to multiple insecticides. Although no resistance has been reported in Utah, it is crucial to rotate insecticide groups to prevent the development of insecticide resistance. Consider chemical treatment options when 5% of the crops are infested with larvae and before they move into crop heads or broccoli and cauliflower buds expand. *Bacillus thuringiensis var. kurstaki* (Bt) and spinosad (e.g. Entrust) are organic options that can control small populations of diamondback moth, but may not be effective in major outbreaks.

SEARCH THE INTERNET FOR MORE INFORMATION:

- UC Davis IPM Cole Crops Diamondback Moth
- Penn State Diamondback Moth
- Oregon State University Diamondback Moth
- Cornell Insects of Crucifers Diamondback Moths

Flea Beetles

Order Coleoptera: Family Chrysomelidae

DESCRIPTION:

Adult: About 1/8-inch long with small dark metallic bodies and enlarged hind legs that enable them to jump long distances (hence the name "flea") (Fig. 4.11). Some adult flea beetle species are striped (Fig. 4.12).

Egg: Elliptical in shape, and white to yellowish gray. Laid in clusters or singly in the soil at the base of host plants.

Larva: Small, white, and worm-like with a brown head.

Pupa: Small and cream to white; pupate in the soil.

LIFE HISTORY:

Flea beetles overwinter as adults in protected areas under soil clods, plant debris, and weeds. They emerge from overwintering sites in mid- to late- spring and mated females lay eggs in the soil at the base of host plants. Larvae feed on below-ground portions of the plant. Pupation then takes place in the soil and adults emerge to feed on above-ground plant parts. One to three generations of flea beetles are possible, depending on the species of flea beetle and temperatures.

DAMAGE:

Larvae can reduce plant health by feeding on roots and fine root hairs, but this does not usually cause economic loss. However, some species, such as the tuber flea beetle, may cause significant damage in potato tubers, leaving shallow, winding grooves on the tuber surface or burrowing into the tubers, causing tunnels filled with frass that may stain the potato. Some flea beetle larvae may tunnel in carrots. Most damage is caused by adult flea beetles and occurs as shallow pits and small rounded, irregular, holes in the foliage, cotyledons, and stems of host plants (Fig. 4.13).

Host plants include those in the brassica (kale, broccoli, cabbage, etc.), solanaceous (tomato, potato, eggplant, etc.), and cucurbit (squash, pumpkin, melon) families. Non-crop hosts include alder, currant, evening primrose, sedum, skunkbrush, sumac, willow, and many weeds and grasses. Plants less tolerant to flea beetle damage include cole crops (such as cabbage), edible greens, and seedlings.

MONITORING:

- *Use yellow sticky traps and visual scouting to monitor for flea beetle presence*. Place traps near host plants as soon as seedlings emerge. Also, scout susceptible plants for the presence of flea beetles.
- *Inspect crops for flea beetle adult injury (small holes in leaves)* near field borders with cruciferous weeds, such as mustards. Adults overwinter on weeds, and fly into host crop fields in the early season.

MANAGEMENT:

Cultural:

- *Avoid planting susceptible crops after potatoes*. Crop rotations are generally not effective against flea beetles because of their extreme mobility, however, in potato crops, potato tuber flea beetle populations tend to be greater in areas where potatoes were previously planted.
- *Control weeds around planting sites*. Weeds can provide food sources for flea beetle larvae development.
- *Plant crops as late as possible, when feasible*. Adult flea beetle populations generally decline throughout the summer, and warmer temperatures can help plants outgrow feeding damage.
- *Plant trap crops*. Before you plant your main crop, plant a highly favored trap crop such as radish, to attract flea beetles away from the main crop. Flea beetle adults will be attracted to the earliest and tallest plants and can be controlled in trap crops with insecticides or physical removal (e.g. bug vacuum or harvesting).
- *Use companion crops and living or non-living mulches to obscure host plants from the flea beetles*. Companion crops such as bunching green onions, dill, and marigolds, can help divert flea beetles from feeding on main crops. Living mulches such as legumes (e.g. clover and vetch), as well as non-living mulches, can also be used to obscure host plants from flea beetles.
- *Use row covers during seedling establishment*. Remove row covers during flowering to allow for pollination.
- *Eliminate old crop debris and other surface trash*. This will help remove overwintering sites for adults.

Chemical:

Flea beetle damage is most severe in the spring. Thus, monitoring for their presence early in the season can indicate whether insecticides are necessary. Seedlings are less tolerant of flea beetle damage and may require a treatment if there are 1-5 flea beetles per plant or defoliation reaches 10-30%.

Biological:

Natural enemies of flea beetles include *Microctonus vittatae* (parasitic wasp), entomopathogenic nematodes, white muscadine (fungal pathogen), and generalist predators such as lacewing larvae, adult big-eyed bugs, and damsel bugs. *M. vittatae* wasps kill flea beetle adults when they emerge after development. The larvae of *M. vittatae* also sterilize female flea beetles as they develop inside her body.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Pacific Northwest Extension Organic Management of Flea Beetles
- University of Vermont Flea Beetles Management

Imported Cabbageworm *(Pieris rapae)*

Order Lepidoptera: Family Pieridae

DESCRIPTION:

Adult: White butterfly with a wingspan of about 1.75 in. and one to four black spots on the wings (Fig. 4.14).

Egg: Rocket-shaped, white to cream in color (eventually turning yellow); laid on the undersides of leaves (Fig. 4.15).

Larva: About 1¼ inches long at maturity with a green, velvet-like body, and a yellow-orange stripe down the center of the back (Fig. 4.16).

Pupa: Green in color with yellow stripes on the back and sides; there is no outer cocoon.

LIFE HISTORY:

Overwinter as pupae near host plant debris and emerge as adults in mid-spring. Eggs are laid singly on the undersides of outer leaves and hatch after 4-8 days. Larvae mature after 2-3 weeks and pupate on the host plant. Pupation takes 1-2 weeks and emerged adults mate and lay eggs for a second generation. One generation takes about 3-6 weeks from egg to adult and 3-5 generations can occur each year.

DAMAGE:

Imported cabbageworm prefers broccoli, cabbage, and cauliflower, but will feed on all cole crops. Larvae feed on outer leaves, resulting in round holes (Fig. 4.16). Frass (excrement) can stain or discolor broccoli and cauliflower heads. As crop heads develop, cabbageworms feed on outside leaves and bore into heads, resulting in unmarketable produce.

MONITORING:

- *Scout weekly.* Start at the button stage (before cauliflower and broccoli heads begin to elongate and expand). Pull 10 leaves from 10 different plants at 10 different locations of the field to total 100 leaves. Look for small larvae and eggs on the undersides of leaves and larger caterpillars toward the center of the plant or near the midribs of leaves. Watch for the white butterflies flying during the day. Scout for other caterpillars at the same time.

MANAGEMENT:

Cultural:

- *Plant cabbage as an early crop.* Harvest before cabbageworm populations build to damaging levels.
- *Plant resistant varieties to lessen cabbageworm damage.* Resistant varieties include: 'Mammoth', 'Red Rock', 'Chieftan Savoy', and 'Savoy Perfection Drumhead'.
- *Harvest as early as possible and destroy or plow under plant residues.*
- *Rotate crops and distance susceptible hosts from current and previous susceptible crop plantings.*
- *Use row covers to exclude butterflies from laying eggs on host plants.* Remove covers during flowering for pollination.

Biological:

Natural enemies can be a major contributor to reductions in cabbageworm populations. *Trichogramma* wasps and tachinid flies parasitize cabbageworm eggs, pupae, and larvae. Commercially purchased *Trichogramma* can be released at peak flight of cabbageworm as an effective form of control. *Bacillus thuringiensis var. kurstaki* (Bt) and spinosad (e.g. Entrust) are especially effective when applied to young caterpillars of imported cabbageworm.

Chemical:

If 2 or more medium sized larvae are found per 10 leaves at the button stage, two sprays will be needed: 1) a spray at button stage and 2) a clean-up spray 7-10 days before harvest.

SEARCH THE INTERNET FOR MORE INFORMATION:

- UC Davis IPM Imported Cabbageworm
- Oregon State University Cabbage White Butterfly
- PNW Handbooks Imported Cabbageworm

Root Maggots

Order Diptera: Family Anthomyiidae

Cabbage Maggot (Delia radicum)

DESCRIPTION:

Adult: Dark gray fly about half the size of the common house fly.

Egg: Small white, oval-shaped; typically laid on the soil near the stem of the host plant.

Larva: Small, white, legless maggot with a blunt tail-end and pointed head.

Pupa: About ¼-inch long and brown in color.

LIFE HISTORY:

Cabbage maggot pupae overwinter in crop debris and soil. Adults emerge in early May, and mated females lay eggs in the soil at the base of host plants. Small maggots hatch in 4-10 days and immediately burrow into the stem of the host plant. After about 3 weeks, mature larvae leave the stems and pupate in the soil close to the soil surface. About 2 weeks later, adult flies emerge and lay eggs for another generation. Larvae from this generation feed on roots or stems and develop into the overwintering pupae.

DAMAGE:

Cabbage maggot larvae feed on the roots of cole crops, and can tunnel through tap roots. Tunnels provide an entry for decay, fungi, and bacteria. Damaged plants show wilting, reduced growth, and lighter green plant parts (Fig 4.17). Cabbage maggot prefers cauliflower, Brussels sprouts, radish, cabbage, broccoli, collards, kohlrabi, and turnip. Cress, beet, and celery can also be infected. Cauliflower and Brussels sprouts can be more susceptible than hybrid cultivars of broccoli. Seedlings and young plants are most vulnerable while healthy plants can tolerate moderate infestations.

MONITORING:

After susceptible crops emerge, watch for wilting, reduced growth, and signs of chlorosis (yellowing). If cabbage maggots are suspected, pull up affected plants and check the roots and soil to confirm maggot presence. If tunnels are found in roots, but no maggots are present, then maggots have already exited roots to pupate in the soil. This timing is too late for an insecticide treatment to be effective.

MANAGEMENT:

Cultural:

- *Rotate crops*. Plant susceptible hosts as far away as possible from where they were planted the previous year.
- *Use a set of drag chains when direct-seeding susceptible crops.* Drag chains can help eliminate moisture where seeds have just been planted. Adult flies may be more attracted to moist areas for egg-laying.
- *Be aware of cabbage maggots in cool, wet spring weather* as these conditions are more favorable for cabbage maggot development.
- *Plant seeds into raised soil beds* to promote soil drying and warming, and discourage egg-laying by cabbage maggots.
- *Immediately after harvest, destroy or disc under crop residues.* Maggots are able to survive for an extended time in crop residues.
- *When several rows of seedlings are infested, remove them and replant.*

Biological:

Carabid beetles, rove beetles, and parasitic wasps may help suppress cabbage maggots. However, biological controls alone generally do not keep cabbage maggot populations below economically damaging levels, especially once a population has established.

Chemical:

Fumigate or treat infested soil before planting. In areas where cabbage maggot causes economic injury, treat with a band of insecticide at the base of the plant at the time of planting or transplanting.

SEARCH THE INTERNET FOR MORE INFORMATION:

- UC Davis IPM Cabbage Maggot
- Pacific Northwest Handbook Cabbage Maggot
- Penn State Extension Cabbage Maggot
- Oregon State University Cabbage Maggot

Seedcorn Maggot *(Delia platura)*

DESCRIPTION:

Adult: Seedcorn maggot adults are about 0.2 inches (5 mm) long with gray to brown bodies and are similar in appearance to the onion maggot.

Egg: White elongated; deposited in soils rich in organic and decaying matter and on seeds and seedlings.

Larva: Maggots are legless, tapered, about 0.25 inches (6 mm) long, and yellowish-white in color. Head-ends are wedge shaped with small black mouth hooks in front.

Pupa: Oval shaped, dark brown, about the size of a grain of wheat, and found in the soil.

LIFE HISTORY:

Adult flies emerge in April and May and begin mating within 2 to 3 days. Females lay eggs in or on soils and/or on seeds. Eggs hatch in 2 to 4 days at which point the larvae burrow into seeds and feed on emerging cotyledons and plant roots. Mature larvae pupate in the soil and remain in this stage approximately 7 to 14 days. Seedcorn maggots overwinter as pupae. A complete generation takes about 3 to 4 weeks and about 2 to 3 generations occur per year.

DAMAGE:

Maggots prefer feeding in soils rich in organic and decaying matter (such as manure). They burrow into the seeds and roots of many vegetable crops, destroy the seed germ, and may cause rot in plant tissue. Damaged seeds are unable to provide adequate food resources to support initial plant growth. Seeds and plants attacked by seedcorn maggots may not emerge causing reduced stands. Seedcorn maggots cause damage by feeding on roots and tunneling into taproots of susceptible plants. The lower leaves of infested plants often become chlorotic (yellow) and severe damage results in halted plant growth (Fig 4.18).

Seedcorn maggots are polyphagous (feed on several vegetable host plants), and prefer soybeans and corn. Other susceptible plants include brassicas, beans, peas, cucumber, melon, onion, potato, and others.

MANAGEMENT:

Cultural:

- Use the cultural control methods listed above in the cabbage maggot management section.
- *Direct seed when conditions are ideal for rapid seed germination.* Longer germination time results in higher infestation risks.
- *Early season infestations can be avoided by planting susceptible hosts later in the season.*

Biological:

Birds, ants, and spiders have been observed attacking adults and fungal diseases can infect larvae. However, these natural enemies are not considered a significant form of control.

Chemical:

Apply a preventive seed treatment for optimal control.

Disease Management

There are currently no reported occurrences of Brassica diseases in Utah.

Pest Management Tables for Commercial and Home Use

Table 4.5. Herbicides registered for **COMMERCIAL** use on **Brassicas** in Utah.

Brand Name (REI/PHI)	Active Ingredient	Timing and Application Location Relative to Crop				Timing Relative to Weeds		Weed Groups Controlled			Comments
		Pre- Transplanting	Pre-plant Incorporate	Post transplanting	Post-emergence	Pre-emergence	Post-emergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X	X	X	X		X		X	X	Use shield between rows
Command 3 ME (12hr/45d)	clomazone	X	X			X		X	X	X	Note crop restrictions
Dactha;W75 (12h/30d)	DCPA	X	X	X		X		X			Note crop restrictions
Goal (12hr/14-20d)	oxyflourfen		X			X	X		X	X	Note crop restrictions
Gramaxone Inteon (12hr/30d)	paraquat	X	X				X	X	X	X	Restricted use material
RoundUp & others (12hr/14d)	glyphosate	X	X	X	X		X	X	X	X	Used shield between rows
Prefar 4E (12hr/-)	bensulide	X	X			X		X			
Poast (12hr/14-30d)	sethoxydim			X	X		X	X			
Devrinol (12hr/60d)	napropamide	X	X			X		X	X	X	
Select 2EC (12hr/14-30d)	clethodim			X	X		X	X			
Spartan 4F (12hr/14-20d)	sulfentrazone	X				X			X	X	Cabbage only
Stinger (12hr/30d)	clopyralid			X	X		X		X	X	
Treflan & others (12hr/30d)	trifluralin	X	X	X		X		X	X	X	
Organic Products											
Corn Gluten Meal		X	X			X			X	X	
Summerset Alldown	Acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	Cinnamon/Clove Oil	X	X	X			X	X	X	X	
Worry Free	Citrus Oil	X	X	X			X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 4.6. Insecticides registered for **COMMERCIAL** use on **Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, & Kohlrabi** in Utah, Organized by Mode of Action (MoA). For treatment on other brassicas, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Flea Beetles	Imported Cabbageworm	Cabbage Looper	Root Maggots	Diamondback Moth
carbaryl	Carbaryl, Sevin	1A	10-14		X	X			X
methomyl (not kohlrabi)	Corrida[R], Lannate[R], Nudrin[R]	1A	10-14			X	X		X
chlorpyrifos	Chlorpyrifos[R], Eraser[R], Govern[R], Lorsban[R]	1B	---	See label	See label	See label		X	
diazinon (not kale or kohlrabi)	Diazinon[R]	1B	(+)					X	
disulfoton (cabbage only)	Di-Syston[R]	1B	(+)	X	X				
malathion (check label for cauliflower and kale)	Malathion, Fyfanon	1B	5-7	X	See label	X	See label		See label
naled (not kohlrabi)	Dibrom[R]	1B	10-21	X		X	X		X
alpha-cypermethrin (check label for kale)	Fastac[R]	3A	10-14	X	X	X	X		X
beta-cyfluthrin	Baythroid[R]	3A	14		X	X	X		X
bifenthrin (check label for kale)	Bifenture[R], Brigade[R], Discipline[R], Fanfare[R], Tundra[R]	3A	14	X	X	X	X	See label	X
bifenthrin + zeta-cypermethrin	Hero[R], Steed[R]	3A	14	X	X	X	X		X
cyfluthrin	Tombstone[R]	3A	10-14		X	X	X		X
esfenvalerate (not brussles sprouts or kale)	Asana[R], S-fenvalostar[R]	3A	14		See label	See label	See label		
fenpropathrin (not kale)	Danitol[R]	3A	14	X	X	X	X		X
gamma-cyhalothrin (not kale)	Declare[R]	3A	10-14	X	X	X	X		X
lambda-cyhalothrin (not kale)	Grizzly[R], Kendo[R], Lambda[R], Lambda-Cy[R], Lambdastar[R], Paradigm[R], Silencer[R], Warrior[R]	3A	10-14	X	X	X	X		X
permethrin (not kale)	Arctic[R], Perm-Up[R], Permastar[R], Pounce[R]	3A	14	See label for listed pests					
pyrethrins	Pyganic[OB]	3A	3-5	X	X	X	X	X	X

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
(++)= One application per crop per season
(+)= One application per year

Table 4.6, continued. Insecticides registered for **COMMERCIAL** use on **Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, & Kohlrabi** in Utah, Organized by Mode of Action (MoA). For treatment on other brassicas, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Flea Beetles	Imported Cabbageworm	Cabbage Looper	Root Maggots	Diamondback Moth
pyrethrins + piperonyl butoxide	Evergreen	3A	3-5	X	X	X	X		X
zeta-cypermethrin	Mustang[R]	3A	10-14	X	X	X	X		X
lambda-cyhalothrin + thiamethoxam (not kale)	Endigo[R]	3A/3A	10-14	X	X	X	X		X
bifenthrin + imidacloprid	Brigadier[R], Swagger[R], Tempest[R]	3A/4A	14	X	See label	X	X		X
imidacloprid + beta-cyfluthrin	Leverage 360[R]	3A/4A	14	X	X	X	X		
imidacloprid + lambda-cyhalothrin (not kale)	Kilter[R]	3A/4A	10-14	X	X	X	X		X
lambda-cyhalothrin + chlorantraniliprole (not kale)	Voliam Xpress[R]	3A/28	10-14	X	X	X	X		X
pyrethrins + azadirachtin	Azera	3A/ UN	3-7	X	X	X	X	X	X
acetamiprid	Assail	4A	10-14	X					X
clothianidin	Belay	4A	10-14	X	X				
dinotefuran (check label for kale)	Safari, Scorpion, Venom	4A	14	X	See label				
imidacloprid	Admire Pro, Couraze, Lada, Macho, Mana Alias, Montana, Nuprid, Omni, Prey	4A	14	X	X				
thiamethoxam	Actara, Platinum	4A	14	X	X				
thiamethoxam + chlorantraniliprole	Durivo, Voliam Flexi	4A/28	14	X	X	X	X		X
spinetoram	Radiant	5	14			X	X		X
spinosad	Conserve[B], Entrust[OB], Success[B]	5	5-7		X	X	X		X
emamectin benzoate	Proclaim[R]	6	7-14			X	X		X
pymetrozine	Fulfill	9B	7-10	X					
flonicamid	Beleaf	9C	14	X					
Bacillus thuringiensis subspecies *kurstaki* strain ABTS-351	Biobit[OB], Dipel[OB], Xentari[OB]	11A	5-7			X	X		X

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

(++)= One application per crop per season
(+)= One application per year

Table 4.6, continued. Insecticides registered for **COMMERCIAL** use on **Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, & Kohlrabi** in Utah, Organized by Mode of Action (MoA). For treatment on other brassicas, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Flea Beetles	Imported Cabbageworm	Cabbage Looper	Root Maggots	Diamondback Moth
novaluron (not kale)	Rimon	15				X	X		X
methoxyfenozide	Intrepid	18	10-14			X	X		X
tebufenozide	Confirm	18	10-14			X	X		
indoxacarb	Avaunt	22A	10-14			X	X		X
spirotetramat (check label for kale)	Kontos, Movento	23	14	X					See label
chlorantraniliprole	Coragen	28	14			X	X	X	X
cyantraniliprole	Exirel, Verimark	28	14	X	X	X	X	See label	X
azadirachtin	Aza-Direct[OB], Azatin[OB]	UN	7-10	X	X	See label	X	See label	See label
Beauveria bassiana	Botanigard[B]	---	5-7	X	X	X	X		X
Chromobacterium subtsugae strain PRAA4-I and spent fermentation media	Grandevo[OB]	---	5-7	X		X	X		X
kaolin	Surround[OB]	---	5-7		X				
oil: mineral, peppermint, rosemary, cottonseed, clove, garlic (check label for brussels sprout, kale and kohlrabi)	Biocover, Ecotec[OB], Glacial Spray[OB], Pure Spray Green[OB], Ultra-Pure[B]	---	none	X	See label			See label	
potassium salts of fatty acids	M-Pede	---	3	X					
sodium tetraborohydrate decahydrate	Prev-AM	---	5-10	X		X	X		X
sucrose octanoate	SucraShield[B]	---	3-5	X		X	X		X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on brassica crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

Protection of Pollinators: Look for the "bee-box" or "bee hazard icon" on product labels and read the restricitions and instructions to protect bees and other insect pollinators. Bees and other pollinators will forage on plants when they flower, shed pollen, or produce nectar. Follow these steps when using products that are hazardous to bees: 1) minimize exposure of the product to bees and pollinators when they are foraging on pollinator attractive plants around the application site 2) Minimize drift of the product on to beehives or to off-site pollinator attractive habitat as drift into these areas will kill bees.

Warning: Applications of imidacloprid and clothianidin are restricted to post-bloom and only when bees are not active in the site, including on weeds and non-crop plants.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

(++)= One application per crop per season
(+)= One application per year

Table 4.7. Insecticides registered for **HOME** use on **Broccoli, Brussels Sprouts, Cabbage, Cauliflower, & Kale**, organized by Mode of Action (MoA). For treatment on other brassicas, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Flea Beetles	Imported Cabbageworm	Cabbage Looper	Root Maggots	Diamondback Moth
carbaryl	Garden Tech Sevin	1A	14		X	X			
malathion	Spectracide Malathion, Ortho Malathion	1B	7	X		See label	See label		
bifenthrin	Fertilome Broad Spectrum Insecticide, Bonide Eight Insect Control	3	14	See label	See label			See label	
cyfluthrin	Bayer Vegetable and Garden Insect Spray	3	14		X	X	X		X
gamma-cyhalothrin	Spectracide Triazicide	3	14	X	X	X	X		X
pyrethrins	Monterey Bug Buster-O[OB], Garden Tech Worry Free[B]	3	5	X	X	X	X	See label	X
pyrethrins + canola oil (cabbage only)	Earth-tone Insect Control[B], Monterey Take Down Garden Spray[B]	3/	5	X	X				X
pyrethrins + potassium salts of fatty acids (insecticidal soap)	Safer Brand Tomato & Vegetable Insect Killer[OB], Safer Brand Yard & Garden Insect Killer[OB]	3/	5	X	X	X	X		X
pyrethrins + sulfur	Bonide Tomato and Vegetable 3 in 1[B], Natria Insect Disease & Mite Control[B], Ortho Insect Mite & Disease 3 in 1[B]	3/M2	5	X	X	X	X	See label	See label
acetamiprid	Ortho Flower Fruit & Vegetable	4A	14	X	X		X		X
spinosad	Fertilome Borer Bagworn Tent Caterpillar & Leafminer Spray[B], Monterey Garden Insect Spray[OB], Bonide Colorado Potato Beetle Beater[B]	5	7		See label	X	X		X
oil: canola, neem, rosemary, clove, cottonseed	Bayer Natria Multi-insect[B], Monterey All Natural 3 in 1 Garden Insect Spray[B]	---	1	X	See label	See label	See label		See label
potassium salts of fatty acids (insecticidal soap) (cabbage only)	Natria[B]	---	1	X					

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on brassica crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

(++)= One application per crop per season
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Fig. 4.1. Winged cabbage aphid adult with nymphs on a damaged cole crop leaf.

Fig. 4.2. Cabbage aphid colony on a kale leaf.

Fig. 4.3. Cabbage infested with aphids.

Fig. 4.4. Cabbage looper adult moth; note the silvery figure-8 on the front wings.

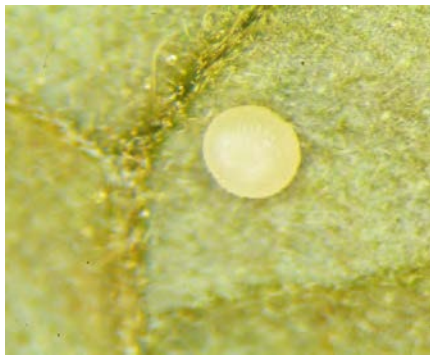


Fig. 4.5. Cabbage looper egg.

Fig. 4.6. Cabbage looper larva or caterpillar; note the "loop-like" crawling.

Fig. 4.7. Adult diamondback moth (DBM).

Fig. 4.8. DBM larva (wriggles or drops from plants on a silk string when disturbed).

Fig. 4.9. DBM pupa and "window pane" damage to the host leaf; note the lace-like cocoon.

Fig. 4.10. DBM damage on cabbage; note the ragged holes and smaller cabbage head (right).

Fig 4.11. Flea beetles have metallic bodies and enlarged hind legs.

Fig 4.12. Some adult flea beetles are striped.

Fig 4.13. Flea beetle damage occurs as shallow pits and small holes.

Fig. 4.14. Imported cabbageworm (or cabbage white butterfly) adult.

Fig. 4.15. Imported cabbageworm eggs on the underside of a leaf; note the rocket shape.

Fig. 4.16. Imported cabbageworm larva and damage; note the yellow stripe on the backside of the larva.

Fig. 4.17. Cabbage maggot damage on a young cabbage plant; note the chlorotic (yellowing) plant parts.

Fig. 4.18. Cabbage infested with seedcorn maggot (left); note the yellow leaves and stunted growth.

CHAPTER 5 CUCUMBER, PUMPKIN, & SQUASH PRODUCTION

Varietal Selection

Variety selection can be challenging given the large number of choices available. Consider the length of the growing season, soil type, climate conditions, and production practices unique to a farms location when selecting varieties. Very little testing of cucumber, squash or pumpkin has been done in Utah as there are not resources available to evaluate varieties in the different regions where cucurbits are produced. To further complicate matters, there are hundreds of different varieties available for purchase. Remember, most varieties will grow and produce fruits in Utah but, not all may be suited to your location. When selecting a new variety, evaluate it based on fruit size, earliness, vine growth habit, and disease resistance. Vigorous vine growth helps produce sufficient leaf cover to minimize sunburn but excessive vine production may limit productivity. If viruses and fungal diseases have been problems, look for varieties with some resistance to these issues. Heirloom varieties, while popular at farmers markets, generally lack disease resistance and are more prone to cosmetic defects.

If certain diseases have been a problem or you're replanting where cucurbits have been grown in the past, you may want to select varieties with some disease resistance/tolerance characteristics. Not all varieties carry disease resistance or some have partial resistance to selected diseases. Some seed suppliers have specific disease abbreviations. Always check with the seed supplier or reference their seed catalog for a full list of varieties and disease resistance packages or talk to your seed salesperson about unique needs and issues.

Table 5.1 shows a few of the types or varieties that are known to be grown under local conditions. We recommend that growers regularly test new varieties and compare them to what you already grow. On-farm testing is the best way to identify varieties that are most suited to your farms local and unique conditions.

Table 5.1. **Variety Suggestions** – Cucumber, Summer Squash, Winter Squash, and Pumpkin

Fruit Types	Varieties or Types
Summer Squash – Types	crookneck, patty pan, round, straight neck, yellow, green and stripped zucchini
Winter Squash – Types	acorn, banana, buttercup, butternut, delicate, hubbard, kabocha, spaghetti, turban
Pumpkins - Varieties	New England Pie, Munchkin, Small Sugar, Spookie, Autumn Gold, Spirit, Connecticut Field, Howden, Big Max, Atlantic Giant, Polar Bear, Moonshine
CUCUMBERS	
Pickling Varieties	Atlantic, Calypso, Cross Country, Jackson, Multipik, Napoleon, Pikmaster, Quest, Shenandoah, Vlasset
Slicing Varieties	Centurion, Dasher II, Meteor, General Lee, Marketmore 76, Raider, Slice Nice, Striker, Turbo
Tunnel Varieties	Unistar, Katrina, Socrates, Iznik, Diva

Transplant Production

Some growers transplant cucumbers, and summer squash particularly, for early production or when planting in high tunnels. Transplants work well in most areas of Utah with shorter growing seasons. Most cucumbers, winter squash, and pumpkins are direct seeded for mid- to late summer production periods. Growers can produce their own transplants, or plants can be purchased from a local greenhouse operation. Sow cucumber seeds into plastic plug trays with 72 or 128 cells per tray filled with a good soilless mix. Sow summer squash seeds into larger plastic plug trays with 50 or 72 cells per tray filled with a good soilless mix. Adequate light is essential to produce a quality plant but temperature management is critical if quality transplants are to be produced.

Greenhouse growth temperatures for cucurbits should be approximately 75 °F during the day and 65 °F at night. Allow 4-5 weeks to grow transplants depending on greenhouse growing temperatures. All cucurbit transplants should have 2-3 mature leaves and a well-

developed root system before transplanting to the field. After seeding and watering the trays, expose the seeds to 85-90 °F temperature conditions for 30-40 hours. You can do this in a dark room with the trays stacked on top of each other or use heating pads if only a few trays are needed. Higher tray temperatures after seeding helps create conditions for more uniform germination and plant stands. However, do not allow the seeds to emerge in high heat conditions. Longer exposures times (+48 hrs.) to high temperatures result in elongated hypocotyls which make the plants grow tall and leggy. These seedlings are then difficult to handle and transplant.

Once seedlings emerge, water regularly and feed twice weekly with a soluble complete fertilizer diluted to 100 ppm nitrogen. Brushing the plants each day, one week before planting, helps strengthen the stem. Brushing should be done when the leaves are dry to minimize disease transfer. Transplant can also be hardened or conditioned by exposing them to wind and cooler temperature to make the plants stocky and strong. Condition or "harden off" transplants for a short time each day by exposing them to cool temperatures (60-65 °F) starting one week before transplanting. Avoid exposing plants to temperatures that are less than 55 °F. Don't over-condition or over-harden the plants as this will delay establishment and plants will be slow to start growing again. For more details on growing high quality plants, refer to the USU extension publication "Vegetable Transplant Production".

Soil

Deep sandy to loamy soil with a pH of 6.5 to 7.5 is ideal for early cucurbits. Heavier soils, while more productive, should be used for main season production. Most soils in Utah are suitable for the cucurbits provided they are well drained, fertile, and do not have a buildup of salt. Crop rotation is necessary. Remember that squash, pumpkins, and cucumbers are related to cantaloupe and watermelons and most insects and diseases are common to all cucurbits.

Most of the cucurbits are quite sensitive to herbicides in soil, so pay special attention to site selection if residual herbicides have been used in the past. Crop rotation is another important consideration. Other cucurbits should not be planted within at least two years of related crops (cucumbers, squash, melons, watermelon, pumpkins or gourds). Plant residue from these related crops serves as a host for plant diseases and insects that may infect or infest the next cucurbit crop. Plant residues from the prior crop should be completely buried at the bottom of the furrow to facilitate decomposition. A well-tilled field will help produce a smooth, fine seed bed for uniform planting and emergence. Several weeks before planting, prepare the field for planting. If soils have drainage issues, create 6-8 inch raised beds. A very loose, somewhat dry soil is ideal for transplanting to ensure good soil contact with the transplant root ball or seed.

Fertility

Prior to planting, have the soil tested to determine nutrient needs and deficiencies (Table 5.2). Soil sampling approaches, forms, test details, and interpretation can be accessed through the Utah State University Analytical Laboratories (www.usual.usu.edu). Organic growers find it is a good idea to incorporate composted organic matter before planting to sustain soil fertility. An initial application of 5 tons per acre of high quality compost of known nutrient analysis may be helpful. This can be broadcast over the whole field or banded and incorporated into the individual rows.

A common practice is to add ⅓ to ½ of the required nitrogen fertilizer and all the phosphorous and potassium prior to planting. This fertilizer is either broadcast or banded. In soils with high P and K levels, broadcasting all of the fertilizer is acceptable. This is done before plowing or disking, then worked into the soil during normal field preparations. Banding is a good method to ensure the fertilizer is near the plant and makes sense for crops like winter squash and pumpkins where wide row spacings are common. Fertilizer bands should be 3 inches beside and 3 inches below the seed or transplant to minimize salt injury during establishment. Often transplanted cucumbers and summer squash are "watered in" with starter fertilizer containing high P levels applied at one quarter to one half pint per plant. Starter fertilizer is applied in addition to the fertilizer that was broadcast or banded.

Table 5.2. Phosphorus (P_2O_5) and Potassium (K_2O) for Cucumber, Pumpkin, and Squash based on soil test results.

Phosphorus Test Results	Lb/ acre	Potassium Test Results	Lb/acre
0-14	100-150	0-74	100-150
15-29	70-100	75-149	50-100
30-45	40-70	150-199	25-50
46-60+	0-30	200+	0-25

Use the higher amount when soil test values are in the lower part of the range.

Nitrogen (N) – Up to 50 lbs. N/acre can be applied prior to planting. Higher rates of N at planting may cause seed or transplant establishment problems. An additional 50-100 lbs. N/acre is often applied in two applications, the first when vines begin to run and again around first flowering. Use the smaller amount if the site has added manure, compost or when cucurbits are grown after a legume crop (beans, alfalfa, etc.).

Planting and Thinning

Planting dates in Utah vary depending local climate conditions. Planting often begins in early to mid-April in southern Utah and may be as late as mid-June in cooler areas of northern Utah. Planting is recommended after danger of frost has passed. Local freeze dates can be accessed through the Utah Climate Center (climate.usurf.usu.edu). Cucurbit seeds germinate poorly in cool soils (below 60 °F) and germination is most rapid around 90-95 °F. The cucurbits grow best when temperatures during the day are 75-85 °F and when night temperatures stay above 60 °F. Temperatures above 95 °F slows plant growth, may increase flower abortion, or influence fruit set and fruit sizing.

Plant and row spacings vary with cultivar grown, plant growth habit (bush/vine types), available equipment, irrigation approach, and market requirements. Typically, in-row plant spacing ranges from 12-18 inches apart for cucumbers in irrigated plantings. Summer squash are often planted 24-30 inches apart while winter squash are planted 30-48 inches apart. Pumpkin spacing in row is commonly 36-60 inches apart depending on vining habit and expected fruit size. Typical row spacings vary from 3 to 10 feet apart. Cucumbers and summer squash are planted at the closer row spacings while winter squash and pumpkin rows are wider apart. Higher yields occur with closer spacings but the grower will need to adjust nutrient or water management and fruit size may be smaller when plant densities increase.

Cucumber seeds are commonly planted at ½ to ¾ inches deep (depending on soil moisture, time of year, and irrigation availability) and require 3-5 pounds of seed per acre. Summer squash (bush types) are commonly seeded at 4-6 pounds of seed per acre and sown ¾ to 1½ inches deep (depending on seed size). Winter squash and pumpkins are seeded at 2-4 pounds of seed per acre at a depth of ¾ to 1½ inches. Hybrid seed is more expensive therefore, reduce seeding rates by modifying planters to only plant one seed at the desired in-row spacing. Once seedlings have emerged and have 1-2 leaves, thin stands back to the desired in-row spacing.

Transplanting

If transplanting cucurbits, plants can be grown in bare soil or through plastic mulch. Transplants are used for early production, when market prices are high, and to decrease seed costs for expensive hybrid seed. It is best to use high quality, uniform, disease and insect free plants. Transplant size is critical to establishment success and plants should have no more than 2-3 true leaves at planting. Plants should be handled and planted carefully as all of the cucurbits are sensitive to transplant shock. Root replacement is slow so don't crush or root prune plants. Plants can be hand or machine planted. Water the plant trays before planting and then water the field as quickly as possible after planting. Starter fertilizers with high phosphorus concentrations help to stimulate root re-growth. Newly transplanted fields should be watched closely and additional water should be provided to the plants if needed. This ensures good root growth out of the root-ball and more uniform establishment and plant growth.

Irrigation

All of the cucurbits require regular, uniform watering during the growing season. Water shortages during establishment can limit seed germination, transplant

establishment, and early vine growth. Inconsistent watering around flowering and fruit set can cause misshapen fruits and induce blossom end rot, and affect fruit sizing, flavor, and color development. Over-watering encourages root rots, belly rot on fruits, and can cause edema or fruit cracking. Furrow irrigation is suitable for the cucurbits and some growers use sprinkler irrigation to aid in stand establishment. Growers who plant through plastic mulches commonly use drip irrigation. Later in the growth of the cucurbits, sprinkler irrigation (solid set, wheel lines, and center pivots) can contribute to foliar diseases and may interfere with bee activity thus reducing fruit set, shape, or size.

Soil water status should be monitored regularly to maintain consistent soil water. Soil moisture monitoring is easily done with a resistance block such as the Irrometer® Watermark sensor. Place sensors at various locations in the field and at several depths in the soil profile to get an accurate measure of soil water content. Sensors typically express soil water content as a tension reading (centibars) that defines effort required to access available water. Soil water monitoring helps determine when to irrigate next. Field capacity describes a soil at 100 percent available water holding capacity after excess water has drained away. Start irrigation for the cucurbits at 25-30% depletion when irrigating by drip systems and at 40-50% depletion of available water holding capacity with furrow or sprinkler systems. Note that irrigation depends on your soil type (Table 5.3). Other low cost tools and methods to monitor soil water can be found at attra.ncat.org/attra-pub/soil_moisture.html.

Specific irrigation details are available in the USU extension bulletin, "Vegetable Irrigation: Squash and Pumpkins".

Table 5.3. Soil tension values for different soil textures for use in scheduling drip irrigation, based on various percentages of depletion of available water holding capacity (Field capacity).

Soil Texture	0%	20-25%	35-45%
	Soil Tension Values (centibars)		
Sand, loamy sand	5-10	17-22	25-30
Sandy loam	10-20	22-27	33-40
Loam, silt loam	15-25	25-30	40-50
Clay loam, clay	20-40	35-45	55-65

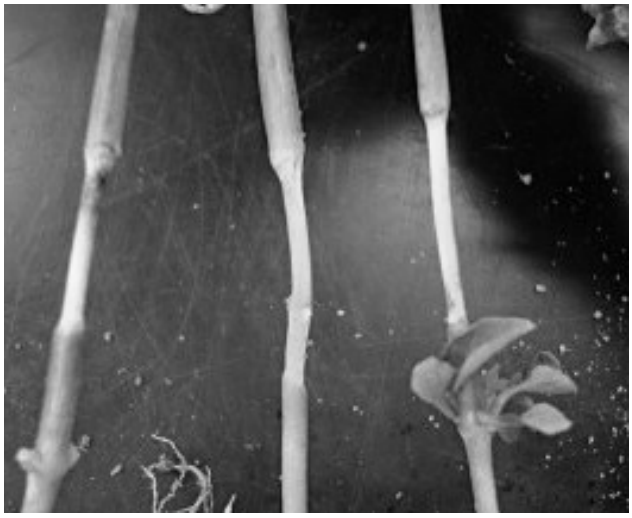
Ground Mulch and Row Covers

Plastic ground mulches are sometimes used for early cucumbers and summer squash as they improve soil temperatures, help control weeds in the row, conserve water, and stimulate early fruiting and productivity. Plastic mulch increases soil temperatures by 10 °F in spring which promotes rapid seed germination and better transplant establishment. Commonly used plastics are embossed black (cheapest) and newer IRT (infrared-transmitting) films which are more expensive, but are quite cost-effective where soil warming is important.

Plastic mulches are laid by machine before planting. Growers commonly use 3 or 4 feet wide plastic mulches which creates a 2 or 3-foot-wide soil cover. Matching the plastic to the laying machine creates the fewest problems during installation. Mulch should be stretched tightly over the bed and have a good seal at the edges. This ensures that the wind cannot dislodge the plastic and pull it out of the ground. Install the drip tape under the plastic at the same time the mulch is laid down. Usually, the mulch is applied several days before seeding or transplant to allow the soil under the plastic to warm.

Plastic mulch laid by a machine and stretched tightly over a bed before planting.

Plant and row covers can help protect early plantings from frost or wind damage, and enhance yield and earliness. Hot caps and spun-bonded row covers (aka Reemay) are commonly used. Row covers rest directly on top of plants, but should be weighted down to avoid



Spun-bonded row covers over transplants (top) and heat damage to plant stems that were touching the hot plastic mulch (bottom).

flapping which causes leaf damage. Remember that row covers need to be opened or removed as plants outgrow the cover, when the plants begin to flower, or when temperatures under the cover regularly exceed 90 °F. When transplanting, plastic mulches can get very hot and this can cause stem damage to transplants if they touch the plastic. Be sure to water immediately after planting or mound some soil around the stem to reduce this problem.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Utah State University Use of Plastic Mulch for Vegetable Production
- Penn State Extension Is There A Difference In Red Mulch?
- Michigan State Extension Row Covers for Frost Protection and Earliness in Vegetable Production

Pollination

High fruit yields and appropriate fruit shapes are achieved when flowers are properly pollinated. The cucurbits require at least one hive per acre and each flower requires 10-15 bee visits to ensure adequate pollen transfer, good fruit set, and proper sizing. Be sure hives are distributed around the field and put hives out just before plants start flowering. Keep hives in place for 2-3 weeks and use pesticides with caution during flowering to minimize bee exposure.

Harvest and Handling

Cucurbit yields vary widely depending on plant spacing, production methods (plastics, row covers, irrigation system), and variety. Cucumbers and summer squash often yield 250-300 cwt/acre. Yield for winter squash and pumpkins average around 350-400 cwt/acre. Higher yields are possible in intensively managed systems. Harvest and handling procedures vary with the type of crop grown and possibly with the intended market. Growers need to carefully supervise and train picking crews to prevent damage or losses from improper harvesting and poor crop handling techniques.

Cucumbers

Pickling cucumbers require 4-5 days after pollination to reach harvestable size (cultivar and temperature dependent) while slicing cucumbers require 15-20 days. Maturity characteristics vary by variety so having an experienced harvester is critical for quality cucumbers. Pickling cucumbers are ready for harvest within days of fruit set and fruit sizes vary depending on market requirements. The indicators of slicing cucumber maturity are glossy green rind sheen, smooth fruits, and no discoloration. Cucumbers should show the characteristic color for the variety, be well formed, fresh and firm, and free from decay and damage. Fruits should be "pushed" or twisted from the vine to avoid vine injury. Pulling fruits often damages or breaks the vines or pulls up the plant. Fields are often harvested for 2-3 weeks and may be picked 3-4 times per week.

Summer Squash

The harvest of summer squash (zucchini, patty pans, crooknecks, ball types) is very labor intensive. For optimum quality, fruits should be tender and have a shiny or glossy appearance. Low quality fruits have a dull color. Fruit size depends on the market, but fruits should never have seed with hard seed coats. Ideally, the crop should be harvested every other day and sometimes every day when temperatures are very warm. When harvesting summer squash, leave a short piece of the stem attached to the fruit. If possible, use cotton gloves when harvesting to avoid scratching and puncturing the fruit and cut the squash from the vine rather than twisting them off. The first flush of fruit (1st week) to be harvested is usually the best quality. Plan to harvest a given planting only 2 to 3 weeks and then start harvesting another planting. This will keep quality at its best, allows for a longer marketing season and minimizes low production due to older plants and disease. Harvest crookneck and straight neck cultivars when fruits are 1¼ to 2 inches in diameter. Zucchini fruits should be 6-8 inches long while scallop or ball types are harvested when they are 3-4 inches in diameter. Plant production drops off significantly if fruits are allowed to grow to larger sizes.

Pickling cucumbers are ready for harvest within days of fruit set. Maturity size varies with market requirements.

Maturity indicators for slicing cucumbers are a glossy green rind sheen, smooth fruits, and no discoloration.

Winter Squash

For optimum quality, harvest the fruits of winter squash and pumpkins only after the shell (or rind) has hardened completely. If you can scratch the rind with a finger nail, the fruit is still not mature. Care should be taken during harvest not to damage or break off the stem. Most winter squash and pumpkins are cut off the vine and stacked 2-4 fruits deep, depending on their size. When loading out of the field, trucks and trailers should be padded and fruit should not be bumped or bruised. Winter squash intended for long term storage should be washed or dipped in a 10% chlorine bleach solution (1 part chlorine bleach to 9 parts water), then dried before storing in a dry, cool place. Storage in the open sun causes excessive spoilage and sunburn.

Summer squash should have a shiny or glossy appearance at harvest for optimum quality.

Pumpkins

Pumpkins are mature when fruits have achieved normal size, are fully colored, and when the rind is hard. Stop watering 7-10 days before harvest to help dry out the vine and soil. Fruits should be cut from the vine at maturity leaving a 3-5-inch-long stem.

Take care to ensure that winter squash stems are not damaged or broken off during harvest.

Generally, growers wait at least 2-3 days after harvest to allow time for the stem to cure. When moving, windrowing, or loading the fruits, do not grasp the stem to avoid breaking it off. Fruits can be windrowed and stacked like the winter squash before loading out of the field. Avoid storage in the open to minimize sunburn damage and fruit softening.

Postharvest Handling and Storage

The optimal storage conditions for cucumbers is 50-55 °F and summer squash is 45-50 °F at 80-90% relative humidity . Cucumbers and summer squash stored at these conditions generally keep for 7-10 days before fruit shriveling, yellowing, or decay occurs. Storage

Pumpkins are ready for harvest when they are fully colored, normal in size, and when the rind has hardened.

or transit temperatures should be kept above 45° F to minimize chilling injury which takes as little as 2-3 days to occur. Chilling injury symptoms are water-soaked areas, fruit wall pitting, fruit color changes, and accelerated decay. Chilling injury may be initiated in the field prior to harvest, and then gets progressively worse during storage. Cucumber and summer squash varieties vary considerably in their susceptibility to chilling injury.

The optimal storage conditions for winter squash and pumpkins are 50-60 °F at 50-70% relative humidity. All cucurbits are sensitive to chilling injury when exposed to or stored at low temperatures (<45 °F). For long-term storage of winter squash, maintain temperatures near 55 °F and relative humidity of 60% with good ventilation. Green skinned winter squash types (acorns, buttercups, or kabocha) tend to loose rind color (de-green) when stored at warmer temperatures and higher relative humidity. If pumpkins are stored in a well ventilated, shaded area, fruits will hold for 3-5 weeks even under the colder temperatures experienced in early-mid October. For fruits intended for long-term storage into the winter, first warm the fruits to condition them, then store near the minimum for the type.

For more detail on storage, handling and ripening techniques of the different cucurbits, refer to the specific produce fact sheets available through the UC Davis Postharvest Technology website: http://postharvest.ucdavis.edu. These fact sheets are comprehensive guides to maintaining postharvest quality of the specific crop of interest.

Weed Management

The cucurbits prefer warm weather conditions to ensure high productivity. Many growers transplant early cucumbers and summer squash or seed cucumber, squash and pumpkins into bare soil and rely on furrow irrigation. Weed control is critical in bare soil systems as weeds in the planted row and furrow are difficult to manage and often compete with the crop before the plants are large enough to shade out weeds. Weeds in and between the rows are typically controlled with cultivation, hand hoeing, herbicides, or a combination of approaches. More growers are planting through plastic mulches to improve early growth and reduce in-row weed pressure associated

with bare soil conditions. Some herbicides can be applied underneath the mulch but it is those weeds growing along the edge of the plastic that are difficult to control with cultivation equipment. Directed or shielded herbicide applications on bed edges helps with weed control but use caution as spray drift and residual herbicides left on the plastic may affect crop growth.

In organic production systems, mulches (such as straw, cardboard, etc.) can provide good weed control in and between rows if applied in a thick mat before weeds emerge. There are OMRI approved organic herbicides that can assist in weed management in organic operations. These herbicides are non-selective, contact herbicides, and must be applied to green tissue. Most organic herbicides have limited residual activity so use a combination of controls like tillage, hoeing, and mulches in addition to herbicides.

Due to space limitations and the large list of chemicals available for weed management, it is not possible to include every comment and suggestion relative to a specific herbicide. It is the grower's responsibility to have a current chemical applicators license, to obtain a copy of the label, and read it carefully. Many herbicides are manufactured by many companies under different trade names. We have provided the chemical name (active ingredient) along with one representative trade name in this publication. Growers should compare costs of different brands having the same active ingredient. Herbicide and pesticide labels change, so growers must always consult a current label to determine 1) is a crop listed for herbicide use, 2) what precautions in use are required, and 3) what rates and application methods are allowed. Follow the precautions stated on the label. It is a violation of federal law to use any herbicides for purposes other than those specified on the approved label. Off-label applications are hazardous to the environment, to people using the product, and can severely injure the crop.

Use herbicides only on the crops for which they are approved and recommended on the label. Some herbicides can be used only on specific cucurbits and off-label use will injure other crops. Use the recommended amount of product and apply it as stated. Pay attention to re-entry intervals (REI) and pre-harvest intervals (PHI). Over-application wastes money and violates the law. Too much material may damage the crop and make it unsafe for consumption. The EPA has the authority to seize any agricultural commodity that carries a pesticide residue in excess of the established tolerance. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

Finally, 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. Don't spray in high wind conditions so drift injury to susceptible crops is minimized. Work with your neighbors as many herbicides are toxic to other crops that are growing nearby. Finally, herbicides are just one tool available for weed control and their use should supplement other good weed-management practices.

Herbicides are applied in the following ways:

- **Pre-transplanting:** incorporated into the soil prior to transplanting the crop.
- **Pre-emergence:** applied to the soil after planting but before the crop or weeds emerge.
- **Post-transplant - directed:** applied to the soil after the crop is transplanted either before weeds emerge or after clean cultivation. In some cases, sprays are directed to row middles and shielded from application to the crop.
- **Post-emergence:** applied to weeds after both weeds and the crop have emerged.

Insect and Mite Pest Management

Aphids

Order Hemiptera: Family Aphididae

GENERAL CUCURBIT APHID INFORMATION:

Aphids do not generally attack cucurbits until the vines form runners.

Green Peach Aphid (*Myzus persicae*)

Adult: Soft, pear-shaped body with red eyes and tailpipe-like appendages called cornicles on the rear of the body. Wingless adults are yellowish or greenish. The winged adult has a yellow-green abdomen, with a large dark patch on its back. It has a black head and thorax and is the same size as the wingless form. The oviparous (egg-laying) form is pinkish (Fig. 5.1).

Egg: Initially yellow or green and become shiny-black as they mature. Eggs measure about 0.02 inches (0.50 mm) long and 0.01 inches (0.25 mm) wide. Eggs are usually deposited near buds of *Prunus* spp. trees.

Nymph: Similar in shape and color to the wingless adult, but are smaller. Nymphs that develop into winged adults may be pinkish.

Melon Aphid (*Aphis gossypii*)

DESCRIPTION:

Adult: Soft-bodied, pear-shaped with dark cornicles. Melon aphid adults are smaller and have shorter appendages than the green peach aphid. Winged adults are about 0.05 inches (1.25 mm) long with yellow to dark green bodies. They have a black head and thorax. Wingless adults are about 0.04 to 0.06 inches (1 to 1.5 mm) long with yellow to dark green bodies.

Egg: Yellow when first deposited, turning shiny black when mature.

Nymph: Resemble adults but are smaller in size, about 0.02 to 0.04 inches (0.5 to 1.0 mm) long.

Potato Aphid (*Macrosiphum euphorbiae*)

DESCRIPTION:

Adult: Larger than the green peach and melon aphids, 0.08-0.16 inch (2-4 mm) long with pink or green bodies (Fig. 5.2).

Egg: Similar to green peach and melon aphid eggs.

Nymph: Similar color and shape as adults, but smaller.

LIFE HISTORY:

The *green peach aphid* overwinters as eggs at the base of buds in peach/nectarine trees, the *melon aphid* overwinters on a variety of woody plants and weeds, and the *potato aphid* overwinters principally on wild and cultivated rose plants and is generally, more common in vegetable crops in the spring and fall. *Green peach aphid* and *melon aphid* populations peak on vegetable crops during July and early August.

DAMAGE:

One of the major concerns of aphids is their ability to transmit plant viruses. Over one hundred different viruses can be transmitted by adults as well as nymphs. Both persistent viruses, which move through the feeding secretions of the aphid, and non-persistent viruses, which are only temporary contaminants of aphid mouthparts, are effectively transmitted by aphids. *Green peach aphids* cause damage by transmitting plant viruses, including Cucumber mosaic virus and Watermelon mosaic virus (see pg. 80 for more information on Watermelon mosaic virus). The *melon aphid* is one of the chief agents in transmitting Cucumber mosaic virus and the *potato aphid* may act as a vector for this virus.

Cultural:

- *Avoid excess fertilization.* Aphid densities tend to be higher on plants that have an excess of nitrogen fertility.
- *Use mulches or row covers.* Metallized/reflective mulches and row covers can help reduce aphid populations on vegetables by interfering with the ability of winged aphids to find plants.
- *Don't plant vegetable crops near overwintering hosts* such as peach or nectarine trees.
- *Remove/destroy plant debris.* Disking fields immediately after harvest will destroy alternate host plants and reduce available aphid and virus sources.
- *Maintain healthy, vigorous plants.* They are more tolerant to attack by aphids.
- *Plant susceptible crops upwind.* Planting upwind from infested plants decreases aphid migration into the crop since aphids are blown downwind.

Chemical:

Many aphids have developed resistance to a number of different insecticides, including some synthetic pyrethroids, carbamates, and organophosphates. Additionally, when selecting insecticides, choose those that are less damaging to natural enemies of aphids and other insects in the crop.

Biological:

Natural enemies include lady beetles, lacewings, syrphid flies, and parasitic wasps. These play a major role in the natural suppression of aphids.

Cucumber Beetles

Order Coleoptera: Family Chrysomelidae

Spotted Cucumber Beetle (Diabrotica undecimpunctata)

Striped Cucumber Beetle (Acalymma trivittatum)

DESCRIPTION:

Adult: *Spotted cucumber beetle*: About 1/3 inch (8-9 mm) long with a black head, yellow prothorax (segment behind head), and 12 black spots on yellowish green wings (Fig. 5.3) with black legs and black antennae. *Striped cucumber beetle*: About 1/3 inch (8-9 mm) long with a black head, yellow prothorax, and alternating yellow and black stripes on yellow wings (Fig. 5.4).

Egg: Oval shaped, with yellow to orange coloring (Fig. 5.5). Eggs are laid near or at the base of cucurbit plants in groups of 200-1,200 and need soil moisture to survive.

Larva: About 1/3-1/2 inch (8-13 mm) long with a wormlike, white to yellowish-white body, a brown head, and three pairs of brown legs (Fig. 5.6).

Pupa: About ½ inch (6 mm) long with a white to yellow body. Pupation occurs in the soil.

LIFE HISTORY:

Cucumber beetles overwinter as adults in protected outdoor areas. They become active and start mating at temperatures above 50°F in the spring. Eggs hatch in 7-10 days and larvae take about 15 days to complete development. Pupae live about 7 days before becoming adults. In east central Utah, two summer generations occur.

DAMAGE:

Both adults and larvae of the *striped cucumber beetle* are pests, whereas only the adult stage of the *spotted cucumber beetle* is a pest. This makes the spotted cucumber beetle a less severe pest of cucurbits than the striped cucumber beetle.

Striped cucumber beetle larvae chew on roots, reduce plant stands, and stunt or kill cucurbit plants. Larvae can also feed on fruit rinds that are touching the soil (Fig. 5.7). Smooth-skinned cucurbits such as watermelon, honeydew, crenshaw, and casaba are highly susceptible to damage. Adults of *both species* feed on immature fruit with soft rinds as well as stems, leaves, and flowers (Fig. 5.8). Injured stems can break during high winds, causing reduced plant stands and reduced runners. Both the spotted and striped cucumber beetles are vectors for diseases.

Other hosts of the cucumber beetles include corn, potato, tomato, bean, and ripening fruits.

MONITORING:

- *Monitor by visual scouting.* Newly emerged or transplanted cucurbits should be inspected two or three times per week. Scout the field margins in the early season and if adult beetles are detected, scout random locations in the center of fields.
- *Monitor with traps.* When populations are high, beetles can be monitored with yellow sticky traps.

MANAGEMENT:

Early season management of cucumber beetles is crucial for success. Start monitoring for adult beetles when seedlings emerge or after transplanting, and through the fruiting stage.

Cultural:

- *Choose less susceptible varieties.* Cucumber beetles have lower preference for some varieties of cucurbits, including:
  - *Summer Squash:* 'Yellow Crookneck' (crookneck), 'Peter Pan' (scallop), 'Goldbar', 'Seneca Prolific' (straightneck), 'Slender Gold', 'Sunbar' (yellow)
  - *Winter Squash:* 'Carnival, 'Table Ace' (acorn), and 'Butternut Supreme', 'Zenith' (butternut)
  - *Pumpkin:* 'Baby Pam', 'Jack-Be-Little', 'Jackpot', 'Munchkin', 'Seneca Harvest Moon', 'Tom Fox'

- *Delay planting until late May, after beetles have laid their first generation of eggs.* Because of the short growing season in Utah, this is more practical for cucumber and summer squash crops (although delayed planting would eliminate early harvests).
- *Lure beetles away with trap crops.* Trap crops such as 'Black Sack' or 'Dark Green' zucchini can help lure cucumber beetles away from the main crops, and help to monitor their populations. Physically remove or treat trap crops while beetles are present.
- *Use floating row covers, where practical* to prevent adult beetles from landing on plants in the spring. Remove covers during flowering for pollination.
- *Use plastic or organic mulches and drip irrigation*. Mulches will deter cucumber beetles from laying eggs in the ground near host plant stems. Mulch and targeted irrigation reduces the occurrence of direct contact between fruits and moist soil, and therefore reduces cucumber beetle feeding on fruits.
- *Avoid planting near other host plants and remove weeds.* See the list of hosts above in the damage section.
- *Limit irrigation near harvest.* Using drip irrigation will decrease the chance of crop injury from moisture-loving cucumber beetles during mid- and late-summer.
- *Destroy crop residues with thorough and deep cultivation after harvest.* This will accelerate the decomposition of residues (especially roots and fruits) that may be hosts to overwintering populations of cucumber beetles.
- *In highly infested organic farms, use bug vacuums to remove beetles from trap crops or main crops.*

Chemical:

Combine cultural, mechanical, and biological tactics for long-term management. When using insecticidal sprays, ensure thorough coverage of plants and soil surface so that it contacts the larvae and/or adult beetles. Treatments should target susceptible life stages as follows:

- *Spring: overwintered adults.* Treat before feeding injury is significant and before mating and egg-laying.
- *Late spring and early summer: larvae.* Treat when eggs hatch and before larvae move to plant roots to feed.
- *Mid and late summer: adults and larvae.* Treat high number of adults and larvae to prevent feeding damage to leaves, stems, flowers, and fruits.
- *Early-season control of overwintering adults.* Time insecticides to target the overwintering generation early in the season. This may be less practical in larger cucurbit production fields as adult beetles may migrate from nearby infested fields, despite early-season control.

Biological:

Natural enemies of cucumber beetles include ground beetles, soldier beetles, braconid wasps, tachinid flies, and entomopathogenic nematodes. Nematodes can suppress larvae and pupae in the soil while the others attack adults, eggs, and larvae. Promote beneficial organisms by developing healthy soil, weed, and pest management practices.

Spider Mites

Order Acari: Family Tetranychidae

Twospotted Spider Mite (Tetranychus urticae)

DESCRIPTION:

Adult: Females 0.017 inch (0.4 mm) long and oval; males slightly smaller with tapered hind end. Orange in color during winter and early spring, then turn yellow-green with two dark spots once feeding begins. Adults have red eyes, and as they mature, their bodies turn dark brown and the two dark spots become less distinct (Fig. 5.9).

Egg: Round, 0.02 inch (0.5 mm) in diameter, and translucent to opaque.

Immature Stages: Initially round, translucent to pale green, with three pairs of legs when first hatched, then oval, dark green with black spots on back with four pairs of legs as it matures. Stages include larvae, protonymph, and deutonymph.

LIFE HISTORY:

Adult females take on an orange color in the fall as their metabolism slows. They then spend the winter in protected sites on the ground, such as on crop debris and weeds. In the spring, mites crawl to nearby host plants to feed, and they are able to 'parachute' on air currents attached to a strand of fine silk. Egg-laying begins a few days after feeding starts. The overwintering females can lay 30 to 50 eggs in a 25-day average life span while the summer females can

lay up to 100 to 150 eggs in a 4 to 6-week period. First generation eggs may take 3 weeks to hatch, depending on temperatures, while egg hatch in the summer may take only 1 to 2 days. A single generation may be completed in as few as 10 to 14 days during the hot summer periods. Eight or more generations occur each year.

DAMAGE:

Spider mite feeding causes fine stippling (small spots) on the upper surface of leaves; leaves can become bronzed and turn brown when injury is severe. Mites produce silk webbing on the undersides of leaves causing a grayish hue in their color. Damage may also cause wilting, deformed leaves, leaf drop, and leaf and stem death.

MANAGEMENT:

Cultural:

- *Keep plants healthy and unstressed, especially by drought.* Unhealthy or drought-stressed plants are more susceptible to mite populations and damage.
- *Avoid using broad-spectrum insecticides and miticides which kill beneficial insects and predatory mites.* Green lacewings, predatory mites, and ladybugs help control spider mite populations.
- *Avoid applications of malathion and pyrethroid insecticides for squash and pumpkin insect pests, such as squash bug.* These insecticides are known to stimulate mite feeding and reproduction (hormoligosis).
- *Use a strong stream of water from a hose-end nozzle to physically wash mites off of infested plants.* Direct a stiff spray of water to the undersides of leaves and the lower portions of plants.
- *Use a slow-release nitrogen fertilizer when possible* as high nitrogen levels in foliage encourage spider mite reproduction.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of California *Spider Mites* Web Page
- Utah Pests Fact Sheet *Web Spinning Spider Mites*

Squash Bug

Order Hemiptera: Family Coreidae

DESCRIPTION:

Adult: About 5/8 inch long and about 1/3 as wide. Wings are folded over a flat back, and the body is brown to gray with orange and brown stripes along the edges of the abdomen and underside (Fig. 5.10).

Egg: Clusters of 15 to 40, shiny bronze to red eggs located on the undersides of leaves starting in mid-spring (Fig. 5.11).

Nymph: Five instars ranging from 3/16 to ½ inch long. The 1st instar has a red head, antennae and legs with whitish to greenish gray bodies. The 2nd and 3rd instars have black appendages and greenish gray bodies (Fig. 5.12). The 4th and 5th instars develop wing pads and begin to resemble adults.

LIFE HISTORY:

Squash bugs overwinter as adults in protected sites around building foundations and under plant debris or compost piles. In southern Utah, they usually emerge in April, and in northern Utah they generally emerge in May. After emerging, adults will fly to host plants to feed, mate, and lay eggs. The new generation of adults show up in June to July in northern Utah and 3 to 4 weeks earlier in southern Utah. There is one generation per year in Northern Utah and a partial second generation is possible in southern Utah.

DAMAGE:

Injury occurs on the leaves, vines, and fruits of cucurbit plants. Squash bugs feed with piercing-sucking mouthparts, which results in speckled leaves that lose nutrients and eventually turn yellow and then brown (Fig. 5.13). Heavy feeding along leaf and plant stems causes wilting. Feeding on fruits can cause scars and death of young fruit and sunken areas that reduce marketability. Fruit feeding can also increase the chance of fruit rot during storage.

Susceptible host plants include all cucurbits, but pumpkin and squash are the most attractive.

MONITORING:

Monitor in the spring for squash bug adults under plant debris, perennial plants, or near buildings. Look daily for eggs under leaves and watch for plant wilt. Place wooden boards in susceptible areas. Lift them up every morning and destroy existing eggs and adults.

MANAGEMENT:

Cultural:

- *Sanitation.* Remove or till under plant debris at the end of the season and keep fields free of trash or

wood that could provide overwintering sites.

- *Hand-picking.* Physically remove adults and nymphs by hand. Kill/remove egg clusters by squashing, tearing out the leaf section, covering in petroleum jelly, or using duct or packaging tape to "peel" them off. Begin physical removal early in the season and continue every 2 to 3 days to keep population numbers low. This may be more practical for home gardens, or small commercial or organic fields.
- *Trellising.* Trellising vining types of squash and melons can make them less accessible to squash bugs as the bugs prefer to hide under vines and leaves near the soil.
- *Resistant varieties.* Although there are no cucurbit varieties that are immune to squash bugs, there are some that have lower susceptibility or relative resistance compared to other varieties. Some variety susceptibilities are as follows: Butternut and Royal Acorn (resistant); Sweet Cheese and Green Striped Cushaw (moderately resistant); Pink Banana and Black Zucchini (susceptible); and Yellow Straightneck, Yellow Crookneck, and Hubbard Pumpkin (highly susceptible and attractive).
- *Trap crops.* Along the borders of the field or planting area, plant cucurbit cultivars that will attract overwintering adult squash bugs. Once adults have been lured to the trap crops, apply an insecticide or mechanically destroy the trap crop before eggs begin to hatch. This will reduce squash bug populations that would later attack the main crop. Yellow straightneck and crookneck have been found to be preferred by squash bugs for egg laying as compared to acorn, zucchini, butternut, and spaghetti squash.
- *Crop rotation.* To avoid overwintering adult squash bugs, rotate to non-cucurbit crops in alternating years.
- *Mulches.* Mulches can harbor squash bugs but may also have benefits such as suppressing weeds, reducing soil moisture loss, and attracting beneficial insects. When used in combination with other cultural practices such as row covers, the benefits of mulches may outweigh the negatives.

Chemical:

Insecticides should be applied shortly after egg hatch, as they work best on nymphs. Sprays must penetrate the plant canopy and thoroughly cover the top and undersides of leaves, fruits, and vines in order to be effective. Sprays will dry more slowly and result in better coverage of vegetation when applied in the early morning or late evening. When plants are blossoming, don't spray during the day to avoid harming pollinators.

Biological:

Natural enemies of squash bugs include several species of parasitic wasps and the tachinid (parasitic) fly *Trichopoda pennipes* (Figs. 5.14 and 5.15), which is squash bug-specific. Although there are predators of squash bugs, predation tends to be low because noxious odors that repel predators are released when squash bugs are attacked.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Utah Pests Fact Sheet Squash Bug
- University of Minnesota Squash Bugs
- UC Davis IPM Squash Bugs

Disease Management

For cucurbit diseases and their management information, see pg. 79-80.

For commercial and home use fungicides for cucurbit diseases see pg. 85 and 87, respectively.

Pest Management Tables for Commercial and Home Use

Table 5.4. Herbicides registered for **COMMERCIAL** use on **Cucumber, Pumpkin, and Squash** in Utah.

Brand Name (REI/PHI)	Active Ingredient	Timing and Application Location Relative to Crop				Timing Relative to Weeds		Weed Groups Controlled			Comments
		Before Transplanting	Pre-emergence	Post transplanting directed, shielded	Post-emerge	Pre-emergence	Post-emergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X		X			X		X	X	
Command 3ME (12hr/45d)	clomazone	X	X			X		X	X	X	Do not apply to pumpkins
Curbit 3EC (12hr/-)	ethalfuralin		X	X	X	X		X	X		Check label for specific uses.
Dual Magnum (12h/30d)	s-metolachlor	X	X	X		X		X	X		Pumpkins only, Between rows
Gramaxone Inteon (12hr/30d)	paraquat	X	X	X			X	X	X	X	Restricted use product
Poast (12hr/14-20d)	sethoxydim				X		X	X			
Prefar 4E (12hr/-)	bensulide	X	X			X		X			
Prism & others (12hr/20d)	clethodim	X	X	X	X		X		X	X	
RoundUp & others (12hr/14d)	glyphosate	X	X	X			X	X	X	X	
Sandea & others (12hr/30d)	halosulfuron	X	X	X	X	X	X		X	X	Check label for specific uses.
Strategy (12hr/30 or 45d)	ethalfluralin + clomazone		X	X		X		X	X		
Treflan & others (12hr/30d)	trifluralin			X		X		X	X		
Organic Products											
Corn Gluten Meal		X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 5.5. Insecticides registered for **COMMERCIAL** use on **Cucumber, Pumpkin, Summer Squash, & Winter Squash** in Utah, Organized by Mode of Action (MoA). For treatment on other cucurbits, always check the label.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Squash Bug	Spider Mites
carbaryl	Carbaryl, Sevin	1A	7-14		X	X	
methomyl (not winter squash, not pumpkin)	Lannate[R], Nudrin[R]	1A	5	X	X		
oxamyl	Vydate[R]	1A	5-7	X			
malathion (check label for pumpkin)	Cheminova, Fyfanon, Malathion	1B	5-7	X	See label		See label
chlorpyrifos + bifenthrin	Tundra[R]	1B/3A	10	X	X	X	X
alpha-cypermethrin	Fastac[R]	3A	10-14	X	X	X	
beta-cyfluthrin	Baythroid[R]	3A	14		X		
bifenthrin	Bifenture[R], Brigade[R], Fanfare[R]	3A	14	X	X	X	X
bifenthrin + zeta-cypermethrin	Hero[R], Steed[R]	3A	3	X	X	X	See label
cyfluthrin	Tombstone[R]	3A	10-14		X		
deltamethrin	Delta Gold[R]	3A	10-14	X	X		
esfenvalerate	Asana[R], S-fenvalostar[R]	3A	14		X	X	
fenpropathrin	Danitol[R]	3A	10-14	X	X	X	See label
gamma-cyhalothrin	Declare[R]	3A	10-14	X	X	X	X
lambda-cyhalothrin	Lambda[R], Paradigm[R], Province[R], Silencer[R], Warrior[R]	3A	10-14	X	X	X	X
permethrin	Ambush[R], Arctic[R], Perm-Up[R], PermaStar[R], Pounce[R]	3A	14	X	X	X	
pyrethrins	Pyganic[OB]	3A	3-5	X	X	X	X
pyrethrins + piperonyl butoxide	Evergreen[B]	3A	3-5	X	X		
zeta-cypermethrin	Mustang[R]	3A	10-14	X	X	X	
lambda-cyhalothrin + thiamethoxam	Endigo[R]	3A/4A	10-14	X	X	X	X
bifenthrin + avermectin	Athena[R]	3A/6	10-14	X	X	X	X
zeta-cypermethrin + avermectin	Gladiator[R]	3A/6	10-14	X	X	X	X
lambda-cyhalothrin + chlorantraniliprole	Voliam Xpress[R]	3A/28	10-14	X	X	X	
pyrethrins + azadirachtin	Azera[OB]	3A/UN	4-7	X	X	X	X
acetamiprid	Assail	4A	14	X	X	X	
clothianidin	Belay	4A	14	X	X	X	
dinotefuran	Scorpion, Venom	4A	14	X	X	X	
imidacloprid	Admire Pro, Couraze	4A	5	X	X		

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 5.5, continued. Insecticides registered for **COMMERCIAL** use on **Cucumber, Pumpkin, Summer Squash, & Winter Squash** in Utah, Organized by Mode of Action (MoA). For treatment on other cucurbits, always check the label.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Squash Bug	Spider Mites
thiamethoxam	Actara, Cruiser, Flagship,	4A	10-14	X	X		
thiamethoxam + chlorantraniliprole	Durivo, Voliam Flexi	4A/28	14	X	X		
abamectin	Abacus[R], Abba[R], Agri-Mek[R], Reaper[R], Zoro[R]	6	14-21				X
pymetrozine	Fulfill	9B	7-10	X			
flonicamid	Beleaf	9C	14	X			
Etoxazole	Zeal		14				X
novaluron	Rimon	15	7		X	X	
spiromesifen	Oberon	23	14				X
cyantraniliprole	Exirel, Verimark	28	14	X			
azadirachtin	Aza-Direct[OB], Azatin[OB]	UN	7-10	X	X	X	
Beauveria bassiana	BotaniGard[B]	---	5-7	X	X		X
Chromobacterium subtsugae strain PRAA4-I and spent fermentation media	Grandevo[OB]	---	5-7	X			X
kaolin	Surround[O]	---	5-7		X		
oil: capsicum oleoresin extract, clove, cottonseed, soybean, garlic, mineral, paraffinic, peppermint, rosemary (check label for pumpkin)	Captiva, Ecotec[OB], GC-Mite[OB], JMS Stylet-oil[B], Pest Out[OB], PureSpray Green[OB], Suffoil-X[OB]	---	none	See label	See label		X
potassium salts of fatty acids (not winter squash)	M-Pede	---	3	X			X
sodium tetraborohydrate decahydrate	Prev-AM	---	7-10	X			X
sucrose octanoate (not winter squash)	SucraShield	---		X			X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on cucurbit crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

Protection of Pollinators: Look for the "bee-box" or "bee hazard icon" on product labels and read the restricitions and instructions to protect bees and other insect pollinators. Bees and other pollinators will forage on plants when they flower, shed pollen, or produce nectar. Follow these steps when using products that are hazardous to bees: 1) minimize exposure of the product to bees and pollinators when they are foraging on pollinator attractive plants around the application site 2) Minimize drift of the product on to beehives or to off-site pollinator attractive habitat as drift into these areas will kill bees.

Warning: Applications of imidacloprid and clothianidin are restricted to post-bloom and only when bees are not active in the site, including on weeds and non-crop plants.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 5.6. Insecticides registered for **HOME** use on **Cucumber, Pumpkin, Summer Squash, & Winter Squash** in Utah, Organized by Mode of Action (MoA). For treatment on other cucurbits, always check the label.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Squash Bug	Spider Mites
carbaryl	Garden Tech Sevin	1A	14		X	X	
malathion	Spectracide Malathion, Ortho Malathion	1B	7	X	See label		
bifenthrin	Fertilome Broad Spectrum Insecticide	3	14	X			
cyfluthrin	Bayer Vegetable & Garden Insect Spray	3	14		X		
deltamethrin	Green Light Many Purpose Dust	3	14	X	X		
pyrethrins	Monterey Bug Buster-O[OB], Garden Tech Worry Free[B]	3	5	X	X	X	See label
pyrethrins + canola oil	Earth-tone Insect Control, Monterey Take Down Garden Spray	3/	5	X	See label		X
pyrethrins + potassium salts of fatty acids (insecticidal soap)	Safer Brand Tomato & Vegetable Insect Killer[OB], Safer Brand Yard & Garden Insect Killer[OB]	3/	5	X	X		See label
pyrethrins + sulfur	Bonide Tomato and Vegetable 3 in 1[B], Natria Insect Disease & Mite Control[B], Ortho Insect Mite & Disease 3 in 1[B]	3/M2	5	X	X	See label	X
acetamiprid	Ortho Flower, Fruit & Vegetable	4A	14	X	X	X	
oil: canola, neem, rosemary, clove, cottonseed	Bayer Natria Multi-insect[B], Monterey All Natural 3 in 1 Garden Insect Spray[B]	---	1	X			X
potassium salts of fatty acids (insecticidal soap)	Natria[B]	---	1	x			X

[B]= Biopesticide
[O]= Organic
(+)= One application per year

Fig. 5.1. Green peach aphid adult.

Fig. 5.2. Potato aphids on tomato leaves late in the season.

Fig. 5.3. Adult spotted cucumber beetles have yellowish green wings and black spots.

Fig. 5.4. Adult striped cucumber beetles have yellow wings with black stripes.

Fig. 5.5. Cucumber beetle eggs are very small and yellow to orange in color.

Fig. 5.6. Cucumber beetle larvae have white to yellow worm-like bodies with a brown head.

Fig. 5.7. Cucumber beetle larval damage on a melon fruit.

Fig. 5.8. Cucumber beetle adult damage on a melon fruit.

Fig. 5.9. Twospotted spider mite.

Fig. 5.10. Squash bug adult on a zucchini plant.

Fig. 5.11. Squash bug eggs are shiny bronze to red eggs laid in clusters of about 15-40 on host leaves.

Fig. 5.12. A squash bug nymph on the underside of a leaf.

Fig. 5.13. Squash bug feeding can cause host leaves to dieback, turning yellow and then brown.

Fig. 5.14. *Trichopoda pennipes* is a squash bug-specific tachinid (parasitic) fly.

Fig. 5.15. Squash bug (right) parasitized by *Trichopoda pennipes*; note the fly's cream-colored egg (on the squash bug body) and dark pupal case (left).

CHAPTER 6 MELON PRODUCTION

Varietal Selection

Selection of melon varieties can be challenging given the large number of choices available. Some of those things that influence production like the length of growing season, soil type, climate conditions, and production practices are unique to a farm's location. Very little testing of melons has been done in Utah due to lack of time or resources to evaluate varieties in the different regions where melons are produced. To further complicate matters, there are hundreds of different varieties available for purchase. We recommend that you regularly test new varieties and compare them to what you already grow. On-farm testing is the best way to identify varieties that are most suited to your farm's local and unique conditions.

Most varieties will grow and produce fruits in Utah but not all may be suited to your location. When selecting a new variety, evaluate it based on fruit size, earliness, soluble solids (sweetness), vine growth habit, and disease resistance. Vigorous vine growth helps produce sufficient leaf cover to minimize sunburn but excessive vine production may limit productivity. If viruses and fungal diseases have been problems, look for resistant varieties. Heirloom varieties are popular but lack disease resistance and are more prone to cosmetic defects.

If certain diseases have been a problem or you are replanting melon sites with melons, you may want to select hybrid varieties with some disease resistance characteristics. Not all varieties carry disease resistance or some have partial resistance to selected diseases. Always check with the seed supplier or reference their seed catalog for a full list of varieties and disease resistance packages or talk to your seed salesperson about unique needs and issues.

Table 6.1. **Variety Suggestions** – Cantaloupe, Honeydew, Specialty Melons, and Watermelons

Fruit Types	Varieties
Cantaloupe	Trinity, Edisto Star, Yuma Grande, Top Net, Anita, Sweet East, Western Charm, Olympic Express, Olympic Gold, Western Express, El Camino, Primo, Torreon, Coronado, USAM90000
Honeydew Melons	Precious Dew, Dewlightful, #252 HQ, Moon Dew, Honeybrew, Snow Mass, USAMX 23000, USAMX 63001, Dulce Nectar
Casaba-Crenshaw-Specialty Melons	Juan Coronel, Ananas Hyb EM815, EM850 Galia F1, Casaba Golden Beauty, Tamara, Visa, Lilly
WATERMELONS	
Seeded (Diploid) – Open Pollinated	Crimson Sweet, Jubilee, Sugar Baby, All Sweet, Cal Sweet, Charleston Grey
Seeded (Diploid) – Hybrid	Sentinel, Sangria, Mara, Sweet Star, Fantasy, Sweet Fashion, EM Scarlet, Carmen, Starbrite,
Seedless (Triploid) – Red Flesh	Coopertown, Majestic, Fascination, Distinction, Marita, Affirmed, Citation, Millionaire, Ruby, Tiger Eye, Liberty, Freedom
Seedless (Triploid) – Yellow Flesh	Yellow Buttercup
Pollinators	Gladiator, Polimax, Ace, Wild Card, Sidekick, Accomplice

Transplant Production

For areas of Utah with shorter growing seasons, we recommend transplanting early melons. Main-season melons are also seeded for mid- to late-summer production. Very few growers direct-seed triploid watermelon because seeds are expensive and germination and early growth is slow, particularly under cooler soil conditions. Transplants can be started on-farm or purchased.

For starting transplants, sow melon seeds into plastic plug trays with 50, 72, or 128 cells per tray filled with a good soilless mix. Adequate light and temperature management are both essential to produce a quality plant. Greenhouse temperatures should be approximately 75°F during the day and 65°F at night. After approximately 4-5 weeks, melon transplants should have 2-3 mature leaves and a well-developed root system before setting in the field.

Growing seedless watermelon transplants requires a bit more finesse. Since seedless types are less vigorous, slow to germinate, and emerge erratically, early temperature management after seeding helps improve establishment and uniformity. After seeding and

watering the plug trays, expose the seeds to 85-90°F temperature conditions for 36-40 hours, but no longer. You can do this in a dark room with the trays stacked on top of each other, or use heating pads if only a few trays are needed. Move seeds to cooler growing temperatures after emergence. Longer exposure to high temperatures results in elongated hypocotyls which make the plants grow tall and leggy. These seedlings are then difficult to handle and transplant.

Water regularly and feed twice weekly with a soluble complete fertilizer diluted to 100 ppm nitrogen after the seedlings emerge. Brushing the plants each day one week before planting helps strengthen the stem. Brushing should be done when the leaves are dry to minimize disease transfer. Transplants can also be hardened or conditioned by exposing them to wind and cooler temperature to make the plants stocky and strong. Condition or "hardened off" transplants for a short time each day by exposing them to cool temperatures (60-65 °F) starting one week before transplanting.

Soil

Most soils in Utah are suitable for melons provided they are well drained, fertile, and do not have a buildup of salt. The ideal soil is sandy to loamy with a pH of 6.5 to 7.5. A very loose, somewhat dry tilled soil is ideal for transplanting to ensure good soil contact with the transplant root ball. Crop rotation is necessary when growing melons to minimize soil disease buildup. Remember that squash, pumpkins, and cucumbers are related to melons and may transmit or harbor diseases common to all cucurbits. Melons are quite sensitive to herbicides in soil, so pay special attention to site selection if residual herbicides have been used in the past.

Fertility

Prior to planting, have the soil tested to determine nutrient needs and deficiencies. The Utah State University Analytical Laboratories can test the soil, and forms and collection techniques are found at usual.usu.edu. Organic growers should incorporate organic matter before planting to sustain soil fertility. One option is to band or broadcast 5 tons per acre of high quality compost of known nutrient analysis.

A common practice is to broadcast or band ⅓ to ½ of the required nitrogen fertilizer and all the phosphorous and potassium prior to planting. In soils with high P and K levels, broadcasting all of the fertilizer is acceptable. This is done before plowing or disking, then worked into the soil during normal field preparations. Banding is a good method to ensure the fertilizer is near the plant and makes sense for crops like melons, where wide row spacings are common. Fertilizer bands should be 3 inches beside and 3 inches below the seed or transplant to minimize salt injury during establishment. Often transplanted melons have starter fertilizer with high P levels applied at one quarter to one half pint per plant. Starter fertilizer is applied in addition to the fertilizer that was broadcast or banded.

Table 6.2. Phosphorus (P_2O_5) and Potassium (K_2O) based on soil test results.

Phosphorus Test Results	Lb/ acre
0-14	120-150
15-29	90-120
30-45	60-90
46-60	30-60
60+	0

Potassium Test Results	Lb/ acre
0-74	100-150
75-149	50-100
150-199	25-50
200+	0

Use the higher amount when soil test values are in the lower part of the range.

Nitrogen (N) – Up to 50 lbs. per acre can be applied prior to planting. Higher rates of N at planting may cause seed or transplant establishment problems. An additional 50-100 lbs. per acre is often applied in two applications, the first when vines begin to run and again around first flowering. Use the smaller amount if the site has added manure, compost or when melons are grown after a legume crop (beans, alfalfa, etc.).

Seeding and Spacing

Melon planting dates in Utah vary depending local climate conditions. Planting often begins in mid-April in southern Utah and may be as late as early June in cooler areas of northern Utah. Planting is recommended after danger of frost has passed. Local freeze dates can be accessed through the Utah Climate Center (climate.usurf.usu.edu). All melon seeds germinate poorly at soil temperatures below 60°F

(seedless above 70°F) and the most rapid germination is around 90-95°F. Melons grow best when temperatures during the day are 75-85°F and when night temperatures stay above 60°F. Temperatures above 95°F may result in poor plant growth, flower abortion, or fruit set problems.

Plant and row spacings vary with cultivar, equipment, irrigation approach, and market requirements. Typically, in-row plant spacing ranges from 18 to 30 inches apart in irrigated land to 36 to 48 inches apart in dry land. Typical row spacings vary from 6 to 10 feet apart. Higher yields occur with closer spacings but require more nutrient and water management.

Plant seed of open-pollinated varieties at 1-2 pounds of seed per acre at a depth of ½ to 1½ inches (depending on soil moisture, time of year, and irrigation availability). Hybrid seed is much more expensive, so reduce seeding rates by modifying planters to only plant one seed at the desired in-row spacing. Once seedlings have emerged and have 1-2 leaves, thin stands back to the desired in-row spacing.

Transplanting

Melons can be transplanted in bare soil or through plastic mulch. Transplants are used for early production, when market prices are high, and to decrease seed costs for expensive hybrid or seedless melons. It is best to use high quality, uniform, clean plants. Transplant size is critical to establishment and plants should have no more than three leaves at planting. Plants should be handled and planted carefully, as melons are sensitive to transplant shock. Root replacement in melons is slow, so don't crush the root ball. Plants can be hand or machine planted. Water the plants before and after planting. Starter fertilizers with high phosphorus concentrations helps to stimulate root re-growth. Newly transplanted fields should be watched closely and watered if needed. This ensures good root growth out of the root ball and uniform plant growth.

To produce seedless watermelon, it is important to understand that triploid (seedless) watermelon flowers do not produce enough pollen to adequately pollinate themselves. Therefore, another source of pollen must be available to achieve acceptable levels of fruit set. A diploid (seeded) cultivar planted within the crop can serve as the pollenizer (see Table 6.1).

Research suggests that 25-33% of the plants in the field should be diploid (seeded) to produce enough pollen for good fruit set in the seedless crop. You can accomplish this by planting the pollenizer between every third and fourth triploid plant within the row. First plant your seedless crop at your normal in-row spacing, then come back and plant the pollinizer periodically down the row. By planting the pollinators in-row rather than having a dedicated pollen row in the field, you increase the number of triploid plants and the yield of seedless watermelons harvested per acre. These pollenizer cultivars commonly have non-marketable fruits, may be all male plants (pollen producing only), or may produce mini- or palm-sized fruits. If you have a market for the seeded fruits, make sure the seeded and seedless watermelons look different from each other at harvest so they are not mixed before going to market.

Irrigation

Melons require regular, uniform watering during the growing season. Water shortages early in the season can limit seed germination, transplant establishment, and vine growth. Inconsistent watering around fruit set can cause misshapen fruits and induce blossom end rot, and affect fruit sizing, flavor, and color development. Over-watering encourages root rots, belly rot on fruits, and can cause cracking. Furrow and drip irrigation is well-suited for melon production and some growers use sprinkler irrigation to aid in stand establishment. Later in the growth of melons, sprinkler irrigation (solid set, wheel lines, and center pivots) can contribute to foliar diseases and may interfere with bee activity, thus reducing fruit set, shape, or size. A small decrease in water after fruits reach mature size can improve fruit quality and flavor.

Soil water status should be monitored regularly to maintain consistent soil water. Soil moisture monitoring is easily done with a resistance block such as the Irrometer Watermark sensor. Place sensors at various locations in the field and at several depths in the soil profile to get accurate measurements. Sensors typically express soil water content as a tension reading (centibars) that defines effort required to access available water. Soil texture (clay, loam, sand) influences the soil's ability to hold water. Soil water

monitoring is useful in helping to determine when to irrigate. Field capacity describes a soil at 100% available water-holding capacity after excess water has drained away. Start irrigation for melons at 20-25% when irrigating with drip systems and at 40-50% with furrow or sprinkler systems. Note that irrigation depends on soil type. Other low cost tools and methods to monitor soil water can be found at attra.ncat.org.

Table 6.3. Soil tension values for different soil textures for use in scheduling drip irrigation, based on various percentages of depletion of available water holding capacity.

Soil Texture	0%	20-25%	35-45%
	Soil Tension Values (in centibars)		
Sand, loamy sand	5-10	17-22	25-30
Sandy loam	10-20	22-27	33-40
Loam, silt loam	15-25	25-30	40-50
Clay loam, clay	20-40	35-45	55-65

Ground Mulch and Row Covers

Plastic ground mulches are highly recommended for melons as they improve early-season soil temperatures, help control weeds, and conserve water. Plastic mulch raises soil temperatures by 10 degrees in spring which promotes rapid seed germination, better transplant establishment, and contributes to an earlier harvest. In order for plastic to raise the soil temperature, there must be good contact between the plastic and the soil. Commonly used plastics are embossed black (cheapest) and newer IRT (infrared-transmitting) films (more expensive) but they provide more soil warming with similar weed control. These films may be cost-effective where soil warming is important. Clear plastic can be used but weed growth under the plastic creates problems. In very warm areas of southern Utah, white plastic helps to reduce soil temperature, particularly when planting in late spring or early summer.

Plastic mulches are laid down by machine prior to planting. Commonly used mulch widths are 3 or 4 feet wide, creating a 2- or 3-foot area of cover. Matching the plastic to the laying machine creates the fewest problems during installation. It should be stretched tightly over the bed and have a good seal at the edges.

Hot caps (top), spun-bonded row covers (center) and plastic row covers (bottom).

This ensures that the wind cannot dislodge the plastic and pull it out of the ground. Be sure to install the drip tape under the plastic at the same time the mulch is laid down. Then at planting, holes can be created with a punch transplanter, by hand with a trowel or planting tool, or with a heated hole cutter.

Row covers (Reemay or plastic) help protect transplants from frost, reduce wind damage to young plants, and enhance yield and earliness. It can rest directly on top of plants, but should be weighted down to avoid flapping which causes leaf damage. Plastic row covers trap more heat during the day than spun-bonded covers, enhancing plant growth and earliness. However, the temperature under the plastic row covers increases quickly and should be monitored closely. Perforated plastics are available to provide some ventilation while retaining heat. Plastic covers should be supported by heavy wire or other support to keep plastic from contacting plants. Spun-bonded and plastic row covers should be opened or removed as plants outgrow the cover, when the plants begin to flower, or when temperatures under the cover regularly exceed 90°F.

Pollination

Optimal fruit yields are achieved when flowers are properly pollinated. Melons require at least one hive per acre and each flower requires approximately 10-15 bee visits to ensure good fruit set and sizing. Be sure hives are distributed around the field and put hives out just before plants start flowering. Keep hives in place for 2-3 weeks and use pesticides with caution during flowering to minimize bee exposure.

Windbreaks

Windy conditions, particularly in early spring can slow early plant growth, reduce plant stands and increase the days to harvest. Windbreaks are very effective way to reduce wind exposure and protect plants from blowing soil or stem twisting. Commonly used windbreaks are fall-planted small grains (wheat, triticale). Spring planted (oats, barley) windbreaks are less effective as they do not grow to sufficient height to protect plants. Utah growers using windbreaks often plant 3-6 rows of melons between windbreak strips. Others plant the drive rows for harvest with the windbreak. Windbreaks can be killed mechanically (mowed, disked), treated with an appropriate herbicide, or left in place.

Harvest and Handling

Melon yields vary depending on plant spacing, production methods (use of plastics, row covers, irrigation system), and variety. Average yield ranges from 15 to 30 tons/acre. Harvest and handling procedures vary with the type of crop grown and possibly with the intended market. Growers need to carefully supervise and train picking crews to prevent losses from improper harvesting (under/over ripe) and poor crop handling techniques.

Watermelon

Watermelons mature five to six weeks after pollination (cultivar and temperature dependent). The indicators of watermelon maturity are rind sheen, strong color differentiation between the stripes, creamy yellow color of the ground spot, and drying of the tendril nearest the fruit. Thumping is less effective, but a dull or muffled sound can indicate over-maturity. Ideally, it is best to cut a few melons in various parts of the field and compare these to other maturity indicators. A refractometer can help determine fruit sugar content and the BRIX values measured should be above 10. Harvesting and marketing under or over-mature fruits can hurt consumer interest and demand. Fruit sugar content does not increase after harvest but red color does continue to develop after picking. Fields are often harvested over a period of 2 to 3 weeks and may be picked once or twice a week.

An indicator for watermelon harvest is the drying if the tendril nearest the fruit.

To harvest watermelons, cut fruit from the vine, leaving some stem on the fruit. Watermelons should not be stood on end as flesh separation (hollow heart) can occur. Also, do not expose the ground spot to the sun to reduce sunburn. Over-stacking fruit piles can lead to bruising and compression injury both in the field and in storage. It is common to create small stacks of fruit in the field at harvest then to come later and load these into bins, trailers, or trucks. Typically, fruit are bulk loaded into 1000-pound cardboard boxes as these are easier to handle during loading, transport, and unloading. Few watermelons are graded here in Utah though specific markets may request some fruit sizing for their customers.

Cantaloupe, Honeydew, and Others

Harvesting specialty melons like cantaloupe and honeydews is very labor intensive. Melons need to be picked every few days and fields may be harvested over a period of 2 to 3 weeks. Length of harvest depends on vine quality, number of fruits, variety, and market demands. Fruit maturity takes four to six weeks after pollination depending on type, temperature, and season.

Cantaloupe are ready for market when fruits are at "half-slip", well-netted, and of appropriate color for the variety. Half-slip is when the abscission zone between the stem and the fruit is partially formed and it takes a slight pull to separate the fruit from the vine. Cantaloupe harvested at half-slip allows sufficient time from harvest to market so that fruits do not arrive over-ripe. Typically, fruit are loaded into 1000-pound cardboard boxes for transport to markets.

An indicator for cantaloupe harvest is when fruits are well-netted.

Honeydew melons are cut from the vine at maturity. Honeydews are ripe and ready for market when plants have achieved normal size, when the ground spot turns a creamy or a light yellow color, when a waxy "bloom" develops on the rind, when the blossom end softens slightly, and when small micro-cracks form near the blossom end (Fig. 6.1). Honeydews do not form an abscission zone where the stem and fruit meet so other maturity indicators are necessary.

Casaba, Crenshaw, and other specialty melons are cut from the vine at maturity. These melons are ripe when the skin color changes slightly from green to yellow and the blossom end of the fruit is slightly soft when pressure is applied with your thumb (similar to honeydew). Use a refractometer to test fruits for sugar content. Cantaloupe and specialty melons with BRIX values above 12 have sufficient sugar to meet market requirements. With all melons, cooling prior to shipping extends marketability, increases the time for the melons to reach maturity, and extends shelf life.

Postharvest Care

Most melons have a relatively short storage life. Larger growers may have refrigerated storage facilities but smaller producers will only hold fruits for a few days. Post-harvest handling is as important as the growing of the crop. If possible, cool the fruits quickly after harvest or harvest is in the early morning when temperatures are cool and plants are well-hydrated.

Watermelons stored at 55-60°F and 90% humidity will keep for 10-15 days. Do not store below 50°F, as fruits are sensitive to chilling injury and disease development. If kept at ambient temperatures, watermelon will hold for about 5-7 days. Cantaloupe are highly perishable and will maintain good quality for about one week. Full-slip cantaloupe can be stored at 40°F but those harvested at half-slip should not be stored below 45°F to ensure they ripen properly. Never store casaba and other specialty melons at temperatures less than 50°F as they are subject to chilling injury. For more detail on storage, handling and ripening techniques of the different melons, refer to the specific produce fact sheets for the different melons available through the UC Davis Postharvest Technology website: postharvest.ucdavis.edu.

Weed Management

Cucurbits prefer warm weather conditions to ensure high productivity. Many growers transplant early melons and then seed them into bare soil later in the year. Most growers also rely on furrow irrigation. Weed control is critical in bare soil systems as weeds in the planted row and furrow are difficult to manage and often compete with the crop before the plants are large enough to shade them out. Weeds in and between the rows are controlled with cultivation, hand hoeing, herbicides, or a combination of approaches.

Plastic mulches improve early growth and reduce in-row weed pressure associated with bare soil conditions. Some herbicides can be applied underneath the mulch but it is those weeds growing along the edge of the plastic that are difficult to control with cultivation equipment. Directed or shielded herbicide applications on bed edges helps with weed control but use caution as spray drift and residual herbicides left on the plastic may affect crop growth.

In organic production systems, mulches can provide good weed control in and between rows if applied in a thick mat before weeds emerge. There are OMRI approved contact organic herbicides that are non-selective and must be applied to green tissue. Most organic herbicides have limited residual activity, so use a combination of controls like tillage, hoeing, and mulches in addition to herbicides.

There are many herbicides available for weed management. It is the grower's responsibility to have a current chemical applicators license, and to read the product label carefully. Many herbicides are manufactured by many companies under different trade names. Be sure to compare costs of different brands having the same active ingredient. Herbicide and pesticide labels change, so always consult a current label to determine if the crop is listed, rate of application, and precautions. It is a violation of federal law to use any herbicides for purposes other than those specified on the approved label. Off-label applications are hazardous to the environment, to people using the product, and can severely injure the crop.

Some herbicides can be used only on specific cucurbits and off-label use will injure other crops. Pay attention to re-entry intervals (REI) and pre-harvest intervals (PHI). The EPA has the authority to seize any agricultural commodity that carries a pesticide residue in excess of the established tolerance. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

Finally, 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. Don't spray in high wind conditions to avoid drift injury to susceptible crops

Herbicides for weed control are applied in the following ways:

- **Pre-plant incorporated:** incorporated into the soil prior to seeding or transplanting the crop
- **Pre-emergence:** applied to the soil after planting but before the crop or weeds emerge
- **Post-transplant:** applied to the soil after crop is transplanted either before weeds have emerged or after clean cultivation
- **Post-emergence:** applied to weeds after both weeds and the crop have emerged
- **Directed post-emergence:** applied as a directed or shielded spray 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.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Penn State Is there a difference in Red Mulch
- Michigan State University Row Covers for Frost Protection and Earliness in Vegetable Production

Insect and Mite Pest Management

Aphids

Order Hemiptera: Family Aphididae

GENERAL CUCURBIT APHID INFORMATION:

Aphids do not generally attack cucurbits until the vines form runners.

Green Peach Aphid (Myzus persicae)

See pg. 57-58 for more information on the description, life history, damage, and management of this pest.

DAMAGE:

Green peach aphids cause damage by transmitting plant viruses: Cucumber mosaic and Watermelon mosaic are particularly damaging viruses transmitted by green peach aphids to cucurbits.

Melon Aphid (Aphis gossypii)

See pg. 57-58 for the description, life history, damage, and management information on this pest.

DAMAGE:

The melon aphid is one of the chief agents in transmitting Cucumber mosaic virus.

Cucumber Beetles

Order Coleoptera: Family Chrysomelidae

Spotted Cucumber Beetle (Diabrotica undecimpunctata)

Striped Cucumber Beetle (Acalymma trivittatum)

See pg. 58-59 for more information on the description, life history, damage, and management of cucumber beetles.

Flea Beetles

Order Coleoptera: Family Chrysomelidae

See pg. 37-38 for more information on the description, life history, damage, and management of flea beetles.

Grasshoppers

Order Orthoptera: Family Acrididae

Redlegged grasshopper (Melanoplus femurrubrum)

Differential grasshopper (Melanoplus differentialis)

Twostriped grasshopper (Melanoplus bivittatus)

Migratory grasshopper (Melanoplus sanguinipes)

DESCRIPTION:

Adult: About 1-2 inches long with a robust body, hind legs with enlarged femurs for long-distance jumping, and relatively short antennae (Fig. 6.2).

Egg: About the size as a grain of rice, eggs are contained in pods of up to 100 eggs in the upper 2 inches of soil.

Nymph: Five nymphal stages or instars. Instars grow from around ¼ inch (1st instar) to 1 inch (5th instar) (Figs. 6.3 and 6.4). Wing pad size gradually increases with each instar until they are able to fly, indicating adulthood.

LIFE HISTORY:

Female grasshoppers lay eggs in undisturbed soils in late summer and fall. Eggs hatch in mid- to late-spring when soil temperatures warm and new nymphs feed on nearby plants. In some years, populations can increase in undisturbed areas and move into crop sites where they cause massive defoliation. Most grasshopper species in Utah have one generation per year.

DAMAGE:

Grasshoppers have chewing mouthparts that leave random, ragged holes in leaves and flowers (Fig. 6.5), and can devour entire plants. In general, they prefer young green plants of corn, lettuce, bean, carrot, onion and some annual flowers. Damage occurs in the early summer after rangeland weeds dry up and usually lasts for a few weeks.

MANAGEMENT:

Because grasshoppers are able to travel long distances, especially as adults, it is important to treat large areas. The best time to treat is in mid-spring when nymphs are young.

Cultural:

- *Use floating row covers or lightweight plant fabric.* Row covers will exclude the grasshoppers, and should be removed during crop flowering for pollination. This can be done in the morning hours when pollinators are most active.
- *Hand removal.* Grasshoppers can be handpicked and squashed, especially when populations are low.

Chemical:

- *Baits.* The insecticide, carbaryl, is mixed with wheat bran to create a bait. Spread it evenly throughout the habitat and re-apply weekly. The bait can also be placed inside a container, such as PVC pipe segments, to protect it from getting wet (wet bait is no longer attractive to grasshoppers).
- *Dusts.* Dusts have short residuals and must be reapplied weekly and after rain or irrigation.
- *Sprays.* Sometimes aerial sprays can be coordinated with the Utah Department of Agriculture and Food. The USDA threshold for rangelands is 9 nymphs per yd^2; agricultural thresholds would likely be lower.

Biological:

Nosema locustae is a biological insecticide bait that must be applied to early nymph stages and is specific to grasshoppers. After feeding on the bait, grasshoppers stop feeding, become lethargic, and die. The disease is contagious and will infect other grasshoppers that cannibalize diseased grasshoppers in the area.

SEARCH THE INTERNET FOR MORE INFORMATION:

- North Carolina State University Grasshoppers
- University of California IPM Grasshoppers
- USU IPM Community-Wide Grasshopper Control

Sowbugs and Pillbugs

Order Isopoda: Family Oniscidae

DESCRIPTION:

Adult: About ¼ to ½ inch long, with a rounded upper surface and flat lower surface. They are dark gray in color with armor-like body segments (Fig. 6.6). Sowbugs and pillbugs are not insects, but are soil dwelling crustaceans. They have 7 pairs of legs, prominent antennae, and two tail-like appendages.

Egg: Up to 200 eggs are carried in a pouch under the female body.

Young: Young sowbugs and pillbugs look like adults but are paler in color and smaller.

LIFE HISTORY:

Eggs hatch into young sowbugs and pillbugs, and remain in the pouch up to 2 months after hatching. It requires about 1 year for young sowbugs and pillbugs to develop into adults. Adults breed mainly in the spring and may live up to 3 years. As many as three broods per year are possible.

DAMAGE:

Sowbugs and pillbugs feed on melon rinds (especially cantaloupe) when fruits rest on soils with high levels of organic matter on the surface. They occasionally damage roots, seedlings, foliage and fruit that contact the soil.

MANAGEMENT:

Cultural:

- *Minimize soil moisture.* Reduce soil moisture as fruits ripen to deter the attraction of sowbugs and pillbugs to the area. Sowbugs and pillbugs rely on moist soil to survive and will not live in soil that is too dry to support them.
- *Remove debris such as trash, plant debris, or wood.* Debris encourages soil moisture and protected sites that will attract sowbugs and pillbugs.
- *Mulches.* Place straw, plastic, cardboard, landscape fabric, carpet, or other types of mulches under cantaloupes and other fruits and vegetables that tend to sit on or contact the soil as they ripen. These mulches will create a barrier between the ripening fruits and the soil where the sowbugs and pillbugs live.

Chemical:

Generally cultural management practices, such as mulches and soil moisture management are the most effective in preventing sowbugs and pillbugs from becoming a problem.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of Kentucky Sowbugs and Pillbugs
- Texas A&M Extension Sowbugs Pillbugs

Spider Mites

Order Acari: Family Tetranychidae

See pg. 59-60 for the description, life history, damage, and management information on this pest.

Squash Bug

Order Hemiptera: Family Coreidae

See pg. 60-62 for the description, life history, damage, and management information on this pest.

Thrips

Order Thysanopetera: Family Thripidae

Thrips will feed on leaves, developing buds, flowers, and fruits; and if populations are high, can cause economic loss. Typical symptoms are "rasping" and stippling injury on leaves, and stunted buds, flowers, and fruits. Thrips feeding on the surface of well-developed fruits can cause scarring. An abundance of dark tar-spots of thrips frass can contaminate fruits.

DAMAGE:

Damage occurs as young and adult thrips feed on flower and shoot tips during the early growth stages, and if populations are high, they may feed on immature fruit. Feeding damage results in a silvering on leaves and sometimes deformed leaves that curl downward (Fig. 6.7).

MONITORING:

Use yellow or blue sticky traps in susceptible fields from seedling through flowering to determine the magnitude of the thrips population.

MANAGEMENT:

Cultural:

- *Disk in weeds before they flower.* This can lessen the attraction of thrips to the field. However, disking weeds after they have flowered (once thrips are present) can cause thrips to move into crop plants.

Chemical:

Before deciding to treat for thrips, be sure to verify that the damage is thrips-related. Unnecessary treatments can cause spider mite buildup, so it is important to only consider treatment if the thrips population is causing serious damage to shoot tips, flowers, or fruit.

See pg. 98 for more information on the management of thrips.

Disease Management

Gummy Stem Blight/Black Rot

CAUSAL AGENT:

Gummy stem blight is caused by the fungus *Didymella bryoniae*. It affects squash, cucumber, melon, and watermelon.

SYMPTOMS:

The disease affects foliage, stems, and fruit. Leaf and stem infections are known as Gummy Stem Blight, appearing as necrotic (dead) spots (Fig. 6.8). Stems sometimes ooze gum (Fig. 6.9). On squash fruit, the disease is called Black Rot (Fig. 6.10). On butternut squash, the disease may form distinct concentric rings (Fig. 6.11).

DISEASE CYCLE:

Didymella is seed- and soilborne. The fungus can survive on infected plant debris for up to two years in the soil. Seedlings can become infected if the seed is contaminated. Optimum conditions for infection range from 65-75°F (depending on the crop) and moisture of up to 10 hours. The fungus can produce fruiting structures on decaying tissue after infection, and the spores move to new leaves and neighboring plants through splashing water.

MANAGEMENT:

- *Use certified disease-free seed or treat seeds.* Seedlings can be infected without showing symptoms.
- *Sanitation is very important if an outbreak occurs in the greenhouse.* There are no products available in Utah that can be applied to seedlings in the greenhouse to control the disease. After removing infected seedlings, disinfect the greenhouse trays, pots, tables, ceiling, etc. Because the spores move by splashing water, they can reside on any part of the greenhouse structure as well.
- *Rotate cucurbit crops for 2-3 years to avoid outbreaks in the field.*
- *Deeply plow crop residues to reduce inoculum left on plant debris.* This is very effective when combined with crop rotation.

There are many fungicides that can be applied. Rotation between fungicide classes is very important for fungicide resistance management. There have been reports of *Didymella bryionae* having developed resistance to some fungicides in other states.

Powdery Mildew

CAUSAL AGENT:

There are two species of fungi that can cause powdery mildew on cucurbits: *Podosphaera xanthii* and *Erysiphe chicoracearum*. In Utah, the most common is *P. xanthii*.

SYMPTOMS:

White powdery spots (Fig. 6.12) appear on the surface of leaves when temperatures start to increase. Over time, the entire leaf can be covered (Fig. 6.13). The "powder" on leaves is the fungal mycelium and spores.

DISEASE CYCLE:

Powdery mildew overwinters in fruiting structures on plant debris. When temperatures warm in late spring, a secondary spore (conidia) forms and blows to leaf tissue to cause infections. In contrast to many fungi, powdery mildew does not thrive with rainfall. The ideal conditions for infection are two or more hours of high humidity or dew on host leaves, which often occurs in cucurbit plantings.

After infection, powdery mildew does very well in dry conditions. Infected tissues form more spores that can also be blown in with the wind to infect plants in new locations. The cycle of spore production, dissemination, and infection occurs continually all summer long. When temperatures cool in late summer, the fungus switches from producing conidia to producing fruiting structures that contain the spores for winter survival.

MANAGEMENT:

- *Monitor.* The key to management is to apply fungicides before the disease spreads. Scout fields for new lesions once per week starting in late spring.
- *Resistant varieties.* Several resistant varieties are available for squash, cucumber, and pumpkin.
- *Remove or plow under infected plant material after harvest.* This is important to prevent powdery mildew from overwintering.
- *Increase plant spacing.* This can help reduce powdery mildew severity with better air movement that reduces humidity in the plant canopy.

For chemical control, sulfur products work very well. Apply when the first white spots are observed, and repeat applications every 7-10 days. Once leaves are covered with powdery mildew, chemical control will no longer be effective. Sulfur products cannot be applied above 90°F as this will cause foliar injury.

Watermelon Mosaic Virus (WMV)

CAUSAL AGENT:

WMV is in the genus Potyvirus. It is spread in a non-persistent manner by aphids. It affects summer and winter squash, zucchini, gourds, and pumpkins.

SYMPTOMS:

The virus causes mosaic patterns and leaf distortion (Fig. 6.14 and 6.15). The fruit frequently show color breaking (Fig. 6.16) and warts (Fig. 6.17).

DISEASE CYCLE:

The virus is not seedborne; it is only spread by aphids, which acquire the virus from infected weeds or alfalfa. Symptoms usually begin to show in June. Often the first symptoms are seen on field edges and aphids continue to move the virus across the cucurbit field. The virus overwinters in infected perennial weeds or alfalfa.

MANAGEMENT:

Management options are very limited, and include weed control, crop rotation, and keeping cucurbit fields away from alfalfa fields. There are resistant summer squash and zucchini varieties (some are GMO) but there are no resistant winter squash or pumpkin varieties. Insecticides for aphids are of limited value to control the disease.

Pest Management Tables for Commercial and Home Use

Table 6.4. Herbicides registered for **COMMERCIAL** use on **Melons** in Utah.

Brand Name (REI/PHI)	Active Ingredient	Timing and Application Location Relative to Crop				Timing Relative to Weeds		Weed Groups Controlled			Comments
		Before Transplanting	Pre-emergence	Post transplanting directed, shielded	Post-emergence	Pre-emergence	Post-emergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X		X			X			X	
Command 3ME (12hr/45d)	clomazone		X			X		X	X	X	Do not use on pumpkins
Curbit EC (24hr/-)	ethalfuralin		X	X		X					
Dacthal products (12hr/-)	DCPA			X	X	X		X			Cantaloupe/ Watermelon only
Gramaxone (12hr/-)	paraquat	X	X	X			X	X	X	X	Restricted use
League	imazosulfuron			X	X	X	X		X	X	Cantaloupe/ Watermelon only
Poast (12hr/14d)	sethoxydim				X		X	X			
Prefar 4-E (12hr/-)	bensulide	X	X			X		X			
Prism (12hr/14d)	clethodim	X	X	X	X		X	X	X	X	
RoundUp and others (12hr/14d)	glyphosate	X	X	X	X		X	X	X	X	
Sandea and others (12hr/30 or 57d)	halosulfuron	X	X			X	X		X	X	Should not contact plants
Sinbar (12hr/70d)	terbacil	X	X			X					Watermelon only
Strategy (12hr/45d)	ethalfluralin + clomazone		X	X		X		X	X	X	Not on cantaloupe
Treflan products (12hr/30 or 60d)	trifluralin			X		X		X	X	X	
Organic Products											
Corn Gluten Meal		X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 6.5. Insecticides registered for **COMMERCIAL** use on **Watermelon** in Utah, organized by Mode of Action (MoA). For treatment on other melons, always check the label first

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Flea Beetles	Squash Bug	Grasshoppers	Spider Mites	Thrips
carbaryl	Carbaryl, Sevin	1A	7-14		X	X	X	X		
methomyl	Corrida[R], Lannate[R], Nudrin[R]	1A	5	X	X	X				
oxamyl	Vydate[R]	1A	5-7	X						X
malathion	Malathion, Malice	1B	5-7	X	X				X	
alpha-cypermethrin	Fastac[R]	3A	10-14	X	X		X			
beta-cyfluthrin	Baythroid XL[R]	3A	14		X			X		
bifenthrin	Bifenture[R], Brigade[R], Sniper[R], Sniper Helios[R], Tundra[R]	3A	14	X	X		X	X	X	
cyfluthrin	Tombstone[R], Tombstone Helios[R]	3A	10-14		X			X		
deltamethrin	Delta Gold[R]	3A	10-14	X	X	X		X		
esfenvalerate	Asana[R], S-fenvalostar[R], Zyrate[R]	3A	14		X		X	X		
fenpropathrin	Danitol[R]	3A	10-14	X	X	X	X		X	
gamma-cyhalothrin	Declare[R]	3A	10-14	X	X	X	X	X	X	X
lambda-cyhalothrin	Grizzly[R], Lambda[R], Lambda-Cy[R], LambdaStar[R], Silencer[R], Warrior II[R], Warior[R]	3A	10-14	X	X	X	X	X	X	X
permethrin	Ambush[R], Arctic[R], Perm-Up[R], Pounce[R]	3A	14	X	X		X			
pyrethrins	Pyganic[OB]	3A	3-5	X	X	X	X	X	X	X
pyrethrins + piperonyl butoxide	Pyrenone[B], Evergreen[B]	3A	3-5	X	X	X		X	See label	X
zeta-cypermethrin	Mustang[R], Mustang Maxx[R]	3A	10-14	X	X		X			
zeta-cypermethrin + bifenthrin	Hero[R]	3A	10-14	X	X		X	X	X	
lambda-cyhalothrin + thiamethoxam	Endigo[R]	3A/4	10-14	X	X	X	X	X	X	X
bifenthrin + avermectin	Athena[R]	3A/6	10-14	X	X		X	X	X	X
zeta-cypermethrin + avermectin	Gladiator[R]	3A/6	10-14	X	X		X		X	

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 6.5, continued. Insecticides registered for **COMMERCIAL** use on **Watermelon** in Utah, organized by Mode of Action (MoA). For treatment on other melons, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Flea Beetles	Squash Bug	Grasshoppers	Spider Mites	Thrips
lambda-cyhalothrin + chlorantraniliprole	Voliam Xpress[R]	3A/28	10-14	X	X	X	X	X		X
pyrethrins + azadirachtin	Azera[OB]	3A/ UN	4-7	X	X	X	X	X	X	X
acetamiprid	Assail, TriStar	4A	14	X	See label		See label			See label
clothianidin	Belay	4A	14	X	X	X	X			X
dinotefuran	Scorpion, Venom	4A	14	X	X	X	X	X		X
imidacloprid	Admire Pro, Alias, AmTide, Couraze, Dominion, Macho, Widow, Wrangler	4A	5	X	X					X
thiamethoxam	Actara, Cruiser, Flagship, Platinum	4A	10-14	X	X	X				See label
thiamethoxam + chlorantraniliprole	Durivo, Voliam Flexi	4A/28	14	X	X	X				See label
flupyradifurone	Sivanto (foliar)	4D	7-14	x			x			
spinetoram	Radiant	5	14							X
spinosad	Entrust[OB], Success[B]	5	7							X
abamectin	Abacus[R], Abba[R], Agri-Mek[R], Reaper[R], Zoro[R]	6	14-21						X	
pymetrozine	Fulfill	9B	7-10	X						
flonicamid	Beleaf	9C	14	X						
etoxazole	Zeal	10B	14						X	
novaluron	Rimon	15	7		X		X			X
spiromesifen	Oberon	23	14						X	
cyantraniliprole	Exirel, Verimark	28	14	X		See label				X
oil: mineral	Pure Spray Green	NC	none	X					X	X
azadirachtin	Aza-Direct[OB], AzaGuard[OB], Azatin[OB]	UN	7-10	X	X	X	See label	See label	See label	X
Beauveria bassiana	Botanigard[B]	---	5-7	X	X	X		X	X	X
Chromobacterium subtsugae strain PRAA4-1	Grandevo[OB]	---	5-7	X					X	X

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 6.5, continued. **Insecticides** registered for **COMMERCIAL** use on **Watermelon** in Utah, organized by Mode of Action (MoA). For treatment on other melons, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Flea Beetles	Squash Bug	Grasshoppers	Spider Mites	Thrips
extract of *Chenopodium ambrosiodes*	Requiem[B]	---	5-7							X
heat-killed *Burkholderia* spp.	Venerate[OB]	---	5-7	x					x	x
kaolin clay	Surround[O]	---	5-7		x			x		
oil: plant-based	Captiva[B], Triact[B]	---	none						x	See label
potassium salts of fatty acids	M-Pede	---	3	x					x	x

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on cucurbit crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

Protection of Pollinators: Look for the "bee-box" or "bee hazard icon" on product labels and read the restricitions and instructions to protect bees and other insect pollinators. Bees and other pollinators will forage on plants when they flower, shed pollen, or produce nectar. Follow these steps when using products that are hazardous to bees: 1) minimize exposure of the product to bees and pollinators when they are foraging on pollinator attractive plants around the application site 2) Minimize drift of the product on to beehives or to off-site pollinator attractive habitat as drift into these areas will kill bees.

Warning: Applications of imidacloprid and clothianidin are restricted to post-bloom and only when bees are not active in the site, including on weeds and non-crop plants.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 6.6. Fungicides registered for **COMMERCIAL** use on **Cucurbits (Cucumber, Squash, & Melons)** in Utah, organized by Mode of Action (MoA). For treatment on other cucurbits, always check the label first.

Active Ingredient	Brand Name	MoA	Powdery Mildew	Gummy Stem Blight/Black Rot
thiophanate-methyl	Incognito, Topsin	1	X	X
tebuconazole	Monsoon, Orius, Tebu-crop, Tebuzol, Toledo	3	See label	See label
mefenoxam + chlorothalonil	Ridomil Gold Bravo SC	4/M5		X
fluxapyroxad + pyraclostrobin	Merivon	7/11	X	X
cyprodinil + fludioxonil	Switch	9/12	X	X
azoxystrobin	Quadris, Satori	11	X	X
kresoxim-methyl	Sovran	11	X	X
pyraclostrobin	Cabrio	11	X	X
polyoxin D zinc salt	Affirm, Ph-D	19	X	X
sulfur	Cosavet[OB], Kumulus[O], Microthiol Disperss[OB], Micro Sulf[OB], Sulfur-DFO, Thiolux[O]	M2	X	
chlorothalonil	Bravo, Chloronil, Echo, Equus, Initiate	M5	X	X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on cucurbit crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals

[B]= Biopesticide
[O]= Organic

Table 6.7. Insecticides registered for **HOME** use on **Melons**, organized by Mode of Action (MoA). For treatment on other melons, always check the label first.

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Cucumber Beetles	Flea Beetles	Squash Bug	Grasshoppers	Spider Mites	Thrips
carbaryl	Garden Tech Sevin	1A	14		X	X	X	X		X
malathion	Ortho Malathion	1B	7	X	X					X
bifenthrin	Fertilome Broad Spectrum Insecticide, Bonide Eight Insect Control	3	14	See label		See label		See label		
cyfluthrin	Bayer Vegetable and Garden Insect Spray	3	14		X			X		
deltamethrin	Green Light Many Purpose Dust	3	14	X	X	X		X		
pyrethrins	Monterey Bug Buster-O[OB], Garden Tech Worry Free[B]	3	5	X	X	X	X	See label	See label	See label
pyrethrins + canola oil	Earth-tone Insect Control[B], Monterey Take Down Garden Spray[B]	3/	5	X	See label	X			X	X
pyrethrins + sulfur	Bonide Tomato and Vegetable 3 in 1[B], Natria Insect, Disease & Mite Control[B], Ortho Insect, Mite & Disease 3 in 1[B]	3/M2	5	X	X	X	See label		X	X
acetamiprid	Ortho Flower, Fruit & Vegetable	4A	14	X	X	X	X			X
spinosad	Fertilome Borer, Bagworn, Tent Caterpillar & Leafminer Spray[B], Monterey Garden Insect Spray[OB], Bonide Colorado Potato Beetle Beater[B]	5	7							X
Nosema locustae	Semaspore Bait[OB], Nolo Bait[OB]	---	10					X		
oil: canola, neem, rosemary, clove, cottonseed	Bayer Natria Multi-insect[B], Monterey All Natural 3 in 1 Garden Insect Spray[B]	---	1	X		See label			X	See label
potassium salts of fatty acids (insecticidal soap)	Bayer Natria[B], Safer	---	1	X				X	X	X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[O]= Organic

Table 6.8. Fungicides registered for **HOME** use on **Cucurbits (Cucumber, Squash, & Melons)**, organized by Mode of Action (MoA). For treatment on other cucurbits, always check the label first.

Active Ingredient	Brand Name	MoA	Powdery Mildew	Gummy Stem/ Black Rot
myclobutanil	Fertilome F-Stop Lawn & Garden, Spectracide Immunox	3	X	
Bacillus subtilis strain QST 713	Serenade Garden Disease Control[B]	44	X	
copper	Natural Guard Copper Soap, Monterey Liqui-Cop	M1	X	
sulfur + pyrethrins	Natria Insect Disease & Mite Control, Bonide Tomato & Vegetable 3 in 1	M2/IRAC 3A	X	
chlorothalonil	Fertilome Broad Spectrum Landscape & Garden Fungicide, Hi Yield Vegetable, Flower Fruit & Ornamental Fungicide, Ortho Max Garden Disease Control	M5	X	X
oils: rosemary, clove, cottonseed, canola	Monterey All Natural 3 in 1[B], Natria Multi-Insect Control[B]	---	X	

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide

Fig 6.1. An indicator for honeydew harvest is a creamy/light yellow ground spot and a waxy "bloom" on the rind.

Fig 6.2. An adult grasshopper; note the fully developed wings.

Fig 6.3. A grasshopper nymph; note the small wing pads and lack of developed wings.

Fig 6.4. Grasshopper nymphs are smaller than adults and have small or discrete wing pads.

Fig 6.5. Grasshoppers feed on leaves and flowers leaving ragged holes and can devour entire plants.

Fig 6.6. Pillbugs and sowbugs have dark gray or brown bodies with armor-like body segments.

Fig 6.7. Close-up of silvering on leaves caused by thrips feeding damage.

Fig 6.8 Gummy stem blight (GSB) causes necrotic (dead) spots on infected leaves.

Fig 6.9. GSB sometimes causes infected stems to ooze a gummy substance.

Fig 6.10. On squash, the GSB disease is called black rot.

Fig 6.11. Black rot may form distinct concentric rings on butternut squash fruit.

Fig 6.12. Powdery mildew appears as white powdery spots.

Fig 6.13. Over time, powdery mildew can cover the entire leaf.

Fig 6.14. Watermelon mosaic virus (WMV) causes mosaic patterns.

Fig 6.15. WMV causes leaf distortion.

Fig 6.16. Fruit infected with WMV frequently exhibit color breaking.

Fig 6.17. Fruit infected with WMV frequently exhibit warts.

CHAPTER 7 ONION PRODUCTION

Onion (Allium cepa) is a cool-season annual crop grown commercially on 1,600 to 1,800 acres in northern Utah. It is grown by direct seeding or by setting transplants out in the field in early spring. Onions grown from sets are expensive, produce smaller bulbs, and are not typically recommended for commercial plantings. Green bunching onions are grown from seed and are harvested while the leaves are still green but before the bulbs start to develop. Dry bulb onions are harvested after the leaves have senesced and fallen over and bulbs are mature.

Onions in Utah require timely applications of water, fertilizer, and other inputs throughout the growing season to meet market requirements. Utah State University (USU) research and extension personnel have worked in cooperation with the Utah Onion Growers Association to identify important production problems and reduce their negative impacts on this important food crop. In addition to USU resources, there is a wealth of information available from other sources such as onion processors, seed companies, crop consultants, and regional and national onion organizations.

Onion Types

Onion is a diverse agricultural crop that is classified into groups based on response to day-length. Onions form bulbs in response to a critical day-length and are classified as short-, intermediate-, and long-day types. Bulbs also vary in color (red, yellow, and white) (Fig. 7.1), shape (flat, globe, grano, torpedo), flavor (sweet or pungent), and market use (fresh, storage and processing). Most onion varieties grown in Utah are long-day, pungent, storage types that respond favorably to local growing conditions.

Selection of appropriate onion varieties for a location and market is an important decision. There are numerous onion varieties available and seed companies introduce new ones each year. Some varieties commonly grown in Utah include 'Calibra', 'Candy', 'Charismatic', 'Crockett', 'Delgado', 'Desperado', 'Granero', 'Joaquin', 'Legend', 'Maverick', 'Mesquite', 'Ranchero', 'Redwing', 'Sedona', 'Swale', 'Tequila', and 'Vaquero'.

USU Extension conducts field trials to evaluate onion varieties under local conditions. Data is gathered on yield quantity and quality, timing of crop maturity, pest tolerance, and storage quality (extension.usu.edu/productionhort/htm/vegetables/commercial-vegetables/onions).

Seed-Bed Preparation

Onion seeds need firm, finely textured soil in the seed bed for good germination and stand establishment. Onions grow best in a soil with good organic matter and a pH between 6.0 and 7.8. Seed-bed preparation begins in the fall of the previous year. First, the field is plowed to improve soil condition, and then the soil is shaped into beds that are allowed to settle through freezing and thawing action during the winter months. In the spring just before planting, the beds are smoothed with a bed shaper harrow or roller, and planted. Because some onion diseases will carry-over in the soil, most fields should be planted to onions only once every five to seven years.

Seeding Rates and Spacing

Fields should be seeded from early March through mid-April when onion beds are dry enough to avoid compaction or germination problems during planting. Onion seeds germinate at temperatures above 40°F; the optimum soil temperature is 75°F. If seeds are planted too early, cooler air and soil temperatures will delay germination and emergence (15- to 25-day

Onions should be spaced 3 to 4 inches apart.

requirement), and cause seedling growth to slow. Irrigation water is generally not available until after mid-April, so planting in March and April allows onion seeds to germinate following spring rain storms. Research has shown that most plantings made before April 15 will allow for the best onion crop yields. If seeded later, hot summer temperatures induce bulb development before sufficient leaf growth has occurred, leading to reduced final bulb size.

Onions may be grown from sets, seed, or transplants. An onion set is a small, dormant bulb that will produce a larger bulb once it is planted. Onion transplants are started from seed in a greenhouse or are field grown (in the southwest U.S.) then shipped to growers prior to planting in the field. Growers who are looking to produce onions for niche markets like farmers' markets, roadside stands and community supported agriculture (CSAs), may want to use transplants, which allow for earlier harvest.

Fertility

Onions require timely applications of nutrients to achieve maximum plant development and yield. Onion roots are mostly confined to the top 18 inches of soil, which can make supplying nutrients to the crop difficult. A soil test in the fall, while forming the seed bed, is the most accurate way to address fertilizer requirements. Soil test results, field experience, and knowledge of specific crop requirements can help to determine the nutrients needed and the rate of application. Select fertilizer type and rate to insure that all important nutrient levels are adequate for high productivity. Optimum fertilization is essential for top quality onions and yields.

Nitrogen is one of the most important nutrients for onion plant growth and development. A typical onion crop will use about 150-200 pounds of actual nitrogen per acre during the growing season, with a majority of the nitrogen taken up after the plant has started to bulb. Side-dress with nitrogen by applying low amounts to avoid burning the plants. It is critical to avoid late (after mid-July) and heavy applications of nitrogen after bulb initiation as it will encourage late maturity and large necks that are difficult to cure. Excess nitrogen in the bulb at harvest will result in soft onion bulbs and poor storage quality.

Most of the phosphorus and potassium should be applied and worked into the seedbed prior to planting. Phosphorus is essential for vigorous early growth of seedlings. If phosphorus is banded at planting time, it should be placed two inches to the side and two inches below the seed. Onions require medium levels of potassium and most soils in Utah contain sufficient levels for onion growth and development.

Planting

Onions are seeded on beds of varying width, depending on the cropping system and the equipment of the individual grower. Use a bed width of 26 to 44 inches (from center to center) with two to four seed rows per bed. Uniform seed placement and in-row plant spacing has a major influence on bulb size and is critical to a good stand establishment. Seeds should be planted 0.5 to 1 inch deep. Avoid wide spacings which promote large bulbs with thick necks. Generally, an in-row spacing of 3 to 4 inches ensures both high total yield and a higher percentage of onions in the jumbo (3.0-3.5"), large jumbo (3.5-4.0"), and colossal (4+") market classes.

Many types of planters are used to seed onions and all must be carefully set to maintain proper seeding depth and rate. A 'small seed' type planter with short seed drop is recommended. Vacuum and other types of precision planters can be very effective at controlling plant spacing and reducing the amount of seed used.

Soil Crusting

Springtime weather can bring heavy rain storms that can lead to crusting in seed beds with heavy-textured soil. To break the soil crust prior to onion emergence, run a harrow, spiked rollers, or finger-type cultivators lightly over the soil surface. Take extra care not to disturb the seed row during this process. If seeds/seedlings are disturbed prior to emergence, onion stands can be severely reduced.

Cultivation

Cultivation can begin as soon as onion seedlings emerge from the soil. Many types of equipment are used to cultivate; however, the standard set-up uses

disks, knives, duck feet, and furrow openers. The disks are placed on either side of the onion rows to cut the crust. A knife is mounted behind each disk to undercut weeds on either side of the onion row and fill in the furrows made by the disks. A single duck foot might be centered in the furrow to undercut weeds, followed by the furrow opener which remakes the ditch for the next irrigation. Most onion fields need to be hand-hoed at least once to eliminate weeds that escaped the herbicide treatments and mechanical cultivation.


Onion field being cultivated.

Irrigation

Onions are shallow-rooted with 90% of the roots located in the top 12 inches of the soil. Because of the shallow root system, deficient irrigation can trigger early bulb initiation, resulting in smaller sized onions and reduced yield. Intervals between irrigations will depend upon the soil type, stage of crop development, weather conditions, pest pressure, and the irrigation system. Light, frequent irrigations should be used when the plants are small to minimize leaching of nitrogen from the root zone. Increase the amount of water applied as plants and roots increase in size. During the summer, onions may use 0.15 to 0.25 inches of water per day, and thus, may require irrigation every 5 to 10 days. Irrigation during July and August should thoroughly wet the soil 20 to 24 inches deep. In most years, seeded onions should be irrigated 10 to 15 times during the growing season, applying 1.5 to 3 inches of water each time.


Irrigation is critical for high yields.

The critical period for irrigation is from the plant establishment through bulb expansion stage. Soil type usually does not affect the amount of total water needed during a growing season, but does dictate the frequency of the water application. Lighter soils need more frequent water applications, but a less amount per application. Heavier soils need less frequent irrigation and a greater amount of water applied per irrigation set. It is important to maintain moisture near the soil surface for good root generation. Research has shown that onion roots generate at the stem plate only when moisture is present. Proper moisture management is also important for general root health, bulb growth, and vigor. Watering should be terminated after the bulbs have reached full size and tops have begun to senesce (at least two weeks prior to lifting).

Harvesting

For spring-seed onions, harvest starts near the end of August and continues through early October, with the main harvest season being in September. The average yield of onions in Utah is approximately 1,200-1,500 bags/acre (600-750 cwt/A) with higher yields reaching 2,000 bags/acre (1000 cwt/A).

Research has shown that the optimum harvest time is when onion foliage is still partially erect (Fig. 7.2), and long before maximum yield is attained (when tops are completely down and dry). Yields can increase 30-40% between the stage when tops begin to go down, and the leaves are fully down and dry. It may be tempting to leave onions to cure in the field as long as possible before lifting, but this will reduce the time available for drying. If it rains after onions have been lifted, bulbs may not dry out in the lower daytime temperatures of the early fall. Lifting and curing onions too late into the fall can also expose them to


Onion harvest occurs from August to early October.

freezing temperatures.

Once harvested, onions need several weeks of warm temperatures in storage to complete the curing process. If bulbs are left too long in the field, quality will be sacrificed when they are brought out of storage due to rots and other storage problems. The optimum time for harvest, therefore, is a balance between highest yields and storage quality.

Undercutting

Mechanically undercut bulbs with rod-weeder diggers or knife undercutters when 60 to 70% of the tops have tipped over and allow bulbs to cure in the field. After about 10 days, the undercut onions are lifted and windrowed.

Onions that have been undercut.

Topping

Onions can be topped with a Vegi-Vac or a Top-Air machine prior to storage. Some machines perform the topping and windrowing operations at the same time. It is common in other parts of the country to undercut or lift, cure, then top/load onions. This top/load method requires the onions to cure completely before they are topped/loaded. However, in Utah, this harvesting method is not recommended because of unpredictable fall rain showers. Onions should be lifted, cured, top/windrowed, and then loaded.

Topping/windrowing works well because the bulb root plate is removed from the soil so the roots will not regrow following a fall rain shower. If onions are to be stored, tops must be totally dry or else only the dry portion cut and removed. Cutting through any portion of the top while it is still green or moist may result in neck rot in storage. Adequate curing time in the field is typically two to three weeks, depending upon the weather.

Onion bulbs intended for immediate sale (farmers' markets, CSA, or road stands) or short-term storage are mechanically undercut, green-topped by hand or machine, and then may be partly cured in sacks in a cool dry place. Since these onions are not to be stored for a long period, complete curing of necks and scales is not as important.

Postharvest Care

Storage

Onions are typically stored in bags, crates, bulk bins, or pallet boxes that hold about a half ton of loose onions. Bags of onions should be stored on pallets and stacked to allow proper air circulation. Air-cooled storage facilities use forced ventilation systems in which air, heated if necessary, is introduced through floor racks beneath the onions. Bulk onions are stored on the floor up to 10 feet deep. When piles are too deep, onions near the bottom exhibit significant compression injury. Bulk floor storage should have air pipes running through the bottom of the pile or have holes and pipes in the concrete floor for ventilation. Bin-stored onions can be as high as 25 feet with air blown through the boxes from the head wall.

Onions stored in bags can be stacked on crates.

Onions can be stored in either common or cold storage. The storage quality of onions is influenced by cultivar and by the conditions under which they are grown, harvested, cured, and stored. Onions to be held in cold storage should be placed there immediately after curing. A temperature of 32°F will keep onions dormant and reasonably free from decay, provided the onions were disease-free and well-cured when placed in storage. Onions will sprout and decay rapidly when stored at temperatures between 40 and 50°F. Sprout

growth indicates a high storage temperature, poorly cured bulbs, or storage of immature bulbs. Root growth indicates that relative humidity in the storage facility is too high. Onions that freeze in the field need to be allowed to completely thaw out before handling. Onions that are damaged by freezing will have water-soaked scales when the thawed onions are cut.

Grading and Packaging

Onions are graded according to size and quality. A high-quality pack is obtained by eliminating immature, decayed, sunburned, mechanically injured bulbs, double bulbs, and bulbs with secondary growth. Bulbs are sorted, cleaned, sized and graded, just prior to bagging. They are packaged in 50-lb sacks or in consumer packs of 2, 5, and 25-lb mesh sacks.

Marketing

Fresh market options for Utah-grown onions include wholesale markets, farmers' markets, community supported agriculture (CSA) shares, restaurants, and roadside stands. Sales to local retail markets, such as supermarkets, are also an option. Buyers usually specify minimum sizes of the onions they will purchase. This minimum is usually two inches in diameter, with bulbs greater than three inches bringing a much higher price.

Weed Management

Weed control is critical early in the season since spring weeds germinate rapidly and grow vigorously relative to the slower growing onion plants. If weeds are not adequately managed during this early period, they become difficult to manage as time progresses and will out-compete the onion crop. Onion fields and borders should be maintained weed-free for the first 10 to 12 weeks so that weed pressure will not significantly impact plant growth and ultimately reduce onion yields.

Weeds can be controlled with cultivation and herbicides or a combination of the two approaches. Hand weeding crews may be needed to control those weeds that escape cultivation or herbicide applications. Onion seedlings are very sensitive to herbicides and few herbicides are registered as pre-emergents. A contact herbicide (RoundUp, Gramoxone) can be applied before onion seedlings emerge to help manage weeds until seedlings have two or more true leaves and are more tolerant to herbicides.

In organic systems, mulches (such as straw, cardboard, etc.) can provide good weed control in and between rows if applied in a thick mat before weeds emerge (Fig. 7.3). There are also OMRI-approved organic herbicides that can assist in weed management in these operations. These organic herbicides are primarily contact herbicides and must be applied to the green tissue of the weeds. Care must be taken when using these contact herbicides that the chemical does not get on the onion seedlings. Most organic herbicides have limited residual activity so weed control involves a combination of approaches like tillage, hoeing, and mulches, in addition to the herbicides.

Herbicide labels often change, so make sure to always consult the label to determine if onion is listed on the label, what precautions are required, and what rates and application methods are allowed. It is critical to read and understand the label.

Unmanaged weeds may outcompete the onion crop.

Important Considerations for Herbicide Use

- Carefully read and follow all label directions.
- Use herbicides only on crops for which they are approved and recommended on the label.
- Use the recommended amount of product and apply it as stated. (Too much material may damage the crop and make it unsafe for consumption.)
- Apply herbicides only at times specified on the label

and observe the recommended intervals of the time of planting and the time between treatments.

- Follow re-entry intervals (REI) and pre-harvest intervals (PHI).
- Don't spray in high wind conditions.
- It is a violation of the law to use herbicides other than as directed on the label. The EPA has the authority to seize any agricultural commodity that carries a pesticide residue in excess of the established tolerance levels. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

Finally, herbicides are just one tool available for weed control and their use should supplement other good weed-management practices.

Herbicides for weed control are applied in the following ways:

•**Pre-plant incorporated:** incorporated into the soil prior to seeding or transplanting onions

•**Pre-emergence:** applied to the soil after planting but before onions or weeds emerge

•**Post-transplant:** applied to the soil after crop is transplanted either before weeds have emerged or after clean cultivation

•**Post-emergence:** applied to weeds after both weeds and onions have emerged

•**Directed post-emergence:** applied as a directed or shielded spray 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.

Insect and Mite Pest Management

Thrips

Onion Thrips (*Thrips tabaci*)
Order Thysanoptera: Family Thripidae

DESCRIPTION:

Adult: About 0.06 inch (1.5 mm) long; elongate, yellow and brown body with two pairs of fringed (hairy) wings. Mouthparts are beak-like, eyes are gray, and antennae are 7-segmented (Fig. 7.4).

Larva: Early larvae, instars I and II (0.02-0.04 inch; 0.5-1.0 mm in length), are active feeding stages. Larvae are white to pale yellow, have an elongate and slender body, and resemble adults but without wings. Antennae are short and eyes are dark in color. Early larvae feed on new leaves in the center of the onion neck. Late larvae, instars III and IV (0.04-0.05 inch; 1.0-1.2 mm long), are inactive, non-feeding stages. They are pale yellow to brown with a stout body. Antennae are bent to the head and wing buds are visible. They are found in the soil, at the base of the onion plant neck, and underneath bulb scales (Fig. 7.5).

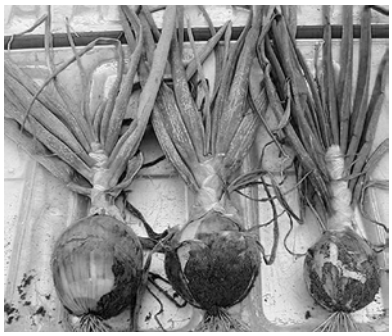
Egg: White to yellow; kidney-bean shaped; microscopic in size. Develop within leaf tissue with one end near the leaf surface (Fig. 7.6).

LIFE HISTORY:

Onion thrips is the dominant thrips species in onion fields. They overwinter as adults and become active in the spring, dispersing into onion fields. In Utah, females reproduce asexually (parthenogenesis) and insert eggs individually into leaves. Females will lay eggs for about three weeks. A complete generation requires 3 to 4 weeks during the summer months, and 5 to 8 generations may occur each year. Thrips populations increase rapidly under hot, arid conditions, leading to economic crop losses.

DAMAGE:

Yield reduction, from smaller bulb size, is the primary crop loss caused by onion thrips. Both adult and early stage larval thrips feed within the mesophyll layer of leaves with a punch-and-suck behavior that removes leaf chlorophyll causing white to silver patches and streaks (Fig. 7.7). Thrips prefer to feed on the newly emerged leaves in the center of onion necks (Fig. 7.8). When feeding injury is severe, leaves take on a silvery cast and can wither. Tiny black "tar" spots of excrement are evident on leaves with heavy feeding injury. Damaged plants are prone to water stress, resulting in reduced growth. Onions are most sensitive to thrips injury during the rapid bulb enlargement phase that occurs in July and early August (in northern Utah). Accelerated plant maturity and senescence due to thrips injury may shorten the bulb growth period resulting in reduced bulb size. If thrips are present on stored bulbs, they may continue to feed, causing scars that reduce the quality and aesthetic appearance of bulbs.



Reduced bulb size due to thrips.

Western Flower Thrips (*Frankliniella occidentalis*)
Order Thysanoptera: Family Thripidae

DESCRIPTION:

Western flower thrips (WFT) are similar in appearance to onion thrips; however, adult females are slightly longer (0.08 inch or 2.0 mm), more yellow in color, and have 8-segmented antennae, red eyes, and longer setae (hairs) on the segment just behind the head (prothorax) (Fig. 7.9 and 7.10).

LIFE HISTORY:

WFT reproduce sexually; males and females are common. WFT populations typically increase in the late summer to early fall, especially on plants that have bolted and produced seed.

DAMAGE:

WFT injure onion plants similarly to onion thrips; however, their populations are typically 10 to 100 times lower, and so cause much less onion crop damage.

MANAGEMENT: OF ONION AND WESTERN FLOWER THRIPS

Cultural:

- *Remove or destroy volunteer onion* plants and debris. Thrips can use these as overwintering hosts from which they can infest newly emerging onion plants.
- *Avoid planting onion adjacent to alfalfa* fields when feasible, since alfalfa harbors overwintering thrips.
- *Plant younger fields upwind* from older fields to avoid thrips infestation of less mature fields downwind.
- *Inspect transplants* for thrips infestation and discard infested onions. Thrips from these transplants may be different strains than those that occur in Utah. Introducing different strains may increase insecticide resistance and transmission of iris yellow spot virus and other diseases.
- *Fertilize onions* with adequate, but not excessive amounts of nitrogen. In Utah, it is recommended that no more than 200 lbs of nitrogen per acre be applied in multiple applications throughout the onion growth period. Moderate, consistent availability of nitrogen has been associated with a healthy onion crop and reduced onion thrips densities.
- *Mulch* with straw or other materials. Mulch placed on the plant bed may reduce onion thrips populations and improve onion growth. Mulches suppress thrips populations by enhancing predator populations, creating barriers that prevent the resting stage larvae from accessing the soil, and lowering soil temperatures, slowing thrips development and population increase.
- *Use trap crops.* Plant small strips or patches of an alternate crop (buckwheat, carrot, crucifer, cucurbits, and some flowers, such as phacelia, are highly attractive to onion thrips) within an onion field to attract thrips. These alternate crops can then be disked under or sprayed with an insecticide when thrips populations increase.
- *Use overhead sprinkler irrigation.* Sprinklers can reduce thrips populations by physically washing thrips from plants and forming a crust on the soil surface, reducing thrips' ability to seek shelter there.
- *Plant onion varieties that are more tolerant to thrips injury.* Varieties with tolerance to thrips injury require fewer insecticide applications. Using less insecticide can result in lower control costs, slower development of resistance, and preservation of natural enemies. Onion varieties with an open neck growth and dark, glossy leaves are less attractive to thrips than varieties with tight necks and lighter green leaves. Studies conducted in Colorado showed relative susceptibilities of some onion varieties:
  - *Highly Tolerant:* 'White Keeper'
  - *Moderately Tolerant:* 'El Charro', 'Snow White', 'Vega', 'X201', 'Zapotec'
  - *Susceptible:* 'Blanco Duro', 'Brown Beauty', 'Brown Beauty 20', 'Colorado 6', 'Sweet Perfection', 'Tango', 'Valdez', 'White Delight'
  - *Highly Susceptible:* 'Early Red Stockton', 'Mambo', 'Red Baron', 'Redman'

Chemical:

The high frequency of insecticide use for managing onion thrips, as high as eight applications per season, has caused rapid development of resistance to several classes of insecticides, including organophosphates, synthetic pyrethroids, and carbamates. Because onion thrips reproduce without mixing genes with males, have a high reproduction potential, and short generation time, the likelihood of insecticide resistance is increased. Despite the ease of use and widespread accessibility of many insecticides, they are most effective when used in conjunction with other management practices as described above.

Biological:

Natural enemies of onion thrips include the banded thrips (*Aeolothrips spp.*) (Fig. 7.11), big-eyed bug, minute pirate bug, green lacewing larvae, and predaceous mites. These predators, however, are usually not abundant in onion fields until late in the summer when most thrips feeding damage is already done. Incorporating management practices that reduce the use of toxic insecticides and increase cultural practices will promote onion thrips predation.

SEARCH THE INTERNET FOR MORE INFORMATION:

Onion Thrips:

- Utah Pests Fact Sheet Onion Thrips
- Texas Agricultural Extension Service Fact Sheet Thrips on Onions
- IPM PIPE Onion web page
- High Plains IPM Onion Thrips web page

Western Flower Thrips:

- University of California Fact Sheet *Management of Thrips in Onions and Garlic*
- University of California, Riverside *Biological Control of Western Flower Thrips* web page

Seed, Root, and Bulb Maggots

Onion Maggot *(Delia antique)*
Order Diptera: Family Anthomyiidae

DESCRIPTION:

Adult: Onion maggot flies are small, about 0.25 inch (6.35 mm), with brownish-grey bodies, and large-wings. They resemble houseflies, but have longer legs, are more slender, and overlap their wings while at rest.

Egg: White, elongated, about .03 inch (0.8 mm). Eggs are deposited in or on the soil, near young leaves, necks, or bulbs.

Larva: Maggots are legless, tapered, about 0.3 inch (8 mm) long, and creamy-white in color. They have hooked mouthparts for rasping their way into plant tissue and require 2 to 3 weeks to complete development.

Pupa: Chestnut brown, about 0.3 inch (8 mm) long, and may be found 1-6 inches (2.5-15 cm) deep in soil.

LIFE HISTORY:

There are normally three generations of onion maggots per year. The first, usually the largest and most damaging, generally emerges in mid- to late-May. Females begin laying eggs 7 to 10 days after emergence. Adult onion maggot flies survive about 2 to 3 weeks during which hundreds of eggs may be laid. Eggs will hatch into maggots within 2 to 3 days. Maggots feed on roots and bulbs below the soil surface for about 2 to 3 weeks and when mature they burrow 1 to 4 inches (2.5 to 10 cm) deep to pupate. First and second generation pupae remain in the soil for 2 to 4 weeks before adults emerge. Pupae from the third generation will overwinter in the soil among un-harvested onions and culls before emerging as adults in the following spring.

DAMAGE:

First generation onion maggot larvae feed on the roots and bulbs of young onion plants, which causes wilting and plant death. One larva typically kills several adjacent onion seedlings during its growth and development. Damage caused by 2nd and 3rd generation larvae is typically less severe (i.e., doesn't kill the whole plant), since it is more difficult for the larvae to penetrate the developing bulb. However, feeding from later larvae can still result in rotting bulb tissue and provide openings for other diseases, reducing bulb quality and storability (Fig. 7.12).

Seedcorn Maggot *(Delia platura)*
Order Diptera: Family Anthomyiidae

DESCRIPTION:

Adult: Seedcorn maggot adults are about 0.2 inches (5 mm) long with gray to brown bodies and are similar in appearance to the onion maggot.

Egg: White elongated; deposited in soils rich in organic/decaying matter and on seeds and seedlings.

Larva: Maggots are legless, tapered, about 0.25 inches (6 mm) long, and yellowish-white in color. Head-ends are wedge shaped with small black mouth hooks.

Pupa: Oval shaped, dark brown, about the size of a grain of wheat, and found in the soil.

LIFE HISTORY:

Adult flies emerge in April and May and begin mating within 2 to 3 days. Females lay eggs in or on soils and/or on seeds. Eggs hatch in 2 to 4 days at which point the larvae burrow into seeds and feed on emerging cotyledons and plant roots. Mature larvae pupate in the soil and remain in this stage approximately 7 to 14 days. Seedcorn maggots overwinter as pupae. A complete generation takes about 3 to 4 weeks and about 2 to 3 generations occur per year.

DAMAGE:

Maggots prefer feeding in soils rich in organic and decaying matter (such as manure). They burrow into the seeds and roots of many vegetable crops, destroy the seed germ, and may cause rot in plant tissue. Damaged seeds are unable to provide adequate food resources to support initial plant growth. Seeds and plants attacked by seedcorn maggots may not emerge causing reduced stands.

MANAGEMENT OF ONION AND SEEDCORN MAGGOTS:

Onion and seedcorn maggot damage is uncommon in Utah due to soils low in organic matter and typical dry, warm conditions in the spring. Any practice that speeds up germination and plant emergence will help reduce crop losses from maggots.

Cultural:

- *Sanitize fields.* Remove or destroy onion culls and debris from fields after harvest and volunteer onions in the spring. Culls and volunteer onions can be burned or buried and should be eliminated before emergence of the current season's crop.
- *Rotate onions* with unrelated crops. Onions should be planted at least one mile from previous onion plantings. Maggot populations are generally higher after a legume (e.g. alfalfa, beans, peas) has been plowed into the soil than when a grass (e.g. corn, rye, wheat) is incorporated.
- *Delay planting onions in problem field sites.* This will shorten the time the flies have to lay their eggs and allow the soil to warm up and dry out.
- *Plant more tolerant varieties.* No commercial onion varieties are resistant to early or mid-generation onion maggot attacks, but some earlier maturing onions are more tolerant to 3rd generation larvae.
- *Handle seeds carefully* to avoid cracking the seed coat. A cracked seed coat provides entry points for maggots and other diseases.
- *Avoid planting in soils that are high in undecomposed organic matter.*
- *Plant during fly free periods* determined by monitoring.
- *Use sticky traps.* Yellow sticky cards serve as a monitoring tool to assess pest infestation levels around fields and may serve as a control measure by reducing the amount of adult populations before egg laying occurs.
- *Use row covers in small-scale production sites* (impractical for large fields). Row covers placed over transplants at the time of planting can reduce egg laying. Cover seedbeds with a floating row cover immediately after sowing to prevent infestation. Be sure the cover extends at least 6" on each side of the seed row. Covers can be removed when plants are big enough to tolerate damage.

Chemical:

Seed or furrow treatments with insecticides are effective for preventive measures. An insecticide applied to the soil at planting protects seedlings from damage by 1st generation larvae. Two common methods that protect onions include an in-furrow application of a granular or liquid insecticide, or planting seed treated with a systemic insecticide. Areas infested with seedcorn maggots may need to be replanted after preventive measures are taken.

Biological:

Natural enemies of onion maggots include a rove beetle which destroys fly pupae and is both a predator and a parasite, ground beetles that consume soil stages of the maggots, and some parasitic wasps and flies. Although much of the seedcorn maggot's life cycle is spent protected underground, naturally occurring fungi may attack and decrease seed corn maggot larval populations. Predation by spiders, ants, and birds upon adults may also occur. Selective insecticides, such as seed treatments, are conducive to allowing these natural enemies to supplement maggot control.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Pacific Northwest Insect Management Handbook *Onion Maggot* web page
- North Carolina State University *Seedcorn Maggot In Onions* web page
- AgBio Seedcorn/Onion Maggot Trap
- ChemTica web page on Seedcorn Maggot

Leafminers

Order Diptera: Family Agromyzidae

Pea Leafminer (Liriomyza huidobrensis)

DESCRIPTION:

Adult: Small, about 0.06 to 0.08 inch (1.5 to 2.0 mm) long, with a wing length of 0.07 to 0.09 inch (1.7 to 2.25 mm), and black bodies with yellow markings on the back, sides of body, and head. Larger body and overall darker color than the vegetable and American serpentine leafminers.

Larva: White to yellow in color, wedge-shaped.

Egg: White, oval.

Pupa: Brown, seed-like.

Vegetable Leafminer (Liriomyza sativae)

DESCRIPTION:

Adult: Smaller than pea leafminer, black and yellow flies with a shiny black back and black margins behind eyes. Wing length 0.05 to 0.07 inch (1.25 to 1.7 mm).

Larva: Initially colorless, becoming yellowish as they mature with black mouthparts.

Egg: White, oval, 0.01 inch (0.23 mm) long.

Pupa: Reddish brown, 1.5 mm long.

American Serpentine Leafminer (Liriomyza trifolii)

DESCRIPTION:

Adult: Less than 0.08 inch in length, wing length of 0.05 to 0.07 inch. Yellow head, red eyes, grayish black back, and yellow margins behind eyes.

Larva: White to yellow, wedge-shaped, 0.02 to 0.08 inch in length.

Egg: White, oval, 0.04 inch long.

Pupa: Initially golden brown and later, darker brown.

LIFE HISTORY:

Leafminers overwinter as pupae and emerge as adults in the spring. After mating, females lay eggs within the undersides of leaves. Eggs hatch within 2 to 4 days and larvae feed underneath the leaf epidermis, creating serpentine (snake-like) mines. Mines gradually increase in width as the larvae grow and mature. Larvae pupate within the mines or cut their way out of the leaf and pupate in the soil. Adults emerge after about 10 days during the summer months. One generation takes about a month; several generations occur each year.

DAMAGE:

Females puncture the leaf mesophyll with their ovipositor, and use these punctures to feed and lay eggs. Larvae cause the most injury and feed by removing the mesophyll between the surfaces of the leaves, creating lightly colored, irregularly winding mines. Damage caused by mines is not significant enough to reduce onion yield except when infestations are exceptionally high or in green onion crops where visible damage affects marketability.

MANAGEMENT

Cultural:

- *Clip and remove* older infested leaves.
- *Plant resistant varieties.*
- *Use adequate irrigation* to keep plants healthy.
- *Eliminate alternate hosts.* Destroy weeds and deep plow crop residues which can be food and overwintering sources for leafminers.

Chemical:

Leafminers can be difficult to control with insecticides. Broad-spectrum chemicals are not advised as they can eliminate natural predators and cause increased crop injury from leafminers.

Biological:

Generally, leafminer numbers are strongly suppressed by natural predators and outbreaks are usually associated with the use of insecticides. Several parasitic wasps and predators, including vespid wasps (yellow jacket and European paper wasp) will attack leafminers.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of California IPM Leafminers-*Liriomyza* spp. web page
- University of Florida Pea Leafminer web page
- University of Florida American Serpentine Leafminer web page
- University of Florida Vegetable Leafminer web page

Mites

Spider Mites

Order Acari: Family Tetranychidae

See pg. 59-60 for more information on the description, life history, damage, and management of this pest.

Bulb Mites

Order Sarcoptiformes: Family Acaridae

DESCRIPTION:

Adult: Shiny, creamy white, bulb shaped, and about 0.03 inch (.8 mm) long. Wingless with four pairs of short brown legs. Mouthparts and legs are purplish-brown. Often described as tiny pearls with legs.

Egg: White, minute, and laid singly on bulbs.

Immature Stages: White to brown, oval, 0.15 to 0.4 mm long, with three pairs of legs initially then four pairs as the mite matures. Stages include larva, protonymph, and deutonymph.

LIFE HISTORY:

Bulb mites have a wide host range and overwinter on decaying vegetation such as weeds or plant debris from previous crops. Males die shortly after mating but females may live for about a month. Females will lay 50 to 100 eggs in a lifetime (about six to eight per day). Eggs hatch in 2 to 7 days. One generation can be

completed in 2 to 4 weeks under favorable conditions. Bulb mites are slow moving and generally occur in clusters deep in the crevices between the roots and stem plate.

DAMAGE:

Bulb mites feed on the roots, basal plate, and outer skin layers of onion bulbs. Feeding injury provides openings for soil-borne fungal pathogens such as *Pythium*, *Rhizoctonia*, and *Fusarium*. Bulb mites can reduce plant stands and vigor. Injury typically occurs during early vegetative growth stages of onion. Symptoms resemble those of damping-off caused by *Pythium*. Infestations affect onion bulbs both in field and in storage.

MANAGEMENT:

Cool, wet weather that retards plant growth favors bulb mite injury, and cultural practices that promote rapid growth can allow plants to outgrow injury.

Cultural:

- *Allow crop residues to fully decompose* prior to planting onions. This will discourage bulb mites.
- *Use clean seed* and transplants. Examine transplant seedlings for presence of mites prior to planting and discard any that are soft when squeezed.
- *Rotate onions.* Mite populations will increase in soil following successive plantings of onion.
- *Store bulbs under cool temperatures* and low relative humidity. Storing onion bulbs under the appropriate conditions minimizes diseases and reduces build-up of bulb mite populations.
- *Use hot water treatments.* For bulbs to be planted as onion sets, dip bulbs in hot water before planting. ***Note:*** Hot water treatment can weaken bulbs.

Chemical:

Pre-plant soil fumigation can be used to control mites that are found in the soil prior to planting. Soaking bulbs in a miticide before planting can help prevent bulb mite injury.

Biological:

Bulb mite populations may be suppressed by the soil-dwelling predatory mite *Hypoaspis aculeifer.*

SEARCH THE INTERNET FOR MORE INFORMATION:

- UMass Amherst Bulb Mites web page
- University of Florida Bulbmites web page

Disease Management

Iris Yellow Spot Virus (IYSV)

IYSV was first reported in Utah in 2001. It is a tospovirus that, in Utah, is transmitted by onion thrips (*Thrips tabaci*). Thrips have to acquire the virus as larvae to be able to transmit it to healthy plants. Once thrips larvae have acquired the virus they will transmit it for the rest of their lives. The virus has several known hosts related to onion, including shallots and garlic. The virus has also been reported in other parts of the world in iris and *Lisianthus* cut flower production. More recently, several weeds such as prickly lettuce, sowthistle, green foxtail, and saltbush have been reported as hosts. Common mallow has been identified as a potential host for the virus but has not been confirmed. Not all susceptible weeds show virus symptoms.

SYMPTOMS:

Symptoms of IYSV consist of lens-shaped bleached spots on leaves (Fig. 7.13) that sometimes have a green center (Fig. 7.14). In severe cases, the entire onion foliage will die back (Fig. 7.15).

DISEASE CYCLE:

Plants become infected when virus-carrying thrips feed on healthy plants, depositing virus particles. Infected plants may not show symptoms for several weeks and in some cases, symptoms may never appear. It is currently unknown what triggers symptom expression. Once a plant is infected, there is no cure and an infected plant can serve as an inoculum source for neighboring plants. The effect of IYSV infections on yield depends on how early symptoms develop. If symptoms develop while bulbs are still growing, bulb size and quality will be reduced.

MANAGEMENT:

Since there is no cure for infected plants, they should be removed and destroyed. The best management strategy is prevention.

- *Control thrips* (see insect management section).
- *Good weed control.* Weeds can be a host for IYSV and thrips reproduction where they acquire the virus. Research in Utah has indicated that fields with good weed control along field borders had lower IYSV infections than fields with weedy borders.

Pink Root

Pink root is a fungal disease caused by *Phoma terrestris*. The fungus is commonly found in soil and is a concern in onion growing areas in Utah.

SYMPTOMS:

The characteristic symptom of pink-colored roots gives the disease its name (Fig. 7.16). The roots later turn dark red or purple, start to dry up, and eventually die. The fungus will spread to new roots, restricting the plant's root system, which leads to reduced bulb size. Primarily, the above-ground symptom of pink root is stunting (Fig. 7.17). In severe cases, foliage will die back resembling drought stress.

DISEASE CYCLE:

Phoma terrestris is most common in poorly drained soils that are low in organic matter. Unfavorable conditions (heat, cold, drought, flooding, nutrient deficiencies) weaken the roots and increase their susceptibility to the disease. To infect and colonize the roots, the fungus produces hyphae which penetrate young onion roots and grow around the cortical tissue. Optimum infection occurs at soil temperatures of 75-85°F. Visible symptoms on onions usually appear 7 to 21 days after infection has occurred. Open wounds are not necessary for infection, but weakened plants are more susceptible. *P. terrestris* is spread by transplanting onion seedlings, on garden tools, and in water.

MANAGEMENT:

P. terrestris can survive in the soil for many years. While waiting for a suitable host, the fungus survives on roots of other plants without causing damage to them.

- *Use resistant varieties.*
- *Maintain healthy, vigorous plants.* Keep plants free from insects and other diseases.
- *Use crop rotation.* Inoculum in the soil builds up and increases disease severity if onions are grown in the same field for several years in a row.

Purple Blotch and Stemphylium Leaf Blight

Purple blotch is caused by *Alternaria porri* and Stemphylium leaf blight is caused by *Stemphylium vesicarium*. Both pathogens cause similar symptoms and are managed in the same way.

SYMPTOMS:

Early symptoms include small brown elliptical spots on leaves, similar to IYSV lesions, which enlarge over time and may result in brown, necrotic streaks (Fig. 7.18). When *Alternaria* is the causal agent, the brown lesions will eventually turn purple (Fig. 7.19) as fungal spores develop. Lesions caused by *Stemphylium* often appear dark brown to black (Fig. 7.20) from the production of dense masses of spores.

DISEASE CYCLE:

These fungi are introduced into onion fields by windblown spores from nearby plants. Within the fields, the fungi persist by surviving on infected plant debris. Optimum temperatures for infection are between 77 to 85°F for *Alternaria* and 65 to 77°F for *Stemphylium*. Both pathogens require wounds caused by other diseases (e.g. botrytis), thrips feeding, or hail, to enter the plant. In severe cases, lesions enlarge and coalesce to blight the entire leaf. Spores are produced on the lesions throughout the growing season and disperse to adjacent leaves and plants. As leaves get older, they become more susceptible.

MANAGEMENT:

- *Use crop rotation.* A 3- to 4-year rotation can reduce the amount of inoculum present and reduce disease incidence.
- *Avoid excessive nitrogen* applications which can increase disease severity.
- *Bury or dispose culls* and other plant debris. Culls and plant debris can be a source for both pathogens and insects that cause wounding on new onion plants. Debris can be buried or disposed of in the trash.
- *Use fungicides.* There are several fungicides available that can be used to control both pathogens.

Botrytis Neck Rot

Botrytis aclada and *B. allii* cause postharvest storage disease. Severe infections can lead to over 60% loss.

SYMPTOMS:

The first symptoms of botrytis neck rot are seen in the neck area during storage. The neck may appear sunken and scales may have a water-soaked appearance that turn gray to dark brown (Fig. 7.21). Over time, the decay will move through the entire bulb (Fig. 7.22). Sometimes white to gray mycelium can be seen developing between scales (Fig. 7.23).

DISEASE CYCLE:

Botrytis overwinters in the soil and in plant debris left behind in the fields or in cull piles. The fungus produces overwintering structures called sclerotia (Fig. 7.24) that can survive for several years until a suitable host (onion) is planted again. It also produces spores on plant debris (Fig. 7.25) that are blown by wind to the onion fields from miles away.

Occasionally, the disease can be seedborne. Leaf tissue and bulbs can be infected in the field from soil or seedborne inoculum without showing any symptoms during the growing season. Most infections occur when onions are harvested before the leaves and necks are dry. The fungus infects the green neck area after the leaves are cut off. Symptoms usually don't develop until onions have been in storage for one to two months.

MANAGEMENT:

- *Store onions with dry, well cured necks.* The fungus is unable to penetrate and infect a dry neck.
- *Ensure proper curing.* Proper curing can be achieved by undercutting onions at maturity, severing all roots, refraining from applying any nitrogen fertilizer once bulbs have been initiated, and planting at the correct plant density in the field. If it is difficult to dry onions due to environmental conditions, forced air (93°F) at 0.06 m^3 per minute per 0.03 m^3 of bulbs can reduce losses to neck rot.
- *Maintain proper storage conditions.* The best storage conditions include air movement, temperatures between 33-34°F, and 70-75% relative humidity. Air movement must be monitored to avoid condensation on bulbs.

Pest Management Tables for Commercial and Home Use

Table 7.1. Herbicides registered for **COMMERCIAL** use on **Onions** in Utah.

Brand Name (REI/PHI)	Active Ingredient	Timing and Application Location Relative to Crop			Timing Relative to Weeds		Weed Groups Controlled			Comments
		Pre-emergence	Delayed Pre-emergence	Post-emergence	Pre-emergence	Post-emergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/-)	carfentrazone	X	X	X		X	X	X	X	Use with shields between rows
Dacthal (12hr/-)	DCPA	X	X		X		X	X	X	
Fusilade (12hr/-)	fluazifop		X	X		X	X			
GoalTender, plus others 12hr/45d)	oxyfluorfen			X		X	X	X	X	After 2-leaf stage; Do not use on stressed onions
Gramaxone Inteon 12hr/60d)	paraquat	X	X			X	X	X	X	Restricted use product
Nortron SC (12hr/30d)	ethofumesate	X	X	X	X		X	X	X	
Outlook (12 hr/30d)	dimethenamid-P			X	X		X	X	X	Apply after 2-leaf stage

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 7.2. Insecticides registered for **COMMERCIAL** use on **Onions** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Thrips	Maggots	Leafminers	Spider Mites
oxamyl	Vydate[R]	1A	5-10	X			
chlorpyrifos	Chlorpyrifos[R], Lorsban	1B	7-10		X		
diazinon	Diazinon[R]	1B	7-14		X		
malathion	Fyfanon, Malathion	1B	7	X	X		
gamma-cyhalothrin	Declare	3	5	X	X	X	
lambda-cyhalothrin	Paradigm[R], Province[R] Silencer[R], Warrior[R]	3	5-7	X	X	X	
permethrin	Ambush[R], Artic[R] Perm-up[R], Pounce[R] Perma star[R]	3	7-10	X	X	X	
pyrethrin	Pyganic[O]	3	5	X	X	X	X
zeta-cypermethrin	Mustang[R]	3	7	X	X		
pyrethrin + piperonyl butoxide	Evergreen[B]	3/	5	X	X		
pyrethrin + azadirachtin	Azera[OB]	3/UN	3	X	X	X	X
spinosad	Entrust[OB], Success[B]	5	7-10	X		X	
spinetoram	Radiant	5	4	X		X	
abamectin	Abba[R], Agri-mek[R] Epi-mek[R], Reaper[R]	6	7	X		X	
pyriproxyfen	Esteem	7C	14	X			
spirotetramat	Movento	23	7	X			
azadirachtin	Aza-direct[OB], Azatin[OB], Azatrol[B], Ecozin, Molt[O]	UN	5-10	See label for listed pests			
Beauveria bassiana strain gha	Mycotrol O[B]	---	2-10	X			
insecticidal soap (potassium salts of fatty acids)	M-pede, Safer's[O]	---	7	See label for listed pests			
kaolin clay	Surround	---	1	X			
oils: peppermint, rosemary, petroleum	Ecotec[OB], Omni Supreme[B], Saf-t-side[B]	---	1	See label for listed pests			

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 7.3. Fungicides registered for **COMMERCIAL** use on **Onions** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Purple Blotch	Stemphylium Leaf Blight	Botrytis Neck Rot	Pink Root
iprodione	Iprodione, Meteor Nevado, Rovral	2	7-14	See label for listed diseases			
propiconazole	Amtide, Bumper Fitness, Propi-star Propimax, Shar-shield, Tilt, Topaz	3	7	X			
tebuconazole	Monsoon, Orius, Tebu-crop Tebuzol, Toledo	3	10	X			
difenoconazole + cyprodinil	Inspire	3/9	7	X	X		
difenoconazole + azoxystrobin	Quadris Top	3/11	7	X	X		
propiconazole + azoxystrobin	Quilt	3/11	7	X			
mefenoxam + chlorothalonil	Ridomil	4/M5	7	X			
boscalid	Endura	7	7	X			
penthiopyrad	Fontelis	7	7	X	X	X	
boscalid + pyraclostrobin	Pristine	7/11	14	X	X	X	
cyprodinil	Vangard	9	7	X		X	
pyrimethanil	Scala	9	7	X		X	
cyprodinil + fludioxonil	Switch	9/12	7	X	X	X	
azoxystrobin	Quadris, Satori	11	7	X			
fenamidone	Reason	11	5	X			
pyraclostrobin	Cabrio	11	7	X			
famoxadone + cymoxanil	Tanos	11/27	5	X			
fluazinam	Omega	29	7	X		X	
fosetyl-al	Aliette, Linebacker	33	7	X			
Bacillus subtilis strain QST 73	Cease[OB] Serenade[OB]	44	7	See label for listed diseases			
copper-based	Champ, Cuprofix Cuproxat, C-O-C-S, Kocide, Mastercop Nordox, Nucop	M1	7	X			

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 7.3, continued. Fungicides registered for **COMMERCIAL** use on **Onions** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Purple Blotch	Stemphylium Leaf Blight	Botrytis Neck Rot	Pink Root
copper hydroxide + mancozeb	Mankocide	M1/M3	7	X			
mancozeb	Dithane, Manzate, Penncozeb, Roper	M3	7	X		X	
chlorothalonil	Bravo, Chloronil, Echo, Equus, Initiate	M5	7	X		X	
chlorothalonil + azoxystrobin	Quadris Opti	M5/11	7	X		X	
extract of *Reynoutria sachalinensis*	Regalia[B]	P	7-14	X	X	X	
Bacillus amyloliquefaciens strain D747	Double Nickle[OB]	---	7	X		X	
hydrogen dioxide	Oxidate[OB]	---	5			X	
mono- and di-potassium salts of phosphorous acid	Prophyt	---	?	X			
oils: rosemary, thyme	Sporatec[OB]	---	N/A			X	
Streptomyces griseoviridis strain K61	Mycostop[B]	---	?			X	

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 7.4. Insecticides registered for **HOME** use on **Onions** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Thrips	Maggots	Leafminers	Spider Mites
malathion	Bonide Malathion, Hi Yield, Ortho Max Malathion	1B	5	See label for listed pests			
gamma-cyhalothrin	Spectracide Triazicide	3	14	X	X	X	
pyrethrin	GardenTech Worry Free[B]	3	5	X	X	X	
sulfur and pyrethrin	Bayer Natria[B]	3/M2	5	X	X	X	X
acetamiprid	Ortho Fruit and Vegetable	4A	14	X		X	
spinosad	Bonide Captain Jack's[B]	5	7-10	X		X	
insecticidal soap	Safer's[B], Natural Guard[B], Bayer Natria[B]	---	7	See label for listed pests			
neem oil plus pyrethrin	FertiLome Triple Action[B]	---	3	X		X	X
oils: neem, canola, rosemary, clove, and cottonseed	Green Light[B], Bayer Natria Multi Insect[B], Monterey Neem Oil[B], Monterey All Natural Mite and Insect[B], Natural Guard Neem[B]	---	1				X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide

Table 7.5. Fungicides for **HOME** use on **Onions** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Purple Blotch	Stemphylium Leaf Blight	Botrytis Neck Rot	Pink Rot
chlorothalonil	FertiLome; Bonide Fung-onil	M1	7	X			
copper	Monterey Liqui-cop; Bonide Copper Spray	M1	7	See label for listed diseases			
Bacillus subtilis strain QST 713	Bayer Natria[B]	M5	7	X		X	

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide

Fig. 7.1. Bulbs of onion varieties vary in color.

Fig. 7.2. Harvest onions when foliage is partially erect.

Fig. 7.3. Straw mulch between rows of onion helps suppress weeds.

Fig. 7.4. Adult onion thrips have 7-segmented antennae.

Fig. 7.5. Onion thrips larva.

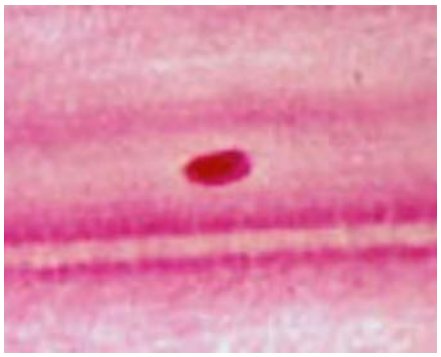


Fig. 7.6. Stained onion thrips egg.

Fig. 7.7. Onion thrips feeding causes silvery streaks.

Fig. 7.8. Thrips are most commonly found in the neck of the onion.

Fig. 7.9. Adult western flower thrips have 8-segmented antennae.

Fig. 7.10. Life stages of western flower thrips.

Fig. 7.11. Banded thrips adults are important predators of onion and western flower thrips.

Fig. 7.12. Onion maggot levels of injury.

Fig. 7.13. Iris yellow spot virus lesion.

Fig. 7.14. Iris yellow spot virus lesion with green island.

Fig. 7.15. Severe leaf dieback due to iris yellow spot virus.

Fig. 7.16. Pink root.

Fig. 7.17. Aboveground symptoms of pink root.

Fig. 7.18. Leaf dieback due to purple blotch.

Fig. 7.19. Purple blotch.

Fig. 7.20. Stemphylium leaf spot.

Fig. 7.21. Early stage of botrytis neck rot.

Fig. 7.22. Advanced decay by botrytis neck rot.

Fig. 7.23. White mycelium of *Botrytis* growing between scales.

Fig. 7.24. "Sclerotia" spores produced by *Botrytis* on onion bulbs.

Fig. 7.25. Grey *Botrytis* spores produced on onion.

CHAPTER 8 POTATO PRODUCTION

Varietal Selection

Potato variety selection can be challenging given the number of choices available. Consider the length of the growing season, soil type, climate conditions, and production practices when selecting varieties. Very little testing of potato varieties has been done in Utah but with our close proximity to Idaho, variety selection based on their recommendations would be a good place to start. Remember, most varieties will grow and produce tubers but not all may be suited to your location. When selecting a new variety, compare it to existing varieties grown on your farm. Evaluate new varieties based on earliness, vine growth habit, and disease resistance. If viruses and fungal diseases have been problems, look for varieties with some resistance to these issues. Heirloom varieties, while popular, generally lack disease resistance, and are more prone to cosmetic defects.

Table 8.1. **Variety Suggestions***

Fruit Types	Varieties	Tuber Characterstics
Early	CalWhite	white skin; white-flesh
	Irish Cobbler	buff skin; white flesh
	Russett Norkotah	russet skin; white flesh
	Dark Red Norland	dark red skin; white flesh
	Norland	red skin; white flesh
Mid-Season	French Fingerling	pink skin; yellow flesh
	Gold Rush	russet skin; white flesh
	NorValley	white skin; white flesh
	Chieftain	red skin; white flesh
	Red La Soda	deep red skin; white flesh
	Red Pontiac	red skin; white flesh
Late-Season	Bannock Russet	russet skin; white flesh
	Katahdin	whitish skin & flesh
	Russet Burbank	russet skin; white flesh
	Yukon Gold	yellow; buff skin; yellow flesh
	Ida Rose	red skin; white flesh
	Russian Banana	yellow skin; yellow flesh
	Western Russet	russet skin; white flesh

*Variety recommendations from University of Idaho Commercial Potato Production in North America

We recommend that growers regularly test new varieties and compare them to what you already grow. On-farm testing is the best way to identify varieties that are most suited to your farms local and unique conditions.

Potato Seed Handling and Treatment

Always plant Foundation or Certified seed. Tubers or seed-pieces showing decay should not be planted. Store seed potatoes at 38-40°F and 95% relative humidity until planting, then warm tubers to 50-55°F for 2 weeks prior to cutting or planting. Cut seed can be planted immediately. If conditions after cutting delay planting, store seed stock in sacks or crates to allow air movement about them and keep in a humid environment for 2 or 3 days. Cut seed pieces should be blocky, have at least one eye, and weigh 1.5 - 2 oz. per piece. Seed pieces of uniform size and weight are easier to plant, so try to be consistent when cutting.

The ideal seedbed conditions for planting potatoes is warm soil, moderately moist, and of uniform particle size. Soils should be 50-60°F which encourages cut seed wound healing and rapid sprouting and emergence. Seed piece decay is more common when planted in cool (< 45°F) wet soils.

Seed pieces can be pre-sprouted (called green sprouting or chitting) which accelerates plant emergence and speeds tuber development. Green sprouting combined with close plant spacing (about 6") can lead to an earlier harvest by 7-14 days. Plants are commonly harvested when tubers are small and marketed as small new potatoes.

To green sprout seed, about 6 weeks prior to planting spread out seed tubers 1 layer deep with the eyes up. Seed should be chitted warm (~ 70°F) and at medium light intensities (bright shade - not direct sunlight). The warm stimulates strong shoots while the bright light keeps the shoots short. The sprouts should be about 1" long at planting. Do not cut the seed before green sprouting as this encourages desiccation.

Soil

Deep sandy to loamy soil with a pH of 6.5 to 7.5 is ideal for early potatoes. Heavier soils while more productive, should be used for main season production. Most soils in Utah are suitable for potatoes provided they are well drained and fertile. Practice good crop rotations remembering that potatoes are related to eggplant, peppers and tomatoes and most insects and diseases are common to all solanaceous vegetables. Note: plant residue from these related crops serves as a host for plant diseases and insects that may infect or infest the next crop. Plant residues from the prior crop should be completely buried at the bottom of the furrow to facilitate decomposition.

When green-manure or cover crops are part of the production system, incorporate these early and allow sufficient breakdown time of crop residues so they do not tie-up nutrients or interfere with planting. Some residues (straw, corn stalks, grassy sod, or grain stubble) require additional nitrogen to enhance breakdown. Manures are also beneficial in providing extra nutrients and maintain organic matter. Prior to planting, be sure to incorporate green manures, cover crops, residues, composts and manures.

Potato fields should be well-tilled to create a smooth, firm seed bed for uniform planting and emergence. Several weeks before planting, prepare the field to create a loose, moist seedbed which ensures good soil-seed piece contact. Over-working the seedbed encourages soil crusting and compaction.

Planting and Spacing

Planting dates in Utah vary depending local climate conditions. Planting often begins in late March in southern Utah and may be as late as early-June in cooler areas of northern Utah. Planting is recommended after danger of frost has passed. Local freeze dates can be accessed through the Utah Climate Center (climate.usurf.usu.edu).

Potato seed requirements depend on between and in-row spacing (Table 8.2), variety, and local conditions. Close spacing (6 - 8") are used to reduce tuber size and increase the number of tubers set. Closer spacings also reduces hollow heart and growth cracks. Seed pieces should be planted 2 - 4" deep. For more rapid emergence, plant shallow. If soils are dry, plant a bit deeper. Rapid emergence is necessary to reduce soil-borne diseases such as Rhizoctonia.

Table 8.2. Potato seed requirements (lbs.) per acre for different between and in-row spacing.

Seed Piece Spacing (in)	32 inch row spacing		36 inch row spacing		40 inch row spacing	
	1.5 oz. pieces	2 oz. pieces	1.5 oz. pieces	2 oz. pieces	1.5 oz. pieces	2 oz. pieces
6	3060	4085	2725	3630	2450	3270
8	2300	3065	2040	2725	1840	2450
10	1835	2450	1630	2180	1470	1960
12	1535	2040	1360	1810	1225	1635
16	1150	1535	1020	1360	920	1225

Fertility

Prior to planting, have the soil tested to determine nutrient needs and deficiencies (Table 8.3). Soil sampling approaches, forms, test details, and interpretation can be accessed through the Utah State University Analytical Laboratories (www.usual.usu.edu). Organic growers find it is a good idea to incorporate composted organic matter before planting to sustain soil fertility. An initial application of 5 tons per acre of high quality compost of known nutrient analysis may be helpful. This can be broadcast over the whole field or banded and incorporated into the individual rows.

A common practice is to add ¼ to ⅓ of the required nitrogen fertilizer and all the phosphorous and potassium prior to planting (See Table 8.3). In soils with high P and K levels, broadcast applications are acceptable, then work the fertilizer into the soil during normal field preparations. Banding is a good method to ensure the fertilizer is near the plant and makes sense where wide row spacings are common. Fertilizer bands should be 3 inches beside and 3 inches below the seed to minimize salt injury.

Nitrogen (N) – Nitrogen fertilizer is most efficiently used in split applications. Apply up to 50 lbs. N/acre prior to planting with an additional 100-150 lbs. N/acre applied in two or three applications. The first side dressing occurs when stolons start to form, the next around flowering, and the last during early bulking. Use the smaller amount if the site has added manure, compost, or when potatoes are grown after a legume

crop (beans, alfalfa, etc.). Nitrogen is particularly suited for application by sprinkler or drip irrigation. In these systems, it is common to apply 20-30 lbs. N/A every 10-14 days. Nitrogen management can be greatly improved through tissue testing.

Table 8.3. Phosphorus (P_2O_5) and Potassium (K_2O) based on soil test results.

Phosphorus Test Results	Lb/ acre	Potassium Test Results	Lb/ acre
0-14	100-150	0-74	100-150
15-29	70-100	75-149	50-100
30-45	40-70	150-199	25-50
46-60+	0-30	200+	0-25

Use the higher amount when soil test values are in the lower part of the range.

Weed Management

Weed control is critical for potatoes as weeds in the planted row and furrow compete with the crop before the plants are large enough to shade out weeds. Weeds in and between the rows are typically controlled with cultivation, herbicides, or a combination of approaches. An effective weed control program identifies the weeds common to the farm, assesses cultivation practices used, reviews available herbicides, and determines the competitive ability of the potato varieties grown. If herbicides are used, they should be tailored to the weeds present in the field.

In organic production systems, mulches (such as straw, cardboard, etc.) can provide good weed control if applied in a thick mat. There are OMRI approved organic herbicides that can assist in weed management in organic operations. Most organic herbicides have limited residual activity so use a combination of controls like tillage, hoeing, and mulches in addition to herbicides.

Many herbicides are manufactured by different companies under different trade names. The use of chemical names (active ingredient) along with one representative trade name is listed at the end of this section. Herbicide and pesticide labels change so growers must always consult a current label to determine 1) if the crop is listed for herbicide use; 2) what precautions in use are required; and 3) what rates and application methods are allowed. Off-label applications are hazardous to the environment, to people using the product, and can severely injure the crop.

Use herbicides only for those crops for which they are approved and recommended. Use the recommended amount of product and apply it as stated. Pay attention to re-entry intervals (REI) and pre-harvest intervals (PHI). The EPA has the authority to seize any agricultural commodity that carries a pesticide residue in excess of the established tolerance. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

Don't spray in high wind conditions so drift injury to susceptible crops is minimized. Work with your neighbors as many herbicides are toxic to other crops that are growing nearby. Finally, herbicides are just one tool available for weed control and their use should supplement other good weed-management practices.

Herbicides are applied in the following ways:

- **Before planting:** incorporated into the soil prior to seeding or transplanting the crop.
- **Pre-emergence:** applied to the soil after planting but before the crop or weeds emerge.
- **At/after hilling:** applied to the soil after the crop is transplanted either before weeds emerge or after clean cultivation. In some cases, sprays are directed to row middles and shielded from application to the crop.
- **Directed / Shielded:** applied as a directed or shielded spray 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.
- **Post-emergence:** applied to weeds after both weeds and the crop have emerged.

Cultivation and Hilling

Cultivation operations often begin after potatoes begin to emerge. The purpose of cultivation is to maintain soil aeration, shape the beds to maximize tuber growth and reduce tuber greening, establish irrigation furrows, and control weeds. Hilling should be completed prior to the plants filling half of the row being careful to minimize foliar, stolon, and/

or root damage. Hilling allows for shallow planting depth to speed emergence while providing the soil depth necessary for proper tuber development and protection from sunlight. Discs, hilling listers, and rolling cultivators are commonly used. Hills should be broad with flatter tops rather than narrow and peaked. Cultivation during hilling provides weed control and incorporates soil-applied herbicides.

Irrigation

Potatoes require regular, uniform watering during the growing season for optimal productivity. Potatoes are sensitive to water shortages due to the plant's shallow root system and large leaf area. Water shortages during establishment can limit emergence and early vine growth. Inconsistent watering at flowering impacts stolon initiation and number. Water deficits during tuber bulking limits size, shape and contributes to reduced tuber quality (necrosis, black spot, hollow heart, heat sprouting). Over-watering encourages foliar and root diseases, impacts tuber quality, delays senescence and skin set, and interferes with harvest.

Common irrigation methods include furrow, sprinkler and in some areas drip irrigation. Regardless of the system used, the goal of soil water management is to maintain adequate soil moisture while avoiding extreme or excessive fluctuations. The amount of water applied during an irrigation event depends of the infiltration rate and water-holding capacity of the soil. Specific guidelines on irrigation depend on soil type, stage of growth, and local conditions (temperature, RH, wind). Soil water status should be monitored regularly to maintain consistent soil water using a resistance block such as the Irrometer Watermark sensor. Place sensors throughout the field and at several depths to get an accurate measure of soil water content. Start irrigations at 15-25% depletion during vegetative growth. During tuber initiation and tuber bulking, soil should be maintained at 80-90% of available soil water (10-20% depletion) for optimal production.

Vine Removal and Desiccation

In preparation for harvest, it may be necessary to remove potato vines prior to harvesting the tubers. Vine removal can be done mechanically (flail beaters, rotary choppers) or by the application of chemical vine-killers. Mechanical beaters effectively remove potato tops, but should be adjusted to remove the tops without injuring any tubers near the soil surface. Organic growers prefer this method of top-killing.

When potatoes have excessive amounts of top growth, use a chemical vine-killer first, followed by mechanical removal to shred tops. This combination provides effective vine kill. Potato vines should be chemically killed approximately 21 days prior to harvest. This provides time to insure good skin set. Note, rapid vine desiccation (either chemical or mechanical) can cause stem-end discoloration in tubers.

With chemical vine-killers, use the lower application rates if plants are stressed (see the label). Good spray coverage is important for these chemicals to work effectively and the speed of vine desiccation varies greatly between the different chemicals.

CAUTIONS: When using chemical vine-killers, ALWAYS FOLLOW LABEL INSTRUCTIONS. The information provided below is very general and does not provide full label instructions regarding the application or full use of the materials.

- carfentrazone (Aim): 3.2 to 5.8 oz/A (7 dh; REI 12h) and spray adjuvant (NIS, MSO, or COC) is required (1-2% v/v). Suitable for seed and storage potatoes. Thorough coverage is essential. May be tank mixed or used sequentially with other desiccants (see labels for restrictions).
- diquat (Reglone): 1 to 2 pt/A (7 dh; REI 12h) and always use a spray adjuvant (0.1-0.5% v/v NIS). Suitable for seed and storage potatoes.
- glufosinate-ammonium (Rely): 3 pt/A (9 dh; REI 12h). Do NOT use on seed potatoes.
- paraquat (Firestorm or Parazone 3SL): 0.7 to 1.3 pt/A (9 dh; REI 24h) and always use either NIS (0.125% v/v) or COC (1.0% v/v). NOTE: paraquat is NOT registered as a vine desiccant for storage or seed potatoes. May ONLY be used for Fresh Market Potatoes. Potatoes must be harvested promptly and processed or consumed immediately.
- pyraflufen-ethyl (Vida): 2.75 to 5.5 oz/A (7 dh; REI 12h). Apply when vines are starting to senesce for best results. May be tank-mixed in sequence with other desiccant products.

Harvest and Handling

Harvest potatoes for storage when tuber temperatures are between 45-60°F. At warmer soil temperatures (above 60°F), field heat contributes to tuber quality deterioration before cooling can occur in storage. When tubers are cold (below 45°F), potatoes bruise easily during harvest. If days are warm, harvest early in the day, conversely, if it's cold, start harvest later in the day and continue into the evening. The ideal temperature during harvest is 60-70°F.

Bruising can be further reduced by controlling fertilizer and irrigations late in the season. Initiate better skin set through vine killing, controlling late season nutrient/water management, ensuring harvesters (chain and forward speed ratios) are adjusted properly, and keeping harvester chains filled. Potatoes should not drop more than 4-6" and equipment surfaces should be properly padded. Premature harvesting results in reduced yields and low specific gravity. When harvesting is delayed, frost and diseases can cause serious storage losses.

Potatoes intended for long-term storage are often treated with sprout inhibitors (pre- or post-harvest) to extend storage life. Use maleic hydrazide (MH-30) pre-harvest (one application; 1-1.33 gal/A (REI 12h)), four to six weeks before potatoes are mature and ready for harvest. Potatoes treated with MH-30 cannot be used for seed. Chlorpropham (CIPC) is the most effective post-harvest sprout inhibitor registered. CIPC requires licensed commercial applicators to apply the aerosol formulation while the EC formulation can be applied as a direct spray during the fresh packing operation. CIPC can be applied any time after wound healing but before tubers break dormancy or sprouts start to grow.

For organic growers, some essential oils (peppermint, spearmint, and clove oils) have been shown to reduce sprouting in potatoes. These alternative compounds are not true "sprout inhibitors" like CIPC but are "sprout suppressors" since they physically damage developing sprouts. Because of their high volatility, these oils leave behind little or no residue. However, new sprouts continue to develop so repeat applications are required every two to three weeks. Timing is critical with all the sprout suppressors. They are most effective when applied before sprouts are one-eighth (1/8") inch long. Organic growers should check with their certification agency and the National Organic Standards for current regulations regarding alternative sprout control products.

Postharvest Handling and Storage

An important aspect of potato quality control is to provide a pathogen-free storage environment. All storage and potato handling equipment surfaces should be cleaned and disinfected prior to placing the crop into storage. Surfaces should be well moistened by the disinfectant spray. Spray bin walls until there is a slight runoff. Several disinfectant materials are available including quaternary ammonium compounds; (Prosan and Ster-Bac); sodium hypochlorite products (Agclor); and hydrogen dioxide products (Storox). Consult the labels for specific directions. Once the storage environment is clean and sterilized, it is ready for potatoes.

Healing of cuts and bruises that occur during harvest is most rapid in storage when the environment has a high relative humidity (95%), when tubers are at an appropriate temperature (50-60°F), and when adequate ventilation is provided throughout the pile. These conditions should be provided for 2 to 3 weeks at the beginning of storage and helps the tubers suberize. Effective suberization reduces tuber water loss and prevents rot organisms from entering damaged tubers. After suberization the temperature should be gradually lowered to 40°F (table stock or seed potatoes) or maintained at 50°F (chipping potatoes). When rot potential is high (field frost, late blight, or if ring rot is present) the curing period should be eliminated, the temperature dropped immediately, and the ventilation increased. Crops with these issues should be utilized as soon as possible.

Storage temperature control is best achieved with forced air ventilation. Storage relative humidity should be kept as high as possible without causing condensation on the storage walls and ceilings. Good insulation properly protected with a vapor barrier reduces the danger of condensation.

Once potatoes reach the long-term storage temperature, ventilate several hours per day or just enough to maintain pile temperature. Continuous ventilation is not necessary unless condensation or rot development occurs within the storage area or pile. Constant ventilation increases tuber weight loss

and influences quality. A relative humidity of 95% is desirable for long term storage to maintain quality and minimize shrinkage.

For more detail on storage, handling and maintaining postharvest quality of potatoes, refer to the specific produce fact sheet available through the UC Davis Postharvest Technology website: http://postharvest.ucdavis.edu. These fact sheets are comprehensive guides to maintaining postharvest quality of the specific crop of interest.

Physiological Disorders

Potatoes are susceptible to a variety of noninfectious disorders that affect the shape, function, and appearance of the plants or tubers. These are referred to as physiological disorders since they are often caused by abiotic, nonpathogenic, nonparasitic, or noninfectious maladies that have nothing to do with diseases or pests. Physiological disorders cause changes in growth or appearance which contribute to economic losses since the tubers may not make grade standards. Table 8.4 on the next page lists the name of some of the more important disorders, the plant part affected, and a description of and ways to minimize or control the problem. Most physiological disorders develop slowly, may not be observed till very late in the crops growth cycle, are difficult to correctly identify, and thus make it hard to determine when the problem started. Most occur erratically both in time (not evident each year) and location (field to field).

SEARCH THE INTERNET FOR MORE INFORMATION:

Potato growth

- University of Idaho Growth and Development

Fertility

- University of Idaho Potato Nutrient Management
- University of Arizona Nitrogen Management Guide for Potato
- Pacific Northwest Extension Soil Fertility in Organic Systems

Irrigation

- University of Idaho Potato Irrigation
- Oregon State Drip Irrigation Guide for Potatoes
- Colorado State University Irrigating with Limited Water Supplies

Organic Potato Production Guides

- Cornell Organic Production and IPM Guide

Table 8.4. Potato physiological disorders

Name	Plant Part Affected	Cause, Control or Management
Frost Damage	Leaves/Foliage	Injury occurs when the leaf temperature falls below freezing. Tissue turns dark and dries out after warm up. Leaves/stems may turn yellowish and be distorted.
Hail Damage	Leaves/Foliage	Foliage shows tears, ragged holes or complete defoliation. Stems may have grey to white colored impact injuries or bruises.
Lighting Damage	Leaves/Foliage	Circular areas in the field that have dead plants in the centers with stunting of plants as one moves further away from the strike site.
Cracking	Tubers - External	Growth cracks are shallow to deep fissures in the tuber surface. These are commonly caused by uneven watering. Dry, then wet conditions result in changes in growth rate that cause the tuber to split. Maintain more constant water supply.
Enlarged Lenticels	Tubers - External	Lenticels are small pores on the surface of the tubers. When tubers are oxygen starved (waterlogged soils) or in dry, compacted soils, lenticels enlarge giving the tuber a warty, scab like appearance. Maintain constant water supply and provide good field drainage.
Freezing/ Chilling	Tubers - External	When tubers are exposed to temperatures (32-38°F), they become chilled. They appear wrinkled, feel soft, and may have a blackish coloration just below the skin. Tubers that have been frozen (<31°F) become soft, watery and disintegrate when re-warmed.
Greening	Tubers - External	Exposure to light (sunlight or artificial light) enhances the development of chlorophyll by the tubers. Control by providing good tuber cover in the field and keeping storage facilities dark.
Malformation	Tubers - External	Deformities are also called bottlenecks, chains, dumbbells, heat sprouts, knobby, or pointed tubers. Tubers have multiple areas of growth and are oddly shaped. The severity of deformity depends on the stage of tuber growth, the severity of stress, and size of the tuber.

Insect and Mite Pest Management

Aphids

Order Hemiptera: Family Aphididae

Aphids on potatoes are serious pests because of their ability to transmit potato viruses.

Green Peach Aphid *(Myzus persicae)*

See pg. 57-58 for more information on the description, life history, damage, and management of this pest.

LIFE HISTORY:

Populations peak during July and early August.

DAMAGE:

The green peach aphid is the most important vector of potato leaf roll virus (PLRV). It also vectors potato virus Y (PVY). Both diseases are particularly damaging viruses in solanaceous crops such as potato. See the diseases section of this chapter for more information on PLRV and PVY.

Potato Aphid *(Macrosiphum euphorbiae)*

See pg. 57-58 for more information on the description, life history, damage, and management of this pest.

LIFE HISTORY:

Generally, populations are highest in spring and fall.

DAMAGE:

The potato aphid may act as a vector for potato virus Y (PVY) and cucumber mosaic virus (CMV). See the diseases section of this chapter for more information on PVY.

Colorado Potato Beetle

Order Coleoptera: Family Chrysomelidae

DESCRIPTION:

Adult: Similar size (3/8 inch long) and shape as lady beetle, but with yellow and black stripes (Fig. 8.1).

Egg: Small, bright yellow to orange ovals laid in clusters of about 20-45 on the underside of leaves (Fig. 8.2).

Larva: About ½ inch-long when mature. Small bulbous larvae that are reddish in color with two rows of black spots along the side of the body (Fig. 8.3).

Pupa: Oval in shape and cream to orange in color (Fig. 8.4).

LIFE HISTORY:

Overwintering adults emerge from under plant debris and in the soil around May in northern Utah. Females lay clusters of eggs on the undersides of leaves of potato, tomato, pepper, eggplant, nightshade, and other solanaceous plants. Larvae feed for 10-30 days, and then pupate in the soil. There are two to three generations per season.

DAMAGE:

Colorado potato beetle (CPB) adults and larvae feed on foliage and can defoliate plants if not controlled. The last (4^{th}) instar larva causes most of the feeding damage (Fig. 8.5). Potatoes in the vegetative stage can usually tolerate up to 30% defoliation, but when tubers start to bulk, plants can tolerate no more than about 10% defoliation. Thus, it is crucial to manage CPB soon after flowering as this is when tuber bulking begins. Other CPB hosts include eggplant, tomato, pepper, and other nightshade or solanaceous plants.

MONITORING:

Start monitoring fields at crop emergence for the presence of CPB. Larvae prefer to feed at the tops of plants making it simple to scout by checking these areas when walking through fields. Because small populations are easier to manage than large ones, the goal is to limit population growth and spread.

MANAGEMENT:

Cultural:

- *Crop rotation and sanitation.* Crop rotation delays and reduces infestations. If potatoes follow potatoes, overwintering CPB will immediately infest the new crop. Destroy any solanaceous plant residues that may provide alternate food sources.

Biological:

Damsel bugs and big-eyed bugs feed on eggs and young larvae; predatory stink bugs will attack larvae. Two bioinsecticides are effective on young larvae: the bacterium, *Bacillus thuringiensis* var *tenebrionis* (Bt), and the fungus, *Beauveria bassiana.*

Chemical:

CPB has developed resistance to nearly every class of chemicals. Thus, it is critical to carefully rotate insecticide modes of action. In spring, wait until eggs have hatched for the first application. Border sprays may provide a more economical choice, especially

early in the season before populations increase and spread throughout fields.

Several economic treatment thresholds have been developed. In general, 1 adult or larva per plant early in the season may warrant control. After flowering/tuber bulking, treat when there are an average of 1.5 large larvae or adults per plant.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Pacific Northwest Insect Handbook Colorado Potato Beetle
- Penn State Colorado Potato Beetle
- University of Minnesota Colorado Potato Beetle in Home Gardens

Cutworms

Order Lepidoptera: Family Noctuidae

Subterranean Cutworms:

Pale Western Cutworm *(Agrotis orthogonia)* (Fig. 8.6)

Glassy Cutworm *(Crymodes devastator)* (Fig. 8.7)

Army Cutworm *(Euxoa auxiliaris)* (Fig. 8.8)

Black Cutworm *(Agrotis ipsilon)* (Fig. 8.9)

Variegated Cutworm *(Peridroma saucia)* (Fig. 8.10)

DESCRIPTION:

Adult: Moths are brown or dark gray with front wings that have irregular bands or spots and lighter-colored hind wings. Average wingspan ranges from 1¼ to 1½ inches (Fig. 8.11).

Egg: Extremely small spherical eggs are white or pale yellow when first laid, changing to brown before hatching (Fig. 8.12). Depending on the species, eggs are laid singly or in irregular clusters of 30-360 on leaves or stems of plants or near the base of the plant.

Larva: Dull gray to brown caterpillars with black stripes or spots. Up to 2 inches long when full grown. Most cutworms curl into a 'C' shape when disturbed and during the day, are usually found in dirt clods or just below the soil surface.

Pupa: Dark brown to orange in color with two spines on one end. Sizes range from ½ to 1-inch long (Fig. 8.13).

LIFE HISTORY:

Cutworms overwinter as larvae in the soil or under plant debris. In the spring, larvae become active and begin to feed on roots and plant stems. Larvae then pupate in the soil and emerge as adults. Female moths lay eggs on the undersides of leaves and hatched larvae feed on plant foliage, and then pupate in the soil. Some species of cutworms will have a second generation of adults (or more during hotter seasons) that emerge and deposit eggs. Larvae that hatch from these eggs feed until the weather cools and then enter the soil for overwintering. Black and variegated cutworms usually have 2 overlapping generations per year. Army, pale western, and glassy cutworms usually have one generation per year.

DAMAGE:

Cutworms feed on a wide range of crops. Some plant hosts include: potato, winter wheat, corn, tobacco, asparagus, bean, beet, cabbage, castor bean, grape, lettuce, peanut, pepper, radish, spinach, squash, strawberry and tomato. Cutworm larvae feed at the soil surface and may cut off the stems of young plants during stand establishment (Fig. 8.14). Later in the season, some species can be found feeding on plant foliage which may cause wilting and possibly complete defoliation when infestations are high. Larvae can feed on tubers, causing gouged-out cavities. Tubers that are exposed by soil cracks or those that set very shallow in the soil may be more susceptible.

MONITORING:

- *Conduct regular scouting for larvae and damage.* Monitor early, when seedlings emerge, to detect cutworms when larvae are small. Young larvae are easier to control. Focus on fields with an early season weed infestation, and those planted late. Cutworms preferentially attack these types of fields. When injured plants are found, dig about 1-inch-deep around the base of plants to see if live cutworms are present. Look for wilted plants that may indicate stem feeding injury. Later in the season, monitor plants for foliage damage.
- *For black cutworms, use pheromone traps.* A threshold of 2 black cutworm moths per trap per day indicates significant egg-laying pressure. Increase field scouting efforts during crop emergence when threshold numbers are met or exceeded.

MANAGEMENT:

Cultural:

Weedy fields and field borders, and high levels of plant residue provide food sources for cutworms. Thoroughly till crop residues and control weeds to reduce cutworm overwintering and feeding sites. Remove cool-season weeds along field edges to starve young caterpillars. Lambsquarters and wild mustards are attractive host plants for egg-laying. Fall tillage can also help destroy or expose overwintering pupae.

Biological:

Many predators, parasites, and diseases attack cutworms, but because cutworms dwell beneath the soil surface, few of these natural enemies are effective in controlling their populations. *Bacillus thuringiensis* (Bt) products can be effective in controlling young cutworm larvae.

Chemical:

The sporadic occurrence of cutworm infestations typically doesn't support the use of soil insecticides; however, if chronic cutworm infestations have been experienced, or large numbers of overwintering cutworms are observed, insecticides incorporated at planting provides a good preventive strategy. Young larvae at the soil surface will feed on foliage at night; thus, foliar applications in the spring can protect young plants.

Consider treatment options when thresholds reach 2 cuts per 100 seedlings, and 3-7 cuts for older plants (the older the plant the higher the threshold).

SEARCH THE INTERNET FOR MORE INFORMATION:

- Oregon State University Black Cutworm and Variegated Cutworm
- UC Davis IPM Potato Cutworms
- Penn State Black Cutworm

Flea Beetles

Order Coleoptera: Family Chrysomelidae

See pg. 37-38 for more information on the description, life history, damage, and management of this pest.

DAMAGE:

Adults will chew holes in leaves and larvae can reduce plant health by feeding on roots and fine root hairs, but both of these types of injuries do not usually cause economic loss. However, some species, such as the tuber flea beetle (Fig. 8.15), may cause significant damage in potato tubers. Tuber flea beetle larvae feed on roots, underground stems, and tubers. Tuber feeding results in small brown tunnels in the tuber and a pimpled surface. Severe tuber feeding can leave potatoes unmarketable for the fresh and processing markets. Tunnels will be filled with insect frass (excrement) that may stain the potato skin and flesh (Fig. 8.16).

MANAGEMENT

Cultural:

- *Avoid planting susceptible crops after potatoes.* Crop rotations are generally ineffective against flea beetles because of their extreme mobility; however, potato tuber flea beetle populations tend to be greater in areas where potatoes were previously planted. Thus it is important to avoid planting highly susceptible crops after potatoes.

Potato Psyllid

Order Hemiptera: Family Triozidae

DESCRIPTION:

Adult: Less than 1/8 inch long with clear wings that rest like a tent over the body. Related to aphids and leafhoppers, and resemble small cicadas (Fig. 8.17). Black in color with white markings and a white inverted 'V' on the back. Readily jump when disturbed.

Egg: Extremely small (just larger than potato leaf hairs), foot-ball shaped eggs are orange to yellow in color, supported individually by a short stalk, and laid in the upper canopy of plants on the undersides and edges of leaves.

Nymph: Flat, green (yellowish green to orange when newly hatched), red eyes, and an oval-shaped body with spines around the edge (Fig. 8.17). Nymphs resemble immature soft scale insects or whiteflies but differ in that they readily move when disturbed.

LIFE HISTORY:

Potato psyllids do not overwinter in northern Utah; they migrate north on air currents from warmer areas. Psyllid population dynamics and dispersal are greatly dependent on temperatures. Movement and dispersal increases at or above 92°F.

In the Pacific Northwest, potato psyllids are typically first detected in early July, although it is possible they may colonize potato fields around mid-June (possibly

later in Utah). Each female lays about 200 eggs that hatch in 6 to 10 days. Early hatching will occur with warmer temperatures; however, temperatures above 90°F reduce reproduction and survival. Nymphs complete five instars (molts) in 13-24 days. Under optimal conditions, potato psyllids can complete a generation in less than a month. Multiple generations occur each season, depending on temperatures and when the psyllids arrive. Adults lay eggs over an extended period of time, resulting in overlapping generations.

DAMAGE:

Adult potato psyllids vector the bacterium, *Candidatus Liberibacter solanacearum*, that causes Zebra chip disease (ZC). ZC significantly impacts potato production. Adults and nymphs acquire the bacterium by feeding on an infected plant, and will carry the bacterium for the rest of their life. Some eggs laid by infected adults will also become carriers of the bacterium. See the diseases section of this chapter for more details on ZC.

All stages of potato psyllids feed on potato foliage with needle-like mouthparts that suck out plant juices. Toxins from their saliva are injected into the plant as they feed. This causes "psyllid yellows" which turns leaves yellow or purple (Fig. 8.18). Psyllid yellows also results in fewer, smaller, or misshapen tubers.

MONITORING:

Sampling and monitoring programs are a critical component of making management decisions.

- *Use yellow sticky cards.* Hang sticky cards when potato seedlings emerge from the soil, and replace them weekly. Early in the season, place sticky cards on field edges to detect immigrating psyllids. As the season progresses, distribute sticky cards evenly throughout the field. Place at least five sticky cards per field to enhance psyllid detection.
- *Visually inspect leaves for psyllid eggs and nymphs.* Collect 10 mature leaves from the middle of the plant at 10 locations among the outer rows of the field. A hand lens is needed to see nymphs on the undersides of leaves and eggs on leaf edges and undersides. Note that by the time psyllids are detected in the field, if any individuals are carrying the Zebra chip bacterium, infection will likely have already occurred.

MANAGEMENT:

Cultural:

There are currently no effective non-chemical controls for potato psyllids.

Chemical:

If potato psyllids have caused Zebra chip disease or psyllid yellows in past years, or if nearby fields are experiencing these problems, several insecticide applications may be required to reduce psyllid populations.

Biological:

Because potato psyllid is a non-native pest, natural enemies have not been very effective to-date. Predators that feed on psyllids include lady beetles, lacewing larvae, and minute pirate bugs.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of Minnesota Management of Potato Psyllids
- Oregon State University Potato Psyllid Vector of Zebra Chip Disease in the Pacific Northwest
- UC Davis IPM Potato Psyllid
- UC Riverside Potato Psyllid
- UC Davis IPM Tomato (Potato) Psyllid

Wireworms

Order Coleoptera: Family Elateridae

Pacific Coast Wireworm *(Limonius canus)*

Sugar Beet Wireworm *(L. californicus)*

Western Field Wireworm *(L. infuscatus)*

Columbia Basin Wireworm *(L. subauratus)*

Great Basin Wireworm *(Ctenicera pruinina)*

DESCRIPTION:

Adult: About ¼ to ½ inch long. Known as click beetles with a hard-shelled body that is black to brown in color. Make distinctive clicking noises with a "hinge" between the thorax and abdomen. Use clicking mechanism to escape threats (Fig. 8.19).

Egg: Small, round, and white; laid singly or in clusters in the moist soil of grassy areas (Fig. 8.19).

Larva: About ½ to 1 ½ inches long when mature with a wiry look. Shiny white at first, but become light brown or straw colored with age (Fig. 8.19).

Pupa: White-colored; contained in an earthen cell in the soil (Fig. 8.19).

LIFE HISTORY:

Adults overwinter in the soil and emerge in late April to early May in northern Utah. Between late May and early June, females lay 50 to 400 eggs in the soil about 6 inches deep. Larvae live in the soil for 1 to 6 years, and are closer to the soil surface in spring and fall. During hot summer periods, larvae move deeper into the soil. Some larvae can be found at depths of 1-5 feet or at the hard pan level.

DAMAGE:

Wireworms are uncommon, but there have been a few cases in Utah. *Limonius* species (Pacific Coast, Sugar Beet, Western Field, Columbia Basin wireworms) favor moist conditions while *Ctenicera pruinina* (Great Basin wireworm) prefers dry lands where annual rainfall is less than 15 inches. All crops are susceptible to wireworm attack; however, bean, grain, corn, potato, and other annual crops are preferred hosts.

In potato, wireworms will feed on seeds and roots of young plants. Larvae can cause severe damage to potato by creating tunnels in tubers as they feed (Fig. 8.19). Infestations do not spread rapidly from one field to another because female beetles are poor flyers.

MONITORING

- *Monitoring.* Inspect the soil surface for wireworms after plowing or disking fields. Baits can also be used to detect wireworms. Baits include: carrots, untreated corn or wheat seed, or ground whole wheat flour. Place baits 4-6 inches deep in the soil when soil temperatures are at 50°F. If wireworms are detected, collect soil samples in spring with a 6-inch post hole digger and a shake/sifter to estimate the density of wireworms. Table 8.5 shows a soil sampling guide from the University of California, Davis.

MANAGEMENT

Although wireworms are generally uncommon in Utah, there have been a few cases reported. Once present in a field, wireworms can be difficult to eradicate.

Cultural:

- *Establish a dense plant stand* to reduce the impact of wireworm damage.
- *Crop rotation.* Fields previously planted to grasses, including grass grains, or pasture are at a higher risk for high wireworm populations. Red and sweet clover and small grains, especially barley and wheat, can increase wireworm populations. Include alfalfa and mustards in crop rotations to reduce wireworm populations over time.
- *Sanitation.* Remove dead plants and tubers throughout the season and at harvest. Wireworm damage typically peaks at mid-season (showing up at harvest as scabbed-over holes in the tubers), and tubers of dead plants can be re-infested, resulting in an increase in wireworm population. Thus, it is important to avoid prolonged periods of time between vine death and harvest.
- *Soil drying.* Sugar beet and Pacific Coast wireworm (*Limonius* spp.) populations prefer moist soil and can be reduced by drying the top 15 inches of the soil for several weeks at midsummer. This will especially kill eggs and young larvae. Soil drying is more effective in light sandy to silt loam soils. Conversely, great basin wireworms (*Ctenicera* spp.) prefer dry soil and can be eradicated by converting dryland fields to continual irrigation.
- *Soil flooding.* Thoroughly saturating or flooding soils for at least 2 weeks when soil temperatures are above 68°F will significantly reduce wireworm populations. To increase wireworm mortality, alternate periods of flooding and drying.
- *Intensive plowing.* Wireworm populations can be reduced by plowing three or more times during late spring and early summer.
- *Resistant varieties.* There are some resistant varieties that may be worth testing if wireworms are a potential problem. A study in Oregon found a range

Table 8.5. Wireworm soil sampling guide

Acres in field	Number of soil samples	Treatment threshold (# of wireworms)
10	30	1
22	45	2
40	60	2
90	90	4
160	120	5

Godfrey, L. D., Entomology, UC Davis, D. R. Haviland, UC Cooperative Extension, Kern Co., UC IPM Pest Management Guidelines: Potato, UC ANR Publication 3463, Insects

of potato varietal susceptibility to wireworms. These varieties are shown in Table 8.6.

- *Soil health.* Maintaining healthy soils with compost, manure, or green manures, may reduce wireworm damage.

Chemical:

Chemical options for wireworm control are few. Organophosphate chemicals have shown to be the most effective and consistent when applied at pre-plant as a broadcast treatment, or planting-time as a furrow application.

Biological:

Birds may feed on wireworms in recently plowed fields, but will not reduce populations below economic levels in seriously infested areas. There are no known biological insecticides.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Pacific Northwest Insect Handbook Potato Irish-Wireworm
- Wireworm Biology and Non-chemical Management in Potatoes in the Pacific Northwest
- UC Davis Pest Management Guidelines Potato Wireworms

Table 8.6. Percentage of wireworm infected tubers for various potato varieties.

Variety	Percent Infected
AC9531	1%
VC1009	1%
Cherry Red	3%
Ozette	13%
Yukon Gold	15%
Colorado Rose	16%
Austrian Crescent	17%
Red LaSoda	17%
Satina	20%
Mountain Rose	20%
Nicola	24%
POR01PG22	24%
Sangre	27%
Huckleberry	28%
Jacqueline Lee	30%

Disease Management

Alfalfa Mosaic Virus

CAUSAL AGENT:

Alfalfa mosaic virus (AMV) is in the genus Alfamovirus and is spread by aphids.

SYMPTOMS:

Yellow mosaic or calico patterns occur on the foliage (Fig. 8.20). Some strains of AMV can cause severe stunting of plants and tuber necrosis. Sometimes corky or brown areas will develop in potato tubers.

DISEASE CYCLE:

The virus is commonly found in alfalfa. Aphids feed on infected alfalfa, acquire the virus, and transmit it to healthy potato plants. Aphids need to feed on another infected plant to spread the disease again. The virus is not seedborne in potatoes.

MANAGEMENT:

Insecticides to control aphids will be of limited help. The best management option is to avoid planting potatoes close to alfalfa fields.

Late Blight

CAUSAL AGENT:

Phytophthora infestans is a fungal-like organism that causes late blight.

SYMPTOMS:

Phytophthora affects foliage, stems, and tubers of potatoes. Initially, foliar lesions are greasy-appearing, with a light yellow halo around them (Fig. 8.21). They quickly enlarge and turn black-brown (Fig. 8.22). Infected tubers decay (Fig. 8.23) either in the soil or in storage.

DISEASE CYCLE:

Phytophthora overwinters in the soil and in decaying potato tubers or cull potato/tomato piles. It produces spores that are blown by wind or splashed by rain onto new host tissue. The disease occurs when temperatures range from 50°F to 78°F and relative humidity is above 90%.

MANAGEMENT:

- *Remove cull piles.*
- *Allow plants with infected foliage to dry for 2-3 weeks before harvest* to ensure Phytophthora has died. It cannot survive on dry dead plant material.
- *Apply a fungicide.* Options are: azoxystrobin, chlorothalonil, pyraclostrobin, famoxadone, cymoxanil, dimethomorph, fenamidone, propamocarb hydrochloride or mefenoxam + chlorothalonil.

Potato Virus Y

CAUSAL AGENT:

Potato virus Y is in the genus Potyvirus. There are three strains: PVYO, PVYN and PVYNTN. This virus is transmitted by aphids.

SYMPTOMS:

Symptoms vary depending on the strain. PVYO causes mosaic symptoms on the leaves (Fig. 8.24) and no symptoms on tubers. PYVN causes necrotic spots on leaves and tubers. PVYNTN causes necrotic lesions on leaves and necrotic ringspots on the tuber surface that extend into flesh (Fig. 8.25 and 8.26).

DISEASE CYCLE:

The virus is most frequently introduced into a field on infected seed pieces. It can be spread within a field and beyond by aphids and farm equipment. When aphids feed on an infected plant, they can then transmit the virus to a single healthy plant. They have to feed on another infected plant to transmit the virus again. This type of transmission is called "non-persistent." The virus overwinters in infected seed pieces and in solanaceous weeds such as nightshade or ground cherry.

MANAGEMENT:

There are no resistant potato varieties, however, some are more susceptible than others depending on the strain. For example, Yukon Gold is very susceptible to tuber necrosis. The best option is to use certified seed potatoes. Unfortunately, these potatoes will not be certified as 100% disease-free, and small amounts of PVY may still be introduced. Therefore, scouting for infected plants and removing them from the fields is important for early detection.

Remove alternative hosts by controlling weeds. Since the virus is transmitted in a non-persistent manner, insecticides used to control aphids will have negligible effects.

Verticillium Wilt

CAUSAL AGENT:

Verticillium dahliae is a soilborne fungus that infects many hosts.

SYMPTOMS:

Infected plants initially show wilting of the lower leaves during the hot part of the day with recovery in the evening. Eventually the plants permanently wilt. The vascular tissue of the main stem will be discolored (Fig. 8.27). Diseased plants may also show early senescence. Occasionally the vascular tissue inside the tubers can be discolored as well (Fig. 8.28).

DISEASE CYCLE:

Verticillium infects through plant roots, and the fungus grows through the vascular tissue up into the main stem. The wilting is caused by the fungal growth clogging the xylem and the plant trying to stop the movement of the fungus by blocking the colonized vascular tissue.

Verticillium produces an overwintering structure called a microsclerotium which is a hard black ball of fungal tissue. The microsclerotia germinate when a suitable host is planted and then infect the plant. Microsclerotia can survive in the soil for up to 10 years, depending on environmental conditions, while it waits for a suitable host. If root-feeding nematodes are present in high numbers in the soil, they can increase the severity of the disease by creating wounds on roots during feeding.

MANAGEMENT:

Management of verticillium wilt is very difficult, and can be prevented with careful crop rotations. There are no resistant potato varieties. If crop rotation is not possible and verticillium is present, the field should be planted with grass, cereals or legumes for several years to reduce the number of microsclerotia in the soil. In severe cases, fumigation with 1,3-dichloropropene (e.g. Telone II) may be necessary. Telone II is a restricted product with application requirements.

Zebra Chip Disease

CAUSAL AGENT:

Zebra chip disease is caused by the bacterium *Candidatus* Liberibacter solanacearum. The bacteria are transmitted when potato psyllids feed on susceptible hosts (Fig. 8.29). The bacteria colonize the vascular tissue in the plant and tubers.

SYMPTOMS:

There are no above-ground symptoms specific to zebra chip disease. When psyllids feed, they cause pink to reddish discoloration of the foliage (Fig. 8.30) (sometimes mistaken for nutrient deficiency). If psyllids are detected along with the discolored foliage, there is a high chance that the bacteria are present as well.

Below-ground symptoms on potato tubers are only visible when they are cut. The vascular tissue in the tuber has a brown discoloration (Fig. 8.31). The discoloration is even more pronounced when the potatoes are fried (Fig. 8.32).

DISEASE CYCLE:

The bacteria are acquired by potato psyllids and then transmitted during feeding, where they then colonize the vascular tissue in the plant and tubers. Seed pieces from infected plants either do not sprout or produce only small, weak plants.

MANAGEMENT:

Management options are very limited.

- *Control potato psyllids early in the season.* Early detection of potato psyllids is important.
- *Use yellow sticky cards.* They will attract adult psyllids.
- *Look for psyllids on the underside of the leaves.* A hand lens helps to see them.
- *There are no resistant potato varieties.* Once the potatoes are infected there is no cure.

Pest Management Tables for Commercial and Home Use

Table 8.7. Herbicides registered for **COMMERCIAL** use on **Potatoes** in Utah.

Brand Name (REI/PHI)	Active Ingredient	Timing and Application Location Relative to Crop					Timing Relative to Weeds		Weed Groups Controlled			Comments
		Before Planting	Pre-emergence	At/After Hilling	Between rows, directed/shielded	Post-emerge over crop	Pre-emergence	Post-emergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X			X			X		X	X	
Chateau (12h/-)				X			X			X	X	
Dual Magnum (12h/30d)	s-metolachlor	X	X	X	X		X		X	X		
Eptam (12h/45d)		X					X		X			
Gramaxone Inteon (12hr/30d)	paraquat	X	X		X			X	X	X	X	Restricted use product
League (12h/45d)	imazosulfuron		X	X		X	X	X		X	X	
Linuron (12h/-)	linuron		X				X	X	X	X	X	
Matrix (4h/60d)	rimsulfuron		X	X			X	X	X	X	X	
Metribuzin (12h/60d)	metribuzin		X			X	X		X	X	X	
Outlook (12h/40d)	dimethenamid-p		X				X		X	X		
Pendimethalin (12h/-)	pendimethalin		X			X	X		X	X		
Poast (12hr/14-20d)	sethoxydim	X	X	X		X		X	X			
Reflex (12h/70d)	fomesafen		X				X			X	X	
RoundUp, others (12hr/14d)	glyphosate	X	X		X			X	X	X	X	
Select Max, others (12h/30d)		X	X	X		X		X	X			
Treflan, others (12hr/-)	trifluralin		X		X		X		X	X		
Organic Products												
Corn Gluten Meal		X	X				X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X				X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X				X	X	X	X	
Worry Free	citrus oil	X	X	X				X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 8.8. Insecticides registered for **COMMERCIAL** use on **Potatoes** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Colorado Potato Beetle	Flea Beetles	Cutworms	Potato Psyllid	Wireworms
carbaryl	Sevin	1A	10-14		X	X	X		
methomyl	Lannate[R]	1A	14-18	X		X	X		
oxamyl	Vydate[R]	1A	14-18	X	X	X			
ethoprop	Mocap[R]	1B	(++)						X
fipronil	Regent[R]	2B	(+)						X (at planting)
beta-cyfluthrin	Baythroid XL[R]	3A	14	X	X	X	X	X	
bifenthrin	Bifenture[R], Brigade[R], Fanfare[R], Sniper[R], Tundra[R]	3A	14			X			X
bifenthrin + zeta-cypermethrin	Hero[R], Steed[R]	3A	14	X	X	X	X		
cyfluthrin	Tombstone[R], Tombstone Helios[R]	3A	10-14	X	X	X	X	X	
deltamethrin	Delta Gold[R]	3A	10-14	X	X	X	X		
esfenvalerate	Asana[R]	3A	14	X	X	X	X	X	
lambda-cyhalothrin	Province[R], Silencer[R], Warrior[R], Warrior II[R]	3A	10-14	X	X	X	X	X	
permethrin	Ambush[R], Arctic[R], PermaStar[R], Permethrin[R], Perm-UP[R], Pounce[R]	3A	14	X	X	X	X	X	
zeta-cypermethrin	Mustang[R], Mustang Maxx[R]	3A	10-14	X	X	X	X		
beta-cyfluthrin + imidacloprid	Leverage 360[R]	3A/4A	14	X	X	X	X	X	
bifenthrin + imidacloprid	Brigadier[R], Skyraider[R], Swagger[R]	3A/4A	14	X	X	X		X	X
lambda-cyhalothrin + thiamethoxam	Endigo ZC[R]	3A/4A	10-14	X	X	X	X	X	
bifenthrin + avermectin	Athena[R]	3A/6	14	X	X	X	X	X	
lambda-cyhalothrin + chlorantraniliprole	Besiege[R], Voliam Xpress[R]	3A/28	10-14	X	X	X	X	X	
acetamiprid	Assail	4A	14	X	X	X			
clothianidin	Belay	4A	14	X	X	X		X	X

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

(++)= One application per crop per season
(+)= One application per year

Table 8.8, continued. Insecticides registered for **COMMERCIAL** use on **Potatoes** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Colorado Potato Beetle	Flea Beetles	Cutworms	Potato Psyllid	Wireworms
dinotefuran	Scorpion, Venom	4A	14	X	X	X		X	
imidacloprid	Pasada, Prey, Sherpa,	4A	5	X	X	X		X	
imidacloprid	AmTide, Macho, Malice 2F, Montana 2F, Nuprid 2SC, Widow	4A	ST	X	X	X		X	X
thiamethoxam	Actara, Cruiser[ST], Platinum	4A	14	X	X	X		See label	
imidacloprid + mancozeb	Guacho-MZ	4A/ FRAC M3	ST	X	X	X		X	X
chlorantraniliprole + thiamethoxam	Voliam Vlexi	4A/28	14	X	X	X			
flupyradifurone	Sivanto	4D	7-14	X	X			X	
spinetoram	Radiant	5	14		X	X		X	
spinosad	Blackhawk[B], Entrust[B], Success[B]	5	7		X				
abamectin (avermectin)	Abacus[R], Abba[R], Agri-mek[R], Epi-Mek[R], Nufarm Abamectin[R], Reaper[R], Zoro[R]	6	14-21		X			X	
pymetrozine	Fulfill	9B	7-10	X				X	
flonicamid	Beleaf 50 SG	9C	14	X				X	
Bacillus thuringiensis subspecies kurstaki, aizawai	Biobit[B], Dipel[OB], Xentari[OB]	11A	5-7				X		
novaluron	Rimon	15	7		X			X	
cyromazine	Trigard	17	7-14		X				
indoxacarb	Avaunt	22	7-14		X				
spiromesifen	Oberon	23	7-14					X	
spirotetramat	Movento	23	7-21	X				X	X
chlorantraniliprole	Coragen	28	7-14		X				
cyantraniliprole	Verimark	28	14	X	X	X		X	
azadirachtin	Aza-Direct[OB], Azatin[OB], Azatrol[B], Molt[OB]	UN	7-10	X	X	X	X	See label	See label
Beauveria bassiana	Botanigard[B]	---	5-7	X	X	X		X	
Chromoacterium subtsugae and spent fermentation media	Grandevo[OB]	---	57	X				X	

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment

Table 8.8, continued. Insecticides registered for **COMMERCIAL** use on **Potatoes** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Colorado Potato Beetle	Flea Beetles	Cutworms	Potato Psyllid	Wireworms
dichloropropene	Telone II (soil fumigation)	---	---						X
extract of *Chenopodium ambrosioides* near *ambrosioides*	Requiem[B]	---	3-5					X	
kaolin	Surround[OB]	---	5			X			
oil: petroleum oil	Suffoil X[O], many others	---	1	X					
potassium salts of fatty acids	M-Pede	---	3	X					

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on potato crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

Protection of Pollinators: Look for the "bee-box" or "bee hazard icon" on product labels and read the restricitions and instructions to protect bees and other insect pollinators. Bees and other pollinators will forage on plants when they flower, shed pollen, or produce nectar. Follow these steps when using products that are hazardous to bees: 1) minimize exposure of the product to bees and pollinators when they are foraging on pollinator attractive plants around the application site 2) Minimize drift of the product on to beehives or to off-site pollinator attractive habitat as drift into these areas will kill bees.

Warning: Applications of imidacloprid and clothianidin are restricted to post-bloom and only when bees are not active in the site, including on weeds and non-crop plants.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

(++)= One application per crop per season
(+)= One application per year

Table 8.9. Fungicides registered for **COMMERCIAL** use on **Potatoes**, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Late Blight	Verticillium Wilt
chlorothalonil	Bravo, Chloronil, Echo, Equus, Initiate, Orondis Opti	M5	X	
mefenoxam + chorothalonil	Ridomil Gold Bravo SC	4/M5	X	
fluxapyroxad + pyraclostrobin	Priaxor	7/11	X	
azoxystrobin	Aframe, Azoxystar, Equation SC, Quadris, Satori	11	X	
pyraclostrobin	Headline	11	X	
fenamidone	Reason	11	X	
azoxystrobin + chlorothalonil	Quadris OPTI	11/M5	X	
famoxadone + cymoxanil	Tanos	11/27	X	
zoxamide + chlorothalonil	Zing	22/M5	X	
cymoxanil	Curzate	27	X	
propamocarb hydrochloride	Previcur Flex	28	X	
dimethomorph	Forum	40	X	
1,3-dichloropropene	Telone II[RF]	---		X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on potato crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals

[R]= Restricted Use
[F]= Fumigation

Table 8.10. Insecticides registered for **HOME** use on **Potatoes,** organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Colorado Potato Beetle	Flea Beetles	Cutworms	Potato Psyllid
carbaryl	Garden Tech Sevin	1A	14		X	X	X	
malathion	Hi Yield, Spectracide Malathion, Ortho Malathion	1B	7	X				
cyfluthrin	Bayer Vegetable and Garden Insect Spray	3	14	X	X	X	X	X
deltamethrin	Green Light Many Purpose Dust	3	14	X	X	X	X	
pyrethrins	Monterey Bug Buster-O[OB], Garden Tech Worry Free[B]	3	5	X	X	X	See label	X
pyrethrins + canola oil	Earth-tone Insect Control[B], Monterey Take Down Garden Spray[B]	3/	5	X	X	X		X
pyrethrins + potassium salts of fatty acids (insecticidal soap)	Safer Brand Tomato & Vegetable Insect Killer[OB], Safer Brand Yard & Garden Insect Killer[OB]	3/	5	X	X	X		
pyrethrins + sulfur	Bonide Tomato and Vegetable 3 in 1[B], Natria Insect[B], Disease & Mite Control[B], Ortho Insect Mite & Disease 3 in 1[B]	3/M2	5	X	X	X		X
acetamiprid	Ortho Flower Fruit & Vegetable	4A	14	X	X	X		X
spinosad	Fertilome Borer Bagworn Tent Caterpillar & Leafminer Spray[B], Bonide Colorado Potato Beetle Beater[B]	5	7		X		X	
oil: canola, neem, rosemary, clove, cottonseed	Bayer Natria Multi-insect[B], Monterey All Natural 3 in 1 Garden Insect Spray	---	1	X	See label	See label		X
potassium salts of fatty acids (insecticidal soap)	Bayer Natria[B]	---	1	X				X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on potato crops in Utah. The availability of products changes over time. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Table 8.11. Fungicides registered for **HOME** use on **Potatoes** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Blight
Bacillus subtilis strain QST 713	Serenade Garden Disease Control[B]	44	X
copper	Natural Guard Copper Soap, Monterey Liqui-Cop, Bonide Copper Fungicide	M1	X
chlorothalonil	Fertilome Broad Spectrum Landscape & Garden Fungicide, Hi Yield Vegetable Flower Fruit & Ornamental Fungicide, Ortho Max Garden Disease Control	M5	X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Fig 8.1. Colorado potato beetles (CPB) have black and yellow stripes and a shape similar to ladybugs.

Fig 8.2. CPB eggs are bright yellow-orange and laid in clusters on the underside of leaves.

Fig 8.3. CPB larvae are bulbous in shape, reddish in color, and have black spots.

Fig 8.4. CPB pupate in the soil after larval feeding.

Fig 8.5. CPB larvae feed on potato foliage resulting in defoliation.

Fig 8.6. Pale western cutworm larva.

Fig 8.7. Glassy cutworm larvae.

Fig 8.8. Army cutworm larva.

Fig 8.9. Black cutworm larva.

Fig 8.10. Variegated cutworm larva.

Fig 8.11. Cutworm moths have varied wing patterns and wingspans.

Fig 8.12. Cutworm eggs are laid in clusters.

Fig 8.13. Cutworm pupae are dark brown to orange in color with two spines on one end.

Fig 8.14. Cutworm larvae feed at the soil surface and can cut off the stems of young plants.

Fig 8.15. Tuber flea beetles can damage potato foliage and tubers.

Fig 8.16. Tuber flea beetle larval feeding results in a pimpled surface and small dark holes.

Fig 8.17. Potato psyllid adults and nymphs. Adults vector the zebra chip disease bacterium.

Fig 8.18. Psyllid feeding causes "psyllid yellows", resulting in yellow or purple host leaves.

Fig 8.19. Wireworm adult, egg, larva, pupa, and damage; note tunneling damage in potato tuber.

Fig 8.20. Alfalfa mosaic virus causes yellow mosaic or calico patterns on potato foliage.

Fig 8.21. New late blight lesions may have a yellow halo.

Fig 8.22. Late blight lesions quickly enlarge and turn black-brown.

Fig 8.23. Tubers infected with late blight decay either in the soil or in storage.

Fig 8.24. Potato virus Y (PVY) causes mosaic symptoms and necrotic spots on potato leaves.

Fig 8.25. PVY causes necrotic ringspots on the potato tuber surface.

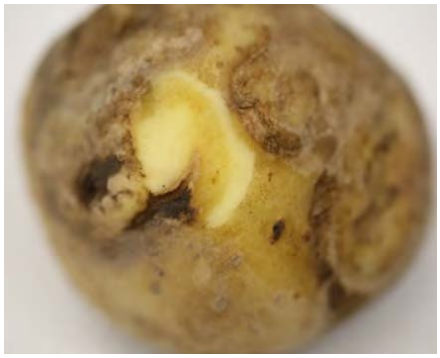


Fig 8.26. PVY necrotic ringspots extend into the flesh of potato tubers.

Fig 8.27. Verticillium wilt causes discoloration of the vascular tissue in the main stem of the host plant.

Fig 8.28. Verticillium wilt occasionally causes discoloration of the potato tuber vascular tissue.

Fig 8.29. Zebra chip disease is transmitted by adult potato psyllids that carry the bacterium.

Fig 8.30. Zebra chip disease causes foliage of infected plants to turn pink to reddish in color.

Fig 8.31. Zebra chip disease results in a brown discoloration of the vascular tissue in the potato tuber.

Fig 8.32. Zebra chip disease is more pronounced on fried potatoes.

CHAPTER 9 TOMATO, PEPPER, & EGGPLANT PRODUCTION

Varietal Selection

Since adequate testing of all the varieties in all the conditions present in Utah is impossible, the following information is meant as a guideline for identifying varieties that will grow well on your farm.

Eggplant and Pepper

Eggplant and pepper fruits are frequently categorized by shape, size, color, and flavor (Fig. 9.1). Fruits vary greatly within these categories and varieties should be selected to meet production goals and market demands. Some factors to consider when choosing varieties are: growing environment, available space, market requirements, and desired use. Consult seed providers or other reputable sources to help identify eggplant and pepper varieties that meet your production criteria.

If you have had issues with certain diseases, many of the hybrid varieties have unique disease resistance/tolerance characteristics. To identify varieties with disease resistance, look for abbreviations of disease names listed with the variety name on seed packets. Verticillium (V) and Fusarium (F) wilt, and root-knot nematode (N) are common (for example, 'Better Boy' VFN). Some seed suppliers provide more specific disease abbreviations. Reference the specific seed catalog for a full list.

Tomato

Selection of tomato varieties can be daunting since factors such as length of growing season, soil types, climate conditions, and production practices are unique to a farm's location. To further complicate matters, there are in excess of 700 different tomato varieties available for purchase. When selecting a new variety, evaluate it based on fruit size, color, earliness, soluble solids (sweetness), growth habit (determinate or indeterminate), and disease resistance. In determinate varieties, vine growth is limited, making it easier to stake plants or grow without trellising. Trellising or caging is recommended for indeterminate varieties since they continue to grow, flower, and fruit throughout the season. Heirloom varieties offer a wide range of fruit flavors and colors, and are popular at farmers markets, but generally lack disease resistance and are more prone to cosmetic defects.

We recommend trying new varieties and compare them to what you already grow. On-farm testing is the best way to identify varieties that are most suited to your farm's local and unique conditions. Keep in mind that although you can grow all the different varieties, not all may be suited to your location. Varieties that are known to be grown under local conditions are shown in Tables 9.1- 9.3.

Table 9.1. **Eggplant** Variety Selection

Fruit Types	Varieties
Eggplants	Cappi, Epic, Megal, Millionaire, Nadia, White Star
Heirloom	Black Beauty, Long Purple, Rosa Bianca

Table 9.2. **Pepper** Variety Selection

Fruit Types	Varieties
Bell Peppers	Ace, Aristotle, Bell Boy, California Wonder, King Arthur, Revolution, Socrates
Banana Types	Ethem, Key West, Sweet Savannah,
Sweet (non-bells)	Aruba, Cubanelle, Giant Marconi, Pimento, Sweet Cherry, Sweet Hungarian,
Hot Peppers	Cayenne, Chili, Habanero, Hungarian, Jalapeno, Serrano
Heirloom	Chocolate Beauty, Emerald Giant, Golden Calwonder, Orange King Bell, Yolo Wonder

Table 9.3 **Tomato** Variety Selection

Fruit Types	Varieties
Large Fruited	Mountain Glory, Mountain Fresh, Mountain, Majesty, Celebrity, Sunbrite, Sunshine, Jet Star, Empire, Heatmaster
Cherry – Saladette Types	Sweet Million, Sweet Gold, Sweet Hearts, Juliet, Verona
Heirloom	Branscomb, Golden Swedish, Black Prince, Black Zebra, Chocolate Stripes, Beafsteak, Brandywine, Cherokee Purple, Coldset, San Marzano, Red Heart

Transplant Production

If starting your own transplants, sow seeds into plastic plug trays with 50-72 cells per tray filled with a good soilless mix. Adequate light is essential to produce a quality plant. Supplemental light may be necessary when growing transplants in the winter and early spring. Cool white fluorescent lights positioned 2 to 3 inches above the plants for 14 to 16 hours per day will ensure large and healthy seedlings. Optimum germination occurs at 86°F, and the use of heating mats will increase speed of germination and the percentage of seedlings that emerge. Optimal temperatures for plant growth are 75°F during the day and 65°F at night.

Allow 8 to 10 (pepper and eggplant) or 6 to 8 (tomato) weeks for growth of transplants depending on greenhouse temperatures. Transplants should have 5 to 7 mature leaves and a well-developed root system. Irrigate plants regularly to avoid excessively dry soil. Apply a complete soluble fertilizer (20-20-20) diluted to 100 ppm once or twice a week. Gently brushing the plants each day or exposing them to wind helps make the plants stocky and strong. Condition or "harden off" transplants for a short time each day by exposing them to cool temperatures (60-65°F for eggplant and pepper, and 50-60°F for tomato), starting one week before transplanting. This prepares the plant for fluctuating light and temperature conditions prior to transplanting outdoors.

Soil

Deep sandy to loamy soil with a pH of 6.5 to 7.5 is ideal for eggplant, pepper, and tomato production. Most soils in Utah are suitable for production, provided they are well-drained, fertile, and do not have a buildup of salt. Rotate the location of your crop every 1 to 2 (tomato) or 3 (pepper and eggplant) years to soil where solanaceous plants (eggplant, pepper, tomato, or potato) were not previously grown in the preceding three years to reduce the buildup of soil-borne diseases. A loose, somewhat dry, tilled soil is ideal for transplanting eggplant, pepper, and tomatoes to ensure good soil contact with the transplant root ball. Tomato plants are sensitive to herbicides in soil; select sites without herbicide residues.

Fertility

Prior to planting, test the soil to determine nutrient needs and deficiencies. If over-fertilized, yield, earliness, or fruit quality may suffer (Fig 9.2). Incorporate composted organic matter before planting to sustain soil fertility. An initial application of 5 tons per acre of high quality compost of known nutrient analysis is recommended. For synthetic fertilizers, apply half the recommended nitrogen and all the phosphorous and potassium, based on soil test results, prior to planting (Peet 2005).

Eggplant and Pepper

Nitrogen (N) – Incorporate 50-75 lb/acre nitrogen prior to planting, and an additional 150-200 lb/acre throughout the growing season. Following this fertilization protocol will ensure plants keep growing for the whole season. Use a lower rate for eggplant to avoid excessive leaf growth and delayed flowering.

Phosphorous (P) – Incorporate 50–200 lb/acre phosphorous prior to planting depending on the soil analysis if extractable phosphorous is less than 15 ppm. Higher rates of P may be needed for early plantings when soils are cold or if soil pH is 7.5 or above.

Potassium (K) – Incorporate 50–150 lb/acre Potassium prior to planting depending on the soil analysis if extractable potassium is less than 150 ppm.

Tomato

Nitrogen (N) – Incorporate 50-75 lbs/acre nitrogen prior to planting, and another 50-75 lbs/N when first fruits are 1" in diameter. Use the smaller amount if manure or compost has been applied to the soil.

Phosphorous (P) – Incorporate 50–150 lbs/acre phosphorous prior to planting depending on soil analysis. Use 150 lbs/acre if phosphorous is low (<15 ppm), and 50 lbs/acre if phosphorous is high (>25 ppm).

Potassium (K) – Incorporate 60–180 lbs/acre potassium prior to planting depending on the soil analysis. Use 180 lbs/acre if potassium is low (<130 ppm) and 60 lbs/acre if potassium is high (>250 ppm).

Planting

Planting dates for eggplants, peppers, and tomatoes in Utah vary depending local climate conditions and range from early April in southern Utah to mid-May in northern Utah. Planting is recommended after danger of frost has passed (Fig. 9.3). Information on local freeze dates can be accessed through the Utah Climate Center (climate.usurf.usu.edu). Eggplants, peppers, and tomatoes grow best when daytime temperatures are 75 to 85°F and when night temperatures stay above 60 to 65°F (eggplant and pepper) or 50°F (tomato). Temperatures above 95°F may result in flower bud drop and pollen death.

Spacing

Eggplant

Space plants 18 to 24 inches apart in the row, with 3 to 4 feet between rows.

Pepper

Space plants 12 to 18 inches apart in the row with approximately 15 inches between rows, with two rows per 30 inch bed. Beds can be spaced on 36 to 42 inches from center to center, leaving 6 to 12 inches between beds. Paired rows help reduce sunscald. This supports a plant population of 16,000-29,000 plants/acre (Fig. 9.4). Plan road ways within the field for more convenient access during harvest. Transplants should be set so the soil level reaches the cotyledon leaves or the first true leaf. Plants placed at these depths grow larger and produce more leaves. Total fruit weight has been shown to be 26% higher on plants set to cover the cotyledons than on plants set to cover just the top of the root ball (Vavrina et al. 1994).

Tomato

Space plants 18 to 24 inches apart in the row and space rows 36 to 48 inches apart depending on the variety. Indeterminate varieties will need more space than determinate varieties. The stem of a tomato transplant may be buried in soil up to the first leaves (or more if the plant is spindly) since tomato plants produce adventitious roots on buried stem tissue.

Irrigation

Eggplants, peppers, and tomatoes require regular, uniform watering during the growing season. Inconsistent water availability can cause several problems including poor early vigor, inadequate leaf cover, flower drop, sunburn, blossom end rot and fruit cracking. For this reason, drip irrigation is well-suited for production of these plants. Water deeply and infrequently to encourage deeper root growth. As temperatures increase and plants grow, irrigation rates should be increased to meet plant needs. A small decrease in water after fruits reach mature size is beneficial in that it can trigger fruit ripening. Soil water status should be monitored regularly to maintain consistent soil water. This is easily done with a resistance block such as the Irrometer Watermark sensor. Place sensors at various locations in the field and depths in the soil profile to get a more accurate measurement of soil water content. Sensors typically express soil water content as a tension reading (centibars) that defines the resistance in the plant to access available water. Soil texture (clay, loam, sand) influences the soil's ability to hold water. Field capacity describes a soil at 100 percent available water holding capacity after excess water has drained away. Start drip irrigation at 20-25% depletion of available water holding capacity depending on your soil type (Table 9.4). Other low cost tools and methods to monitor soil water can be found at attra.ncat.org/attra-pub/soil_moisture.html.

Table 9.4. Soil tension values for different soil textures for use in scheduling drip irrigation.

Soil Texture	0% Depletion of Available Water Holding Capacity (Field Capacity)	20-25% Depletion of Available Water Holding Capacity
	Soil Tension Values (in centibars)	
Sand, loamy sand	5-10	17-22
Sandy loam	10-20	22-27
Loam, silt loam	15-25	25-30
Clay loam, clay	20-40	35-45

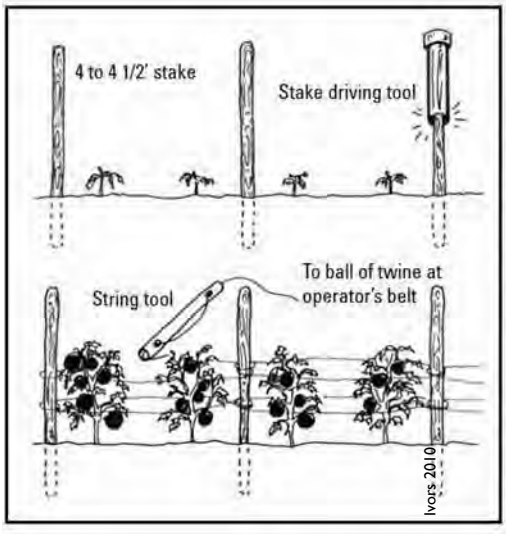
Ground Mulch and Row Covers

The use of black plastic ground mulch is recommended to control weeds in the row and conserve water. Plastic mulch may also raise soil temperatures in spring to promote an earlier harvest. In order for black plastic to raise the soil temperature, there must be good contact with the soil beneath. New plastic films called IRT (infrared-transmitting) provide more soil warming with similar weed control, but are more expensive. Red plastic mulch does not raise soil temperature as much as black plastic, but has been reported to improve yield specifically for tomato up to 20% compared to black plastic. However, results are inconsistent between field studies, possibly due to variation in plastic quality (Orzolek and Otjen). Cover crop mulches and other organic mulches can also be beneficial. For more information on mulches, reference the online University of California Davis Publication 8129 "Mulches in California Vegetable Crop Production."

Row covers provide a windbreak that helps protect plants from frost, and can enhance yield and earliness. Spun-bonded row covers (such as Reemay) made of lightweight polyester or polypropylene can rest directly on top of plants, but edges should be secured. Plastic row covers trap more heat during the day than spun-bonded covers, enhancing plant growth and earliness, but they overheat more quickly and require careful monitoring. Perforated plastics are available

Spun-bonded row covers (left) and perforated plastic row covers (right).

to provide some ventilation while retaining heat. Plastic covers should be supported by heavy wire or other secure support to keep plastic from contacting plants. Spun-bonded and plastic row covers should be removed as plants outgrow the cover, if plants begin to flower, or when temperatures under the cover regularly exceed 90°F.



The stringing tool extends the worker's reach and helps to keep the twine tight.

Staking

Support for eggplant, pepper, and tomato is not required, but offers a number of advantages. Fruits grown on staked and pruned plants can mature earlier, and are cleaner and easier to pick. However, extra labor is needed for pruning and tying. Determinate tomatoes are commonly trellised using the stake and weave system (Fig. 9.5). It involves driving 4 foot long wooden stakes 18 in. deep between every other plant and weaving string horizontally between the stakes.

Prior to applying the first string, suckers (secondary shoots) are removed. Suckers are the vigorous new growth found at the base of the leaves. Remove suckers from the bottom three leaves on determinate varieties when the suckers are 3 to 4 inches long. Suckering reduces vine growth, but promotes earlier and larger fruit. After suckering, attach the first string one foot above the ground and add additional strings after every 8 to 12 inches of new growth. Generally, plants are suckered once and tied three to four times.

The most common method of trellising indeterminate varieties is a vertical wire system. Six foot tall support posts are placed every 5 to 10 feet with a 12-guage wire running between them. Plants are then tied to a vertical piece of twine attached to the overhead wire. Plants are twisted around the twine and suckered regularly to control growth. Additional ties and/or clips are used to keep the vine attached to the twine.

Harvest and Handling

Eggplant

Approximate eggplant yield is between 190 and 250 cwt per acre (Ivors 2010). Pepper harvest ranges from 10 to 40 days after flowering depending on the variety. Generally fruit are harvested immature before seeds begin to significantly enlarge and harden. High quality fruit is full size, firm, and glossy. Eggplant fruits become pithy and bitter as they reach an over mature condition.

Pepper

Pepper yields vary widely depending on plant spacing, production methods (use of plastics), and type of pepper. Average pepper yield ranges from 100 to 300 cwt/acre (Ngouajio 2009). Bell peppers are hand harvested by cutting from the plant leaving a one inch stem on the fruit, or carefully twisting the fruit to break the stem. Peppers may be harvested at the immature (green) stage or after the mature color develops. Pepper harvest starts about 30 days after flowering (mature green) and it takes an additional 10 to 20 days before fruits are fully colored.

Tomato

An acre of tomato plants yields an average of 200 cwt/acre (1 cwt is equivalent to 100 lb.); however use of plasticulture techniques such as plastic mulch and row covers has been reported to increase yields up to 600 cwt/acre (Hemphill 2010). Tomatoes may be harvested at the mature green stage to the fully ripe stage depending on transport logistics and marketing requirements. Tomatoes closer to the fully ripe stage are more susceptible to surface and internal damage during handling; however, fully ripe tomatoes tend to have a superior flavor expected for direct market sales.

Postharvest Care

Peppers

Post-harvest handling is as important as the growing of the crop. A high quality, mature, fresh pepper is firm, bright, and has a fresh, green calyx. Fruit should be cooled quickly after harvest. The best time to harvest is in the early morning when temperatures are cool and plants are well hydrated.

Proper storage conditions will reduce injury from pests.

Store sweet peppers between 45 to 55°F, and 90 to 95% humidity. Peppers are sensitive to chilling injury and disease development below 45°F. Temperatures above 55°F encourage ripening and spread of bacterial soft rot. Pre-packaging peppers in plastic films helps retain moisture and can prolong the storage life up to a week longer than non-packaged peppers.

Eggplant

Store eggplant between 45 to 55°F, and 90 to 95% humidity. Eggplants are sensitive to chilling injury below 50°F; however, sensitivity varies with variety, maturity, and size of fruit. Eggplant quality degrades quickly after 7 to 10 days of storage.

Tomato

Store mature green tomatoes at 55 to 60°F, and ripe fruit at 45 to 50°F. Firm ripe fruit can be stored 3 to 5 days. Relative humidity should be kept at 90 to 95% to maintain quality and limit water loss. Tomatoes are sensitive to chilling injury below 50°F if held longer than two weeks, and below 41°F if held longer than 6 to 8 days. Chilling injury may result in failure to ripen evenly and cause premature softening and decay. For even ripening, keep temperatures at 65 to 70°F with 90 to 95% relative humidity. For slower ripening (in transit) keep temperatures at 57 to 61°F.

For further detail on proper storage, handling and ripening techniques, refer to the publication *Recommendations for Maintaining Postharvest Quality*, available through the UC Davis California (see links below).

- postharvest.ucdavis.edu/pfvegetable/Eggplant/
- postharvest.ucdavis.edu/pfvegetable/BellPepper/
- postharvest.ucdavis.edu/pfvegetable/ChilePeppers/
- postharvest.ucdavis.edu/pfvegetable/Tomato/

Weed Management

The fruiting vegetables (eggplant, pepper, tomato) are almost exclusively started as transplants in Utah. These plants prefer warm weather conditions, where early establishment is necessary to ensure high productivity. Fruiting vegetables are often transplanted into bare soil and rely on furrow irrigation. Weed control is critical in the bare soil systems since weeds in the planted row and furrow are difficult to manage and compete with the desired crop. Weeds in and between the rows are typically controlled with cultivation, hand hoeing, herbicides, or some combination of the three approaches.

Planting through plastic mulches to improve early growth and reduce weed pressure associated with bare soil conditions may help manage weeds. Herbicides can be applied underneath the mulch, depending on the weed pressure and available labor. Weeds growing along the edge of the plastic mulch, however, are difficult to control with cultivation equipment. Use directed or shielded herbicide applications in these areas helps. Be cautious when using this method since spray drift and residual materials left on the plastic may affect the desired crop.

In organic systems, mulches (such as straw, cardboard, etc.) can provide good weed control in and between rows if applied in a thick mat before weeds emerge. There are OMRI approved organic herbicides that can assist in weed management in organic operations. These herbicides are primarily contact herbicides and must be applied to the green tissue of the weeds. Most organic herbicides have limited residual activity so weed control involves a combination of approaches like tillage, hoeing, and mulches in addition to the herbicides.

Most herbicides are now manufactured by many companies under different trade names. Herbicide and pesticide labels often change, so make sure to always consult the label to determine if the crop is listed on the label, what precautions are required, and what rates and application methods are allowed. It is critical to read the label before applying. Comparing the costs of different brands that may have the same active ingredient and percent of active ingredient is also a good idea.

Considerations for Herbicide Use

- Carefully read and follow all label directions and precautions.
- Use herbicides only on crops for which they are approved and recommended on the label.
- Use the recommended amount of product and apply it as stated. (Too much material may damage the crop and make it unsafe for consumption.)
- Apply herbicides only at times specified on the label and observe the recommended intervals of the time of planting and the time between treatments.
- Follow re-entry intervals (REI) and pre-harvest intervals (PHI).
- Don't spray in high wind conditions.
- It is a violation of the law to use herbicides other than directed on the label. The EPA has the authority to seize any agricultural commodity that carries a pesticide residue in excess of the established tolerance levels. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

Herbicides are just one tool available for weed control and their use should supplement other good weed-management practices.

Herbicides for weed control are applied in the following ways:

•**Pre-plant incorporated:** incorporated into the soil prior to seeding or transplanting the crop

•**Pre-emergence:** applied to the soil after planting but before the crop or weeds emerge

•**Post-transplant:** applied to the soil after crop is transplanted either before weeds have emerged or after clean cultivation

•**Post-emergence:** applied to weeds after both weeds and the crop have emerged

•**Directed post-emergence:** applied as a directed or shielded spray 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.

Insect and Mite Pest Management

Aphids

Order Hemiptera: Family Aphididae

Green Peach Aphid (*Myzus persicae*)

See pg. 57-58 for information on the description, life history, damage, and management of this pest.

Melon Aphid (*Aphis gossypii*)

See pg. 57-58 for the description, life history, damage, and management information on this pest.

Potato Aphid (*Macrosiphum euphorbiae*)

See pg. 57-58 for more information on the description, life history, damage, and management of this pest.

APHID DAMAGE:

Aphid feeding may cause yellow spots, water stress, and reduced plant growth rate. If aphid feeding is prolonged, or heavy infestations occur, reduction of yield may result (Fig. 9.6). One of the major concerns of aphids is their ability to transmit plant viruses (see the disease management section of this chapter for information on virus diseases of concern for eggplant, pepper, and tomato).

Armyworms and Cutworms

See pg. 184-187 for information on the description, life history, damage, and management armyworms and cutworms.

Beet Leafhopper (*Circulifer tenellus*)

Order Hemiptera: Family Cicidellidae

DESCRIPTION:

Adult: Wedge-shaped with a pale green, gray, or tan colored body and about 0.13 inches (3 mm) long (Fig. 9.7).

Egg: Tiny, white.

Nymph: Similar in appearance to the adult but smaller and wings are not fully developed.

LIFE HISTORY:

Beet leafhopper overwinters as mated females on weed hosts and in uncultivated areas in the southern U.S. They migrate or are blown north in early summer. Adults move into cultivated fields, when weeds begin to dry up, where they feed and reproduce on suitable host plants. Development from egg hatch to adult can take about 2-3 months. Multiple generations occur each year.

DAMAGE:

Adults and nymphs use their piercing sucking mouthparts to remove plant tissue from leaves and stems of host plants. When leaf hopper infestations are severe, feeding can result in shriveled and burned leaves which is often referred to as 'hopper burn'. The most severe damage to tomato and pepper crops; however, occurs when the beet leafhopper transmits curly top virus (see page 150-151). The leafhopper picks up the virus while feeding on infected weeds in the spring. As infected leafhoppers move into cultivated fields and gardens they spread the virus to all plants they feed on. Leafhoppers can transmit the virus to an uninfected host even if they only feed for a brief period (minutes). A virus-infected leafhopper will transmit the virus for the duration of its life, often resulting in long distance spread of the virus, but does not pass the virus on to its progeny in utero.

MANAGEMENT:

Management decisions should be focused on preventing leafhoppers from feeding and spreading the curly top virus.

Cultural:

- *Destroy and remove plant debris.* Weeds or volunteer plants from previous crops can act as overwintering hosts for leafhoppers and the virus. Keep field borders and interiors clear of weeds; this will reduce food sources for incoming infected leafhoppers in the spring and summer.
- *Plant virus resistant varieties.* Trials in St. George, Utah showed that the following resistant-labeled varieties performed well: 'Rowpac', 'Roza', 'Salad Master', and 'Colombian'.
- *Plant higher than normal density.* This will help to lower the probability that every plant in the field will be infected.
- *Use floating row covers, or reemay fabric.* Reemay is a white mesh, breathable fabric to cover plants and reduce feeding by beet leafhopper and other insects.

Biological:

Few natural enemies of the beet leafhopper have been identified. Research has shown a fly parasitoid

(Pipunculidae) attacks beet leafhoppers, but the potential for population reduction is unknown.

Chemical:

The beet leafhopper's wide host range, ability to migrate long distances, and rapid virus transmission when feeding make management with insecticides difficult. Insecticides may prevent some within-field spread, but most applications should be directed towards other hosts, such as weeds, in order to prevent leafhopper spread into the desired crop. However, this method may be costly and have less than ideal results, making cultural control the primary approach to management.

SEARCH THE INTERNET FOR MORE INFORMATION:

- US Pest Beet Leafhopper
- UC Davis IPM Online Beet Leafhopper
- California Department of Food and Agriculture Curly Top Virus Biological Control of the Beet Leafhopper

Stink Bugs

Order Hemiptera: Family Aphididae

DESCRIPTION:

Adult: Shield-shaped, 1/2 to 2/3 inch (13 to 16 mm) long, brown or green in color, with an inverted triangle on the upper back (Fig. 9.8).

Egg: Barrel-shaped, and white when first laid, then darken as they mature. Eggs are laid in clusters of 10-30 on undersides of leaves (Fig. 9.9).

Nymph: Resemble adults but are smaller and more rounded with brightly patterned black, red, white and green bodies (Fig. 9.10).

LIFE HISTORY:

Stink bugs overwinter as adults on the ground under leaves, plant debris, and weedy areas. They become active in the spring, and can feed on a wide range of fruits and vegetables. Nymphs hatch from eggs and initially begin feeding in close proximity to each other but scatter as they mature and grow. Stink bug infestations typically occur along field edges that border weeds and other desirable host plants. When disturbed, they emit a foul odor.

DAMAGE:

Stink bugs insert their straw-like mouthparts into the fruits or seeds of vegetables, piercing the skin, and suck out the juices. The stink bug may probe in several locations causing the fruit to develop hard, whitish, callous tissue beneath the skin at the feeding site. Feeding injury becomes more apparent as fruits ripen, and appears as cloudy areas of hard yellow spots just under the fruit of the skin. Stink bug feeding can also result in misshapen or shriveled fruits and seeds. On green fruit, damage appears as dark pinpricks surrounded by a light colored area that remains green or turns yellow when the fruits ripen. Severe injury may cause the entire fruit to develop a golden color. Stink bug damage is not as common in peppers and eggplants as it is with tomatoes. Damaged fruits are safe to eat, but the flavor may not be well developed, and are usually undesirable for the fresh market.

MANAGEMENT:

Stink bugs are difficult to control because they are strong fliers and readily migrate in and out of vegetable fields and gardens, and will have dispersed by the time plant symptoms appear. In tomatoes, management should begin when fruits are one inch in diameter.

Cultural:

- *Monitor for presence of stink bugs.* Shake foliage over a tray or onto the ground. Count fallen nymphs and adults. Treatment thresholds will vary with plant types and intended use, but generally one-third to one-half of a stink bug per tray shake will result in about 5% damaged fruit.
- *Handpick stink bugs from plants.* In small gardens, handpick adults, nymphs, and eggs from plants. Stink bugs can be squashed or drowned in a bucket of soapy water.
- *Eliminate weedy areas along field borders and within fields and gardens.* Remove weeds, especially along field borders and in the spring and late summer to decrease attraction of stink bugs to vegetable crops.

Chemical:

Small numbers of stink bugs can cause serious damage to fruits of vegetables; therefore, insecticide applications are often necessary. Treatment is needed when stink bug counts average one in three shake samples. Tomatoes destined for the fresh market, will tolerate less injury than those for processed markets. In tomatoes, stink bugs should be managed starting at the point when fruits reach 1 inch in diameter.

Biological:

Natural enemies of stink bugs include birds, spiders, and several species of insects including wheel bugs, assassin bugs, predatory stink bugs, and parasitic wasps.

Search the internet for information on an important new invasive species, the ***brown marmorated stink bug***, found in the Salt Lake Valley of Utah since 2012.

- USU Extension Fact Sheet: Brown Marmorated Stink Bug
- University of Florida, BMSB
- Penn State University BMSB

Tomato Hornworm

(Manduca quinquemaculata)
Order Lepidoptera: Family Sphingidae

DESCRIPTION:

Adult: Grayish-brown in color with a wing span of 4 to 5 inches (10 to 13 cm). Sides of abdomen have 5 orange-yellow spots. Forewings are longer than hind wings; hind wings have two narrow, dark, zigzag, diagonal lines running across the center (Fig. 9.11).

Egg: Spherical to oval in shape, 1/16 inch (1.60 mm) in diameter, and vary in color from light green turning to white as they mature.

Larva: Cylindrical with five pairs of prolegs and three pairs of thoracic legs, and 3 to 4 inches (8 to 10 cm) in length. Green body with eight white "v" shaped marks along each side. Black pointed structure, "horn", located on the terminal abdominal segment (Fig. 9.12).

Pupa: Dark brown, elongate-oval with pointed posterior; 1.8 to 2.4 inches (45 to 60 mm) in length. A sheath for the mouthparts projects from the head and curves downward extending about 1/3 of the body and resembles the handle of a pitcher.

LIFE HISTORY:

Adults of tomato hornworm, also known as the five-spotted hawk moth, begin to emerge in late spring to early summer. Adult moths use their long, coiled, tube-like mouthparts to imbibe nectar from flowers. They can be seen hovering above flowers of dusk-blooming plants resembling hummingbirds in flight. Females deposit eggs individually on the undersides of host plant leaves. Heavy egg deposition is common late in the summer and early fall. Hornworm larvae emerge from eggs after 2-8 days, depending on temperature, and begin feeding. Larvae prefer tomato and tobacco, but will feed on eggplant, pepper, potato, and some species of *Solanum* weeds. Larvae feed for 3 to 4 weeks and then burrow 3-4 inches (8-10 cm) deep into the soil to pupate. In the summer, adult moths will emerge after about 3 weeks and begin the cycle again. Tomato hornworms spend the winter as pupae in the soil. There are one to two generations per year in Utah.

DAMAGE:

Hornworm larvae use their chewing mouthparts to feed primarily on leaves but will also eat blossoms, stems, and fruits. Larvae feed initially in the upper part of plants and create dark green or black droppings. As larvae mature, they consume large amounts of plant tissue and can defoliate plants and scar fruits, especially when populations are high (Fig. 9.13).

MANAGEMENT:

Cultural:

- *Monitor for hornworm damage.* Look for plants that are defoliated or have fruits with large, deep, cavities. Larvae can be handpicked from plants; they are easiest to see when actively feeding near dusk and dawn.
- *Spot treat infected plants.* Hornworm infestations tend to be spotty and it is rare for an entire field to be infested.
- *Plow field after harvest.* Normal tillage practices move pupae to the soil surface where they freeze during the winter resulting in up to 90% mortality.
- *Rotate crops.* In sites with high overwintering populations, rotate to crops that are not attacked by hornworms (i.e., non-solanaceous plants).

Biological:

Natural enemies include several species of *Trichogramma* wasp parasitoids and parasitic brachonid wasps. Brachonid wasps oviposit eggs into hornworms, and when the eggs hatch larvae begin feeding inside. When brachonid larvae are mature, they pupate on the back of the hornworms. Hornworms with pupal cases appear to have white projections on their backs (Fig. 9.14). The wasp *Trichogramma pretiosum* will attack hornworm eggs and is available from commercial insectaries.

Chemical:

Hornworm populations often do not exceed economic thresholds due to predation from natural enemies. Treat for hornworms only if they are causing extensive defoliation, or if they are feeding on fruit. Target young larvae and eggs as they are easier to kill. Apply insecticides to the foliage for larval suppression.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of Florida Featured Creatures Tobacco Hornworm
- CSU Extension Hornworms and "Hummingbird" Moths PDF
- UM Extension Tomato Hornworms in Home Gardens

Thrips

Order Thysanopetera: Family Thripidae

See pg. 97 and 98 for more information on the life history and management of thrips.

The western flower thrips (*Frankliniella occidentalis*) and onion thrips (*Thrips tabaci*) are the two most common vectors of tomato spotted wilt virus (TSWV) in solanaceous crops. See TSWV disease description below. In addition to virus transmission, thrips will feed on leaves, developing buds, flowers, and fruits; and if populations are high, can cause economic loss. Typical symptoms are "rasping" and stippling injury on leaves (Fig. 9.15), and stunted buds, flowers, and fruits. Thrips feeding on the surface of well-developed fruits can cause scarring. An abundance of dark tar-spots of thrips frass can contaminate fruits.

Tomato Fruitworm/Corn Earworm *(Helicoverpa zea)*

Order Lepidoptera: Family Noctuidae

See pg. 181-183 for more information on the description and life history of corn earworm.

DAMAGE:

Tomato fruitworm (TFW) causes damage when larvae feed on leaves and reproductive structures of tomato, pepper, and eggplant. Larvae have chewing mouthparts which they use to remove plant tissue resulting in distorted leaves (Fig. 9.16). When fruit is present, the tomato fruitworm will often attack fruit without any leaf feeding (Fig. 9.17). TFW bore deeply into the fruit to feed and complete larval development resulting in watery internal cavities filled with cast skins and frass (feces). Damaged fruit ripens prematurely and becomes unmarketable when larvae are present or when fruits rot due to secondary invasion of diseases. Unlike corn, where one larva is found per ear, a single larva can enter several fruits during feeding and development.

MANAGEMENT:

Cultural:

- *Monitor with traps.* Place pheromone traps on perimeters of fields. Traps can be used to indicate relative adult densities and/or peak activity (see pg. 182 for further description of traps).
- *Search leaves and fruit for eggs and larvae.* Begin sampling when moths are present in traps. Search leaves above and below the highest flower cluster for eggs. When fruit is present, check for damage and presence of larvae. Check several plants in 4-5 locations.
- *Look for signs of parasitism or predators.* Parasites and other natural enemies often destroy significant numbers of eggs, but are sensitive to insecticide sprays.
- *Avoid planting tomato, pepper, and eggplant near post-silking corn fields.* When corn silks turn brown, TFW moths will seek out other nearby hosts for egg-laying.
- *Remove and destroy cull fruits and plant debris.* Disk or plow plant debris, including weeds, to eliminate overwintering host sites and to destroy infested fruits and pupating larvae.

Chemical:

Use monitoring techniques to help determine when chemical control is needed. Although larvae may remain partially unprotected in the fruit and be exposed to insecticides when moving from fruit to fruit, it is best to target treatment towards eggs and newly hatched larvae before they enter the fruit in large numbers.

Biological:

Natural enemies include parasitic wasps (*Trichogramma* spp.) which parasitize TFW eggs, and generalist predators such as lacewings (*Chrysopa* spp. and *Chrysoperla* spp.), big-eyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), and minute pirate bugs (*Orius* spp.) which attack TFW eggs and young larvae.

Trichogramma pretiosum is available from commercial insectaries.

Tomato Russet Mite *(Aculops lycopersici)*

Order Acari: Family Eriophyidae

DESCRIPTION:

Adult: Bodies are cigar-shaped, yellowish-tan or pink, microscopic, and 0.01 inch (0.3 mm) long (Fig. 9.18).

Egg: Colorless to white, roughly hemispherical and extremely small. Requires a 100-power or greater magnification to be seen.

Nymph: Resemble adults but are smaller.

LIFE HISTORY:

Tomato russet mites are most abundant during hot, dry weather in the mid- and late summer. They attack a variety of vegetables including tomato, eggplant, pepper, potato, and other solanaceous plants. The russet mite has a high reproductive potential (up to 53 eggs per female) and can complete a life cycle (egg to adult) in a week at warm temperatures. Females live for about 22 days laying eggs on the undersides of leaves, leaf petioles, and stems. Young nymphs tend to feed close to where they hatch. Mite feeding is usually concentrated on the lower part of the plant, but when infestations are severe and plants become heavily damaged, mites will disperse to upper leaves. Tomato russet mites can crawl between closely spaced plants that are touching, and can be carried by the wind.

DAMAGE:

The presence of tomato russet mites often goes unnoticed due to their microscopic size until feeding injury is evident. Adults and nymphs insert their piercing-sucking mouthparts into plant tissue to imbibe plant juices. Injury from mite feeding can cause bronzing or "russeting" of the surface of stems, leaves, and fruits (Fig. 9.19). Damaged leaves may turn yellow, curl, wither, and fall from plants (Fig. 9.19). Mite feeding on fruits can cause longitudinal cracks and bronze coloration.

MANAGEMENT:

Cultural:

- *Use clean transplants.* Inspect transplants carefully to be sure they are free of russet mites.
- *Avoid planting during hot, dry periods.* Stressed seedlings are more vulnerable to attack by the mites.
- *Avoid transplanting seedlings near infested crops or weeds.*
- *Promptly remove or destroy infested plant debris.*
- *Sanitize equipment.* Make sure any tools or equipment used on infested plants are properly cleaned before being used on healthy plants.

Chemical:

Once russet mites are present on plants, insecticide treatment is the primary control option. Apply the insecticide to the undersides of leaves where most mites are located.

Biological:

There are several predatory mites that feed on tomato russet mites; however, there is often a lag time between increase in populations of tomato russet and predatory mites.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of Florida IFAS IPM Tomato Russet Mite PDF
- UC Davis IPM Online Tomato Russet Mite
- Hawaii.edu Crop Knowledge Master Tomato Russet Mite

Disease Management

Several pathogens can cause diseases on tomato, pepper and eggplant while others only affect one or two of these plants. It is therefore essential to identify the pathogen causing the problem before it spreads to other host plants. One of the most critical steps to disease prevention is to start with healthy disease-free transplants or seed.

Tomato Spotted Wilt Virus (TSWV)

TSWV is a tospovirus that is transmitted by thrips species. In Utah, the most common vector is the western flower thrips (*Frankliniella occidentalis*), but onion thrips (*Thrips tabaci*) can also spread the virus. TSWV has increased in Utah in the last two years. The virus has over 1,000 known hosts, among them are many weeds that do not show symptoms. Thrips have to acquire the virus as larvae to be able to transmit it to a healthy plant. Once thrips larvae have acquired the virus they will transmit it for the rest of their lives.

SYMPTOMS:

Symptoms of TSWV vary between plant species and within a species depending on the strain of the virus, time of infection, and plant variety.

TSWV-infected **eggplants** will die back from tips of new shoots, and the fruit will have orange and yellow rings (vric.ucdavis.edu/pdf/eggplant.pdf).

Leaf symptoms on **peppers** consist of chlorotic ring spot patterns (Fig. 9.20). Fruit can display blotchiness ranging from green to red (Fig. 9.21), or display ring spots (Fig. 9.22, Fig. 9.23) similar to tomatoes.

On **tomatoes**, symptoms on leaves consist of brown (necrotic), irregular shaped spots (Fig. 9.24). Initially, the spots are very small and can be overlooked on young transplants. On green, immature fruit, brown ring spots occur (Fig. 9.25) that can also be seen on ripe tomatoes (Fig. 9.26). On some tomato varieties, such as 'Roma' types, the ripe fruits develop blotches of variable colors from yellow to orange and red (Fig. 9.27). Plants are often stunted.

DISEASE CYCLE:

Plants get infected when thrips carrying the virus feed on a healthy plant, thus depositing virus particles. The first symptoms often appear 7-10 days later. In some cases the virus remains localized where only the plant part on which thrips fed show symptoms. More often, the virus spreads from the original point of infection throughout the entire plant. Once a plant is infected there is no cure, and if thrips are reproducing on the plant, it can serve as an inoculum source for neighboring plants.

MANAGEMENT:

The most effective management strategies are to prevent infection and use resistant varieties.

- *Control thrips* (see thrips section above and pg. 97-99 for information on thrips management).
- *Remove and destroy all infected plants.*
- *Purchase healthy transplants***.** If transplants have suspect brown spots on the leaves, even if it is only one spot, plants should not be used.
- *Use resistant varieties:* (The varieties listed below are not common in Utah suppliers but can be purchased over the Internet.)
  - Resistant tomato varieties include 'Jimbo', 'Southern Star', 'Amelia', 'Crista', 'Red Defender', 'Primo Red', and 'Talledaga'.
  - Resistant pepper varieties include 'Stileto', 'Heritage', 'Plato' and 'Magico' (www.tomatospottedwiltinfo.org/vegcrops/index.html).
  - There are no resistant eggplant varieties.
- *Provide good weed control.* Weeds can be a host for both TSWV and thrips. Thrips can reproduce on host weeds and increase the number of thrips that acquire the virus. Good weed control on field edges and in home gardens and landscapes can reduce the chance of virus infection.

Curly Top Disease (Beet Curly Top Virus)

Curly top disease of tomato and pepper is caused by beet curly top virus, of the Curtovirus group. In recent years, due to molecular identification, it was discovered that there is not just one beet curly top virus, but several viruses with different characteristics causing similar symptoms on tomatoes and peppers. The disease can be devastating on tomatoes and peppers. Other hosts include: beets, chard, spinach, beans, and cucurbits.

SYMPTOMS:

Tomato and pepper plants infected with curly top are

stunted and have upwards curled, yellow leaves (Fig 9.28, Fig 9.29). The veins on the underside of tomato leaves are purple (Fig. 9.30). Infected plants may not produce fruit, or fruit that develops will ripen prematurely. While older plants are less susceptible to the virus, plants that are infected at an early stage may die.

DISEASE CYCLE:

The virus is transmitted by the beet leafhopper (*Cicurlifer tennellus*) (Fig. 9.7). In late spring, when weeds and grass growing along the foothills dry up, leafhoppers migrate to greener plants which are often in and near vegetable fields. The leafhopper probes plants indiscriminately to find suitable feeding hosts. Tomato and pepper are not preferred feeding hosts, which is why beet leafhopper is rarely found on these plants. However, they may feed on these hosts for a very short time, and any beet leafhoppers infected with the virus will transmit it within a matter of seconds while they "taste" the plant. Symptoms appear within 7 to 14 days after infection.

MANAGEMENT:

Management of curly top disease is challenging in part because there are no resistant tomato or pepper varieties available. The following suggestions may help reduce disease incidence.

- *Delay planting by one or two weeks.* Planting after migration of leafhoppers has moved through can reduce disease incidence significantly, depending on the area.
- *Manage weeds.* Weeds can be treated with insecticides against beet leafhoppers but it will be ineffective to treat tomatoes.
- *Use dense plant spacing.* Dense plantings will make it more difficult for the insects to find the plants.
- *Use row covers.* Row covers for the first 6-8 weeks of planting will exclude leafhoppers.
- *Use intercropping or trap crops.* Leafhoppers are attracted to plants that highly contrast with their surroundings (entoweb.okstate.edu/ddd/diseases/curlytop.htm).

Tobacco Mosaic Virus (TMV) and Tomato Mosaic Virus (ToMV)

Tobacco mosaic virus (TMV) and Tomato mosaic virus (ToMV) are two very closely related viruses with similar symptoms. Antibody-based molecular testing is necessary for accurate identification. TMV and ToMV are two of only a few plant viruses that are not transmitted by insects. In contrast to many other plant viruses, TMV and ToMV can survive for up to 50 years in plant debris and for weeks to months on trellises or wooden stakes.

SYMPTOMS:

Infected **eggplants** have small leaves with mosaic patterns.

On **pepper**, leaves will grow in the shape of an oak leaf (jalapeño peppers) (Fig. 9.31) or show mosaic patterns (other pepper types). Fruit is often smaller, distorted and has blotches and/or necrotic spots.

Tomato foliage displays mosaic symptoms that can range from a faint light and dark green pattern to a darker yellow and green pattern. Mosaic symptoms depend on plant cultivar and temperature. Symptoms are fainter at high temperatures. Other foliar symptoms include leaf distortion (fan shape) and occasionally leaf curling. In some cases, fruit symptoms will not occur. In other cases, yellow rings or brown sunken lesions will show on ripe fruit (Fig. 9.32 and 9.33), or the parenchyma layer of cells inside the fruit will turn brown (Fig. 9.34). Because fruit symptoms can be mistaken for TSWV infection, the virus should be identified by a plant diagnostic lab. Samples can be submitted to the Utah Plant Pest Diagnostic lab (UPPDL) for identification at utahpests.usu.edu/uppdl.

DISEASE CYCLE:

TMV is transmitted by artificial grafting, and by contaminated seed. The virus can be spread on pruning tools or by bare hands, such as during sucker pruning or staking. The virus can also be spread by growers' hands that handled tobacco cigarettes or chew that is infected with TMV. If seedlings are planted in pots or beds where previously infected plants grew, they can become infected. A common mode of TMV infection in greenhouses is through contaminated seed. Once the virus has entered the plant, through wounds as small as torn plant hairs, it spreads though the entire plant, including roots.

MANAGEMENT:

Tobacco and tomato mosaic virus are difficult to control, as they can survive harsh conditions for many years. Once a plant is infected, there is no cure.

- *Remove infected plants immediately.* Do not compost infected plants due to the longevity of the virus.
- *Use certified disease-free seed.* When preserving seed from your own plants, do not keep seed from infected plants.
- *Disinfect tools that came into contact with infected plant material.* Reports from Florida indicate that dipping contaminated tools for one minute in a 20% powdered milk solution will kill the virus.
- *Use new potting soil, pots, and string every time*, when growing your own transplants, to minimize infection.
- *Use resistant varieties.*
  - TMV resistant **eggplant** varieties including 'Epic', 'Dusky' and 'Imperial' (http://vric.ucdavis.edu/pdf/eggplant.pdf).
  - TMV or ToMV resistant **pepper** varieties include 'Telestar', 'Crusader' and 'Paladin'.
  - There are many TMV and ToMV resistant **tomato** varieties (vegetablemdonline.ppath.cornell.edu/Tables/TomatoTable.html). Most heirloom varieties are susceptible to both viruses. The correct identification of the virus is necessary if resistant varieties are to be used. Some varieties are only resistant to one of the two viruses. Break-down in resistance of some tomato varieties to the viruses has occurred.

Early blight

Early blight disease affects tomato and eggplant, but not pepper. It is caused by the fungus *Alternaria solani.* Potatoes are also susceptible to early blight.

SYMPTOMS:

Lesions can develop on leaves, fruit, and stems. The first foliar symptoms are brown necrotic spots on older leaves (Fig. 9.35) that enlarge over time. Younger leaves do not show visible symptoms. A yellow halo may develop around the lesions, and concentric rings develop when spores are produced (Fig. 9.36). When there are numerous or large lesions,, the entire leaf may become yellow and fall off, exposing fruit underneath to potential sunscald. Severe infections result in reduced yield and lower quality of fruit. Seedlings can develop stem infections. Infected seedlings planted in the field either die as stem lesions enlarge or the plants may be stunted and unproductive. Fruit may also be infected. Lesions on green or ripe fruit develop near the calyx end and become leathery over time (Fig. 9.37).

DISEASE CYCLE:

Optimum conditions for infection occur during warm (78-84^{0}F), wet periods of rain, overhead irrigation, or heavy dew. The fungus survives in plant debris in the soil (main source for inoculum) and on seed. After landing on tomato plants, spores only require two hours to germinate and infect the plant. Lesions become evident two to three days later. Spores develop on lesions and are dispersed by wind.

MANAGEMENT:

- *Use resistant varieties.* 'Mountain Supreme', 'Mountain Fresh', 'Plum Dandy', 'Mountain Magic', and 'Defiant PhR' have resistance to the disease.
- *Only use pathogen-free seed.*
- *Use Crop rotation.* Rotate soil out of all solanaceous crops for at least two years.
- *Provide good weed control* and remove volunteer host plants (all solanaceous crops) this will help to reduce potential sources of inoculum.
- *Keep plants vigorous* through good soil fertility regimes.
- *Use fungicides.* See fungicide table below for a list of effective products for control of early blight.

Late Blight

Late blight is a disease that can infect many solanaceous plants such as tomato, potato, and solanaceous weeds, however, there have been no reports of late blight in pepper or eggplant. The disease is caused by *Phytophthora infestans* and is infamous for causing the potato famine in Ireland in the 1840s.

SYMPTOMS:

All above-ground parts of tomato and potato plants can become infected. Foliar infections start out as small, water-soaked lesions that enlarge rapidly and become pale green (Fig. 9.38). Eventually the leaves dry up and die. Severely infected plants can die. On

the underside of leaves, growth of a white mold (Fig. 9.39) becomes visible on the lesions. Infected green fruit has brown or olive-colored lesions (Fig 9.40) and often develop a soft rot. Infected vines also rot and have a foul odor to them.

DISEASE CYCLE:

Infections occur during periods of cool, moist weather, when temperatures are between 66 and 72^{0}F. Above 86°F, infections will stop, but the pathogen can still survive and cause new infections when temperatures again become favorable. Symptoms can occur within three days of infection and plants can collapse so rapidly that they may appear to have been damaged by frost (Stevenson and Bolkan 2014). *Phytophthora infestans* survives on volunteer tomato and potato plants, solanaceous weeds (for example, hairy nightshade and bittersweet nightshade), petunia plants, and in tomato and potato cull piles.

MANAGEMENT:

- *Use resistant varieties.* Burpee, Johnny's Seed, and other seed companies have varieties with resistance to late blight including 'Mountain Magic', 'Defiant PhR', and the cherry tomato variety 'Lizzano' (www.johnnyseeds.com/; www.burpee.com/).
- *Use fungicides.* See fungicide table below for a list of effective products for control of early blight.

Additional information on late blight of tomato can be found at: www.pubs.ext.vt.edu/ANR/ANR-6/ANR-6_pdf.pdf.

Bacterial Speck

Bacterial speck is caused by *Pseudomonas syringae pv. tomato* and only affects tomato. Infected tomato fruit is unacceptable for fresh market production, but fruit can be used for canning where tomatoes are peeled.

SYMPTOMS:

Tomato leaves develop small irregular shaped brown, necrotic lesions (Fig. 9.41), often surrounded by a yellow halo. On small fruit (about 1 mm in size), round, black, superficial skin lesions develop (Fig. 9.42).

DISEASE CYCLE:

The bacteria can be seedborne and can survive for at least a year in plant debris. There have been reports that the bacteria can also survive on weeds. Spread between plants occurs by splashing water from overhead irrigation or rain, by using contaminated tools, and by workers brushing along plants. Transplants in greenhouses may carry the bacteria on the surface without disease development. However, once the plants are in the field and environmental conditions are conducive to infection, the disease can develop. Generally, bacterial speck is considered to start under cool, moist conditions but it has been observed in Utah during hot temperatures as well.

MANAGEMENT:

- *Only use disease-free seed.* When saving seed from plants, do not use seed from infected plants.
- *Use resistant tomato varieties* when available.
- *Avoid overhead irrigation.*
- *Apply preventive copper-based bactericides.* Once infection occurs, bactericides will no longer be effective.
- *Remove plant debris and weeds.*
- *Rotate out of tomato* for two years to non-host crops.

Bacterial Canker

Bacterial canker disease is caused by *Clavibacter michiganensis* subsp. *michiganensis*. Bacterial canker can occur on tomato and pepper, but is generally only economically important on tomato.

SYMPTOMS:

The main symptom is wilting. Young plants will wilt entirely whereas on older plants, wilting starts with just the lower leaves or just leaves on one side, and may end with the entire plant. Cut stems show vascular discoloration (Fig. 9.43). Infected leaves may develop yellow margins, known as "firing". In most cases, leaf symptoms do not progress to a vascular wilt.

Secondary infections cause spots on leaves and fruit. On fruit, spots are white with a dark center (Fig. 9.44). The bacteria infect fruits through infected flowers or the base of trichomes (hairs on leaves and stems). Wilting symptoms can be mistaken for wilt diseases and samples should be sent to a diagnostic lab to determine the cause. Samples can be submitted to the Utah Plant Pest Diagnostic lab (UPPDL) for identification at utahpests.usu.edu/uppdl.

DISEASE CYCLE:

Clavibacter bacteria are spread on seeds from infected plants, and by using contaminated pruning tools, trays, stakes, and benches. It survives on plant debris for at least two years, and on weeds and volunteer tomatoes. Handling infected plants and then touching healthy plants can spread the bacteria, as does splashing water. The most likely means of spread is during clipping of transplants. One infected out of 10,000 transplants can result in a severe disease outbreak. Some infected seedlings show symptoms and die, but others will remain asymptomatic.

MANAGEMENT:

- *Use disease-free seed.*
- *Use clean equipment.* Equipment such as trays, pots, benches, and pruning tools should be cleaned and disinfected after each use. Tools can be disinfected with a 70% ethanol solution.
- *Avoid overwatering.* Time irrigation so that leaves are dry in the evening.
- *Rotate with non-host crops* for three to four years.
- *Remove solanaceous weeds.*
- *Deep plow soil to bury plant debris.*
- Copper-based products have been shown to be effective in greenhouse transplant production for processing tomato, but were ineffective in the field after transplanting.

Powdery Mildew

There are two species of powdery mildew that can affect tomatoes: *Leveillula taurica* and *Erysiphe lycopercici.* In Utah, so far only *Leveilulla* sp. has been reported. *L. taurica* also affects peppers. Powdery mildew has not been reported to affect eggplant.

SYMPTOMS:

The two species cause different signs and symptoms. *E. lycopersici* causes the usual powdery mildew signs and symptoms on **tomato** (Fig. 9.45). The leaves show white, powdery spots that enlarge to cover the entire leaf. *L. taurica* is an unusual powdery mildew. On the upper leaf surface, it causes chlorotic areas on **tomato** and **pepper** (Fig. 9.46) rather than the usual powdery appearance. The fungus grows within the plant tissue and the spore-bearing structure (conidiophores) emerge from the stomates, visible with a strong hand lens or dissecting microscope.

DISEASE CYCLE:

Powdery mildews need living plant material to survive. When plant tissue dies, they produce resting spores that can survive the winter. On living tissue, the mildew produces a different type of spore that is for fast, mass dispersal.

Infection occurs in early summer either from spores released from fruiting structures in plant debris or by spores blown by the wind from warmer areas in the south. Spores can be carried by wind currents for hundreds of miles. In contrast to many fungi, powdery mildews do not grow well in rain or free water. For infection, powdery mildews only need high humidity or dew for a few hours. After a spore lands on a suitable plant surface, it germinates and the germ tube penetrates the tissue and starts growing either on the plant surface (*E. lycopersici*) or within the plant tissue (*L. taurica*). It takes about a week after infection before the first spores are produced and dispersed. Once spores are produced in a field, powdery mildew spreads quickly from plant to plant by air movement and on clothes of workers going through the rows.

MANAGEMENT:

Powdery mildew must be controlled early when the first lesion is seen. Once the fungus grows over the leaf tissue or entire leaves are yellow, it is too late to control the disease.

- *Remove infected plant debris* from fields before planting a new crop.
- *Use fungicides.* Apply fungicides throughout the growing season after the first symptoms have developed, according to label directions.

Wilt Diseases

There are two fungi that cause wilt of tomato, pepper and eggplant: *Verticillium spp*. and *Fusarium oxysporum* types called *formae specialis*. Both fungi are soilborne. The *formae specialis* are host specific. The one infecting tomato will not infect pepper or eggplant and vice versa.

SYMPTOMS:

Initial symptoms include wilting of infected plants during the hot part of the day with recovery in the evening. Eventually, the wilt is permanent. A discoloration of the vascular tissue can be seen by cutting through the main stem (Fig. 9.47). Leaves of plants infected with *Verticillium* may develop marginal

chlorosis and v-shaped necrotic lesions.

DISEASE CYCLE:

Both fungi infect through roots. They grow through the vascular tissue up into the main stem. Wilting is caused in part by the fungal growth clogging the phloem and xylem and by the plant trying to stop the movement of the fungus by blocking the colonized vascular tissue.

Fusarium infections are favoured by high soil temperatures (90^0F) and high soil moisture. When the plants are dead, *Fusarium oxysporum* produces salmon colored spores, called conidia, on the plant surface that are washed into the soil by rain and irrigation water. *Fusarium* also produces resting spores, called chlamydospores that can survive for several years in soil and plant debris.

Verticillium occurs more during cooler temperatures ($68\text{-}74^0$F) and in soils with a high pH which are very common in Utah. It produces an overwintering structure (survival structure) called a microsclerotium, which is a hard black ball of fungal tissue that can survive for a decade or more in the soil, waiting for a suitable host to be planted.

MANAGEMENT:

Both diseases are very difficult to control due to the production of the long-term survival structures in the soil.

- *Use resistant varieties* when available. Resistant tomato varieties are available for *Verticillium* race 1 but not race 2, and for *Fusarium oxysporum* races 1, 2 and 3.
- *Plant on raised beds* for better water drainage.

Root-knot Nematodes

Root-knot nematodes are microscopic roundworms. Juveniles and male nematodes are worm-like whereas female nematodes are lemon-shaped. There are many species. For vegetables, the most important species in Utah are *Meloidogyne hapla* and *Meloidogyne incognita*.

SYMPTOMS:

Above-ground symptoms of root-knot nematode infection resemble nutrient deficiency. Plants are chlorotic and stunted. The roots of infected plants are galled (Fig. 9.50). Large galls can merge and look like one big tumor.

DISEASE CYCLE:

Second-stage juvenile root-knot nematodes (J2) enter the plant through the root tips and move up in the root until they find a preferred spot to feed. The nematode then initiates a feeding site by releasing chemicals that cause cell nuclei to divide without cell division, creating giant feeding cells. Division of the cells and nuclei cause the galls. The plant moves more nutrients to this area and the nematode has its stylet in the giant plant cells, constantly feeding. All J2s moving into the root are female. Eventually, the nematode becomes lemon-shaped and breaks through the root surface. She produces egg masses that are released into the soil, but can sometimes be seen on the root surface under a dissecting microscope.

MANAGEMENT

Root-knot nematodes are very difficult to control since the soil fumigant, methyl bromide, was phased out.

- *Use tolerant varieties* when available.
- *Keep infested fields fallow* for two to three years.
- *Remove all weeds.* They can host root-knot nematodes.
- *Roto-till fallow areas* once every three to four weeks during the hot, dry summer months. Roto-tilling can reduce nematode populations to levels that allow crop production again. Tilling moves soil from deeper depths to the surface exposing the nematodes to the dry heat and causing them to die.

Blossom End Rot

Blossom end rot of tomato is caused by calcium deficiency. Blossom end rot also occurs in peppers, eggplant, and cucurbits.

SYMPTOMS:

Brown, enlarged spots develop usually at the blossom end of the tomato or fruit, but can sometimes also develop in other areas or internally (without showing external symptoms). Over time, the lesions turn dark and leathery, and may be colonized by mold.

MANAGEMENT:

Utah soils generally have plenty of calcium and calcium additions are not recommended.

Control blossom-end rot by using cultural practices that allow for proper uptake of calcium by the plant.

- *Test soil* before planting to determine if an adequate concentration of calcium is available.
- *Use infrequent, deep irrigation* to keep the soil uniformly moist and avoid water stress of fluctuating soil moisture.
- *Consider using drip irrigation* for more direct and uniform watering.
- *Do not allow plants to be water stressed at night.*
- *Maintain even soil moisture by using organic or plastic mulch.* Grass clippings/straw/etc. (2-3 inches thick) can be placed around the base of the plant to keep the soil cooler and reduce water loss.
- *Avoid over-fertilizing.* Do not use ammonium-based nitrogen fertilizers.
- *Avoid injuring roots.* Do not hoe or cultivate near plants. Pull weeds next to plants or use a plastic mulch.
- *Do not overwater*, especially in heavy clay soils.
- *Foliar sprays* of anhydrous calcium chloride can reduce symptoms during the growing season, but are generally not recommended in Utah.

Pest Management Tables for Commercial and Home Use

Table 9.5. Herbicides registered for **COMMERCIAL** use on **Tomato** in Utah.

TOMATO		Application Relative to Crop				Application for Weeds		Weed Groups Controlled			
Brand Name (REI/PHI)	Active Ingredient	Before Transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broad-leaves	Broadleaves	Comments
Aim (12hr/-)	carfentrazone	X	X	X		X			X	X	Use on transplants only
Dacthal products (12hr/-)	DCPA	X	X	X		X		X			
Devrinol (12hr/30-60d)	napropamide	X				X		X	X		
Dual Magnum (12hr/60-90d)	S-metolachlor	X	X	X		X					
Gramaxone Inteon (12hr/30d)	paraquat	X	X	X	X		X	X	X	X	Restricted use product
Matrix (12hr/45d)	rimsulfuron		X	X	X	X	X	X	X	X	
Poast (12hr/7-20d)	sethoxydim				X		X	X	X		
Prowl H2O (12hr/70d)	pendimethalin	X	X	X	X	X		X	X		Supplemental label – tomato only
RoundUp and others (12hr/14d)	glyphosate	X	X	X			X	X	X	X	
Sandea (12hr/30d)	halosulfuron	X		X	X		X		X	X	Helps control nutsedge
Select products (12hr/20d)	clethodim	X	X	X	X		X		X	X	
Spartan (12hr/-)	sulfentrazone	X				X			X	X	Helps controls nutsedge
Treflan products (12hr/-)	trifluralin	X		X		X		X	X	X	
Tricor (12hr/7d)	metribuzin			X	X	X			X	X	Not for direct-seeded
Organic Products											
Corn Gluten Meal	corn meal	X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 9.6. Herbicides registered for **COMMERCIAL** use on **Peppers** in Utah.

PEPPERS		Application Relative to Crop				Application for Weeds		Weed Groups Controlled			
Brand Name (REI/PHI)	Active Ingredient	Before Transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broad-leaves	Broadleaves	Comments
Aim (12hr/-)	carfentrazone	X	X	X		X			X	X	Use on transplants only
Command (12hr/-)	clomazone	X	X	X		X		X			All peppers but not banana types
Devrinol (12hr/30-60d)	napropamide	X				X		X	X		
Gramaxone Inteon (12hr/30d)	paraquat	X	X	X	X		X	X	X	X	Restricted use product
Poast (12hr/7-20d)	sethoxydim				X		X	X	X		
Prefar 4E (12hr/-)	bensulide	X				X		X			
Prowl H2O (12hr/70d)	pendimethalin	X	X	X	X	X		X	X		
RoundUp and others (12hr/14d)	glyphosate	X	X	X			X	X	X	X	
Sandea (12hr/30d)	halosulfuron	X		X	X		X		X	X	Helps control nutsedge
Select products (12hr/20d)	clethodim	X	X	X	X		X		X	X	
Treflan products (12hr/-)	trifluralin	X		X		X		X	X	X	
Organic Products											
Corn Gluten Meal	corn meal	X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus Oil	X	X	X			X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 9.7. Herbicides registered for **COMMERCIAL** use on **Eggplant** in Utah**.**

EGGPLANT		Application Relative to Crop				Application for Weeds		Weed Groups Controlled			
Brand Name (REI/PHI)	Active Ingredient	Before Transplanting	Preemergence	Post transplanting directed, shielded	Post-emergence	Preemergence	Post-emergence	Annual grass	Small-seeded broad-leaves	Broadleaves	Comments
Aim (12hr/-)	carfentrazone	X	X	X		X			X	X	Use on trans-plants only
Dacthal products (12hr/-)	DCPA	X	X	X	X	X		X			
Devrinol (12hr/30-60d)	napropamide	X				X		X	X		
Gramaxone Inteon (12hr/30d)	paraquat	X	X	X	X		X	X	X	X	Restricted use product
Poast (12hr/7-20d)	sethoxydim				X		X	X	X		
Prefar 4E(12hr/-)	bensulide	X				X		X			
Prowl H2O (12hr/70d)	pendimethalin	X	X	X	X	X		X	X		
RoundUp and others (12hr/14d)	glyphosate	X	X	X			X	X	X	X	
Sandea (12hr/30d)	halosulfuron	X		X	X		X		X	X	Helps control nutsedge
Select products (12hr/20d)	clethodim	X	X	X	X		X		X	X	
Treflan products (12hr/-)	trifluralin	X		X		X		X	X	X	
Organic Products											
Corn Gluten Meal	corn meal	X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/ clove oil	X	X	X			X	X	X	X	
Worry Free	citrus Oil	X	X	X			X	X	X	X	

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 9.8. Insecticides registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Armyworms	Beet Leafhopper	Cutworms	Stink Bugs	Tomato Hornworm	Tomato Fruitworm	Tomato Russet Mite
carbaryl	Carbaryl, Sevin,	1A	3		X	X	X	X	X	X	
methomyl	Lannate[R], Nudrin[R]	1A	5	X	X		X[TP]	X[TP]	X[T]	X[TE]	
oxamyl	Vydate[R]	1A	5-7	X							X[E]
acephate (pepper only)	Acephate, Bracket, Orthene	1B	3-7	X					X		
diazinon (tomato only)	Diazinon[R]	1B	(+)				X				
dimethoate (not eggplant)	Dimate 4E, Dimethoate	1B	6-7	X		X					
malathion	Cheminova, Fyfanon, Malathion	1B	5	X							
naled (pepper and eggplant only)	Dibrom 8 Emulsive[R]	1B	7	X							
endosulfan (not eggplant)	Thionex[R]	2A		X	X	X[P]		X[T]	X	X[T]	X[T]
alpha-cypermethrin	Fastac[R]	3	3	X	X	X	X	X	X	X	
beta-cyfluthrin	Baythroid[R]	3	7	X	X		X	X	X	X	
bifenthrin	Bifenture[R], Brigade[R], Capture[R], Fanfare[R]	3	7	See Label for listed pests							
bifenthrin + indole-3-butyric acid (not tomato)	Empower[R]	3	7-9				X				
bifenthrin + zeta-cypermthrin	Hero[R], Steed[R]	3	3	X (not hero)	X	X	X	X	X	X	
cyfluthrin	Tombstone[R]	3		X	X		X	X	X	X	
deltamethrin	Delta Gold[R]	3	5	X	X	X	X	X	X	X	
esfenvalerate	Asana[R], S-Fenvalorstar[R]	3	7	X[T]	X[TP]		X[T]		X[T]	X	
fenpropathrin	Danitol[R]	3	7	X	X	X	X	X	X	X	
gamma-cyhalothrin	Declare[R], Proaxis[R]	3	5	X	X	X	X	X	X	X	
lambda-cyhalothrin	Lambda[R], Paradigm[R], Silencer[R], Warrior[R]	3	5	X	X	X	X	X	X	X	
permethrin (not eggplant)	Ambush[R], Arctic[R], Permethrin[R], Pounce[R]	3	7		X[T]		X		X[T]	X	
pyrethrins	Pyganic[OB]	3		X	X	X		X	X	X	X
zeta-cypermethrin	Mustang[R]	3	7	X	X	X	X	X	X	X	
pyrethrins + piperonyl butoxide	Evergreen	3/	3	X	X	X		X	X	X	
zeta-cypermethrin + avermectin B1	Gladiator[R]	3/	7	X	X	X	X	X	X	X	X

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment
[T]= for tomato
[P]= for pepper
[E]= for eggplant

Table 9.8, continued. **Insecticides** registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Armyworms	Beet Leafhopper	Cutworms	Stink Bugs	Tomato Hornworm	Tomato Fruitworm	Tomato Russet Mite
beta-cyfluthrin + imidacloprid	Leverage 360[R]	3/4A	7	X	X	X	X	X	X	X	
bifenthrin + imidacloprid	Brigadier[R], Swagger[R], Tempest[R]	3/4A	7-10	See label for listed pests							
lambda-cyhalothrin + imidacloprid	Kilter[R]	3/4A	5	X	X	X	X	X	X	X	
lambda-cyhalothrin + thiamethoxam	Endigo[R]	3/4A	5	X	X	X	X	X	X	X	
bifenthrin + abamectin	Athena[R]	3/6	10	X	X	X	X	X	X	X	X
lambda-cyhalothrin + chlorantraniliprole	Voliam Xpress[R]	3/28	5	X	X	X	X	X	X	X	
pyrethrins + azadirachtin	Azera[OB]	3/UN	5-7	X	X	X	X	X	X	X	
acetamiprid	Assail	4A	7	X							
clothianidin	Belay	4A	7	X		X		X			
dinotefuran	Safari, Scorpion, Venom	4A	(++)	See label for listed pests							
imidacloprid	Admire Pro, Couraze, Marathon	4A	5	X		X					
thiamethoxam	Actara, Flagship, Platinum	4A	5	X		X		X (not platinum)			
spinetoram	Radiant	5	2		X				X	X	
spinosad	Entrust[O], Success	5	5-7		X				X	X	
abamectin	Agri-mek[R], Reaper[R], Zoro[R]	6	7								X
emamectin benzoate	Proclaim[R]	6	7		X				X	X	
pymetrozine	Fulfill	9B	7	X							
flonicamid	Beleaf 50	9C	7	X							
Bacillus thuringiensis subspecies aizawai strain	Xentari[OB]	11A	3		X		X		X	X	
Bacillus thuringiensis subspecies kurstaki strain	Biobit[B], Dipel[B]	11A	3		X		X		X	X	
chlorfenapyr	Pylon	13	5-7		X				X	X	X
novaluron	Rimon	15	7		X			X	X	X	
methoxyfenozide	Intrepid	18	5		X				X	X	
tebufenozide	Confirm	18			X				X		
indoxacarb	Avaunt	22A	3		X				X	X	
spiromesifen	Oberon	23	14								X

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[P]= for pepper
[E]= for eggplant

Table 9.8, continued. Insecticides registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Armyworms	Beet Leafhopper	Cutworms	Stink Bugs	Tomato Hornworm	Tomato Fruitworm	Tomato Russet Mite
spirotetramat	Kontos, Movento	23	7	X		X only Kontos					X
chlorantraniliprole	Coragen	28	1		X				X	X	
cyantraniliprole	Exirel, Verimark	28	5	X	X				X	X	
flubendiamide	Belt	28	3		X		X		X	X	
chlorantraniliprole + thiamethoxam	Durivo, Voliam Flexi	28/4A	(++)	X	X	X		X only Voliam	X	X	
Sulfur (not eggplant)	Golden Micronized Sulfur[O]	M2 Fungicide									X
azadirachtin	Aza-Direct[OB], Azatin[OB], Azatrol[B], Ecozin[B], Molt-X[OB]	UN	5-7	See Label for listed pests							
dicofol (not eggplant)	Dicofol	UN	(++)								X
Beauveria bassiana GHA	Mycotrol O[OB]	---	2-5	X	X	X		X			
capsaicin and related capsaicinoids	Bugitol[B]	---		X			X		X	X	
Chromobacterium subtsugae strain PRAA4-1t and spent fermentation media	Grandevo[OB]	---		X	X		X		X	X	X
extract of *Chenopodium ambrosioides* near *ambrosioides*	Requiem[B]	---		X							
kaolin	Surround[O]	---	5			X					
Metarhizium anisopliae Strain F52 (not eggplant)	Met52[OB]	---	5-10								X
oil: petroleum, peppermint, rosemary, garlic, paraffinic	Allityn[B], Biocover[B], Ecotec[O], Omni (not eggplant), Purespray[O], Saf-T-Side, Suffoil-X[O], Ultra-Pure, Stylet Oil[O]	---		See Label for listed pests							
potassium salts of fatty acids (insecticidal soap)	M-Pede	---	7	X		X					X
sodium tetraborohydrate decahydrate	Prev-AM	---	7-10	X	X	X					X
sucrose octanoate	SucraShield	---		X		X	X		X	X	X

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment
[T]= for tomato
[P]= for pepper
[E]= for eggplant

Table 9.9. Fungicides registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Blight	Powdery Mildew	Wilt diseases
myclobutanil	Rally	3		X	
difenoconazole + cyprodinil	Inspire	3/9	X	X	
difenoconazole + azoxystrobin	Quadris Top	3/11	X	X	
difenoconazole + mandipropamid	Revus Top	3/40	X[T]	X[T]	
mefenoxam + copper hydroxide	Ridomil Gold Copper	4/M1	X[TP]		
mefenoxam + mancozeb	Ridomil Gold MZ WG	4/M3	X[T]		
mefenoxam + chlorothalonil	Ridomil Gold Bravo	4/M5	X[T]		
boscalid	Endura	7	X[PE]		
penthiopyrad	Fontelis	7	X	X	
fluxapyroxad + pyraclostrobin	Priaxor Xemium Brand	7/11	X	X	
pyrimethanil	Scala	9	X[T]		
cyprodinil + fludioxonil	Switch	9/12	X	X	
azoxystrobin	Quadris, Satori	11	X	X	
fenamidone	Reason	11	X		
fluoxastrobin	Aftershock, Evito	11	X		
pyraclostrobin	Cabrio EG	11	X	X	
trifloxystrobin	Flint, Gem	11	X	X[TP]	
famoxadone + cymoxanil	Tanos	11/27	X[TP]		
azoxystrobin + chlorothalonil	Quadris OPTI	11/M5	X[T]	X[T]	
quinoxyfen	Quintec	13		X	
cyazofamid	Ranman	21	X		
cymoxanil	Curzate	27	X[T]		
propamocarb hydrochloride	Previcur	28	X[T]		
zoxamide + mancozeb	Gavel	22/M3	X[T]		
potassium phosphite	Alude, Fosphite, Rampart	33	X	X	X
dimethomorph	Forum	40	X		
mandipropamid	Micora, Revus	40	X[PE]		
dimethomorph + ametoctradin	Zampro	40/45	X		
fluopicolide	Presidio	43	X		
Bacillus subtilis strain QST 713	Cease[OB], Rhapsody[OB], Serenade[OB]	44	See label for listed diseases		
basic copper sulfate	Basic Copper, Cuprofix-Ultra, Cuproxat	M1	See label for listed diseases		
copper hydroxide	Champ, Kocide, Nu-cop	M1	See label for listed diseases		
copper oxychloride sulfate	C-O-C-S WDG	M1	X		
copper sulfate pentahydrate	Mastercop	M1	X		
cuprous oxide	Nordox	M1	X		
copper hydroxide + mancozeb (not eggplant)	Mankocide	M1/M3	X		

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
[T]= for tomato
[P]= for pepper
[E]= for eggplant

Table 9.9, continued. Fungicides registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Blight	Powdery Mildew	Wilt diseases
sulfur	Cosavet[O], Kumulus, Microthiol Disperss[O], Micro Sulf[O], Sulfur-DF, Thiolux	M2	See label for listed diseases		
mancozeb	Dithane, Manzate, Penncozeb, Roper DF Rainshield	M3	X[TP]		
ziram	Ziram	M3	X[T]		
chlorothalonil	Bravo, Chloronil, Echo, Equus, Initiate	M5	X	X[PE]	
extract of *Reynoutria sachalinensis*	Regalia[B]	P	X	X	X
Bacillus amyloliquefaciens strain D747	Double Nickel[OB]		X	X	
Bacillus pumilus strain QST 2808	Sonata[OB]		X	X	
Bacillus subtilis var. *amyloliquefaciens* strain FZB24	Taegro[B]		X[TP]	X[TP]	X[T]
hydrogen dioxide + peroxyacetic acid	Oxidate[O]		X	X	X
oils: clove, rosemary, thyme	Sporatec[B]		X	X	
potassium bicarbonate	Kaligreen[O], Milstop[O]		See label for listed diseases		
Streptomyces lydicus WYEC 108	Actinovate Ag[OB]		X	X	X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[O]= Organic
[T]= for tomato
[P]= for pepper
[E]= for eggplant

Table 9.10. Insecticides registered for **HOME** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Armyworms	Beet Leafhopper	Cutworms	Stink Bugs	Tomato Hornworm	Tomato Fruitworm	Tomato Russet Mite
carbaryl	Garden Tech Sevin	1A	3	X	X	X	X	X	X	X	
malathion	Bonide Malathion, Ortho Max Malathion	1B	5	X		X					
bifenthrin	Bonide Eight Flower and Vegetable Granules, FertiLome Broad Spectrum, Monterey Vegetable Garden Soil Insecticide, Ortho Bug-B-Gon Max	3	7	X	X	X	X				
cyfluthrin	Bayer Veg. and Garden Insect Spray	3	2	X	X		X	X	X	X	
deltamethrin	Green Light Many Purpose Dust	3	1	X	X		X	X		X	
esfenvalerate	Monterey Bug Buster II	3		X	X	X	X	X	X	X	
lambda-cyhalothrin	Bonide Caterpillar Killer, Spectracide Triazicide	3	7	X	X	X	X	X	X	X	
permethrin	Bayer Complete Insect Dust, Bonide Eight Vegetable, Fruit and Flower, Lily Miller Multi-Purpose Insect Spray	3	3	X	X	X	X	X	X	X	
pyrethrins + piperonyl butoxide	Bonide Pyrethrin Garden Insect Spray[B], Garden Tech Worry Free Insecticide and Miticide	3	3	X	X	X	X	X	X	X	
pyrethrins + canola oil (tomato only)	Monterey Take Down Garden Spray	3/		X		X					X
pyrethrins + sulfur (not eggplant)	Bayer Natria Insect, Disease and Mite Control, Bonide Tomato and Vegetable 3 in 1	3/M2	7	X	X	X					X
acetemiprid	Ortho Flower, Fruit, & Vegetable	4A	7	X	X	X		X	X	X	
spinosad	Bonide Captain Jack's Deadbug Brew[B]	5	4		X		X		X	X	
spinosad + iron phosphate	Monterey Sluggo Plus[OB]	5	4				X				
Bacillus thuringiensis	Bonide Thuricide[B], Green Light BT[B], Monterey Bt[OB]	11A	3						X	X	
capsaicin and related capsaicinoids	Bonide Hot Pepper Wax Insect Repellent			X	X	X					
oils: canola, clove, cottonseed, garlic, neem, paraffinic, peppermint, rosemary	Bayer Natria Multi-insect control[O], Bonide All Seasons Horticultural and Dormant Spray[O], Green Light Neem Concentrate[O], Monterey All Natural 3 in 1			X	X	X	X	X	X	X	X
potassium salts of fatty acids (insecticidal soap)	Bayer Natria, Bonide, Safer, Natural Guard		7	X		X					X

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[O]= Organic

Table 9.11. Fungicides registered for **HOME** use on all 3 crops (unless otherwise noted) in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Blight	Powdery Mildew	Wilt diseases
myclobutanil (tomato only)	Spectracide Immunox Multi-purpose Fungicide for Gardens	3		X	
chlorothalonil (tomato only)	Bonide Fung-onil; Monterey Fruit Tree, Vegetable & Ornamental; Ortho Max Garden Disease Control	M1	X		
copper	Monterey Liqui-cop; Lily Miller Kop-R-Spray; Bonide Copper Fungicide	M1	X		
sulfur (plus pyrethrin) (not eggplant)	Bonide Tomato and Vegetable 3 in 1; Bayer Natria Insect, Disease and Mite Control	M2	X	X	
mancozeb (tomato only)	Bonide Mancozeb with Zinc	M3	X		
oils: clove, cottenseed	Monterey all natural 3 in 1 Garden Insect Spray[B]		X	X	

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic

Fig. 9.1. Pepper varieties.

Fig. 9.2. Proper fertilization can lead to better yield and fruit quality.

Fig. 9.3. Tomato transplants are planted after frost has passed.

Fig. 9.4. Pepper spacing ensures adequate light and nutrients.

Fig. 9.5. Fruits grown on staked plants mature earlier.

Fig. 9.6. Aphid infestations early in the season can reduce yield.

Fig. 9.7. Adult beet leafhopper.

Fig. 9.8. Adult stink bug.

Fig. 9.9. Stink bug eggs.

Fig. 9.10. Stink bug nymph.

Fig. 9.11. Adult tomato hornworm.

Fig. 9.12. Tomato hornworm larva on tomato plant.

Fig. 9.13. Tomato hornworm feeding limits ability to produce fruit.

Fig. 9.14. Parasitized tomato hornworm.

Fig. 9.15. Thrip feeding damage on tomato leaves.

Fig. 9.16. Typical foliar injury caused by tomato fruitworm (shown here on soybean).

Fig. 9.17. Tomato fruitworm larva feeding on fruit.

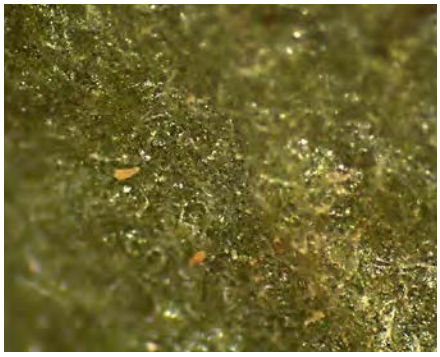


Fig. 9.18. Tomato russett mites are abundant during hot, dry weather.

Fig. 9.19. Injury from mite feeding can cause "russetting" on plants, and leaves that curl, whither, and fall.

Fig. 9.20. Tomato spotted wilt virus causes chlorotic ring spot patterns.

Fig. 9.21. Jalapeno peppers with tomato spotted wilt virus (TSWV).

Fig. 9.22. TSWV can also appear as ring spots on peppers.

Fig. 9.23. Ring spots on bell pepper.

Fig. 9.24. Foliar symptoms of tomato spotted wilt virus.

Fig. 9.25. Brown ring spots on TSWV infected immature fruit.

Fig. 9.26. Brown ring spots on TSWV infected mature fruit.

Fig. 9.27. Blotchiness on tomatoes caused by TSWV.

Fig. 9.28. Plants affected by curly top disease.

Fig. 9.29. Tomato plant with curly top disease.

Fig. 9.30. Purple veins on the underside of leaves due to curly top.

Fig. 9.31. TMV leaf with mosaic patterned lesions.

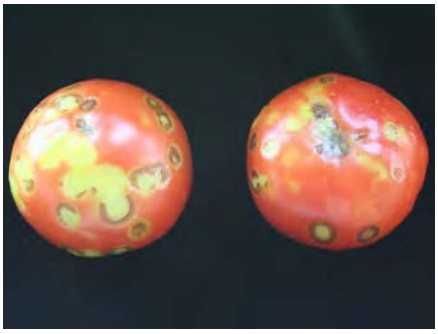


Fig. 9.32. Tomato mosaic virus can cause yellow rings to appear.

Fig. 9.33. Brown sunken lesions are also symptoms of TMV.

Fig. 9.34. TMV can cause fruit tissues to be discolored.

Fig. 9.35. Brown spots on leaves caused by early blight.

Fig. 9.36. Early blight can cause concentric rings to develop when spores are reduced.

Fig. 9.37. Early blight on fruit.

Fig. 9.38. Late blight leaf symptoms.

Fig. 9.39. Late blight appearing as a white mold on leaves.

Fig. 9.40. Late blight causes brown or olive-colored lesions on fruit.

Fig. 9.41. Bacterial speck on leaves.

Fig. 9.42. Bacterial speck on fruit.

Fig. 9.43. Bacterial canker causes vascular discoloration in stems.

Fig. 9.44. Bacterial canker causes white spots with dark centers on fruits.

Fig. 9.45. Powdery mildew causes white powdery spots on leaves.

Fig. 9.46. Powdery mildew also causes chlorotic areas on the surfaces of leaves.

Fig. 9.47. Wilt diseases cause vascular discoloration.

Fig. 9.48. Root-knot nematode can cause galls to form on roots (left-diseased, right-healthy).

CHAPTER 10 SWEET CORN PRODUCTION

Sweet corn is a warm-season crop grown for commercial production in many areas of Utah. There are several common classes of sweet corn available differing in sweetness, color (yellow, bicolor, or white), and storage characteristics. The sweetness classes include standard, sugar enhanced, shrunken, and others.

Sweet corn varieties are grouped by classes, depending on sweetness, color, and storage characteristics.

Classes of Sweet Corn

Standard Sugary

Standard sugary is the oldest and most vigorous class of sweet corn. Example varieties include 'Earlivee', 'Honey & Cream', 'Jubilee', and 'Silver Queen'. This class is often used in processing and sometimes sold fresh from heirloom and organic operations. A limitation of standard sweet corn is that the kernels contain less sugars and they convert sugars to starch within a few days after harvest so it must be consumed or processed quickly.

Sugar Enhanced

Sugar enhanced corn is also commonly known as sugary enhancer or EH sweet corn (e.g. 'Sugar Buns', 'Bodacious', 'Fantasia', 'Luscious', 'Miracle', 'Temptation'). It is primarily grown for direct retail sale or wholesale market. It offers a more tender and creamy texture than other sweet corn classes. Kernels have more sugar than the standard types so storage life is extended a few days over less sweet types.

Shrunken-2

Shrunken-2 sweet corn gets its name from the seed having a wrinkled appearance and is also referred to as shrunken, super sweet, ultra sweet, or extra sweet (e.g. 'Devotion', 'How Sweet It Is', 'Obsession', 'Vision', 'Xtra-Tender' series). Up to 90% of corn sold for fresh consumption is the shrunken-2 variety. Sugar levels in this class of corn are up to twice that of other sweet corn types. Additionally, the conversion of sugar to starch within the kernels occurs at a slower rate, so varieties can be stored for 5 to 10 days. A common complaint, especially about older varieties, is that the skin covering the kernels is tough. Kernels of newer shrunken-2 varieties are less tough. Seeds may germinate poorly in cold soils and should be planted after soil temperatures are optimal.

Synergistic and Others

Synergistic and other new varieties (e.g. 'Cameo', 'Gourmet Sweet', 'Vitality') are continually being released. They are bred using combined genetics of other sweet corn types to enhance quality. Recent reports from the Midwest indicate many newer varieties perform reasonably well and are of good quality. However, some varieties, especially some of the initial introductions, have limitations including:

- Poor germination, especially at temperatures below 60°F.
- Brittle seed that can be easily damaged with rough handling.
- Smaller seed that may not work with seeding equipment.
- Poor vigor in cold conditions.
- Poor ear tip cover on some varieties.
- Lodging (wind blowing cornstalks over).
- Low yields.

Consult local seed dealers for varieties that best fit your needs.

Isolation

Isolation is necessary to maintain kernel sweetness and color. All sweet corn varieties should be isolated from field corn by 250 feet or 14 days-difference in pollen shed (tasselling dates). Isolate shrunken-2 varieties from standard and sugar enhanced types to minimize starchy kernels. While isolation of sugar enhanced from standard types is not necessary, it does ensure full expression of the different sweetness characteristics of the variety.

To maintain kernel color, white varieties need to be isolated from yellow or bicolor corn. Yellow is the dominant color so pollen from yellow corn will cause fewer white kernels in both bicolor and white varieties. However, white pollen does not influence color formation in yellow or bicolor varieties.

Soil Requirements

Sweet corn can be grown in most Utah soil types that are suitable for growing other vegetable crops. Soil electrical conductivity (EC; measure of salinity) should be below 1.7 ds/m. Yields become detrimentally affected above this point.

Soil Preparation

Soil should be plowed deeply, free of clods and other debris, but not over-worked. Before planting, the soil surface should be smooth and even. These steps will ensure even plant emergence, proper irrigation, and consistent maturity across the entire stand.

Fertility

Profitable sweet corn production requires maintaining adequate soil nutrition to maximize ear size, encourage dark green husks, and optimize tip fill. Keep records of previous crops grown in the field and of previous nutrient applications to determine future applications. Regular soil testing will minimize costs and maximize profits by allowing for customized nutrient applications. For more information about soil testing visit the Utah State University Analytical Laboratory website at: www.usual.usu.edu.

Nitrogen

Both urea and ammonium sulfate are acceptable nitrogen (N) sources. Incorporate the fertilizer into the soil to minimize N volatilization and leaching. Sweet corn requires 125 to 150 units of N per acre per season. Several small applications will maintain a more constant amount of available N for the crop and minimize leaching. Apply and disk into the soil around 50 pounds N at the preplant stage. Another option is to band the fertilizer (apply a line of fertilizer 2 inches to the side and 2 inches below the seed furrow) when seeding using the same application rate. Do not use banding if applying more than 80 pounds of N per acre or if potassium (K) is also being applied. High N and K applications can potentially reduce emergence and damage young seedlings. Apply the remainder of the N in two side dressings when plants are in the 5th and 10th leaf stages. Nitrogen leaching is greater in sandy or sandy-loam soils so split applications are important in these soil types. (See Fig. 10.1 for symptoms of nitrogen deficiency.)

Phosphorus and Potassium

Applications of the commonly used forms of phosphorus (P) and potassium (K) using $P_2 0_5$ and K_2O sources may not be needed in Utah soils. Conduct soil testing before planting and follow test recommendations. Rates may vary from 0 to 150 units per acre depending on soil test results. If needed, band P and K at the recommended amount at planting. Phosphorus is fairly immobile in the soil, and later applications may be ineffective. (See Fig. 10.2 for symptoms of phosphorous deficiency.)

Planting

Sweet corn is a warm-weather vegetable. Germination and growth start at 55°F and the optimum temperature range is 70 to 86°F. To avoid seed rot and to maximize germination, soil temperatures at planting time should be at least 60°F. When soil temperatures at planting are below 75°F, it is recommended to use seed that has been pretreated with a fungicide to reduce loss of seed due to rots.

Seeding

When planting, space rows 28 to 32 inches apart and plant seeds 7 to 8 inches apart within rows and about

1 inch deep. Planting at this spacing and depth results in approximately 24,000 plants (10 to 15 pounds of seed) per acre. A minimum of 30-inch spacing is recommended for machine harvesting. Additionally, spacing rows every 36 inches with seeds every 7.5 to 8.5 inches in the row maximizes ear size. This results in 20,000 to 23,000 plants per acre.

Plant corn seeds about 7 to 8 inches apart.

Planting Intervals

To ensure a steady supply of sweet corn through the summer, successive plantings are recommended, especially when similar varieties are planted. There are four general methods to predict timing of sweet corn maturity:

1. Time plantings by the calendar (every 10 days when temperatures are warmer).
2. Plant subsequent planting based on when the first leaf un-furrows.
3. Use the days to maturity listed on the package as a general guide. (***Note***: If a variety is supposed to mature in 69 days, it may be ready to harvest sooner or later depending on temperatures during the growing season.)
4. Calculate growing degree units.

Using Growing Degree Units

Growing degree units (GDU), or cumulative heat units, is an accurate method to predict crop maturity. Most seed companies provide information for either the time from field planting to maturity, or the time from seedling emergence to maturity. Be sure that you understand the GDU value your vendor provides when you purchase corn seed. Additionally, some models monitor soil temperature (max/min) and use this because it reflects more of what the seed is experiencing.

For the GDU method to work, you need to know four things:

1. The GDU of the variety.
2. The average GDU during the anticipated harvest period.
3. The base (minimum) temperature for sweet corn (50°F).
4. The daily high and low temperatures during the growing season (from planting until harvest). Since you want a continuous supply of corn, you will be planting several times throughout the spring.

If you don't have weather data for your farm, try accessing the Utah Climate Center's climate database (climate.usu.edu). Growing degree units for many locations in Utah can be found on the Utah TRAPs website (climate.usu.edu/traps). Select a location and GDU (base 50) from the drop-down menus.

The formula for GDU is as follows:

GDU = [(Tmax + Tmin) / 2] – 50

GDU = Growing Degree Unit

Tmax = The daily maximum temperature (if the daily max exceeds 86˚F, use 86˚F as the maximum in the formula).

Tmin = The daily minimum temperature (if the daily minimum remains below 50˚F, use 50˚F as the minimum temperature in the formula).

50 = Sweet corn base temperature (F) for growth.

Example 1

The daily maximum temperature was 84 and the low was 56.

[(84 + 56) / 2] – 50 = 20 GDU

Example 2

The daily maximum temperature was 96°F and daily minimum was 48.

[(86+50] / 2] – 50 = 18

Note: Substitute max and min temperatures were used because the daily high exceeded 86°F and the daily low was below 50°F.

Example 3

The daily maximum temperature was 54 and the low was 34.

[(54 + 34) / 2] – 50 = 0

Note: GDU's cannot be negative because you cannot have negative growth. So if GDU is less than the base temperature 50, the corn has NO growth for that day.

Example 4

If a variety requires 1400 GDU to reach maturity and we know that this variety generally matures in Utah around the third week of July (say July 20 to 23), we can use historic weather data to estimate the daily GDU during the anticipated harvest window. If you live in Layton, UT, you plant corn on April 20, and you expect to harvest the corn for four (4) days, then you need to calculate the total GDU's during this four day period. The four day average daily max/min temperature for July 20-23 in Layton is 91°F/63°F.

GDU = [(86 + 63) / 2] – 50 = 25.

WHEN SHOULD YOU PLANT YOUR NEXT FIELD OF SWEET CORN?

1. Planted Field #1 on April 20.
2. Expect harvest from July 20-23. Average GDU is 25 per day or 100 for the four (4) days.
3. Monitor max/min temperature starting on April 21 using the GDU formula.
4. Add the GDU from planting until they equal the GDU for the harvest window (100 GDU).
5. Make planting #2 when spring conditions accumulate 100 GDU's.
6. Repeat for subsequent plantings or other varieties.

Another option to provide mature sweet corn over an extended time period is to plant several varieties with different ripening dates at the same time. For example, 'Early Sun Glow' (standard) matures in approximately 63 days, 'Honey and Pearls' (shrunken-2) matures in approximately 76 days, and 'Serendipity' (shrunken-2) matures in 82 days.

Irrigation

Sweet corn requires 18 to 28 inches of water per acre, depending on weather conditions, throughout the growing season. Soils should be maintained at 85% of available field capacity, meaning that soils should not be permanently waterlogged but also should not be allowed to dry out. Water needs are especially critical during tassel, silk, and ear formation. Drought stress during ear development will decrease yield, lower kernel quality, and negatively affect flavor. Appropriate irrigation frequency depends on soil type. Although flood irrigation is especially common, sprinkler or drip irrigation may produce more consistent ear size and a 25 to 40% reduction in water use.

A wheelmove system may be used for just one or two early irrigations in a corn field.

Plasticulture

Depending on the cost of plastic mulch, equipment availability, early market opportunities, and field installation systems, it may be economically viable to grow corn using plasticulture. Potential benefits include improved weed control, warmer soils, increased soil moisture retention, earlier first harvest, and increased yields. One study from the Iowa State University using 'Temptation' sweet corn found that clear plastic mulch shortened the first harvest date by four days. Additionally, all of the various colors of plastic mulch tested increased yield by 5 to 12% as compared to the bare ground control. Other studies have reported earlier ripening times of up to seven days.

When considering using plastics, planting is either done in furrows with clear plastic installed over the rows (low tunnel) or plastic is laid first and then the seeds are planted through the plastic. The second system requires either specialized plastic planters or planting is done by hand (Fig. 10.3).

Productivity

Yields for processing corn average between 4 and 6 tons per acre. For fresh market varieties, expect between 17,000-20,000 ears/acre (1,000 and 1,200 dozen) per acre. Higher yields, upwards of 2,000 dozen ears per acre, can be obtained with careful irrigation and nutrient management.

Harvest

Most sweet corn is ready 15 to 22 days after silking, and is hand harvested by grasping the ear and pulling downward while twisting the wrist to snap the ear off the stalk. Sweet corn may also be harvested using machines, which are becoming more common. As the kernels mature, they pass through growth stages termed pre-milk, milk, early dough, and dough. At the dough stage, sugars in the kernels' pericarp change to starch and the kernels become tough. The time to harvest is when kernels just reach the milk stage. Look for the following:

- Kernels will be nearly full-size, but still soft and tender and filled with clear to milky juice when punctured with the thumbnail.
- The tip of the ear will be filled out.
- Silks will be dried and brown beyond the end of the husk (Fig. 10.4).

Harvest when 70% of the ears in the patch are in this condition. Sweet corn may only stay in prime condition for 1 to 2 days if daytime temperatures are consistently above 86°F, so harvest timing is critical for optimal flavor and quality.

Corn harvester.

Postharvest Care

Postharvest temperature management is imperative to maintain ear quality. Ears will be 15 to 30°F cooler in the morning than at midday, so pick ears early, if possible. Chill corn as soon as possible after picking. Standard sugary (su) types lose sweetness in just a few days. In fact, half of the sugar in su kernels is lost within 24 hours when stored above 86°F. When kept near freezing, only 8% of the sugar is lost each day. Extra sweet and super sweet types remain sweet for a longer period, but cooling the harvested ears is still critical to maintain quality.

When sweet corn is shipped or stored for more than 2 to 3 days, maintain the corn at 32°F. Cooling with air is common but not as effective as other options because it often takes 24 to 48 hours for ears to become sufficiently chilled.

In larger operations, hydro-cooling (soaking or sprinkling ears in chilled water) and then top-icing is commonly used to reduce ear temperatures quickly. Temperatures can be reduced by 20°F in as little as 20 minutes if ears are immersed. When using sprinklers, one gallon of water is needed for every 4 lbs of corn.

Hydro-cooling and ice making systems are expensive, costing several thousand dollars for refrigeration units and assembly. Refrigeration systems that produce crushed ice will dissipate heat more quickly than those producing cubed ice. For shipping, add one lb of ice for every five lbs of pre-chilled corn in the shipping containers. Contact the local health department or government food safety administrator for potential restrictions, building codes, and other safety issues.

If using an air refrigeration system, immerse sweet corn ears in tanks of pre-chilled water to lower their temperature quickly. After the initial bath, store the ears in the cooler at approximately 98% humidity to maintain ear quality.

Weed Management

Weeds compete with sweet corn for sunlight, water, and nutrients. Historically, cultivation was used as the primary weed control option. This necessitated wider rows and limited production per acre. Herbicides are now the primary choice for weed management.

Many pre-and post-emergent herbicides are available

that control the problematic grassy and broadleaf (lambs-quarter and various pigweed species) weeds. Researchers from Iowa State University reported that they achieved excellent season-long weed control using a pre-treatment of s-metachlor (Dual II Magnum) + mesotrione (Callisto) + atrazine (AAtrex 4L). They reported that corn could be seeded right after using the combination of the three pre-emergent herbicides, or that the three products could be applied soon after seeding. They concluded that weed control at the pre-plant and early post-plant times is imperative, and that later rescue treatments with herbicides controlled weeds far less effectively and greatly reduced yields.

Other combinations of herbicides and cultivation can be effective if timed correctly. Some common herbicides used in sweet corn include dimethenamid-p (Outlook, Frontier-P, others), S-metolachlor (Dual), and water-based 2,4-D and 2,4-D related products. Some of the newer varieties of sweet corn, however, are sensitive to selected herbicides, so ask about these limitations when purchasing sweet corn seed. There are also several new sweet corn varieties that have built-in crop safety to in-crop applications of Roundup herbicide. Refer to the sweet corn herbicide table (Table 10.2, at the end of the chapter) for further information on application timing and efficacy against certain weeds.

Most herbicides are manufactured by many companies under different trade names. Pesticide labels often change, so make sure to always consult the label to determine if sweet corn is listed on the label, what precautions are required, and what rates and application methods are allowed. It is critical that a copy of the label is obtained and read carefully before purchasing and applying any chemical. Comparing the costs of different brands that may have the same active ingredient and percent of active ingredient is also a good idea.

Important Considerations for Herbicide Use

- Carefully read and follow all label directions and precautions.
- Use herbicides only on crops for which they are approved and recommended on the label.
- Use the recommended amount of product and apply it as stated. (Too much material may damage the crop (Fig. 10.5, 10.6) and make it unsafe for consumption.)
- Apply herbicides only at times specified on the label and observe the recommended intervals of the time of planting and the time between treatments.
- Follow re-entry intervals (REI) and pre-harvest intervals (PHI).
- Don't spray in high wind conditions.
- It is a violation of the law to use herbicides other than as directed on the label. The EPA has the authority to seize any agricultural commodity that carries a pesticide residue in excess of the established tolerance levels. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

Finally, herbicides are just one tool available for weed control and their use should supplement other good weed-management practices.

Herbicides for weed control are applied in the following ways (Table 10.2 at the end of this chapter):

•**Pre-plant incorporated:** incorporated into the soil prior to seeding or transplanting onions

•**Pre-emergence:** applied to the soil after planting but before onions or weeds emerge

•**Post-transplant:** applied to the soil after crop is transplanted either before weeds have emerged or after clean cultivation

•**Post-emergence:** applied to weeds after both weeds and onions have emerged

•**Directed post-emergence:** applied as a directed or shielded spray 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.

Insect and Mite Management

Seedcorn Maggot *(Delia platura)*

Order Diptera: Family Anthomyiidae

DESCRIPTION:

Adult: Seedcorn maggot adults (flies) are about 0.2 inches (5 mm) long with gray to brown bodies. They resemble houseflies but are about half their size and overlap their wings at rest (Fig. 10.7).

Egg: White, elongated; deposited in soils rich in organic and decaying matter and/or on seeds and seedlings.

Larva: Maggots are legless, tapered, about 0.25 inches (6 mm) long, and yellowish-white in color. Head-ends are wedge shaped with small black mouth hooks in front (Fig. 10.8).

Pupa: Oval shaped, dark brown, about the size of a grain of wheat, and found in the soil.

LIFE HISTORY:

Adult flies emerge from overwintering pupae in April and May, and begin mating within 2 to 3 days. Females lay eggs in or on soil and/or on seeds. Eggs hatch in 2 to 4 days, and larvae burrow into seeds to feed on emerging cotyledons and plant roots. After about 21 days, mature larvae pupate in the soil and remain there for approximately 7 to 14 days. A complete generation takes about 3 to 4 weeks and about 2 to 3 generations occur per year.

DAMAGE:

Maggots prefer feeding in soils rich in organic and decaying matter (such as manure). Seedcorn maggot feeding can destroy the seed germ and may cause plant tissue to rot. Larvae burrow into the seeds, leaving the plant with insufficient resources to sprout and/or survive (Fig. 10.9). Maggots also attack the underground stems and roots of sprouted corn resulting in weakened seedlings that often die. Seeds and seedlings attacked by seedcorn maggots may not emerge, causing reduced stands which are evident about a week after plant emergence.

MANAGEMENT:

Practices that speed up germination and plant emergence will reduce crop losses from maggots.

Cultural:

- *Handle seeds carefully* to avoid cracking the seed coat. A cracked seed coat provides entry points for maggots and other diseases.
- *Avoid planting in soils that are high in undecomposed organic matter.*
- *Delay planting to allow soil to warm.* Warm and moist, but not saturated, soils encourage rapid plant growth and decrease maggot infestation.
- *Place seeds at a shallow depth.* Shallow planting of seeds in well-prepared seedbeds can enhance germination and emergence.
- *Use traps with lures.* Yellow or white sticky cards with lures (decaying plant matter, yeast and molasses, enzymatic yeast hydrolyzate, blood and bone meal or fish meal) serve as a monitoring tool to assess pest infestation levels around fields and may serve as a control measure by reducing the adult populations before egg-laying occurs. Search the internet for more information.
  - AgBio seedcorn/onion maggot trap
  - ChemTica page on seedcorn maggot
- *Plant during fly-free periods* determined by monitoring (see above).
- *Don't over-water.* Seedcorn maggots like moisture.
- *Use row covers.* Row covers placed over transplants at the time of planting can reduce egg laying.
- *Sanitize fields* by removing and/or destroying plant residues.
- *Rotate crops* each season. Maggot populations are generally higher after legumes (e.g., beans and peas, etc.) have been plowed into the soil than when a grass (e.g., corn, rye, wheat) is incorporated.

Chemical:

Seed or furrow treatments with insecticides can prevent infestations, but there are no insecticides that are labeled for use once an outbreak has occurred. Areas infested with seedcorn maggots may need to be replanted if preventative practices fail.

Biological:

The majority of the seedcorn maggot's life cycle is spent protected underground, so there are few natural enemies. Naturally occurring soil fungi may attack and decrease seed-corn maggot larval populations.

Predaceous ground beetles eat seed-corn maggot eggs, larvae, and pupae. Since predatory beetles are susceptible to soil insecticides, they should be used sparingly. Predation of adult flies by spiders, ants, and birds has been reported to occur.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of Minnesota VegEdge Seedcorn Maggot
- Pacific Northwest Insect Management Handbook Seedcorn Maggot

Corn Leaf Aphid *(Rhopalosiphum maidis)*

Order Homoptera: Family Aphididae

DESCRIPTION:

Adult: Oval, wingless, 0.08 inch (2.0 mm) long; pale bluish-green body with black antennae, legs, and cornicles (pair of tubes on posterior back). Winged form: similar in size to the wingless adult but has fragile transparent wings held roof-like over the body (Fig. 10.10).

Egg: None. Females give birth to live young.

Nymph: Similar in appearance to the wingless adult, but smaller.

***Note*:** While other aphids such as the greenbug (*Schizaphis graminum*) and the bird cherry-oat aphid (*Rhopalosiphum padi*) may be present, the corn leaf aphid (CLA) is the most important aphid pest on corn in Utah. The greenbug aphid adult is pear shaped and has a light green abdomen with a darker stripe down the middle. This aphid species is primarily a pest in small grains and sorghum. The bird cherry-oat aphid adult is pear shaped and ranges in color from yellow-green to olive green or black. Their cornicles and antennae are dark and often have a rusty colored patch around the cornicles. Bird cherry-oat aphids prefer wheat, barley, oats, rye, and triticale, and are less common on corn.

LIFE HISTORY:

Corn leaf aphids (CLA) overwinter as adults in warmer and more southern locations. They fly or are carried north on wind currents in the spring, and show up in northern Utah in June and early July. Winged aphids fly in search of suitable hosts which include barley, sorghum, corn and other grasses, including weeds. Females give birth to live nymphs which typically develop into wingless adult females. Males are rare. Development of nymphs into adults requires 7 to 14 days. As the nymphs grow, tiny white, flakey cast skins are shed, which can give the appearance of white mold or ash. Winged females may develop when feeding conditions are unfavorable and the colony becomes crowded. Winged females disperse to establish new colonies while the wingless females remain in the parent colony or walk short distances to also establish new colonies. There are about nine generations per season.

DAMAGE:

CLA populations begin in corn about four weeks prior to tasseling and then will quickly decline after tassel emergence. Damage is most severe between the late-whorl and pollination stages. Aphids feed by sucking sap from young leaves in the whorl of the plant, and then move to the upper leaves and tassels. Aphid feeding on leaves causes mottling and discoloration and can make leaves turn red or yellow when feeding is severe (Fig. 10.11). Infested tassels become covered in a sticky substance excreted by the feeding aphids, known as honeydew, possibly interfering with pollination and causing poor kernel fill. Infested plants may take on a black or sooty appearance due to a fungus that feeds and thrives on the honeydew. Heavily infested tassels may wilt and turn brown. All three aphid species mentioned (CLA, greenbug, and bird cherry-oat) transmit maize dwarf mosaic virus to corn from nearby sources.

MANAGEMENT:

Cultural:

- *Plant early.* CLA tend to be a problem in the fall on late-planted corn.
- *Ensure adequate irrigation.* Drought-stressed plants are more susceptible to aphid feeding injury.
- *Use scouting/monitoring techniques.* Scout for aphids before tasseling (ideally three weeks before). Choose five locations within a field and check at least 10 plants at each location. Use a hand lens to carefully examine the ear, leaves, and stalk of plants. Carefully pull the whorl of leaves away from the stalk and unroll them, examining leaves for aphids. Estimate the number of aphids per plant excluding any that appear off-colored since these aphids may be diseased or parasitized.
- *Use reflective mulches.* Metallic and red mulches can reduce early-season aphid populations.

- *Control weeds.* Good weed control can eliminate or reduce alternate virus and food sources for aphids.

Chemical:

Aphid infestations typically can be controlled by biological and environmental factors, but if 50% or more of the plants checked have more than 100 aphids per plant, the tassels are coated in honeydew, and plants are under drought stress, chemical treatment may be necessary.

Biological:

Natural enemies of aphids include predators such as lacewings, lady beetles, and syrphid or hover flies. The parasitic wasp *Lysiphlebus testaceipes* specializes in attacking aphids. It lays an egg inside the aphid where its larva feeds on internal tissues, killing the aphid. The newly developed adult wasp cuts a hole in the aphid back and emerges. The dead brown body of the aphid is called an "aphid mummy".

***Note*:** Predators and parasites usually don't reduce aphid populations quickly enough to prevent virus infection.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Purdue Field Crops IPM *Corn Leaf Aphid*
- Iowa State University Extension Integrated Crop Management getting to know the aphids in corn

Western Corn Rootworm

(Diabrotica virgifera virgifera)

Order Coleoptera: Family Chrysomelidae

There are two species of corn rootworm in Utah: the western and northern corn rootworms. The western corn rootworm, however, is the one that will typically cause damage at an economic level for which control measures may be needed.

DESCRIPTION:

Adult: A small beetle, about 0.25 inch (6 mm) long, with yellow-green body and three black stripes on the forewings. Black stripes on the abdomen may overlap making the wings appear solid black. Females are slightly larger with an extended ovipositor (Fig. 10.12).

Egg: White, football-shaped, and less than 0.03 inch (0.8 mm) long.

Larva: Nearly colorless when newly hatched but turn white as they feed and develop. Mature larvae are a creamy white color, 0.5 inch (13 mm) long, with a brown head capsule (Fig. 10.13).

Pupa: Translucent white and are similar in appearance to the adult stage.

LIFE HISTORY:

Western corn rootworms (WCR) overwinter as eggs and begin hatching in late spring. Newly hatched larvae seek out and begin feeding on small corn roots and root hairs. As larvae mature, they feed on and tunnel in primary roots. The majority of root-feeding injury occurs in the early to mid-summer. After feeding, WCR will then pupate in the soil for 5-10 days. Adult emergence occurs from late June to mid-July. They feed on corn leaves, green silks, and pollen. After mating, females begin laying eggs around the end of July. Females prefer to lay eggs in moist areas such as near the base of corn stalks or in the soil between the rows of irrigated corn. During their lifetime, adult females can lay between 500 to 1,000 eggs. Eggs laid in late summer require a cold period, known as diapause, before hatching the following spring and attacking the following year's crop. The WCR typically has one generation per year.

DAMAGE:

Larvae are the most damaging stage because they feed on the roots of corn plants. Roots injured by WCR larvae will initially appear brown and have lesions. As the larvae continue to feed they may be found tunneling into larger roots and occasionally into the plant crown. As more roots are damaged by larval feeding, the corn plant becomes unable to absorb water and nutrients effectively, causing corn stalks to grow in a curved shaped also known as "goosenecking" (Fig. 10.14). Yield losses may occur because pollination is often compromised and the misshapen plants are difficult to harvest. Damaged corn roots are also more susceptible to root and stalk diseases. Adults feed on corn leaves, silks, and pollen, which can result in poorly filled ears. Adult feeding, however, typically doesn't result in enough damage to cause economic losses.

MANAGEMENT:

Cultural:

- *Monitor with sticky traps.* Knowing the adult population size will help to determine whether treatment is needed the following season. Using yellow sticky card traps can help determine initial and peak adult

emergence during silking and pollen shed. Adults are attracted to the bright yellow color of the cards and get stuck on the adhesive substance on the surface. Use one sticky card for every 5 acres of corn. Consider treatment the following year in continuous-corn if adults exceed 35 per trap per week.

- *Rotate corn crops.* WCR has one generation per year. Rotating corn every three years with non-related crops will minimize larval survival and root damage. If larvae hatch in a field without corn they will starve to death because they will only feed on corn roots and are not highly mobile.
- *Plant early.* Planting corn early may disrupt the synchrony of adult emergence with corn silking, and will allow plants to develop stronger roots systems.
- *Select varieties* that produce vigorous roots systems and are well adapted to the area. These varieties will be more tolerant of moderate amounts of root feeding.

Chemical:

The number of adults present during the previous growing season is the best guide for selecting the fields to be treated.

- Soil Treatments
  - Use granular insecticides at planting or cultivation. Insecticides can be applied in-furrow, banded over the row, or incorporated into the soil.
  - Liquid insecticides can also be applied at planting or at cultivation by spraying at the base of the plant.
- Seed Treatments
  - Corn seeds treated with an insecticide can help reduce light to moderate corn rootworm populations, but may not be effective under heavy pressure.

Biological:

There are few known natural predators of the western corn rootworm. Some species of predaceous ground beetles and mites feed on rootworm eggs, larvae, and pupae in the soil; however, these predators generally do not have a major impact on rootworm populations. Pathogenic nematodes that infect rootworm larvae are being investigated to find out if they can provide rootworm control.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Utah Pests Fact Sheet western corn rootworm
- Colorado State University Extension western corn rootworm

European Earwig *(Forficula auricularia)*

Order Dermaptera: Family Forficulidae

DESCRIPTION:

Adult: Elongate brown body with a red-brown head; 0.5 to 0.63 inch (12.7 to 15.9 mm) long. Adult earwigs can be easily identified by a prominent pair of "pinchers" (cerci) on the rear of the body. The cerci are used for defense, catching insects, and for the males to grasp females during mating. Male cerci are strongly curved (Fig. 10.15) while those of the female are straighter, but curve slightly towards the tip (Fig. 10.16).

Egg: Elliptical, pearly white, and 0.04 inch (1 mm diameter) long. As hatching nears, eggs darken and increase in size.

Nymphs: There are four immature or nymphal stages (instars). Nymphs are gray to light brown in color and similar in appearance to adults, but smaller.

LIFE HISTORY:

Adults overwinter in the soil as brooding pairs or above ground in aggregations. Females lay eggs in clutches of 30-50 eggs in the spring within nests in the soil; they may lay more than one clutch if resources are sufficient. Egg hatch begins around mid-May in northern Utah. The first and some second instar nymphs remain in the nest where the mother protects them from hazards and maintains the nest by removing mold. The second through fourth instars disperse from the nest in search of food. Earwigs are active during the night (nocturnal) and hide in dark, tight, and moist places during the day. Pheromones from frass (feces) and cuticular hydrocarbons (exoskeleton chemicals) attract earwigs to congregate. There are two or more generations per year, and populations tend to build to their highest densities in mid to late summer.

DAMAGE:

European earwigs are omnivores, feeding on a diverse diet including many types of plants, fungal spores, small invertebrate animals, and decaying organic matter. They also prey on soft bodied plant pests such

as aphids, scales, caterpillars, maggots and mites. The European earwig becomes a problem in corn when it feeds on the silk, preventing pollination and causing poorly developed ears that have many kernels missing on the cobs (Fig. 10.17).

MANAGEMENT:

Since European earwigs can be both beneficial (eat other pest insects) and detrimental to crops, control measures should only be applied if there is unacceptable crop damage.

Cultural:

- *Use Traps.* Trapping earwigs can be an effective way to monitor and reduce earwig numbers. Some of the various types of traps that can be used include:
  - Corrugated cardboard rolled and tied to stakes along borders or dispersed throughout the field.
  - Rolled or crumpled moistened newspaper.
  - Grooved wood placed together.
  - Tuna cans, yogurt or sour cream containers (punch holes in lids). Bait containers with smelly oils such as fish or clam oil, bacon grease, and wheat bran or wheat germ and then bury the bottom of containers in the ground.
- *Check traps twice per week.* Transfer live earwigs into a plastic container with soapy water for disposal. If using bait, replenish as needed.
- *Reduce or remove nesting and hiding places.* Earwigs seek refuge in dark areas during the day. Weeds, plant debris, and volunteer corn plants should be kept clear from fields, especially in the spring.

Chemical:

Insecticides should be applied in the late evening just before earwigs come out to feed. Target sites where earwigs congregate (sites where females brood their young), and on plants when injury appears.

Biological:

Earwigs emit a foul-smelling chemical that is distasteful to many predators; however, natural predators such as toads, song birds, chickens, ducks, and turkeys will eat earwigs. A parasitic tachinid fly will also attack the European earwig.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Utah Pests Fact Sheet European earwig
- UCDavis pest notes earwigs
- Colorado State University Extension European Earwigs

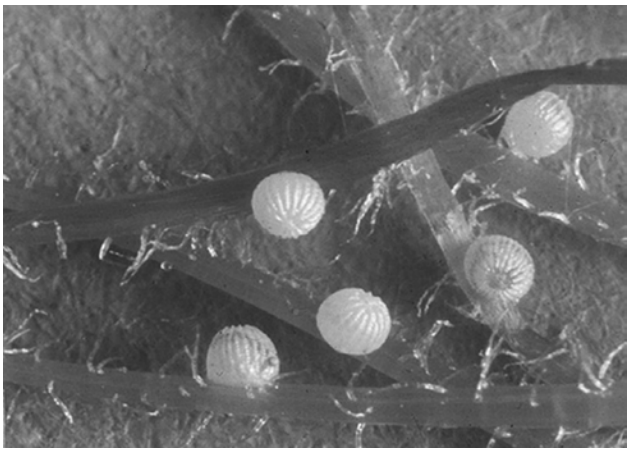
Corn Earworm *(Helicoverpa zea)*

Order Lepidoptera: Family Noctuidae

DESCRIPTION:

Adult: Tannish brown moth with a 1.5 inch (38.1 mm) wingspan. The front wings are marked with a distinct dark spot in the center and darker bands near the outer margins. The hind wings are lighter tan, with a dark band along the outer margins (Fig. 10.18). The male moths have green eyes.

Egg: Very small, one-half the size of a pinhead, creamy white and dome shaped with ridges; darkening in color as they near hatching.



Corn earworm eggs on corn silk.

Larva: Caterpillars are brown-headed with green, brown, or black bodies. Alternating dark and light stripes run lengthwise on the body (Fig. 10.19). Larva length ranges from 0.1 inch (1.5 mm) up to 1.5 inches (38.1 mm) when fully grown.

Pupa: Cylindrical, brown, about 1 inch (25 mm) long.

LIFE HISTORY:

Corn earworms (CEW) overwinter in the soil as pupae in warmer locations of the state and further south. Moths emerge in the spring and migrate or are blown into northern Utah. There are usually three flights, or generations, per year in northern Utah; four or more in southern Utah. The first flight begins in mid-June to early July in northern Utah, and is typically small. The second and third flights are much larger and occur

during August and September, respectively. Moths are active on warm, overcast evenings.

CEW moths typically lay eggs singly on fresh, green corn silks. Each female moth can lay up to 1,000 eggs, and will lay eggs on weeds and selected vegetables when corn silk is unavailable. Eggs hatch in 2 to 10 days, depending upon the temperature. The newly hatched larvae crawl down the corn silk and into the ear tip where they chew into developing kernels, but larvae will also chew on silks and leaves. CEW larvae are cannibalistic and so usually only one larva is found per ear, but several larvae per ear can occur under high population pressure.

Larvae feed within the ear for 10 to 14 days, and then will exit, drop to the ground, and burrow 2 to 5 inches into the soil to pupate. The corn earworm rests as a pupa for 10 to 25 days before emerging as an adult moth for a subsequent generation. Pupae formed in late summer may overwinter in warmer climates, otherwise they are killed by cold winter temperatures.

DAMAGE:

CEW causes direct damage by chewing into kernels near the ear tip and/or chewing on silks, decreasing pollination, and leading to poor ear-fill. Frass within the ear produced by feeding can reduce quality, storage life, and increase mold growth. Additionally, injury at the ear tip provides openings in the husk that can attract sap beetles and earwigs (Figs. 10.20, 10.21, 10.22).

Typically, corn ears never have more than one corn earworm larva inside

MANAGEMENT:

Cultural:

- *Plant resistant corn.* Corn varieties with long, tight husks are physically more difficult for earworms to enter. Some varieties with reported resistance are 'Country Gentlemen', 'Staygold', 'Golden Security', and 'Silvergent'.
- *Plant early.* Plant corn early enough so that the corn will silk before major moth activity occurs to escape injury.
- *Use clothes pins.* Place a clothes pin at the point where silk enters the ear. This helps keep worms out of ears, and should be done soon after the first silk emerges. Leave pins in place until the ear has filled and is ready for harvest.
- *Till soil in the fall.* In places where pupae overwinter, fall tillage of corn fields decreases their survival.
- *Use traps and lures* to monitor CEW populations.
  - Use the net style Heliothis trap and a pheromone lure for baiting CEW monitoring traps.
  - Place the trap by early June along the edge of the corn field; attach the trap to a stake or post so the bottom of the trap is about the same height as the corn silk. Move the trap to different areas of the field to keep it near fresh corn silk.
  - Check twice weekly until first catch, then check daily for best results.
  - Calculate the average number of moths per night, and follow threshold guidelines provided on the next page for deciding when to take treatment action.

Chemical:

Good control is dependent on applying insecticides before larvae enter the ears. Start spraying within two days of the beginning of silking, or as indicated by trap counts. About half of the eggs are laid within two days of silk emergence, and the remainder are laid within the next nine days. Reapply insecticides to keep an active residue on new silk. Silk grows about ½ inch per day. Once silks turn brown, they are no longer attractive as egg laying sites.

The following reapplication intervals are based on guidelines from the University of Maine Extension and seem to work for Utah. Reapply insecticides using the suggested intervals while silks are still actively growing. Stop sprays when silks turn brown.

Table 10.1. Reapplication intervals for corn earworm treatment while silks are actively growing.

Number of Moths Trapped Per Night	Insecticide Reapplication Intervals (Days)
Less than 0.2	None
0.2 to .6	5
0.7 to 6.5	3
More than 6.5	2

Biological:

Many predators and parasites attack corn earworm eggs, including several species of *Trichogramma*, an egg parasitoid wasp. These wasps lay their eggs inside the eggs of the earworm (they are tiny!). Most parasitized CEW eggs turn black, but there may be a lag period before they do so. *Trichogramma* occurs throughout North America, and releases of this parasite into corn fields to control corn earworm have been successful, achieving 50% to 100% parasitism; however, there has been limited success in Utah. Several insectaries offer these biological control agents for sale. Green lacewings, which are generalist predators, occur naturally and are also available to purchase. Other predators include a native soldier beetle (eats larvae in ear tips), minute pirate bugs (eats eggs and larvae on silk), and damsel bugs. A natural bacterial pathogen, *Bacillus thuringiensis* (Bt), and a nuclear polyhedrosis virus also kill earworm larvae. Insecticides made from these natural pathogens target earworm more specifically and are safer for beneficial insects.

SEARCH THE INTERNET FOR MORE INFORMATION:

- Utah Pests Fact Sheet corn earworm
- WSU insect answers corn earworm
- UFL featured creatures corn earworm

Sap Beetles

Order Coleoptera: Family Nitidulidae

Picnic Beetle (Glischrochilus quadrisignatus)

Dusky Sap Beetle (Carpophilus lugubris)

Corn Sap Beetle (Carpophilus dimidiatus)

DESCRIPTION:

Adult: The **picnic beetle** is 1/3 inch (8 mm) long and black with four prominent orange or yellow spots on the wing covers. The **dusky sap beetle** is 1/6 inch (4 mm) long, with dull black, short wings that don't fully cover the abdomen, and club shaped-antennae. The **corn sap beetle** is similar in appearance to the dusky sap beetle, about 1/8 in (3 mm) long, ranging from red-tinged black to brown-yellow (Fig. 10.23).

Egg: Slender, white, about 0.8 mm long and 0.23 mm wide.

Larva: About ¼ inch (6 mm) long, worm-like, with three pairs of short legs near its head, white to cream colored body, and a brown head and posterior (Fig. 10.24).

Pupa: White, turning cream colored and later tan before adult emergence and about 0.2 inches (4.4 mm) in length and 0.1 inches (2 mm) in width.

LIFE HISTORY:

Sap beetles overwinter as adults in protected places such as decaying vegetation, debris, or in soils. In April to early May, females begin laying eggs on or near decomposing plant material, such as corn ears, or in the soil. Later generations often lay eggs loosely under the husk in silk channels or between kernels of sweet corn. Females lay about 5 to 15 eggs per day and around 300 to 400 eggs in their lifetime. Sap beetles are attracted to sweet corn as it tassels, and often prefer to deposit eggs on earworm frass or earworm-damaged ears. The numbers of eggs laid in sweet corn increase as kernels mature and produce sugar. Larvae will feed on any sugary foods they can find and will eventually pupate in the soil. Sap beetles require 3-7 weeks, depending on temperature, to complete a generation. There are several generations per season.

DAMAGE:

Sap beetles are typically secondary pests of corn, but can act as primary pests if populations are high. These opportunistic invaders are attracted to the insect and corn volatiles associated with damage from other primary pests, such as the corn earworm, which also provide entry sites for the sap beetles. Adult sap beetles feed on corn silk and pollen, and chew on tassels. The larvae attack and feed on intact kernels and may hollow out kernels of the upper half of the ear. Super sweet corn varieties are particularly susceptible to sap beetle damage because of the poor tip coverage by corn husks and the higher concentration of sugar in the developing kernels.

MANAGEMENT:

Cultural:

- *Prevent damage* from other primary pests such the corn earworm and European earwig.
- *Use field sanitation.* Sap beetles are attracted to fermented plant juices and damaged sweet corn. Harvest sweet corn as soon as it is ripe. Eliminate food sources by removing or destroying damaged, diseased or overripe corn. Keep surrounding areas clear of plant debris since sap beetle populations will increase in compost or cull piles adjacent to corn fields.
- *Field location.* Locate fields away from favored breeding sites such as vegetable and fruit dumps. Sweet corn that mature after surrounding field corn has dropped pollen tends to have lower sap beetle infestation.
- *Select resistant varieties.* Corn with tight, long husks provide better protection from corn earworm damage and are less likely to be susceptible to sap beetle infestations. Resistant varieties include 'Country Gentleman', 'Golden security', 'Tender Joy', 'Trucker's Favorite', 'Stowell's Evergreen' and 'Victory Golden'.
- *Use bait/pheromone traps.* Traps will monitor and reduce adult sap beetle populations. A trap with both a food base attractant (fermenting fruit juice, bread dough, rotting fruits or vegetables) combined with a lure, containing an aggregation pheromone, will be highly attractive to sap beetles.
- *Disk or plow corn fields* immediately after harvest. Plowing under crop debris will reduce overwintering and breeding sites for sap beetles.

Chemical:

Control of sap beetles with insecticides is difficult because adults and larvae are protected inside the ear, and damage occurs close to harvest. If an application is necessary, products with a short pre-harvest interval should be used.

Biological:

There are few natural predators of sap beetles. The tiny parasitic wasp, *Cryptoserphus abruptus*, parasitizes sap beetle larvae. The insidious flower bug, *Orius insidiosus*, feeds on sap beetle eggs.

SEARCH THE INTERNET FOR MORE INFORMATION:

- UFL featured creatures sap beetles
- Bugwood sweet corn dusky sap beetle

Cutworms

Order Lepidoptera: Family Noctuidae

Western Bean Cutworm (Striacosta albicosta)

DESCRIPTION:

Adult: Brown bodied moths, about ¾ inches (19 mm) long with a wingspan of 1.5 inches (38 mm) and marked with creamy white stripes on the leading edge of the forewings. Adjacent to the stripes, towards the center of the body, and in the middle of the wing lengthwise, is a circular white and tan spot. A crescent shaped mark is also located between the spot and the tip of the wing. The hind wings are light colored with no distinct markings (Fig. 10.25).

Egg: Dome-shaped, and pinhead-sized, white with a thin, red ring around the top when newly hatched. Eggs change color with age from white to brown, and then finally turn a dark purple just before hatching.

Larva: Brown with faint crosshatching on their backs when newly hatched. As larvae mature they lighten to a gray-pinkish color and are about 1.5 inches (38 mm) long with three short dark stripes on the first segment behind the head (Fig. 10.26).

Pupa: Dark brown, oval shape.

LIFE HISTORY:

The western bean cutworm is a late-season pest of corn. Adult moths emerge mid-summer and mate shortly afterwards. Females lay eggs in July and August on a variety of non-cultivated and cultivated host plants including sweet corn. Females are attracted to fields with corn that is in late whorl or tasseling stage. They lay eggs in masses primarily on the upper surface of leaves. Egg masses contain an average of 50 eggs, but can range from 5 to 200 eggs per mass. Eggs mature in about a week. Newly hatched larvae feed on their egg shells before moving to other protected feeding sites. Larvae feed on corn plants for about 30 days. When feeding and development is complete, fully mature larvae drop to the ground and burrow 3 to 9 inches beneath the soil. Once in the soil, larvae construct earthen overwintering chambers with their salivary gland secretions. These larvae remain in a dormant state

throughout the winter. As temperatures rise the following spring and early summer, larvae pupate and complete development into adults. Western bean cutworms have a single generation each year.

DAMAGE:

Larvae feed on leaf tissue, fallen anthers/pollen, and silks on their way to the ear where most of the feeding is concentrated. Larvae enter the ear through the tip or by chewing through the husk and feeding directly on developing kernels. Damaged kernels are more prone to molds and mycotoxin infection. Injury from larval feeding can result in lower quality and reduced yield. Larvae from a single egg mass can invade nearby plants within a 6 to 10 ft circle, causing patchy infestations throughout the field. Several larvae may also feed on a single ear of corn, especially during high infestations.

Pale Western Cutworm *(Agrotis orthogonia)*

DESCRIPTION:

Adult: Mottled gray with yellowish and brownish spots on the forewing and a wingspan of 1.25 inches (32 mm) (Fig. 10.27).

Egg: Spherical and about 1/16 inch (1.6 mm) in diameter. Eggs appear white when first deposited, and then turn a yellow-gray color.

Larva: Young larvae are yellow-brown to slate gray with three pairs of greenish-gray stripes along the back and sides. Head is amber with black markings that resemble an 'H' on young larvae and a 'V' on mature larvae. Mature larvae are 1.25 to 1.5 inches (30-40 mm) long (Fig. 10.28).

Pupa: Yellowish initially, then dark brown, and about 5/8 inches (10 mm) long.

LIFE HISTORY:

Adult moths emerge from the soil in late summer and early fall. Following flight and mating, females begin laying eggs with peak egg laying occurring in mid-September. Females prefer to lay eggs in dry, sandy or dusty soil in the late afternoon before sunset. Eggs are laid about 0.25 to 0.5 inch (7 to 10 mm) deep in clusters of 30 to 40 eggs. Pale western cutworms overwinter as eggs and hatch between late winter and early spring. Newly hatched larvae feed on corn stems throughout the spring and are most commonly found in the driest parts of the field. After feeding is complete, larvae burrow deeper into the soil and construct pupal chambers several inches below the soil surface where they become dormant. Larvae pupate in these chambers in late July or early August and adult emergence follows shortly afterwards. One generation occurs per year. If conditions are dry during egg-laying, cutworm densities may be high.

DAMAGE:

The pale western cutworm is a subterranean cutworm that feeds on the crown just below the soil surface (0.25 to 1 inch (10.4 to 25.4 mm) deep), severing stems of small seedlings and causing them to wilt and die. In larger corn plants they enter the plant and cause the growing point to die. Larvae will typically attack consecutive plants where soil is loose and dry.

CUTWORM MANAGEMENT:

Cultural:

- *Use pheromone traps.* Simple pheromone traps made from milk jugs are an easy way to monitor adult activity. Check traps weekly and begin examining plants when multiple moths are caught frequently (see links in the "more information" section).
- *Scout fields* by examining the upper leaf surface on the upper third part of the plant for egg masses and/or small larvae. Other signs of cutworms include leaf feeding, wilted leaves, and dead tillers. Larvae will be difficult to find once they enter the ear, so the treatment window is restricted to the period surrounding egg hatch.
- *Check multiple plants and locations.* Inspect 10 consecutive plants at several locations (at least five) per field. Make sure enough locations are used to represent all areas of the field.
- *Check fields multiple times.* Infestations can be patchy, and egg laying occurs over several weeks.
- *Manage weeds.* Remove or eliminate cool-season weeds with cultivation or herbicides at least 1 to 2 weeks prior to planting. This starves cutworm larvae by reducing food sources.
- *Avoid fields with cutworm history.* Both the western bean and the pale western cutworm overwinter in the soil and can be a problem if populations were high in previous years. Pale western cutworms are more likely to be found in corn where a wheat field was grown the previous year.

- *Use tillage.* Tilling one to two weeks before planting and after harvest may help reduce cutworm infestations by exposing overwintering cutworms to weather and predators and reducing available food sources such as weeds or plant debris.
- *Use transgenic hybrids.* Transgenic hybrids with the Cry1F gene will offer adequate to near-complete control of western bean cutworm. Hybrids with the Cry1F gene include 'Herculex I', 'Herculex Xtra', and 'SmartStax'.

Chemical:

If an application is necessary, it must be properly timed for cutworm activity. Western bean cutworms spend considerable time inside the husk, while pale western cutworms are primarily in the soil. Chemical control of WBC is recommended when about 8% of the plants have egg masses or small larvae. If most eggs are hatched, treat when the crop is at least 95% tasseled and before larvae begin to feed on the silks. If most eggs have not hatched and the crop is completely tasseled, then treat to coincide with egg hatch (i.e., when most eggs have reached the purple stage, egg hatch usually occurs within 24 hours). Chemical treatment of PWC should be considered when larvae average 2 or more per foot of row.

Biological:

Predaceous ground beetle larvae, damsel bugs, ladybird beetle adults, spiders and song birds are natural predators of western bean cutworms. Additionally, western bean cutworm larvae are susceptible to a naturally occurring disease caused by the microsporidian, *Nosema* sp. Pale western cutworms are less affected by natural enemies because of their subterranean nature. Wet weather, however, can cause larvae to move to the soil surface where they can be attacked by parasitoids and predators. There are several types of wasps (Braconidae, Ichneumonidae, Chalcididae) and flies (Tachinidae and Bombyliidae) that parasitize pale western cutworms (See the References section, Capinera 2001, for a list of specific insect parasitoids). Several predators have been observed to feed on pale western cutworm larvae such as the leaf-footed bug, assassin bug, ambush bug, and ground beetles.

SEARCH THE INTERNET FOR MORE INFORMATION:

- OSU Extension Fact Sheet western bean cutworm
- CSU Extension western bean cutworm
- UC Davis IPM cutworms

Fall Armyworm *(Spodoptera frugiperda)*

Order Lepidoptera: Family Noctuidae

DESCRIPTION:

Adult: Mottled ash-gray in color with white or light gray spots near the tips of the forewings. Hind wings are iridescent silver-white with a narrow dark brown edge. Wingspan of about 1.5 inches (38 mm) (Fig. 10.29).

Egg: Dome shaped, light gray, and laid in clusters. Eggs become dark just before hatching.

Larva: Light tan or green to nearly black with three white stripes running along the back. Dark spots run along the upper top edge of each segment and spots are arranged in a square on the next-to-last segment. Black head capsules turn an orange-brown color and have a distinct light-colored inverted "Y" on the face. Mature larvae may be up to 1.5 inches long (Fig. 10.30).

Pupa: About 0.5 inch (13 mm) long, reddish brown then darkening as it matures.

LIFE HISTORY:

Fall armyworms overwinter as partly grown larvae in southern states along the gulf coast region where the ground does not freeze in the winter. After pupation, adult moths emerge and migrate northward throughout the summer and into the fall as temperature and weather conditions permit. Adults are most active during warm evenings, when females lay egg masses on corn leaves and other vegetation. They deposit most of their eggs during the first four to five days of life but can continue for up to three weeks. Larvae hatch in 2 to 10 days and then feed in the whorl or in the ears during the daylight. After 2 to 3 weeks, they drop to the soil to pupate. Adults emerge 10 to 14 days later. The fall armyworm life cycle lasts about 30 to 50 days depending on temperature, with one to three generations typically occurring in Utah.

DAMAGE:

Most of the damage in corn is caused by mature larval feeding. Young larvae begin consuming leaf tissue and create holes in leaves (Fig. 10.31). As larvae mature, they can cause extensive defoliation, often

with only the leaf ribs and stalks remaining. This intense consumption of leaf tissue makes plants look ragged and torn. Corn plants in the late whorl stage, just before tasseling, are most sensitive to injury from fall armyworm feeding. Larvae can also feed on undeveloped tassels of young plants, bore into stalks, and attack immature ears by burrowing through the husk and feeding on kernels. Stunting of plants can occur when larvae feed on the growing point, but most corn plants can recover from moderate armyworm feeding injury if the growing point is not damaged.

MANAGEMENT:

Cultural:

- *Use traps*, including blacklight and/or pheromone, to detect presence of moths.
- *Scout plants.* When moths are detected, look for armyworm eggs and larvae.
  - Search 20 plants in five locations or 10 plants in 10 locations.
  - Continue to check plants until silks begin to dry.
- *Plant early* and plant early maturing varieties. Late planted corn is more susceptible to larval feeding injury because more plants are in the seedling stage when larval feeding occurs.
- *Use transgenic varieties.* These hybrids can offer partial resistance to armyworm injury.

Chemical:

Insecticides should be applied before larvae burrow deep into the whorl or ear and are protected. Consider chemical control options when egg masses are present on 5% of the plants or when 25% of the plants show damage and live larvae are still present. Apply insecticides early or late in the day, since fall armyworm larvae are most active at these times.

Biological:

Numerous species of parasitoids and generalist predators affect fall armyworms. The most common species that parasitize fall armyworm include braconid wasps and tachinid flies. Predators include various ground beetles, spined soldier bug, the insidious flower bug, and vertebrates such as birds, skunks, and rodents. During favorable seasons, natural enemies can suppress fall armyworm populations; however, in cold, wet springs their effectiveness is limited and fall armyworm population explosions may occur.

SEARCH THE INTERNET FOR MORE INFORMATION:

- University of Florida featured creatures fall armyworm
- Purdue Field Crops IPM fall armyworm
- UKAg fall armyworm in corn
- Cooperative Extension New York State and Cornell University vegetable crops fall armyworm

Twospotted Spider Mite *(Tetranychus urticae)* and Bank's Grass Mite *(Oligonychus pratensis)*

Class Arachnida: Order Acarina: Family Tetranychidae

DESCRIPTION:

Adult: The **twospotted spider mite** (TSM) is eight-legged, variable in color including pale yellow, green, orange and brown. Females are 0.02 inch (0.4 mm) long and males are 0.01 inch (0.3 mm) long. Contents of their gut show through the body wall and appear as two pigmented spots on the topside of their bodies. The **bank's grass mite** (BGM) is similar in appearance, but has two blackish-green pigmented areas that run along its sides and extend the full length of the body.

Egg: Very small, spherical, shiny, and straw-colored.

Larva: Six-legged, colorless; resembles the body form of the nymph and adult. Slightly larger than the egg.

Nymph: Eight-legged, similar in appearance to adults, but smaller. There are two nymphal stages: proto-nymph and deuto-nymph.

LIFE HISTORY:

TSM and **BGM** have similar life cycles. The mites overwinter in non-crop and weedy areas such as grassy banks along irrigation ditches and roadsides, on weeds, in fallow fields, and in pastures. **BGM** can begin feeding on corn in the early to mid-summer and are more likely to remain on lower leaves. **TSM** populations increase in the mid- to late summer, and they will spread onto entire corn plants. Mites can complete their development (one generation) in as quickly as one week; in cooler weather it may take a month. Eggs hatch within 3 to 19 days depending on temperature. Webbing produced by spider mites helps fasten eggs to leaf surfaces and provides protective cover, making the eggs difficult to see. Unfertilized eggs develop into males and fertilized eggs develop into females.

DAMAGE:

Spider mites feed by piercing leaf cell walls with their mouthparts, sucking out the cell's contents, and causing characteristic stippling damage (small spots). Heavily infested leaves are yellow or brown and may also appear burnt on the upper surface (Fig. 10.32). Severe damage from mite feeding causes leaves to dry and fall off, the stalk to break, and kernels to shrink. Infestations start on the undersides of lower leaves and gradually move into the upper part of the plant (TSM). This pattern occurs especially along the field borders or near grassy areas within fields. Corn is most susceptible to yield damage from the tasseling stage to the soft dough stage of growth.

MANAGEMENT:

Proper mite identification is important since efficacy of miticides varies between the two species (TSM is more difficult to kill with miticides).

Cultural:

- *Ensure adequate irrigation.* Mites are more likely to develop economically damaging populations in fields that are moisture-stressed during the drier and hotter summer months. Frequent overhead irrigation or heavy rain can reduce the rate of mite population increase.
- *Use scouting* to detect mite infestations. Check the undersides of leaves for minute webbing on discolored leaves. Check plants that are on the field edges, especially in fields that are close to dusty roads, ditches and grassy areas. Shake discolored leaves over a white piece of paper and look for dark specks that move. Use a hand lens or magnifying glass to see the tiny mites.
- *Control weeds.* Keep fields, field margins, and irrigation ditches clean of weeds. Spider mites use weeds as alternate food sources.
- *Avoid creating heavy dust.* Spider mite populations may increase rapidly in areas where dust deposits are heavy on corn leaves.

Chemical:

Miticides are typically necessary when 15% to 20% of the leaf area is covered with mite colonies, leaf damage is noted, and hot, dry conditions are predicted. Treatments are expensive and difficult to apply when corn is tall due to inadequate spray coverage. The easiest way to increase spray coverage is to increase the number of gallons of spray solution applied per acre. The greatest benefit from chemical control normally occurs when miticides are applied from the pre-tassel through the soft dough stages of plant development. Similar chemicals used to treat TSM and BGM often vary considerably in their effectiveness, in part, due to differences in resistance (fewer insecticides/miticides are toxic to TSM).

When treating with insecticides/miticides remember:

- Treat before full dent stage. Corn that has reached the full dent stage is unlikely to benefit from treatment for spider mites. Additionally, applications made on plants that exceed four feet in height usually result in poor control since good coverage is difficult to obtain.
- Apply spot treatments to drought-stressed areas of the field first. Leave untreated reservoirs of corn to allow mite predators to recolonize the treated areas; the entire field may not require treatment.
- Avoid certain insecticides. Pyrethroid insecticides (e.g., Ambush, Asana, Mustang, Pounce, and Warrior), malathion, and the neonicotinoid, imidacloprid, not only can kill natural enemies, but have been shown to stimulate spider mite feeding and reproduction. Applications of these insecticides may result in flaring of spider mite populations.

***Note*:** Control with any insecticide product will not be adequate if infestations are allowed to become extreme before treatment.

Biological:

Many fields don't require chemical treatment because mite populations are held in check by natural enemies. The most important natural enemies of spider mites are a predatory mite, *Amblyseius fallacis*, minute pirate bug, *Orius insidiosus*, and *Stethorus*, a small black lady beetle known as the "spider mite destroyer." Other predatory mites, thrips, and lacewing larvae prey on spider mites and offer some natural control.

Note: Most insecticides have a detrimental effect on natural enemies of spider mites.

SEARCH THE INTERNET FOR MORE INFORMATION:

- USU Extension
- CSU Extension spider mites in corn
- iGrow SDSU Extension spider mites in corn and soybeans

Disease Management

Corn Smut

Corn smut is caused by the fungus *Ustilago maydis*.

SYMPTOMS:

The symptoms of corn smut are very characteristic. Galls (tumors) are formed on ears, tassels, stalks and leaves (Figs. 10.33-10.36). Initially galls are white to light green turning dark when gall membranes rupture and a mass of dark spores emerge.

DISEASE CYCLE:

The fungus produces dark spores that can overwinter in the soil for several years. When temperatures range from 50-95°F and moisture is present, the fungus produces a second type of spore that is blown by wind or is splashed by water. Once the spores land on young corn plants, they germinate and produce hyphae that enter the plant tissue through stomates or through wounds from de-tasseling, hail, or insect feeding. The fungus causes the plant cells at the infection site to multiply, forming a gall. Over time, the fungus invades the galls and dark powder-like spores are produced that are then blown to infect other corn plants or to overwinter in the soil. Any part of the plant can be infected at any growth stage. Infections in the ear are most common and occur when the spores land on the silk and grow down into the ear.

MANAGEMENT:

- *Use resistant varieties.* The best option is the use of varieties resistant to corn smut. The following resistant varieties have been reported from South Dakota State University: 'Ambrosia', 'Apache Gold', 'Cup', 'Aztec', 'Bellringer', 'Calumet', 'Capitan', 'Cherokee', 'Comanche Hybrid', 'Comet', 'Golden Gleam', 'Golden Security', 'Serendipity', 'Merit', 'Stylepak Hybrid', 'Sweet Sue', 'Tendersweet', and 'Wintergreen' (pubstorage.sdstate.edu/AgBio_Publications/articles/FS918.pdf).
- *Maintain recommended fertility levels.* Plants grown under high nitrogen levels or with high rates of manure are more susceptible to the disease.
- *Deep plowing* of corn stalks moves infected tissue into deeper soils, reducing disease incidence.
- *Avoid plant injury* and insect damage. Fewer injuries reduce the number of entrance points for the fungus, thus reducing disease incidence.

High Plains Virus

This virus is transmitted by the wheat curl mite (WCM), which is also a vector of wheat streak mosaic virus (WSMV) and triticum mosaic virus (TrMV).

The wheat curl mite is small (0.008 inch; 0.2 mm), wingless, cream-colored, and cigar-shaped. WCM typically colonizes the youngest tissue of wheat plants in the winter and uses several grass hosts in the summer, including corn. WCM reproduce rapidly as temperatures reach 75 to 85°F and stop at temperatures near freezing. Under ideal conditions, the WCM can complete a single generation in 8 to 10 days. Although heavy mite populations can cause the leaf margins to role or curl inward, most plant injury results from viruses that the WCM vectors.

SYMPTOMS:

Symptoms vary depending on variety and time of infection. Initial symptoms are stunting and a mosaic pattern on the leaves (Fig. 10.37). As symptoms progress, yellow stripes up to an inch wide can be observed on leaves of infected plants (Fig. 10.38) and in some cases, purple streaks are observed (Fig. 10.39). Striping can occasionally be caused by a genetic mutation and is not always a disease.

DISEASE CYCLE:

The virus infects mostly corn and wheat, but can be found in other grasses as well. The WCM does not have wings and is dispersed by wind from maturing winter wheat to either volunteer wheat, corn, or other grass hosts. As summer hosts die, wheat curl mites are carried to newly emerged winter wheat. Virus transmission occurs while mites are feeding on host plants.

DISEASE IDENTIFICATION:

To confirm the disease, infected plants need to be tested by a diagnostic lab using an antibody-based ELISA test. Samples can be submitted to the Utah Plant Pest Diagnostic Lab in Logan, UT (utahpests.usu.edu/uppdl/).

MANAGEMENT:

There is little that can be done to control the disease. Prevention is the best strategy.

- *Remove volunteer wheat and grass weeds* where both the mite and the virus can survive until corn or wheat are planted
- *Plant seed early in the season.* Mites migrate to corn as wheat dries down mid-summer.

Bacterial Stalk Rot:

Bacterial stalk rot is caused by *Erwinia carotovora* strains.

SYMPTOMS:

The disease usually starts mid-season. Plants suddenly lodge and internodes close to the soil line are discolored and water soaked (Fig. 10.40). When overhead irrigation is used, a top rot can follow quickly during times of fast vegetative growth. When infected stalks are cut, the tissue is slimy and has a foul smell to it.

DISEASE CYCLE:

E. carotovora survive in old stalks above-ground. The bacteria are spread in water and infect the plants through natural openings and wounds. The disease is most prevalent in areas with high rainfall, or where surface irrigation is used from pond or lake water. Surface water running into ponds and lakes can carry soil and the bacteria with it. During overhead irrigation, the bacteria are washed onto the stalks and leaves where they then can enter the plant through openings. Flood irrigation can carry the bacteria to the base of stalks. High temperatures between 90-95°F and high relative humidity increase the disease.

MANAGEMENT:

Good cultural control practices in areas where the disease has occurred are best.

- *Plow plant debris* like stalks deep into the ground.
- *Avoid using surface water* for irrigation (flooding or overhead).

Pest Management Tables for Commercial and Home Use

Table 10.2. Herbicides registered for **COMMERCIAL** use on **Sweet Corn** in Utah.

Brand Name (REI/PHI)	Active Ingredient	Application Relative to Crop			Application Relative to Weeds		Weeds Controlled		
		Before Planting or crop emergence	Post-emergence to defined crop stage	Post-emergence, shielded	Pre-emergence	Post-emergence	Annual Grass	Small-seeded broadleaves	Broadleaves
2, 4-D amine (48hr/-)	2, 4-D		X	X		X		X	X
Surpass/Cadence (12hr/-)	acetochlor	X			X		X	X	X
Aim (12hr/-)	carfentrazone		X	X		X		X	X
alachlor products (12hr/-)	alachlor	X			X		X	X	X
atrazine (12hr/-)	atrazine	X	X		X	X		X	X
Stinger (12hr/30d)	clorpyralid		X			X		X	X
Outlook, others (12hr/-)	dimethenamid-P	X	X		X		X	X	
Define (12hr/-)	flufencaet	X			X		X		
Starane (12hr/31d)	fluroxypyr		X	X		X		X	X
Option (12hr/45d)	foramsulfuron		X	X					
RoundUp and others (12hr/-)	glyphosate	X		X		X	X	X	X
Sandea and others (12hr/30d)	halosulfuron-methyl		X		X	X		X	X
Callisto (12hr/45d)	mesotrione	X	X		X	X		X	X
Accent (Q) (12hr/-)	nicosulfuron		X	X		X			
Gramoxone Max (12hr/24hr)	paraquat		X	X		X	X	X	X
Prowl products (12hr/-)	pendimehtalin	X	X		X		X	X	
Princep/ Simazine/others (12hr/45d)	simazine	X			X		X	X	X
Dual (II) Magnum (12hr/-)	s-metachlor	X	X	X	X		X	X	
Laudis (12hr/-)	tembotrione		X			X		X	X
Impact (12hr/45d)	topramazone		X			X		X	X

Note: The information provided is not an endorsement or recommendation for any particular product. Always read the label before applying and follow the directions. Some of these materials may be tank mixed with other herbicides.

REI = Re-entry Interval (the time required to wait before people can enter field after spraying)
PHI = Post-Harvest Interval (the time required between the last spray and harvest)

Table 10.3. Insecticides registered for **COMMERCIAL** use on **Sweet Corn** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Corn Earworm	Cutworm	Earwigs	Fall Armyworm	Sap Beetle	Seedcorn Maggot	Spider Mites
carbaryl	Carbaryl, Sevin	1A	3		X	X		X	X		
methomyl	Lannate[R], Nudrin[R]	1A	5	X	X	X		X			
chlorpyrifos	Chlorpyrifos[R], Lorsban	1B	10	See label for listed pests							
ethoprop	Mocap[R]	1B	(++)			X					
malathion	Malathion, Fyfanon	1B	5	See label for listed pests							
phorate	Thimet[R]	1B	(++)							X	X
chlorpyrifos + gamma-cyhalothrin	Bolton[R], Cobalt[R]	1B/3	10	X	X	X		X	X	X	
chlorpyrifos + lambda-cyhalothrin	Cobalt Advanced[R]	1B/3	10	X	X	X			X	X	
chlorpyrifos + zeta-cypermethrin	Stallion[R]	1B/3	10	X	X	X		X	X		
endosulfan	Thionex	2A	(+)	X	X						
alpha-cypermethrin	Fastac[R]	3	3	X	X	X		X	X		
beta-cyfluthrin	Baythroid[R]	3	7		X	X		X		X	
bifenthrin	Brigade[R], Capture[R]	3	7	See label for listed pests							
bifenthrin + indole-3-butyric acid	Empower	3	7			X		X		X	
bifenthrin + zeta-cypermethrin	Hero[R], Steed[R]	3	3	See label for listed pests							
cyfluthrin	Tombstone[R]	3	2		X	X		X		X	
deltamethrin	Delta Gold[R]	3	1	X	X	X		X			
esfenvalerate	Asana[R], S-fenvalostar[R]	3	3-5	X	X	X		X	X		
gamma-cyhalothrin	Declare[R], Proaxis[R]	3	7	X	X	X		X	X	X	X
lambda-cyhalothrin	Warrior[R]	3	4-7	X	X	X		X	X	X	X
permethrin	Ambush[R], Arctic[R], Permethrin[R], Pounce[R]	3	3	See label for listed pests							
piperonyl butoxide + pyrethrins	Evergreen	3	7	X	X		X	X			
pyrethrins	Pyganic[OB]	3	1	X	X		X	X		X	X
zeta-cypermethrin	Mustang[R]	3	3-5	X	X	X		X	X		
permethrin + carboxin	Kernel	3/7	ST							X	
lambda-cyhalothrin + chlorantraniliprole	Besiege[R]	3/28	7	X	X	X		X	X		X
pyrethrins + azadirachtin	Azera[OB]	3/UN	5-7	X	X	X	X	X			X
acetamiprid	Assail	4A	7	X					X		
imidacloprid	Axcess, Dyna-shield, Gaucho, Nitro, Senator	4A	ST	X						X	
thiamethoxam	Cruiser	4A	ST	X		X				X	

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment

Table 10.3. continued. **Insecticides** registered for **COMMERCIAL** use on **Sweet Corn** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Corn Earworm	Cutworm	Earwigs	Fall Armyworm	Sap Beetle	Seedcorn Maggot	Spider Mites
spinetoram	Radiant	5	2		X	X		X			
spinosad	Blackhawk, Entrust[O], Success	5	5-7		X	X		X			
hexythiazox	Onager	10A	(+)								X
etoxazole	Zeal	10B	14								X
Bacillus thuringiensis subspecies aizawai strain ABTS-1857	Xentari[B]	11A	3					X			
Bacillus thuringiensis subspecies kurstaki (strains ABTS-351 and HD1	Biobit[B], Dipel[OB]	11A	3	See label for listed pests							
propargite	Comite[R]	12C	(++)								X
novaluron	Rimon	15	7		X			X	X		
methoxyfenozide	Intrepid	18	5			X					
indoxacarb	Avaunt	22A	3		X			X			
spiromesifen	Oberon	23	14								X
chlorantraniliprole	Coragen	28	1		X	X		X			
flubendiamide	Belt	28	3		X	X		X			
sulfur	Cosavet[O], Golden[O], Microthiol Disperss[O]	M2 (fungicide)	7								X
azadirachtin	Aza-Direct[OB], Azatin[OB], Molt[OB]	UN	5-7	See label for listed pests							
Chromobacterium subtsugae strain PRAA4-1t and spent fermentation media	Grandevo[OB]	---		X	X	X		X			X
kaolin	Surround[O]	---	5					X			
oils: mineral, petrolium, peppermint, rosemary	Biocover, Ecotec[OB], Omni, Purespray[OB], Saf-T-Side, Superior, Suffoil-X[O], Ultra[B]	---	1	See label for listed pests							

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[R]= Restricted Use
[O]= Organic
(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment

Table 10.4. Insecticides registered for **HOME** use on **Sweet Corn** in Utah, organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Residual (days)	Aphids	Corn Earworm	Cutworm	Earwigs	Fall Armyworm	Sap Beetle	Seedcorn Maggot	Spider Mites
carbaryl	Sevin	1A	3		X	X		X			
bifenthrin	Ortho Bug-B-Gon Max Lawn and Garden Insect Killer	3	7	X	X	X		X			
cyfluthrin	Bayer Vegetable and Garden Insect Spray	3	2		X	X		X			
deltamethrin	Green Light Many Purpose Dust	3	1	X	X	X		X			
lambda-cyhalothrin	Spectracide Triazicide	3	7	X	X	X		X	X		X
permethrin	Bonide Complete Insect Dust For Gardens	3	3	X	X	X		X			
pyrethrins + piperonyl butoxide	Worry-free Insecticide and Miticide[B]	3	3		X	X		X	X		
pyrethrins + sulfur	Bayer Natria Insect, Disease, and Mite Control[B]	3/M2	7	X			X				X
spinosad	Monterey Sluggo Plus[OB]	5	5-7			X	X				
insecticidal soap	Safer, Natural Guard, Bayer Natria	---		See label for listed pests							
oils: canola, neem	Natria Multi-insect control[OB], Green Light Neem Concentrate[OB]	---		See label for listed pests							

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples. Always check the label for registered uses, application and safety information, and protection and pre-harvest intervals.

[B]= Biopesticide
[O]= Organic

Fig 10.1. Nitrogen deficiency.

Fig 10.2. Phosphorus deficiency.

Fig 10.3. Plasticulture results in improved weed control and greater water retention.

Fig 10.4. Harvest corn after the silks have dried and browned.

Fig 10.5. Herbicide damage on corn.

Fig 10.6. Herbicide damage on corn.

Fig 10.7. Adult seedcorn maggot.

Fig 10.8. Seedcorn maggot larvae may feed on underground stems.

Fig 10.9. Seedcorn maggot damage.

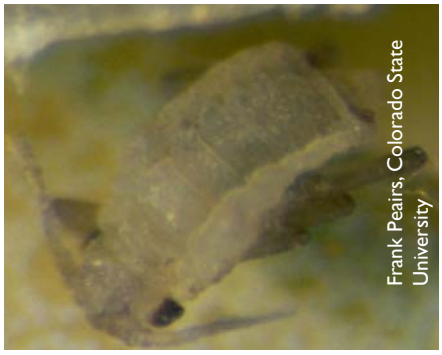


Fig 10.10. Corn leaf aphid adult.

Fig 10.11. Corn leaf aphid feeding causes leaves to turn red or yellow.

Fig 10.12. Western corn rootworm adult.

Fig 10.13. Western corn rootworm larvae are creamy white with a brown head capsule.

Fig 10.14. "Gooseneck" symptom caused by corn rootworm.

Fig. 10.15. Earwig male.

Fig. 10.16. Earwig female.

Fig 10.17. When earwigs feed on silks, preventing pollination.

Fig 10.18. Corn earworm moths are about 1.5 inches in size.

Fig 10.19. Corn earworm larva.

Fig 10.20. Corn earworm feeding.

Fig 10.21. Corn earworm damage.

Fig 10.22. Corn earworm feeding damage.

Fig 10.23. Sap beetles are tiny beetles that feed on over-ripe corn and other vegetables.

Fig 10.24. Dusky sap beetle larva.

Fig 10.25. Western bean cutworm adult stuck on sticky card from Delta trap.

Fig 10.26. Full-grown cutworm larva.

Fig 10.27. Pale western cutworm moth adult.

Fig 10.28. Mature pale western cutworm larva.

Fig 10.29. Fall armyworm adult.

Fig 10.30. Fall armyworm larva.

Fig 10.31. Feeding by young armyworms cause holes in leaves

Fig 10.32. Mite damage on corn resembles a burnt appearance.

Fig 10.33. Smut on corn ear (top), as compared to a healthy ear.

Fig 10.34. Tassel infected with corn smut.

Fig 10.35. Stalk infected with corn smut.

Fig 10.36. Leaf infected with corn smut.

Fig 10.37. Stunted corn plant infected with high plains virus.

Fig 10.38. Yellow stripes on leaves of corn infected with high plains virus.

Fig 10.39. Purple discoloration of high plains virus on leaves.

Fig 10.40. Corn plant infected with bacterial stalk rot.

CHAPTER 11 PESTICIDE INFORMATION

Pesticide Regulation, Safety, and Storage

Emergency Information

The poison control hotline for every state in the U.S. is

(800) 222-1222.

Depending on where you are calling from, the poison control center for that state will respond. In Utah, it is the Utah Poison Control Hotline in Salt Lake City. The hotline is staffed 24/7 to provide treatment recommendations and referral to an emergency medical facility.

Restricted Use Pesticides and Obtaining a Pesticide Applicator License

The Environmental Protection Agency classifies certain pesticides, or uses of pesticides as restricted if they could cause harm to humans (pesticide handlers or other persons) or to the environment unless they is applied by certified applicators who have the knowledge to use these pesticides safely. These are called Restricted Use Pesticides, and they are available for purchase and use only by certified pesticide applicators or persons under their direct supervision.

All restricted use pesticides included in the pesticide tables in this guide are identified by a small R (^{R}).

The EPA defines two categories of pesticide applicators: private and commercial. A private applicator is a person who uses (or supervises the use of) restricted use pesticides on agricultural lands owned or rented by that individual or his/her employer. The private applicator may not apply restricted use pesticides on another person's property if he/she is to receive monetary compensation. A commercial applicator is defined as any person who uses or supervises the use of any pesticides for monetary compensation. Both categories require an applicator's license, however, the testing and recertification differ among the two.

Applicants can pick up study materials at the Utah Department of Agriculture and Food in Salt Lake City or at any UDAF District Field Office. Make an appointment to take the exam, and allow two hours.

- Private applicators' exams (general and agriculture) are open-book and the fee is $20. Upon passing, your license will last 3 years. To recertify, you can re-take the exams or obtain 9 total CEU units.
- Commercial applicators' exams cost $65, and last three years license. Business owners must also obtain a Commercial Pesticide Business license, or else get a Non-Commercial license if this does not apply. The applicant must have 70% to pass. To recertify, you can re-take the exams or obtain 24 total CEU units.

Utah Department of Agriculture and Food
Division of Plant Industry
350 North Redwood Road
Salt Lake City, UT 84114
801-538-7185
www.ag.utah.gov/divisions/plant/pesticide/applicators

Pesticide Record-Keeping

Federal laws requires that private and commercial applicators maintain pesticide records for all applications of restricted use products for at least two years. The laws are enforced through the state departments of agriculture. Applicators can develop their own format for data keeping. Spray dates must be recorded within 14 days after the application is made, and must include:

1. Name and address of property owner
2. Location of treatment site, if different from above, crop treated, and size of area
3. Target pest
4. Exact date of application
5. Brand name and EPA registration number of pesticide used
6. Total amount of product applied
7. Name and license number of the applicator

Because Worker Protection Standards require worker notification of all pesticide applications, it is recommended that comparable records be kept of all pesticide applications. This will enable you to complete a listing of pesticides used at the time of harvest. Packing sheds and processors are

increasingly requiring pesticide usage lists.

EPA Worker Protection Standard (WPS)

EPA's Worker Protection Standard (WPS) for agricultural pesticides is a regulation aimed at reducing the risk of pesticide poisonings and injuries among agricultural workers and pesticide handlers. The WPS offers protections to approximately 2.5 million agricultural workers (people involved in the production of agricultural plants) and pesticide handlers (people who mix, load, or apply pesticides) that work at over 600,000 agricultural establishments. The WPS contains requirements for pesticide safety training, notification of pesticide applications, use of personal protective equipment, restricted-entry intervals after pesticide application, decontamination supplies, and emergency medical assistance.

Avoiding Drift, Runoff, and Spills

Pesticides that enter the environment can cause injury to humans, animals, and non-target plants. Whenever sprays are necessary, only apply when weather conditions are appropriate, application equipment is properly calibrated, and pesticide formulation, droplet size, and adjuvants are used to minimize drift and runoff.

Utah's Groundwater and Pesticide Program

Groundwater is essential to the welfare and vitality of the people and agricultural producers of Utah. Approximately half of the groundwater withdrawn from wells in Utah is used for agriculture. Slightly less than half of the population of Utah, depends on groundwater as a source of drinking water.

In 1997, The Utah Department of Agriculture and Food received approval from the EPA for its Groundwater and Pesticide State Management Plan. The plan outlines plans towards protecting groundwater from pesticide contamination and response to a detection of a pesticide or pesticides in groundwater.

If a pesticide detection in groundwater is confirmed, then a groundwater monitoring plan will be implemented in the area to determine the extent and, if possible, the source of pesticide contamination. This will require the involvement of the Pesticide Committee, a group of agricultural representatives and government scientists appointed by the Utah Department of Agriculture and Food.

The UDAF will work with the landowner to prevent further ground water contamination. A number of different farming practices, called Best Management Practices (BMPs), and simple devices can significantly reduce the possibility of pesticides entering the ground water system. BMPs will be required by the EPA as a condition of future use of the pesticides.

The EPA has identified the five broad-spectrum herbicides due to their high potential to leach into groundwater and to be a possible detriment to public health, safety, and the environment. The pesticides are: alachlor, atrazine, cyanazine, metolachlor, and simazine. Each has been detected in groundwater in several states, with some detections exceeding drinking water standards.

Pesticide Storage and Disposal

In general, pesticides should always be stored in a safe location. The storage facility should be kept locked so that children and other unauthorized people cannot enter and be exposed to pesticide hazards. All pesticides should be kept in their original containers, closed tightly, and with their original labels. If the label has come off or is coming off, paste or tape it back on. All pesticides should be protected from excessive heat, and liquid pesticides should be stored in an area protected from freezing.

You are encouraged to review your annual pesticide needs and stocks on hand well in advance of the growing season to prepare for disposal of unused product. To minimize carryover, base pesticide purchases on the amount projected for use within any given season. Empty containers should be triple-rinsed and drained; they often can then be disposed of through regular trash collection, but be sure to check the label and local regulations. Never dispose of pesticides or containers by dumping them into the sewer, sink, or toilet. Municipal water treatment practices remove little of the pesticides, and such careless disposal can contaminate waterways and is subject to penalties. The best means to dispose of such pesticides is to use them up according to their labeled instructions. The UDAF occasionally holds pesticide disposal drop-offs with no questions asked.

Pesticide Use

Use of Adjuvants

Spray adjuvants are materials added to pesticides in order to enhance their effectiveness. Many insecticides and some fungicides are formulated by the manufacturers with their own adjuvants. Because of the breadth of conditions vegetable growers encounter in Utah, additional adjuvants may further enhance the effectiveness of the product. However, selection must be done with care, considering all the factors that may affect spray performance. Use of the wrong adjuvant for the conditions can decrease product effectiveness. Many pesticides will state the type of adjuvant that can be used.

There are many types of adjuvants, including surfactants (ionic or nonionic wetting agents/ spreaders that improve wetting of foliage), stickers, and emulsifiers, and agents that buffer, defoam, control drift, penetrate soil, filter UV, and more. Each type of adjuvant differs in the way it interacts with spray chemicals and water quality, and weather conditions further affect their potential use. Thus, no one adjuvant can or should be used under all conditions.

Remember that amount and type of the adjuvant needed will vary with the hardness and pH of the water. Use just enough spreader-sticker to break the surface tension and spread the spray uniformly over the leafy surfaces; excessive amounts of surfactants will increase spray runoff. Do not use spreader-stickers with growth regulators (unless specifically called for on the label).

Adjusting for Water PH

The pH of water used to prepare spray solutions is very important. Water in many locations in Utah is alkaline, ranging in pH from 7.4 to 8.5. The use of alkaline water for spray solution preparation can rapidly decompose many insecticides and decrease their activity. The following procedure is strongly recommended:

1. Check the pH of your water supply.
2. Read labels to determine whether water pH is important for that material.
3. If necessary, adjust water pH to the needed level before adding any chemical or pesticide that is sensitive to pH; pH adjusters include Buffercide, Buffer-X, Unifilm-B, and LI 700 Acidiphactant.
4. Apply spray solutions as soon as possible after mixing in the spray tank. Especially avoid leaving mixed spray solutions in the spray tank overnight.

Preparation of Small Spray Quantities

Label directions for mixing and applying pesticides come in two general scenarios: rate per volume (usually 100 gallons of water) or rate per area, (usually acre or 1000 sq. ft.) Mixing directions for small quantities of pesticide vary with the scenario.

If your pesticide mixing directions state an amount of material per 100 gallons, you should adjust the amount of pesticide to the volume of water you mix. Table 11.1 gives mixing rates for label instructions. If your label instructions state a *final spray concentration*, you do not have to calibrate the sprayer, but you must read the label to know how much spray material to apply.

If the pesticide mixing instructions state an application rate in an amount per area (usually acre, but sometimes 1000 sq. ft.), your sprayer must be calibrated.

Densities of solid pesticides vary with the formulation and the amount of shaking or settling within the package during shipping and in storage. An electronic scale should be used to ensure the correct weight of the dry product is used. These scales are readily available on-line and reasonably priced. Many of these scales measure down to 0.1 gram. The use of an electronic scale is essential for the solid form pesticides (e.g., wettable powders, dry flowables, etc.).

Do not use an ordinary teaspoon for measuring liquids as the common teaspoon varies from 4 to 10 ml. Instead, use a graduated medicine spoon. When measuring out small amounts you will need to use a syringe, which are available from your physician, veterinary supply, farm supply, or pharmacy. Graduated spoons and syringes used for a pesticide must not be used for anything other than that pesticide.

Table 11.1. Conversion values for preparation of 1, 3, and 5 gallons of spray from the rate per 100 gallons.[1]

Material	Amount per: 100 gal	5 gal	3 gal	1 gal
Dry: Wettable Powders, & Dry Flowables	4 lbs (1,814.3 grams)	90.7 g or 3.19 oz	54.4 g or 1.92 oz	18.1 g or 0.63 oz
	2 lb (907.2 g)	45.4 g or 1.659 oz	27.2 g or 0.95 oz	9.1 g or 0.32 oz
	1 lb (453.6 g)	22.7 g or 0.79 oz	13.6 g or 0.48 oz	4.5 g or 0.16 oz
	8 oz. (226.8 g)	11.3 g or 0.39 oz	6.8 g or 0.24 oz	2.3 g or 0.08 oz
	4 oz. (113.4 g)	5.7 g or 0.2 oz	3.4 g or 0.11 oz	1.1 g or 0.04 oz
	2 oz. (66.7 g)	2.8 g or 0.06 oz	1.7 g or 0.05 oz	0.6 g or 0.02 oz
Liquids: Liquid or Emulsifiable Concentrates, & Liquid Flowables	1 gallon (3,840 ml)	192 ml, or 12 tbs + 2 tsp + 2.0 ml	115 ml, or 7 tbs + 2 tsp	38.4 ml, or 2 tbs +1 tsp + 0.9 ml
	2 qt (1,920 ml)	96 ml, or 6 tbs + 1 tsp + 1.4 ml	57.5 ml, or 3 Tbs + 2 ½ tsp	19.2 ml, or 1 tbs+¾ tsp+0.45 ml
	1 qt (960 ml)	48 ml, or 3 tbs + ½ tsp + 0.5 ml	28.8 ml, or 1 tbs+2 ¾ tsp+0.5 ml	9.6 ml, or ¾ tsp + 1.05 ml
	1 pint (480 ml)	24 ml, or 1 tbs+1 ¾ tsp+0.25 ml	14.4 ml, or 2 ¾ tsp + 0.65 ml	4.8 ml, or ¾ tsp + 1.05 ml
	1 cup (8 fl oz=16 tbs=240 ml)	12 ml, or 2 ½ tsp	7.2 ml	2.4 ml
	4 fluid oz (120 ml) or 8 tbs	6 ml, or 1 tsp + 1.0 ml	3.6 ml	1.2 ml
	2 fluid oz (60 ml) or 4 tbs	3 ml, or ½ tsp + 0.5 ml	1.8 ml	0.6 ml
	1 fluid ounce (30 ml) or 2 tbs	1.5 ml	0.9 ml	0.3 ml

[1] The measurements in tablespoons and teaspoons are approximate. The use of an electronic scale and syringe will be much more accurate.

Understanding the Pesticide Label

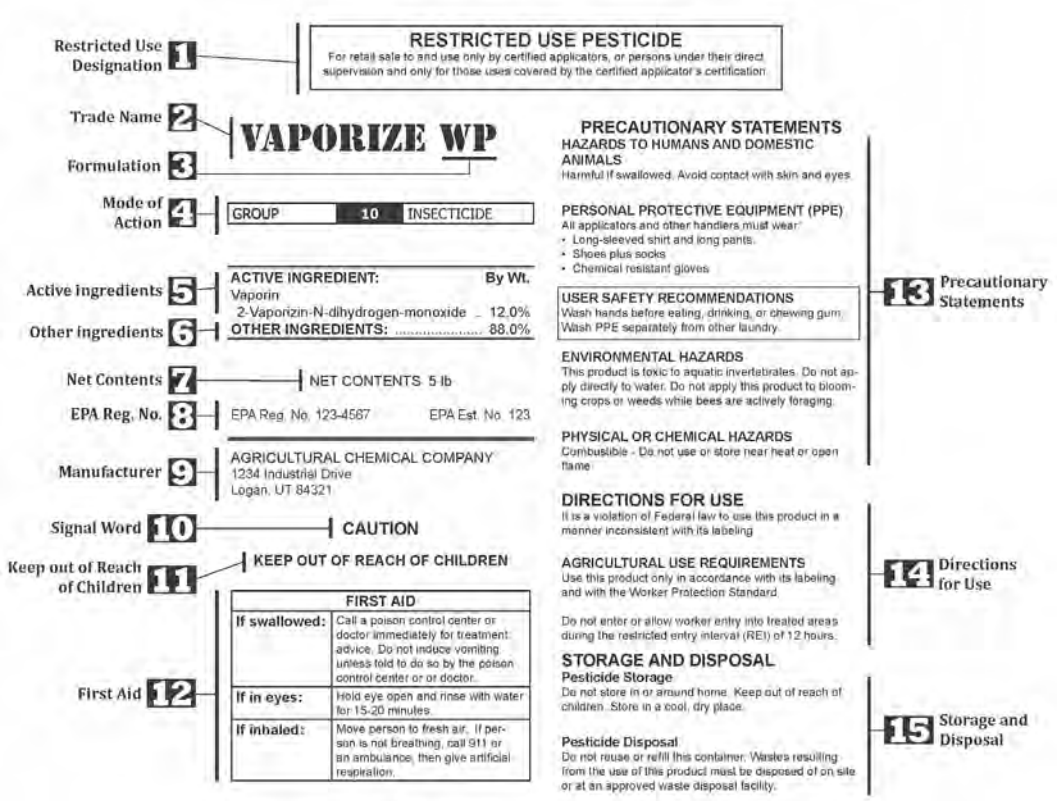
As Extension personnel, we are constantly advising to "read the pesticide label" before making any applications. Understanding the material you are using, how it is applied, and in what rate, is important for the safety of yourself, others, the host plant, and the environment. Also, proper application is required by law.

The information on the pesticide label represents the research, development and registration procedures that a pesticide must undergo before reaching the market, frequently at a cost of millions of dollars to the manufacturer. The U.S. Environmental Protection Agency (EPA) requires a manufacturer to submit data from nearly 150 tests prior to that product's approval for use. The pesticide use information obtained in this process is referred to as the label or labeling, two similar words but with different meanings.

Familiarity with the pesticide label is crucial to selecting the most appropriate pesticide products for your use and therefore receiving maximum benefit from their use. Information contained on most labels can be divided into four major categories: safety, environmental, product and use information.

Product Information

1 ***Product classification:*** When a pesticide is classified as restricted, the label will state "Restricted Use Pesticide" at the top of the front panel. Below this heading may be a reason for the restriction. To purchase and apply restricted-use pesticides, you must be certified and licensed through the Utah Department of Agriculture.



2 ***Trade Name/Brand Name:*** This is the name of the product that the manufacturer has created. Examples include "PyGanic," "Battalion," "Oberon," etc.

3 ***Formulation***

- **emulsifiable concentrate (EC):** an oil-based liquid solution plus an emulsifier that, when mixed with water, forms a milky solution; requires moderate agitation; easy to handle and apply
- **flowable (or liquid) (F or L):** the active ingredient has been imbedded in an inert solid and ground to a fine powder; requires moderate agitation; easy to handle and apply
- **solution (S):** the active ingredient mixes readily with liquid and does not separate
- **wettable powder (WP):** dust-like formulation that does not dissolve in water and must be constantly agitated to remain in suspension
- **soluble powder (SP):** a powder formulation that readily forms a suspension in water; a rare formulation because few pesticide active ingredients are soluble in water
- **water dispersible granules (or dry flowables) (WDG or DF):** small granules that, when mixed with water, disperse to fine particles; constant agitation required
- **water soluble packets (WSP):** a wettable or soluble powder that has been pre-measured into a plastic bag that dissolves in the tank water

4 ***Mode of action:*** This information is sometimes included on a label, and provides the classification group number.

5 ***Active Ingredient:*** The active ingredient, or A.I., is the material that is working to kill the target pest. On a label, the percentage of the A.I. is provided. The A.I. is usually listed as an EPA-approved common name of the chemical. For example, the chemical name for imidacloprid is 1-((6-Chloro-3-pyridinyl) methyl)-N-nitro-2-imidazolidinimine.

6 ***Other/Inert Ingredients:*** These ingredients do not work to control the target pest, but are sometimes added to the product to improve effectiveness (as a dissolving agent, surfactant, etc.).

7 ***Net contents***

8 ***EPA registration number:*** this may or may not be on the first panel

9 ***Manufacturer's address:*** this may or may not be on the first panel.

Safety and Environmental Information

10 ***Signal Word:*** Each pesticide label has a "signal word".

- **"Danger-Poison":** accompanied by a red skull and crossbones, and means that the product can be fatal or illness can occur if swallowed, absorbed, or inhaled. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, or using tobacco.
- **"Danger":** corrosive and can cause irreversible eye damage or skin injury
- **"Warning":** moderately toxic, and can cause moderate eye or skin irritation. Wash thoroughly with soap and water after handling.
- **"Caution":** mildly toxic, but can cause slight eye or skin irritation.

11 ***Keep Out of Reach of Children Warning:*** The front panel of every pesticide label must bear the statement.

12 ***First Aid:*** *(May or may not be on front panel)* It is in this section that proper antidotes and treatment are recommended for medical personnel treating a victim. For this reason, always take the pesticide label with you if you need to visit an emergency medical facility. Products labeled DANGER also bear an 800 telephone number that physicians may call for further treatment advice.

13 ***Precautionary Statements:***

- **Hazards to Humans and Domestic Animals:** This part of the label indicates specific hazards, routes of exposure, and precautions to be taken to avoid human and animal injury, based on the signal word. Protection for mouth, skin, eyes, or lungs you must are provided and what specific action you need to take to avoid acute effects from exposure to the pesticide.
- **Personal protective equipment:** This area provides specific instructions concerning the type of clothing that must be worn during the handling and mixing processes. The personal protective equipment listed is the minimum protection that should be worn while handling the pesticide. In some cases, reduced personal protective equipment is allowed when you will be applying the pesticide in safer situations, such as enclosed cabs.
- **User safety recommendations:** Includes information on proper washing after handling the pesticide.
- **Environmental hazards:** An explanation of the nature of potential hazards and the precautions needed to prevent injury or damage to nontarget organisms or to the environment, especially preventing groundwater contamination.
- **Physical or chemical hazards:** Explains hazards for fire, or other.

Use Information

14 ***Directions for Use:*** This section usually makes up the bulk of a pesticide label and always begins with the wording: "It is a violation of federal law to use this product in any manner inconsistent with its labeling." Products intended for use in agriculture will have an Agricultural Use Requirement box included in this section. It will state that the Worker Protection Standard applies to the product.

Directions for use include:

- the crops to which the product may be applied
- the pests that the product targets
- amount to use
- method of application
- timing of application
- pre-harvest interval
- re-entry period
- other limitations

15 ***Storage and Disposal:*** Storage information such as temperature and light requirements, are provided to prevent the breakdown of the material. Most liquid or flowable formulations have minimum storage temperature requirements. This section also explains how to deal with the unused portion of the product and the container.

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