Utah Vegetable Production and Pest Management Guide 2014

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2014 UTAH VEGETABLE PRODUCTION AND PEST MANAGEMENT GUIDE

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CHAPTER 1 VEGETABLE PRODUCTION RECOMMENDATIONS

Variety 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 handled roughly. When loading or unloading these

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.

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

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.

mixes which may hold excessive water and have poor 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.

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

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.

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

Plastic mulches help regulate soil temperatures.

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.

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.

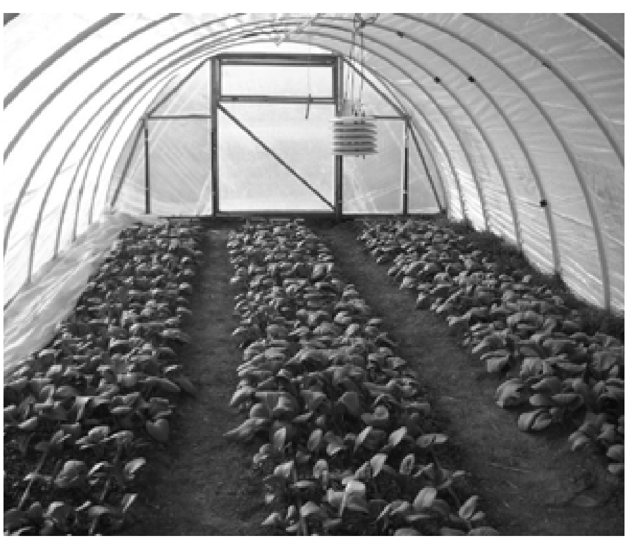
row covers mature earlier and yield more than those grown outside on bare ground. Several different companies make equipment that lay plastic mulch and row covers in one operation. Plastic mulches, fabric, and plastic row covers can be costly, and prices change rapidly because they are manufactured from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

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

diseases (powdery mildew, bacterial diseases, and 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.

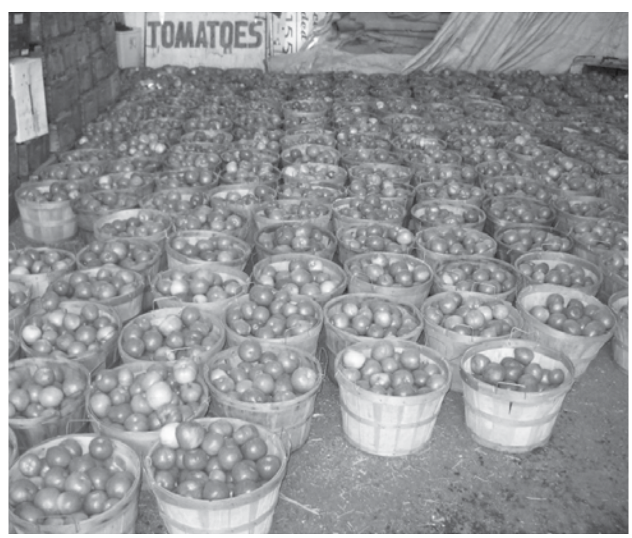
For most plants, pollination must take place on the day the flowers open. For many crops, pollen viability, stigmatic receptivity, and attractiveness to bees last only that day. Bee activity is determined by weather and conditions within the hive. Honeybee activity declines at temperatures below 55°F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

Soil
Nutrient
Water

CHAPTER 2 SOIL, NUTRIENT, AND 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 factors must be considered when estimating ET. Most

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.

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

IPM

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 .

IPM

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

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

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.

Photos


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 EGGPLANT, PEPPER, AND TOMATO PRODUCTION

Varietal Options

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. 4.1). 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 4.1- 4.3.

Table 4.1. **Eggplant** Variety Selection

Fruit Types	Varieties
Eggplants	Cappi, Epic, Megal, Millionaire, Nadia, White Star
Heirloom	Black Beauty, Long Purple, Rosa Bianca

Table 4.2. **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 4.3 **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 4.2). 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. 4.2). 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. 4.4). 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 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.

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

Eggplant
Pepper
Tomato

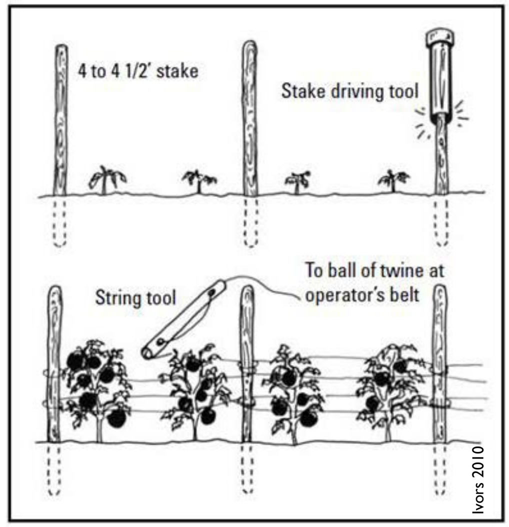
contact with the soil beneath. New plastic films called IRT (infrared-transmitting) provide more soil warming with similar weed control, but are more expensive. Red plastic mulch does not raise soil temperature as much as black plastic, but has been reported to improve yield specifically for tomato up 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 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.

Spun-bonded row covers (left) and perforated plastic row covers (right).

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. 4.3). It involves driving 4 foot long wooden stakes 18 inches deep between every other plant and weaving string horizontally between the stakes.



The stringing tool extends the worker's reach and helps to keep the twine tight.

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 (red, yellow, etc., depending on variety) develops. Pepper harvest starts about 30 days after flowering (mature green) and it takes an additional 10 (partial color change) 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.

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.


Proper storage conditions will reduce injury from pests.

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.

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 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)

DESCRIPTION:

Adults: Soft, pear-shaped bodies with red eyes and tailpipe-like appendages called cornicles on the rear of the body. Wingless adults are yellowish or greenish and about 0.07-0.08 inches (1.8-2.0 mm) long. 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 and about 0.06-0.08 inches (1.5-2.0 mm) long (Fig. 4.6).

Eggs: Initially yellow or green and becoming 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:

Adults: 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.

Eggs: 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:

Adults: Larger than the green peach and melon aphids, 0.08-0.16 inch (2-4 mm) long with pink or green bodies (Fig. 4.7).

Eggs: Similar to green peach and melon aphid eggs.

Nymph: Similar in color and shape to 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. 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 (Fig. 4.8). 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. 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 (see the plant disease section for information on virus diseases of concern for eggplant, pepper, and tomato).

APHID MANAGEMENT

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:

All three species of aphids have developed resistance to a number of different insecticides, including some synthetic pyrethroids, carbamates, and organophophates. 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.

Eggplant
Pepper
Tomato

SEARCH THE INTERNET FOR MORE INFORMATION:

Green peach aphid

- University of Florida Featured Creatures Green Peach Aphid
- Virginia Cooperative Extension Green Peach Aphid on Apples PDF
- UC Davis IPM Online Green Apple Aphid

Melon aphid

- University of Florida IFAS Extension Melon Aphid or Cotton Aphid PDF
- UT Extension Vegetable Pests Melon Aphid PDF

Potato aphid

- UC Davis IPM Online Tomato Potato Aphid
- NCSU IPM Potato Aphid

Armyworms and Cutworms

For information on the biology and management of armyworms and cutworms, see the Sweet Corn chapter.

Beet Leafhopper (Circulifer tenellus)

Order Hemiptera: Family Cicidellidae

DESCRIPTION:

Adults: Wedge-shaped with a pale green, gray, or tan colored body and about 0.13 inches (3 mm) long (Fig. 4.9).

Eggs: Tiny, white.

Nymphs: 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., and migrate or are blown north in early summer. Adults move into cultivated fields when weeds begin to dry up and 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 41). 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 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 remay fabric.* Remay is a white mesh, breathable fabric to cover plants and reduce feeding by beet leafhopper and other insects.

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.

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.

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:

Adults: 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. 4.10).

Eggs: 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. 4.11).

Nymphs: Resemble adults but are smaller and more rounded with brightly patterned black, red, white and green bodies (Fig. 4.12).

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 squished 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:

Spider populations do not typically increase until late summer to early fall after most onion bulb growth is complete. Mites thrive in hot, dry conditions. Their leaf-feeding injury to onion is generally minor, and they can serve as prey for predatory insects and mites that may also feed on thrips and other onion insects.

Adults: 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. 4.13).

Eggs: 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.

Larvae: 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. 4.14).

Pupae: 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:

Adult 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. 4.15).

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).

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.

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. 4.16). The wasp *Trichogramma pretiosum* will attack hornworm eggs and is available from commercial insectaries.

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

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 and thrips life history in the onion production section. 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. 4.17), 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. See thrips management tactics in the onion chapter for control recommendations.

Tomato Fruitworm (Corn Earworm; Helicoverpa zea)

Order Lepidoptera: Family Noctuidae

See *Corn Earworm* in Sweet Corn Production (Chapter 6) for description and life history information.

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. 4.18). When fruit is present, the tomato fruitworm will often attack fruit without any leaf feeding (Fig. 4.19). 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 and enter several fruits during feeding and development.

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:

- *Monitor with traps.* Place pheromone traps on perimeters of fields. Traps can be used to indicate relative adult densities and/or peak activity (see corn earworm section for 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:

Adults: Bodies are wedge-shaped, yellowish-tan or pink; microscopic, 0.01 inch (0.3 mm) long (Fig. 4.20).

Eggs: Colorless to white, roughly hemispherical and extremely small. Requires a 100-power or greater magnification to be seen.

Nymphs: 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. 4.21). Damaged leaves may turn yellow, curl, wither, and fall from plants (Fig. 4.22). Mite feeding on fruits can cause longitudinal cracks and bronze coloration.

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:

- *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

Eggplant
Pepper
Tomato

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 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. 4.23). Fruit can display blotchiness ranging from green to red (Fig. 4.24), or display ring spots (Fig. 4.25) similar to tomatoes.

On **tomatoes**, symptoms on leaves consist of brown (necrotic), irregular shaped spots (Fig. 4.26). Initially, the spots are very small and can be overlooked on young transplants. On green, immature fruit, brown ring spots occur (Fig. 4.27) that can also be seen on ripe tomatoes (Fig. 4.28). On some tomato varieties, such as 'Roma' types, the ripe fruits develop blotches of variable colors from yellow to orange and red (Fig. 4.29). 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 thrips management in the onion chapter).
- *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.)
    - o Resistant **tomato** varieties include 'Jimbo', 'Southern Star', 'Amelia', 'Crista', 'Red Defender', 'Primo Red', and 'Talledaga'.
    - o Resistant **pepper** varieties include 'Stileto', 'Heritage', 'Plato' and 'Magico' (www.tomatospottedwiltinfo.org/vegcrops/index.html).
    - o 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.

SYMPTOMS:

Tomato and pepper plants infected with curly top are stunted and have upwards curled, yellow leaves (Fig 4.30, Fig 4.31). The veins on the underside of tomato leaves are purple (Fig. 4.32). Infected plants may not

Eggplant Pepper Tomato

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. 4.9). 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 reduced 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. TMW 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. 4.33) 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. 4.34 and 4.35), or the parenchyma layer of cells inside the fruit will turn brown (Fig. 4.36). 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 TMW. 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.*
  - o TMV resistant **eggplant** varieties including 'Epic', 'Dusky' and 'Imperial' (http: //vric.ucdavis.edu/pdf/eggplant.pdf).
  - o TMV or ToMV resistant **pepper** 'Telestar', 'Crusader' and 'Paladin'.
  - o There are many TMV and ToMV resistant **tomato** varieties (vegetablemdonline.ppath.cornell.edu/Tables/TomatoTable.html); however, 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.*

SYMPTOMS:

Lesions can develop on leaves, fruit, and stems. The first foliar symptoms are brown necrotic spots on older leaves (Fig. 4.37) 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. 4.38). When there are numerous or large lesions,, the entire leaf may become yellow and fall off, exposing fruit underneath to potential sunscald. Severe infections results 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. 4.39).

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', and 'Mountain Magic', '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. 4.40). Eventually the leaves dry up and die. Severely infected plants can die. On the underside of leaves, growth of a white mold (Fig. 4.41) becomes visible on the lesions. Infected green fruit has brown or olive-colored lesions (Fig 4.42) 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. 4.43), often surrounded by a yellow halo. On small fruit (about 1 mm in size), round, black, superficial skin lesions develop (Fig. 4.44).

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. 4.45). 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. 4.46). 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 (Gleason et al. 2014). 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. 4.47). 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. 4.48) 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 further 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.* Refer to the fungicide table at the end of this chapter for effective products. 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. 4.49). 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^{0}F) 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 (68-74^{0}F) and in soils with a high pH which are very common in Utah. It produces an overwintering structure called a microsclerotium, which is a hard black ball of fungal tissue that can survive for a decade or more in the soil. Both survival structures when a suitable host is 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:

Aboveground symptoms of root-knot nematode infection resemble nutrient deficiency. Plants are chlorotic and stunted. The roots of infected plants are galled (Fig. 4.50). 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.

SYMPTOMS:

Brown, enlarged spots develop usually at the blossom end of the tomato, 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:

- *Irrigate* so that water is applied evenly and maintains consistent soil moisture. If symptoms develop, increased irrigation may help the plants take up calcium.
- *Test soil* before planting to determine if an adequate concentration of calcium is available.
- *Use foliar sprays of anhydrous calcium chloride.* This can reduce symptoms during the growing season.

Pest Management Tables for Commercial and Home Use

Table 4.5. Herbicides registered for **COMMERCIAL** use on **Eggplant.**

EGGPLANT		Application Relative to Crop				Application for Weeds		Weed Groups Controlled			
Product (REI/ PHI)	Common Name	Before Transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	Comments
Aim (12hr/-)	carfentrazone	X	X	X		X			X	X	Use on transplants 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 and others (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	

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)

Eggplant Pepper Tomato

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.

Table 4.6. Hebicides registered for **COMMERCIA**L use on **Peppers**.

PEPPERS		Application Relative to Crop				Application for Weeds		Weed Groups Controlled			
Product (REI/PHI)	Common Name	Before Transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	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 and others (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	

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)

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.

Table 4.7. Herbicides registered for **COMMERCIAL** use on **Tomato** in Utah.

TOMATO		Application Relative to Crop				Application for Weeds		Weed Groups Controlled			
Product (REI/PHI)	Common Name	Before Transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	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 and others (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 ()	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	

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)

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.

Table 4.8. Insecticides registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted). 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, Prokoz Sevin	1A	3		X		X	X	X	X	
methomyl	Lannate[R], Nudrin[R]	1A	5	X	X			X		X	
oxamyl	Vydate[R]	1A	5-7	X							X
acephate (pepper only)	Acephate, Bracket, Orthene	1B	3-7	X							
diazinon (tomato only)	Diazinon	1B	(+)				X				
dimethoate	Dimate 4E, Dimethoate	1B	6-7	X							
malathion	Cheminova, Fyfanon, Malathion	1B	5	X	X					X	X
naled (pepper only)	Dibrom 8 Emulsive[R]	1B	7	X							
endosulfan	Thionex[R]	2A		X	X			X		X	X
alpha-cypermethrin	Fastac[R]	3	3	X			X			X	
beta-cyfluthrin	Baythroid[R]	3	7	X				X	X	X	
bifenthrin	Bifenture[R], Brigade[R], Capture[R], Fanfare[R]	3	7	X	X		X	X	X		
bifenthrin + indole-3-butyric acid (not tomato)	Empower[R]	3	7-9				X				
bifenthrin + zeta-cypermthrin	Hero[R], Steed[R]	3	3	X			X	X	X	X	
cyfluthrin	Renounce[R], Tombstone[R]	3		X				X	X	X	
deltamethrin	Delta Gold[R]	3	5	X	X		X	X	X	X	
esfenvalerate	Asana[R], S-Fenvalorstar[R]	3	7				X		X	X	
fenpropathrin	Danitol[R]	3	7	X							
gamma-cyhalothrin	Declare[R], Proaxis[R]	3	5	X			X	X		X	
lambda-cyhalothrin	Lambda[R], Paradigm[R], Silencer[R], Warrior[R]	3	5	X			X	X		X	
permethrin	Ambush[R], Arctic[R], Permethrin[R], Pounce[R]	3	7		X		X			X	
pyrethrins	Pyganic[OB]	3		X	X			X	X	X	X
zeta-cypermethrin	Mustang[R], Respect[R]	3	7	X			X			X	
pyrethrins + piperonyl butoxide	Evergreen	3/	3	X	X			X	X		
zeta-cypermethrin + avermectin B1	Gladiator[R]	3/	7	X			X			X	X

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

(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment

Table 4.8, continued. **Insecticides** registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted). 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	
bifenthrin + imidacloprid	Brigadier[R], Swagger[R], Tempest[R]	3/4A	7-10	X	X		X	X	X		
cyfluthrin + imidacloprid	Leverage 2.7[R]	3/4A	7	X				X	X	X	
lambda-cyhalothrin + imidacloprid	Kilter[R]	3/4A	5	X			X	X		X	
lambda-cyhalothrin + thiamethoxam	Endigo[R]	3/4A	5	X			X	X		X	
bifenthrin + abamectic	Athena[R]	3/6	10	X	X		X	X			X
lambda-cyhalothrin + chlorantraniliprole	Voliam Xpress[R]	3/28	5	X	X		X			X	
pyrethrins + azadirachtin	Azera[OB]	3/UN	5-7	X	X		X	X			
acetamiprid	Assail	4A	7	X							
clothianidin	Belay	4A	7	X				X			
dinotefuran	Safari, Scorpion, Venom	4A	(++)	X				X			
imidacloprid	Admire Pro, Couraze, Marathon, Provado	4A	5	X							
thiamethoxam	Actara, Flagship, Platinum	4A	5	X				X			
sulfoxaflor	Closer SC	4C	7	X							
spinetoram	Radiant	5	2		X					X	
spinosad	Entrust[O], Success	5	5-7		X					X	
abamectin	Agri-mek[R], Reaper[R], Zoro[R]	6	7								X
emamectin benzoate	Proclaim[R]	6	7						X	X	
pyriproxyfen	Distance	7C	14	X							
pymetrozine	Fulfill	9B	7	X							
flonicamid	Beleaf 50	9C	7	X							
Bacillus thuringiensis subspecies aizawai strain ABTS-1857	Xentari[OB]	11A	3		X					X	
Bacillus thuringiensis subspecies kurstaki strain ABTS-351, HD1, EG7841	Biobit[OB], Crymax, Dipel[B], Foray	11A	3		X				X	X	
chlorfenapyr	Pylon	13	5-7							X	
novaluron	Rimon	15	7		X			X	X	X	

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

(++)= One application per crop per season
(+)= One application per year
ST= Seed Treatment

Table 4.8, continued. Insecticides registered for **COMMERCIAL** use on all 3 crops (unless otherwise noted). 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
methoxyfenozide	Intrepid	18	5						X	X	
tebufenozide	Confirm	18							X		
indoxacarb	Avaunt	22A	3							X	
spiromesifen	Oberon	23	14								X
spirotetramat	Kontos, Movento	23	7	X							X
chlorantraniliprole	Coragen	28	1						X	X	
cyantraniliprole	Exirel, Verimark	28	5	X					X	X	
flubendiamide	Belt, Synapse	28	3		X		X		X	X	
chlorantraniliprole + thiamethoxam	Durivo, Voliam Flexi	28/4A	(++)	X				X		X	
Sulfur	Golden Miconized Sulfur[OB]	M2 Fungicide									X
azadirachtin	Aza-Direct[OB], Azatin[B], Azatrol[OB], Ecozin[OB], Molt-X[B]	UN	5-7	X	X	X	X	X		X	X
cryolite	Kyrocide	UN	7		X						
dicofol	Dicofol	UN	(++)								X
Beauveria bassiana GHA	Mycotrol O[OB]		2-5	X				X			
capsaicin and related capsaicinoids	Bugitol[B]			X		X					
Chromobacterium subtsugae strain PRAA4-It and spent fermentation media	Grandevo[O]			X	X					X	X
extract of *Chenopodium ambrosioides* near *ambrosioides*	Requiem			X							
kaolin	Surround[OB]		5			X					
Metarhizium anisopliae Strain F52	Met52		5-10								X
oil: petroleum, peppermint, Rosemary, Garlic	Allityn[B], Biocover, Ecotec, Glacial, Omni, Purespray[OB], Saf-T-Side, Suffoil-X, Ultra-Pure[B]			X			X		X	X	X
potassium salts of fatty acids (insecticida soap)	M-Pede		7	X							
sodium tetraborohydrate decahydrate	Prev-AM		7-10	X							X
sucrose octanoate	SucraShield[B], Avachem[B]			X		X	X		X	X	X

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

Table 4.9. Fungicides registered for **COMMERCIAL** use in Utah on **Eggplant, Pepper, and Tomato**. 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	3/40	X	X	
mefenoxam + copper hydroxide	Ridomil Gold/Copper	4/M1	X		
mefenoxam + mancozeb	Ridomil Gold MZ WG	4/M3	X		
mefenoxam + chlorothalonil	Ridomil Gold Bravo	4/M5	X		
boscalid	Endura	7	X		
penthiopyrad	Fontelis	7	X	X	
fluxapyroxad + pyraclostrobin	Priaxor	7/11	X	X	
pyrimethanil	Scala	9	X		
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	
famoxadone + cymoxanil	Tanos	11/27	X		
azoxystrobin + chlorothalonil	Quadris OPTI	11/M5	X		
quinoxyfen (pepper only)	Quintec	13		X	
polyoxin D zinc salt	PH-D WDG	19	X	X	
cyazofamid	Ranman	21	X		
cymoxanil	Curzate	27	X		
propamocarb hydrochloride	Previcur	28	X		
zoxamide + mancozeb	Gavel	22/M3	X		
phosphorous acid, mono- and dipotassium salts	Confine; K-Phite	33	X	X	
potassium phosphite	Alude; Fosphite; Rampart	33	X	X	
dimethomorph	Forum	40	X		
mandipropamid	Micora; Revus	40	X		
dimethomorph + ametoctradin	Zampro	40/45	X		
fluopicolide	Presidio	43	X		
Bacillus subtilis strain QST 713	Cease[OB]; Rhapsody[OB]; Serenade[OB]	44	X	X	
basic copper sulfate	Basic Copper; Cuprofix-Ultra; Cuproxat	M1	X		
copper hydroxide	Champ; Kocide; Nu-cop	M1	X		
copper oxychloride sulfate	C-O-C-S WDG	M1	X		
copper sulfate pentahydrate	Mastercop	M1	X		
cuprous oxide	Nordox	M1	X		

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

Table 4.9, continued. Fungicides registered for **COMMERCIAL** use in Utah on **Eggplant, Pepper, and Tomato**. Organized by Mode of Action (MoA)

Active Ingredient	Brand Name	MoA	Blight	Powdery Mildew	Wilt diseases
copper hydroxide + mancozeb	Mankocide	M1/M3	X		
sulfur	Cosavet[OB] Kumulus; Microthiol Disperss[OB]; Micro Sulf[OB]; Sulfur-DF; Thiolux	M2		X	
mancozeb	Dithane; Manzate; Penncozeb; Roper DF Rainshield	M3	X		
ziram	Ziram	M3	X		
chlorothalonil	Bravo; Chloronil; Chlorothalonil; Echo; Equus; Initiate	M5	X	X	
extract of *Reynoutria sachalinensis*	Regalia[B]	P	X	X	
Bacillus amyloliquefaciens strain D747	Double Nickel[OB]		X	X	
Bacillus pumilus strain QST 2808	Sonata[O]		X	X	
Bacillus subtilis var. *amyloliquefaciens* Strain FZB24	Taegro		X	X	
hydrogen dioxide	Oxidate		X	X	
hydrogen dioxide + peroxyacetic acid	Terraclean 5.0				X
oils: clove, rosemary, thyme	Sporatec		X	X	
potassium bicarbonate	Kaligreen[OB]; Milstop[OB]			X	
Streptomyces lydicus WYEC 108	Actinovate Ag[OB]			X	

[B]= Biopesticide
[O]= Organic

Note: All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on solanaceous 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

Table 4.10. Insecticides registered for **HOME** use. 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	
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 Lawn and Garden Insect Killer	3	7	X	X	X	X		X	X	
cyfluthrin	Bayer Vegetable 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 (tomatoes only); Spectracide Triazicide Insect Killer for Lawns & Landscapes	3	7	X	X	X	X	X	X	X	
permethrin	Bayer Vegetable & Garden Insect Dust; Bonide Eight Vegetable, Fruit and Flower; Lily Miller Multi-Purpose Insect Spray	3	3	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 + sulfur	Bayer Natria Insect, Disease and Mite Control; Bonide Tomato and Vegetable 3 in 1	3/M2	7	X	X	X	X		X	X	X
acetemiprid	Ortho Flower, Fruit, & Vegetable	4A	7	X	X	X		X	X	X	
imidacloprid	Bayer Fruit, Citrus & Vegetable Insect Control (apply to soil at transplant or seedling stage)	4A	(+)	X		X					
spinosad	Bonide Captain Jack's Deadbug Brew; Monterey Take Down Garden Spray Sluggo Plus[OB]	5	4		X		X		X	X	
spinosad+iron phosphate	Monterey Sluggo Plus[OB]	5	4				X				
Bacillus thuringiensis	Bonide Thuricide; Green Light BT; Monterey B.t.[OB]	11A	3						X	X	
capsaicin and related capsaicinoids	Bonide Hot Pepper Wax Insect Repellent			X	X	X					

[B]= Biopesticide
[O]= Organic

Table 4.10, continued. Insecticides registered for **HOME** use. 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
oils: canola, clove, cottonseed, garlic, neem, paraffinic, peppermint, rosemary	Bayer Natria Multi-insect control[OB]; Bonide All Seasons Horticultural and Dormant Spray[OB]; Green Light Neem Concentrate[OB]; Monterey All Natural 3 in 1[B]			X	X	X	X		X	X	X
potassium salts of fatty acids (insecticidal soap)	Bayer Natria[B]; Bonide[B]; Safer's[B]; Natural Guard[B]		7	X		X	X				X

[B]= Biopesticide
[O]= Organic

***Note*:** All brands are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of products registered on solanaceous 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

Table 4.11. Fungicides registered for **HOME** use in Utah. Organized by Mode of Action (MoA).

Active Ingredient	Brand Name	MoA	Blight	Powdery Mildew	Wilt diseases
myclobutanil	Spectracide Immunox Multi-purpose Fungicide for Gardens	3		X	
chlorothalonil	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)	Bonide Tomato and Vegetable 3 in 1; Bayer Natria Insect, Disease and Mite Control	M2	X	X	
mancozeb	Bonide Mancozeb with Zinc	M3	X		
oils: clove, cottenseed	Monterey all natural 3 in 1 Garden Insect Spray[B]		X	X	

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

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

Eggplant Pepper Tomato

Fig. 4.1. Pepper varieties.

Fig. 4.2. Proper fertilization can lead to better yield and fruit quality.

Fig. 4.3. Tomato transplants are planted after frost has passed.

Fig. 4.4. Pepper spacing ensures adequate light and nutrients.

Fig. 4.5. Fruits grown on staked plants mature earlier.

Fig. 4.6. Green peach aphid adult.

Fig. 4.7. Potato aphids on tomato leaves late in the season.

Fig. 4.8. Aphid infestations early in the season can reduce yield.

Fig. 4.9. Adult beet leafhopper.

Fig. 4.10. Adult stink bug.

Fig. 4.11. Stink bug eggs.

Fig. 4.12. Stink bug nymph.

Fig. 4.13. Adult tomato hornworm.

Fig. 4.14. Tomato hornworm larva on tomato plant.

Fig. 4.15. Tomato hornworm feeding limits ability to produce fruit.

Fig. 4.16. Parasitized tomato hornworm.

Fig. 4.17. Thrip feeding damage on tomato leaves.

Fig. 4.18. Tomato fruitworm damage on leaves.

Fig. 4.19. Tomato fruitworm larva feeding on fruit.

Fig. 4.20. Tomato russett mites are abundant during hot, dry weather.

Fig. 4.21. Injury from mite feeding can cause "russetting" on plants.

Fig. 4.22. Mite feeding can cause leaves to curl, whither, and fall.

Fig. 4.23. Tomato spotted wilt virus causes chlorotic ring spot patterns.

Fig. 4.24. Jalapeno peppers with tomato spotted wilt virus (TSWV).

Fig. 4.25a. TSWV can also appear as ring spots on peppers.

Fig. 4.25b. Ring spots on bell pepper.

Fig. 4.26. Foliar symptoms of tomato spotted wilt virus.

Fig. 4.27. Brown ring spots on TSWV infected immature fruit.

Fig. 4.28. Brown ring spots on TSWV infected mature fruit.

Fig. 4.29. Blotchiness on tomatoes caused by TSWV.

Fig. 4.30. Plants affected by curly top disease.

Fig. 4.31. Tomato plant with curly top disease.

Fig. 4.32. Purple veins on the underside of leaves due to curly top.

Fig. 4.33. TMV leaf with mosaic patterned lesions.

Fig. 4.34. Tomato mosaic virus can cause yellow rings to appear.

Fig. 4.35. Brown sunken lesions are also symptoms of TMV.

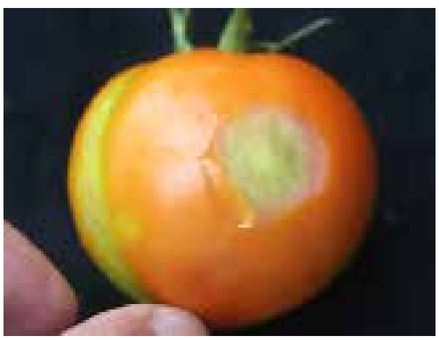


Fig. 4.36. TMV can cause fruit tissues to be discolored.

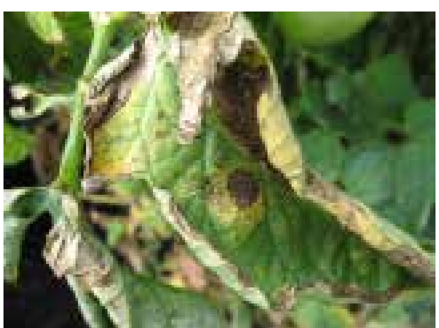


Fig. 4.37. Brown spots on leaves caused by early blight.

Fig. 4.38. Early blight can cause concentric rings to develop when spores are reduced.

Fig. 4.39. Early blight on fruit.

Fig. 4.40. Late blight leaf symptoms.

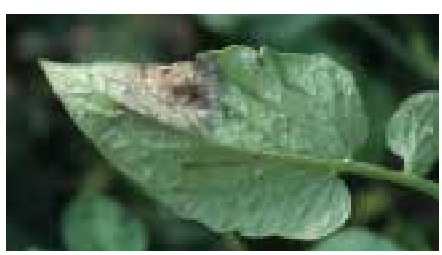


Fig. 4.41. Late blight appearing as a white mold on leaves.

Fig. 4.42. Late blight causes brown or olive-colored lesions on fruit.

Fig. 4.43. Bacterial speck on leaves.

Fig. 4.44. Bacterial speck on fruit.

Fig. 4.45. Bacterial canker causes vascular discoloration in stems.

Fig. 4.46. Bacterial canker causes white spots with dark centers on fruits.

Fig. 4.47. Powdery mildew causes white powdery spots on leaves.

Fig. 4.48. Powdery mildew also causes chlorotic areas on the surfaces of leaves.

Fig. 4.49. Wilt diseases cause vascular discoloration.

Fig. 4.50. Root-knot nematode can cause galls to form on roots (left-diseased, right-healthy).

CHAPTER 5 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. 5.1), 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.

Onion

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.

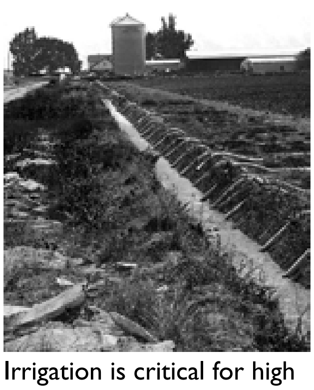
Cultivation

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 stemplate 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).


Onion harvest occurs from August to early October.

Research has shown that the optimum harvest time is when onion foliage is still partially erect (Fig. 5.2), 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 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. 5.3). 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.)

Onion

- 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.

Onion

Insect and Mite Management

Thrips

Onion Thrips (Thrips tabaci)
Order Thysanoptera: Family Thripidae

DESCRIPTION:

Adults: 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. 5.4).

Larvae: 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. 5.5).

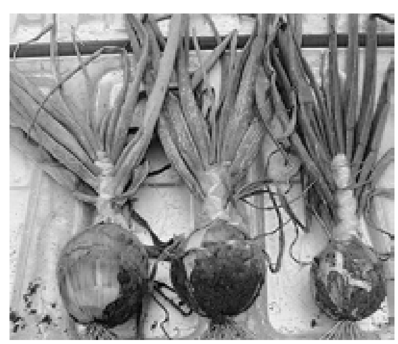
Eggs: White to yellow; kidney-bean shaped; microscopic in size. Develop within leaf tissue with one end near the leaf surface (Fig. 5.6).

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. 5.7). Thrips prefer to feed on the newly emerged leaves in the center of onion necks (Fig. 5.8). 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



Reduced bulb size due to thrips.

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.

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. 5.9 and 5.10).

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, create barriers that prevent the resting stage larvae from accessing the soil, and lower 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 in the soil.
- *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'

Onion

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. 5.11), 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:

Adults: 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.

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

Larvae: 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.

Pupae: Chestnut brown and about 0.3 inch (8 mm) long and may be found 1 to 6 inches (2.5-15 cm) deep in the 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. 5.12).

Seedcorn Maggot (Delia platura)
Order Diptera: Family Anthomyiidae

DESCRIPTION:

Adults: 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.

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

Larvae: 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.

Pupae: 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 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 amount of adult populations before egg laying occurs. www.gemplers.com/tech/itraps.htm
- *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. ccesuffolk.org/assets/Horticulture-Leaflets/Onion-Maggot.pdf

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:

Adults: Small, about 0.06 to 0.08 inch (1.5 to 2.0 mm) long, wing length of 0.07 to 0.09 inch (1.7 to 2.25 mm), bodies black with yellow on the back, sides of body and head. Larger body and overall darker color than the vegetable and American serpentine leafminers.
Larvae: White to yellow in color, wedge-shaped.
Eggs: White, oval.
Pupae: Brown, seed-like.

Vegetable Leafminer (Liriomyza sativae)

DESCRIPTION:

Adults: 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).
Larvae: Initially colorless, becoming yellowish as they mature with black mouthparts.
Eggs: White, oval, 0.01 inch (0.23 mm) long.
Pupae: Reddish brown, 1.5 mm long.

American Serpentine Leafminer (Liriomyza trifolii)

DESCRIPTION:

Adults: Less than 0.08 inch (2mm) in length, wing length of 0.05 to 0.07 inch (1.25 to 1.9 mm) (similar in size to the vegetable leafminer). Yellow head, red eyes, grayish black back, and yellow margins behind eyes.
Larvae: White to yellow, wedge-shaped, 0.02 to 0.08 inch (0.39 to 1.99 mm) in length.
Eggs: White, oval, 0.04 inch (1.0 mm) long.
Pupae: 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 her 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 and vigorous.
- *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. Use of broad-spectrum chemicals can increase their injury by eliminating natural predators.

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

DESCRIPTION:

Adults: 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. 5.14).

Eggs: 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 spot 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 mites are a minor pest in onion. Both the adult and immature stages of spider mites cause injury to plants, and are typically more severe in late summer when weather conditions are hot and dry. Mites feed by piercing leaf tissue with their mouthparts and sucking up plant fluids. Light to moderate feeding results in white speckling or stippling of leaves, while heavy feeding causes leaves to bronze or turn brown, and dry up. Mite feeding can also cause onion leaves to cup or bend while heavily damaged plants may topple.

MANAGEMENT:

Cultural:

- *Control weeds early.* Certain broadleaf weeds, such as common mallow, field bindweed, and prickly lettuce, are reproductive hosts for spider mites and can accelerate mite movement into the onion crop during the spring and early summer. Avoid cutting weeds that have large populations of mites, as they may move into the onion crop.
- *Water plants adequately.* Water-stressed plants, especially during hot and dry conditions, may not be able to combat heavy mite feeding. Overhead sprinklers can decrease mite populations due to the physical force of the water that removes dust that would normally encourage mites.

Chemical:

Miticides are pesticides that are specifically developed for mite control. Overuse of miticides can promote the development of resistance. Cultural and biological controls should be favored over chemical control.

Biological:

Mites can serve as prey for predatory insects and mites that may also feed on thrips and other onion insects. These predators provide a high level of natural control and keep mite populations below economically damaging levels. The minute pirate bug, big-eyed bug, lacewings, and predatory thrips are some of the important natural enemies of spider mites.

SEARCH THE INTERNET FOR MORE INFORMATION:

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

Bulb Mites
Order Sarcoptiformes: Family Acaridae

DESCRIPTION:

Adults: 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.

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

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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 the weeds show virus symptoms.

SYMPTOMS:

Symptoms of IYSV consist of lens-shaped bleached spots on leaves (Fig. 5.15) that sometimes have a green center (Fig. 5.16). In severe cases, the entire onion foliage will die back (Fig. 5.17).

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 depend 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. 5.18). 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. 5.19). 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. 5.20). When *Alternaria* is the causal agent, the brown lesions will eventually turn purple (Fig. 5.21) as fungal spores develop. Lesions caused by *Stemphylium* often appear dark brown to black (Fig. 5.22) 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. Disease severity can be increased by these practices.
- *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 s 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. 5.23). Over time, the decay will move through the entire bulb (Fig. 5.24). Sometimes white to gray mycelium can be seen developing between scales (Fig. 5.25).

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. 5.26) that can survive for several years until a suitable host (onion) is planted again. It also produces spores on plant debris (Fig. 5.27) 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 seed-borne 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 (Nischwitz et al. 2013). If it is difficult to dry onions due to environmental conditions, forced air (93°F) at 0.06m^3 per minute per 0.03m^3 of bulbs can reduce losses to neck rot (Lacy and Lorbeer 2008).
- *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 5.1. 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
Buctril (12hr/-)	bromoxynil			X		X		X	X	Apply to onions that have 2-5 true leaves
Dacthal (12hr/-)	DCPA	X	X		X		X	X	X	
Fusilade (12hr/-)	fluazifop		X	X		X	X			
GoalTender plus others (12hr/45d)	oxyflourfen			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

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)

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.

Table 5.2. 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[R]	1B	7-10		X		
diazinon	Diazinon[R]	1B	7-14		X		
malathion	Malathion, Fyfanon	1B	7	X	X		X
cypermethrin	Battery	3	7	X	X		
gamma-cyhalothrin	Declare, Proaxis[R]	3	5	X	X		
lambda-cyhalothrin	Paradigm[R], Province[R] Silencer[R], Warror[R]	3	5-7	X	X		
permethrin	Ambush[R], Artic[R] Perm-up[R], Pounce[R] Perma star[R]	3	7-10	X	X		
pyrethrin	Pyganic[O]	3	5	X	X		
zeta-cypermethrin	Mustang[R], Respect[R]	3	7	X	X		X
pyrethrin + piperonyl butoxide	Evergreen	3/	5	X	X		
pyrethrin + azadirachtin	Azera	3/UN	3		X		X
spinosad	Success, Entrust[O]	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	X
pyriproxyfen	Esteem	7C	14	X			
spirotetramat	Movento	23	7	X			
azadirachtin	Aza-direct [OB], Azatin[B] Aztrol Ecozin[O], Molt	UN	5-10	X	X	X	X
Beauveria bassiana strain gha	Mycotrol O[B]	---	2-10	X			
insecticidal soap (potassium salts of fatty acids)	M-pede, Safer's[O]	---	7				X
kaolin clay	Surround[B]	---	1	X		X	
oils: peppermint, rosemary, petroleum	Ecotec[B], Omni Supreme[B], Saf-t-cide[B] Stylet Oil[OB]	---	1				X

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

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

Table 5.3. 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	X		X	
propiconazole	Amtide, Bumper Fitness, Propi-star Propimax, Shar-shield, Tilt, Topaz	3	7	X			
tebuconazole	Monsoon, Onset Orius, Tebu-crop Tebuzol, Toledo	3	10	X			
difenoconazole + cyprodinil	Inspire	3/9	7	X	X		
difenoconazole + azoxystrobin	Quadris	3/11	7		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			
pyrimethanil	Scala	9	7	X		X	
cyprodinil + fludioxonil	Switch	9/12	7	X	X		
azoxystrobin	Quadris, Satori	11	7	X			
fenamidone	Reason	11	5	X			
pyraclostrobin	Cabrio	11	7	X	X		
famoxadone + cymoxanil	Tanos	11/27	5	X			
DCNA dicloran	Botran	14	14			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	X		X	X
copper-based	Champ, Cuprofix Cuproxat, C-O-C-S Kocide, Mastercop Nordox, Nucop	M1	7	X			

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

Onion

Table 5.3, 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			
chlorothalonil	Bravo, Chloronil Chlorothanlonil Echo, Equus, Initiate	M5	7	X		X	
chlorothalonil + azoxystrobin	Quadris	M5/11	7			X	
extract of *Reynoutria sachalinensis*	Regalia[B]	P	7-14	X	X	X	
Bacillus amyloliquefaciens strain D77	Double Nickle[OB]	---	7	X		X	
hydrogen dioxide	Oxidate[OB]	---	5			X	
mono- and di-potassium salts of phophorous acid	Prophyt[B]	---	?	X			
oils: rosemary, thyme	Sporatec[O]	---	N/A			X	
Streptomyces griseoviridis strain K61	Mycostop[B]	---	?			X	

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

Onion

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

Table 5.4. 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	X	X	X	
gamma-cyhalothrin	Spectracide Triazicide	3	14	X	X	X	
pyrethrin	Monterey Take Down[B]; Garden-Tech Worry Free[B]	3	5	X	X	X	
sulfur and pyrethrin	Bayer Natria[B]	3/M2	5		X		
acetamiprid	Ortho Fruit and Vegetable	4A	14	X		X	
spinosad	Natural Guard[B]; Bonide Captain Jack's[B]; Ferti-lome Borer and Bagworm Spray[B]; Monterey Garden Spray[B]	5	7-10	X		X	
insecticidal soap	Safer's[B]; Natural Guard[B]; Bayer Natria[B]		7	X			X
neem oil plus pyrethrin	FertiLome Triple Action[B]		3	X		X	X
oils: neem, paraffinic, canola, rosemary, peppermint, clove, sesame, thyme, and cinnamon	Green Light[B]; Bayer Natria Multi Insect[B]; EcoSmart[B]; Mon-terey Neem Oil[B]; Monterey All Natural Mite and Insect[B]; Natural Guard Neem[B]; Ortho Volck[B]		1				X

[B]= Biopesticide

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

Table 5.5. 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		X		
Bacillus subtilis strain QST 73	Bayer Natria[B]	M5	7	X		X	

[B]= Biopesticide

Onion

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

Fig. 5.1. Bulbs of onion varieties vary in color.

Fig. 5.2. Harvest onions when foliage is partially erect.

Fig. 5.3. Straw mulch between rows of onion helps suppress weeds.

Fig. 5.4. Adult onion thrips have 7-segmented antennae.

Fig. 5.5. Onion thrips larva.

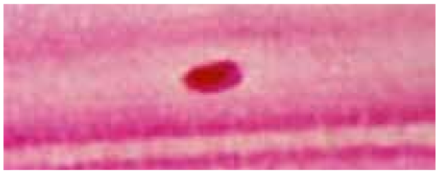


Fig. 5.6. Stained onion thrips egg.

Fig. 5.7. Onion thrips feeding causes silvery streaks.

Fig. 5.8. Thrips are most commonly found in the neck of the onion.

Fig. 5.9. Adult western flower thrips have 8-segmented antennae.

Fig. 5.10. Life stages of western flower thrips.

Fig. 5.11. Banded thrips adults are important predators of onion and western flower thrips.

Fig. 5.12. Onion maggot levels of injury.

Fig. 5.13. Twospotted spider mite.

Fig. 5.14. Iris yellow spot virus lesion.

Fig. 5.15. Iris yellow spot virus lesion with green island.

Fig. 5.16. Severe leaf dieback due to iris yellow spot virus.

Fig. 5.17. Pink root.

Fig. 5.18. Aboveground symptoms of pink root.

Fig. 5.19. Leaf dieback due to purple blotch.

Fig. 5.20. Purple blotch.

Fig. 5.21. Stemphylium leaf spot.

Fig. 5.22. Early stage of botrytis neck rot.

Fig. 5.23. Advanced decay by botrytis neck rot.

Fig. 5.24. White mycelium of *Botrytis* growing between scales.

Fig. 5.25. "Sclerotia" spores produced by *Botrytis* on onion bulbs.

Fig. 5.26. Grey *Botrytis* spores produced on onion.

CHAPTER 6 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 the 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 (Stall et al. 2014). 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 (Taber and Lawson 2005) 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 (Jett 2014).

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 (Kotuby-Amacher et al. 2003).

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 (Stall et al. 2014). (See Fig. 6.1 for symptoms of nitrogen deficiency.)

Phosphorus and Potassium

Applications of the commonly used forms of phosphorus (P) and potassium (K) using P_20_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 (Stall et al. 2014). (See Fig. 6.2 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 (Taber and Lawson 2005).

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 (Taber and Lawson 2005).

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.

Corn

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.

Corn

Irrigation

Sweet corn requires 18 to 28 inches of water per acre, depending on weather conditions, throughout the growing season (Stall et al. 2014). 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 (Taber and Heard 2008). 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. 6.3).

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. 6.4).

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 (Taber and Lawson 2005).

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 (Taber and Lawson 2005). 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 product 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 (Taber and Lawson 2005). 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 6.2, 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. 6.5, 6.6) 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 6.2 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:

Adults: 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. 6.7).

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

Larvae: 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. 6.8).

Pupae: 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 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. 6.9). 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:

Adults: 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. 6.10).

Eggs: 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. 6.11). 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 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.

Corn

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:

Adults: 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. 6.12).

Eggs: White, football-shaped, and less than 0.03 inch (0.8 mm) long.

Larvae: 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. 6.13).

Pupae: 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. 6.14). 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. The use of 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 then 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
  - o Use granular insecticides at planting or cultivation. Insecticides can be applied in-furrow, banded over the row, or incorporated into the soil.
  - o Liquid insecticides can also be applied at planting or at cultivation by spraying at the base of the plant.
- Seed Treatments
  - o 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 (Journey and Ostlie 2000 and Toepfer et al. 2008).

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:

Adults: 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 (males). Male cerci are strongly curved (Fig. 6.15) while those of the female are straighter, but curve slightly towards the tip (Fig. 6.16).

Eggs: 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. 6.17).

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:
  - o Corrugated cardboard rolled and tied to stakes along borders or dispersed throughout the field.
  - o Rolled or crumpled moistened newspaper.
  - o Grooved wood placed together.
  - o 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

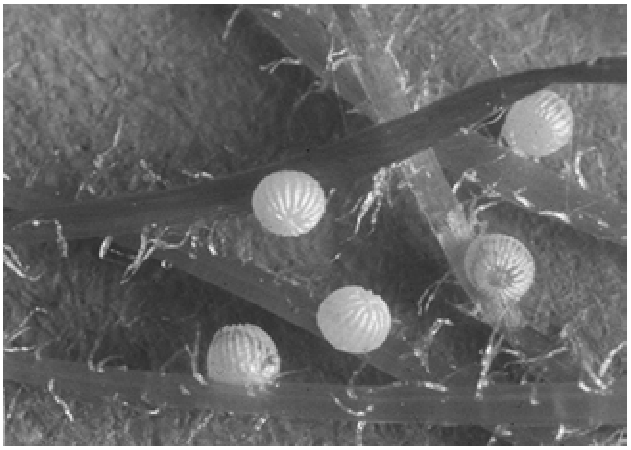
Corn Earworm *(Helicoverpa zea)*

Order Lepidoptera: Family Noctuidae

DESCRIPTION:

Adults: 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. 6.18). The male moths have green eyes.

Eggs: 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.

Larvae: Caterpillars are brown-headed with green, brown, or black bodies. Alternating dark and light stripes run lengthwise on the body (Fig. 6.19). Larva length ranges from 0.1 inch (1.5 mm) up to 1.5 inches (38.1 mm) when fully grown.

Pupae: 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.

Corn

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. 6.20, 6.21, 6.22).

Corn

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 below 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 6.1. 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:

Adults: 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 similar in appearance to the dusky sap beetle, about 1/8 in (3 mm) long, ranging from red-tinged black to brown-yellow (Fig. 6.23).

Eggs: Slender, white, about 0.8 mm long and 0.23 mm wide.

Larvae: 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. 6.24).

Pupae: 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:

Adults: 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. 6.25).

Eggs: 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.

Larvae: 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. 6.26).

Pupae: 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:

Adults: Mottled gray with yellowish and brownish spots on the forewing and a wingspan of 1.25 inches (32 mm) (Fig. 6.27).

Eggs: Spherical and about 1/16 inch (1.6 mm) in diameter. Eggs appear white when first deposited, and then turn a yellow-gray color.

Larvae: 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. 6.28).

Pupae: 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 (6.4 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 under more information).
- *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:

Adults: 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. 6.29).

Eggs: Dome shaped, light gray, and laid in clusters. Eggs become dark just before hatching.

Larvae: 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. 6.30).

Pupae: 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. 6.31). 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 army worm eggs and larvae.
  - o Search 20 plants in five locations or 10 plants in 10 locations.
  - o 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:

Adults: 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 runs along its sides and extend the full length of the body.
Eggs: Very small, spherical, shiny, and straw-colored.

Larvae: 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. 6.32). 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. 6.33-6.36). 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 (Babadoost 2004). 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. (Draper 2004).
- *Avoid plant injury* and insect damage. Fewer injuries reduce the number of entrance points for the fungus, thus reducing disease incidence (Babadoost 1990).

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 generations 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. 6.37). As symptoms progress, yellow stripes up to an inch wide can be observed on leaves of infected plants (Fig. 6.38) and in some cases, purple streaks are observed (Fig. 6.39). 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. 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 (Claflin 2000).

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 6.2. Herbicides registered for **COMMERCIAL** use on **Sweet Corn** in Utah.

Product (REI/PHI)	Common Name	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

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)

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.

Table 6.3. 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			
thiodicarb	Larvin[R]	1A	1		X	X		X			
chlorpyrifos	Chlorpyrifos[R,] Lorsban[R]	1B	10	X	X	X		X		X	
ethoprop	Mocap[R]	1B	(++)			X					
malathion	Malathion, Fyfanon	1B	5	X	X			X	X	X	X
oxydemeton-methyl	MSR[R]	1B	7	X							
phorate	Thimet[R]	1B	(++)							X	
chlorpyrifos + bifenthrin	Tundra	1B/3	10		X	X			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						
chlorpyrifos + zeta-cypermethrin	Stallion[R]	1B/3	10	X	X	X		X	X		
tebupirimphos + cyfluthrin	Aztec[R]	1B/3				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	
bifenthrin	Brigade[R], Capture[R],	3	7	X	X	X		X	X	X	X
bifenthrin + indole-3-butyric acid	Empower	3	7			X		X		X	
bifenthrin + zeta-cypermethrin	Hero[R], Steed[R]	3	3	X	X	X		X	X		X
cyfluthrin	Renounce[R], 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		X	X		X		X	
piperonyl butoxide + pyrethrins	Evergreen	3	7	X	X		X	X			
pyrethrins	Pyganic[OB]	3	1	X	X		X	X			
zeta-cypermethrin	Mustang[R], Respect[R]	3	3-5	X	X	X		X	X		
permethrin + carboxin	Kernel	3/7	ST							X	
lambda-cyhalothrin + chlorantraniliprole	Besiege[R], Voliam[R]	3/28	7	X	X	X		X	X		X
pyrethrins + azadirachtin	Azera[OB]	3/UN	5-7	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

Corn

Table 6.3. 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
metalaxyl + imidacloprid	Concur	4/4A	ST							X	
actetamiprid	Assail	4A	7	X					X		
clothianidin	Poncho	4A		X	X					X	
imidacloprid	Axcess, Dyna-shield, Gaucho, Nitro, Senator	4A	ST	X						X	
thiamethoxam	Cruiser	4A	ST	X						X	
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	11A	3					X			
Bacillus thuringiensis subspecies kurstaki (strains ABTS-351 and HD1	Biobit[OB], Dipel[B]	11A	3		X	X		X			
propargite	Comite[R]	12C	(++)								X
novaluron	Rimon	15	7		X			X			
methoxyfenozide	Intrepid	18	5			X					
indoxacarb	Avaunt	22A	3		X			X			X
spiromesifen	Oberon	23	14								X
chlorantraniliprole	Coragen	28	1		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[B], Azatrol[OB], Ecozin[OB], Molt[B]	UN	5-7	X	X	X		X			X
Chromobacterium subtsugae strain PRAA4-lt and spent fermentation media	Grandevo[O]	---		X	X	X		X			X
kaolin	Surround[OB]	---	5					X			
oils: mineral, petrolium, peppermint, rosemary	Biocover, Ecotec, Omni, Purespray[OB], Saf-T-Side, Superior, Suffoil, Supreme, Ultra[B]	---	1	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

Corn

Table 6.4. 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; Bug-Geta Plus Snail; Slug & Insect Killer	1A	3	X	X	X		X	X		
malathion	Ortho Max Malathion (check label)	1B	5	X							X
bifenthrin	Bug B Gon Max Lawn and Garden Insect Killer	3	7	X	X	X	X	X	X	X	
cyfluthrin	Bayer Vegetable and Garden Insect Spray	3	2	X	X	X		X			
deltamethrin	Green Light Many Purpose Dust	3	1	X	X	X		X			
lambda-cyhalothrin	Triazicide Insect Killer for Lawns and Landscapes	3	7	X	X	X	X	X	X	X	X
permethrin	Complete Insect Dust For Gardens	3	3	X	X	X		X			
pyrethrins + piperonyl butoxide	Worry-free Insecticide and Miticide	3	3	X	X	X		X		X	
pyrethrins + sulfur	Natria Insect, Disease, and Mite Control	3/M2	7	X			X				X
spinosad	Sluggo Plus[O]	5	5-7		X	X	X	X			
insecticidal soap	Safer's[B]; Natural Guard[B]; Bayer Natria[B]	---		X		X	X	X		X	X
oils: canola, neem	Natria Multi-insect control[OB]; Green Light Neem Concentrate[O]	---		X					X		X

[B]= Biopesticide
[O]= Organic

Note: All brands are registered trademarks. Examples of brands be not be all-inclusive, but are meant to provide examples of products registered in Utah. The availability of pesticides change. Always read the label for registered uses, application and safety information, and protection and pre-harvest intervals.

Fig 6.1. Nitrogen deficiency.

Fig 6.2. Phosphorus deficiency.

Fig 6.3. Plasticulture results in improved weed control and greater water retention.

Fig 6.4. Harvest corn after the silks have dried and browned.

Fig 6.5. Herbicide damage on corn.

Fig 6.6. Herbicide damage on corn.

Fig 6.7. Adult seedcorn maggot.

Fig 6.8. Seedcorn maggot larvae may feed on underground stems.

Fig 6.9. Seedcorn maggot damage.

Fig 6.10. Corn leaf aphid adult.

Fig 6.11. Corn leaf aphid feeding causes leaves to turn red or yellow.

Fig 6.12. Western corn rootworm adult.

Fig 6.13. Western corn rootworm larvae are creamy white with a brown head capsule.

Fig 6.14. "Gooseneck" symptom caused by corn rootworm.

Fig. 6.15. Earwig male.

Fig. 6.16. Earwig female.

Fig 6.17. When earwigs feed on silks, preventing pollination.

Fig 6.18. Corn earworm moths are about 1.5 inches in size.

Fig 6.19. Corn earworm larva.

Fig 6.20. Corn earworm feeding.

Fig 6.21. Corn earworm damage.

Fig 6.22. Corn earworm feeding damage.

Fig 6.23. Sap beetles are tiny beetles that feed on over-ripe corn and other vegetables.

Fig 6.24. Dusky sap beetle larva.

Fig 6.25. Western bean cutworm adult stuck on sticky card from Delta trap.

Fig 6.26. Full-grown cutworm larva.

Fig 6.27. Pale western cutworm moth adult.

Fig 6.28. Mature pale western cutworm larva.

Fig 6.29. Fall armyworm adult.

Fig 6.30. Fall armyworm larva.

Fig 6.31. Feeding by young armyworms cause holes in leaves

Fig 6.32. Mite damage on corn resembles a burnt appearance.

Fig 6.33. Smut on corn ear (top), as compared to a healthy ear.

Fig 6.34. Tassel infected with corn smut.

Fig 6.35. Stalk infected with corn smut.

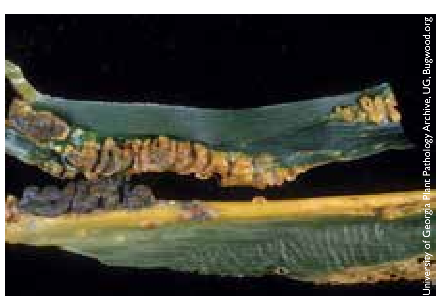


Fig 6.36. Leaf infected with corn smut.

Fig 6.37. Stunted corn plant infected with high plains virus.

Fig 6.38. Yellow stripes on leaves of corn infected with high plains virus.

Fig 6.39. Purple discoloration of high plains virus on leaves.

Fig 6.40. Corn plant infected with bacterial stalk rot.

CHAPTER 7 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 7.1 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 online 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 12.3. 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 Concen-trates, & Liquid Flow-ables	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.

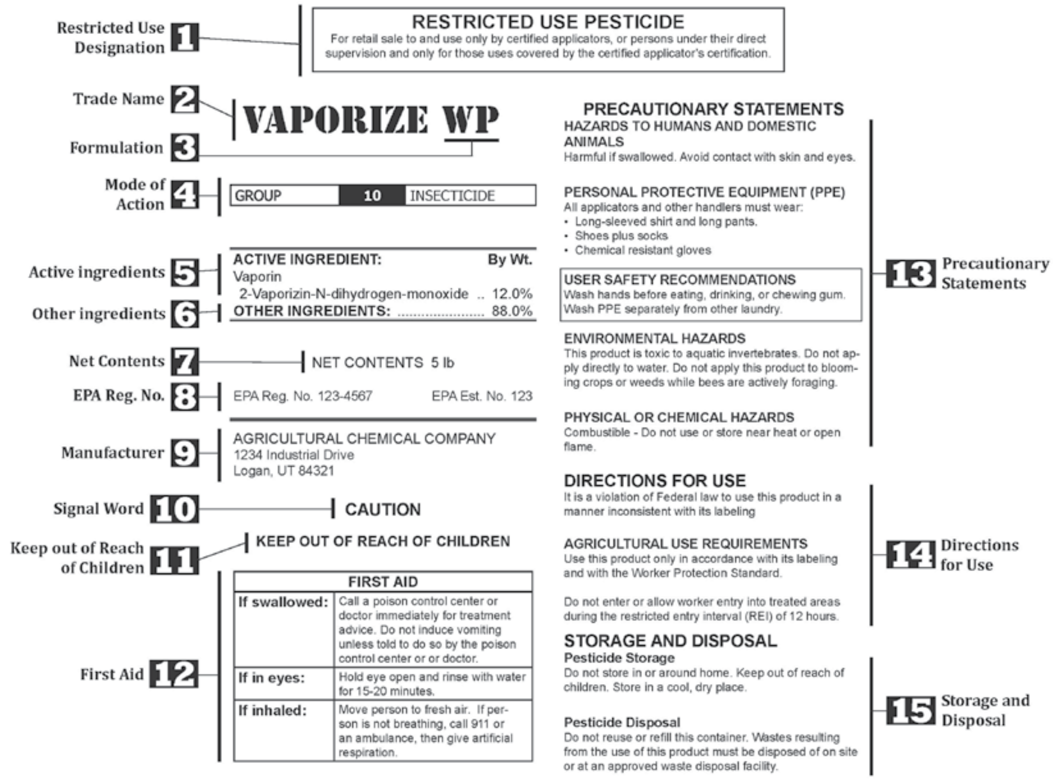
The information on the pesticide label represents the research, development and registration procedures that a pesticide must undergo before reaching the market, frequently at a cost of millions of dollars to the manufacturer. The U.S. Environmental Protection Agency (EPA) requires a manufacturer to 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.

Pesticides



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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