UTAH VEGETABLE PRODUCTION GUIDE (5TH EDITION)

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Vegetable Production
Soil Nutrient Water
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Brassicas
Cucurbits
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Legumes
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Chapter 10: Root Crop Production

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CHAPTER 1: VEGETABLE PRODUCTION RECOMMENDATIONS

Varietal Selection

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

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

1. Use seed catalogs or other sources to identify a variety that has similar production characteristics. These characteristics may include maturity times, growth habits, fruit size, cold/heat tolerance, or pest resistance. Visit SeedQuest (seedquest.com) for a listing of the major seed producers.
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 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. Open-pollinated plants 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. Hybridization aims to isolate unique traits from plants through classical breeding techniques. Once these traits are isolated, specific crosses are made so offspring express the traits. The specific parents are maintainedto continually breed this hybrid. 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.

Developing genetically modified (GM) varieties entails inserting genetic material from different plants, animals, or organisms 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.

USU EXTENSION FACT SHEET REFERENCES

- *Recommended Vegetable Varieties for Northern Utah*

Table 1.1. *General Recommendations for Growing Transplants From Seed*

Crop	Seeds/ft²	Seeding depth (inches)	Optimum germination (°F)	Germination time (days)	Optimal growth temperature		Grow time[a] (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

Note. Temperature, light levels, nutrients and other factors can influence grow times.

[a]Average number of weeks required to grow to transplantable size.

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 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 with high temperatures (greater than 70 °F) or where humidity values are greater than 60%. The ideal storage temperature for seeds is 35 °F to 40 °F with relative humidity less than 40%.

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.

USU EXTENSION FACT SHEET REFERENCES

- *Saving and Storing Seeds for Next Year*
- *Collecting and Storing Seeds from your Garden*

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 with carefully managed growing conditions. 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.

USU EXTENSION FACT SHEET REFERENCES

- *Suggested Vegetable Planting Dates for the Wasatch Front*
- *Wasatch Front Vegetable Chart*
- *Cache Valley Vegetable Chart*
- *Suggested Vegetable Planting Dates for Utah*

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 (50s, 72s) produce earlier yields. Cell size does not affect total yield when

Table 1.2. *Transplant Mixes for Pots, Flats, or Transplant Trays*

Organic Tipi Potting Mix Recipe	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 mixture 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**
Combine equal parts by volume of • vermiculite • peat moss, and • 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 until blocks hold together.

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 (128s, 256s) and keep costs down, these trays may not be appropriate for some vegetables like melons. Transplant production cost depends on the number of plants grown per unit area and the length of time needed to grow the plant to plantable size.

Plant-Growing Mixes

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

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

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

A germination chamber will better control heat when floor or bench heat is not available. Flats, trays, or pots are seeded, watered, and then stacked in the chamber for germination. When using this method, be sure to remove the trays from the chamber and unstack 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 create 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 seedling death.

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% water-soluble and applied 1-2 times per week to maintain steady growth. Use additional feeding to accelerate growth. Always rinse the leaves after liquid feeding. Adding gigher amounts of fertilizer 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 the 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 the 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 waterings 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 withstand harsh conditions in the field (temperature extremes, water stress, wind, pests, etc.).

Generally, impose hardening treatments about 7 to 10 days before field planting, such as:

- Reduce water provided to the plant.
- Lower the growing temperatures.
- Limit fertilizer amounts.

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 temperatures (<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 regrowth may slow under field conditions.

Mulches and Row Covers

Mulch is any material (natural or artificial) used to cover the soil's surface 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 creating conditions that improve the crop's growth. Some 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. Use clear plastic when needing higher soil temperatures 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 °F to 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 manage weeds, diseases, and insects better.

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. Lay the mulch 3 to 6 days before planting to obtain soil temperature benefits. 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 simultaneously. Mulches will work with furrow irrigation so long as furrows and plants are very close to the plastic edge, allowing young plants access to the water.

Other options are photodegradable and biodegradable plastic mulches. These usually cost more than regular plastic films but reduced disposal costs may offset the difference. 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, removed from the field, and disposed of 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 disposal methods. 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). Achieve good weed control by applying organic mulch thickly (>2 inches). Organic mulches are often bulky, hard to apply, and may be difficult to source. There have been instances where insect (slugs, cutworms, etc.) and rodent damage occurs when using organic mulches. Organic windbreaks are commonly used to provide plant protection during establishment and can be used with plastic mulches.

USU EXTENSION FACT SHEET REFERENCES

- *Using Mulches in Utah Landscapes and Gardens*
- *Use of Plastic Mulch for Vegetable Production*
- *Row Covers*
- *Low Tunnels: A Low-Cost Protected Cultivation Option*

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. Orient the tunnels with the ends toward the dominant wind direction. Space them so that they don’t shade each other and have 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.

The keys to successfully producing 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 5 to 6 weeks before planting outdoors. Invest in a good max/min thermometer and carefully track tunnel temperatures. If cold night temperatures are forecasted, 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 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 crop quality.

For crops requiring pollination, like cucumber or squash, fruit set may prove difficult since bees must 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 Utah’s dry climate, some diseases (powdery mildew, bacterial diseases, and root rots) can become troublesome, 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.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Site Selection*
- *Constructing a Low-Cost Tunnel for Tall Crops*
- *Temperature Management in High Tunnels*

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-acreage 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 wind speeds 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 specifying the number and strength of the hives, the rental fee, delivery time, and hive distribution 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 ensure that the vegetables grown will maintain their freshness and quality, including cooling, harvesting and handling, washing, and storage conditions.

Cooling

After harvest, maintain vegetable quality through cooling and slowing down the respiration rate. 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 byproducts 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 postharvest 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 produce temperatures.
- Crop type (fruit, leaf, or root).
- Containers used and their size.

Specific recommendations for cooling times vary with individual vegetable types. For success, 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 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, extend quality, improve shelf-life, and reduce cooling costs.
4. If cold storage is not available, harvest only what you can pack or sell. Refill 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 ethylene's detrimental effects on vegetable quality:

1. Do not store or transport ethylene-sensitive crops with ethylene-producing fruits like apples, cantaloupe, bananas, and tomatoes.

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[a]	Chilling injury[b]
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

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

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

Source Gross et al. (2016).

2. Use electric forklifts in storage and transport areas. One byproduct 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 postharvest, visit the Postharvest Technology Center (postharvest.ucdavis.edu) for detailed information on how to reduce postharvest losses and improve the quality, safety, and marketability of fresh horticultural products.

USU EXTENSION FACT SHEET REFERENCES

- *Harvest and Storage of Vegetables and Fruit*

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 United States Department of Agriculture (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 Standards. 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 producers on these very small farms must use production practices that meet the National Organic Standards requirements

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 submitsan application with 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. Upon compliance verification, the certifier issues an organic certificate. Each year, the farm must go through the recertification 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.

USU EXTENSION FACT SHEET REFERENCES

- *Fruit and Vegetable Organic Certification Basics*
- *Sustainable Manure and Compost Application: Garden and Micro Farm Guidelines*
- *Nutrient Management Strategies for Organic Vegetable Production*

Reference seed catalogs or other sources to identify ideal varieties that may grow well on your farm. Note maturity times, growth habits, fruit size, cold/heat tolerance, or pest resistance.

Proper vegetable seed storage, in a cool and dry environment, is crucial for maintaining seed viability, ensuring they remain viable and capable of producing healthy plants in the future.

Use sterile flats, trays, growing cells, or pots for vegetable transplant production.

Planting seeds for transplant production involves sowing seeds in trays or containers under optimum indoor conditions.

Most commercial media mixes produce quality transplants when used with good management practices. They can vary in composition, particle size, pH, aeration, nutrient content, and water-holding capacity.

Greenhouses provide maximum light and provide good heating and ventilation systems for effective environmental control. Proper growing temperatures ensure uniform growth throughout the greenhouse.

Plastic mulches can improve soil temperatures, increase irrigation efficiency, reduce fertilizer losses, improve weed control, and help manage insects.

Transplanting vegetables involves carefully moving young seedlings from their production trays to the final growing location to promote healthy growth.

Proper vegetable plant spacing is essential for ensuring adequate room for growth and allowing each plant to receive sufficient sunlight, nutrients, and airflow for optimal development.

Row covers can protect plants from pests and cold temperatures, helping to extend the growing season and improve crop yields.

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 various widths and lengths 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.

Handle fresh produce with care. Avoid cuts, abrasions, and bruising damage to the tissue. Harvest produce at the peak of quality.

Washing vegetables immediately after picking removes dirt and other contaminants, ensuring they are clean and ready for processing.

Farmers may use tractors equipped with specialized attachments to efficiently harvest vegetables from their fields.

After harvest, vegetable quality is maintained through cooling and proper transportation.

CHAPTER 2: SOIL, NUTRIENT, AND WATER MANAGEMENT

Soil

The best soils for growing vegetables are well drained, deep, fertile soils, with adequate 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 nutrient retention, availability, and uptake.

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 Utah State University (USU) Analytical Laboratory (USUAL). 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 USU Analytical Laboratories (usual.usu.edu) website.

Soil Test Interpretation

A soil test evaluates the nutrient-supplying capabilities of a soil. A common misunderstanding is that the test provides you with the total amount of nutrients available for plant growth. The soil test only predicts how much fertilizer is required for optimum plant growth. If fertility levels are below optimum, the additional 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 pounds of the particular nutrient per acre (Table 2.1). Reading and understanding the soil test depends on knowing the method used in the test laboratory and the units 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 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).

USU EXTENSION FACT SHEET REFERENCES

- *Solutions to Soil Problems: Soil Structure*
- *Solutions to Soil Problems: High pH*
- *Solutions to Soil Problems: Drainage*
- *Solutions to Soil Problems: High Salinity*
- *Solutions to Soil Problems: Low Organic Matter*
- *Utah Visual Farm Guide: Year-Round Soil Care*
- *Utah Visual Farm Guide: What Is Healthy Soil?*

Nutrient Management

Plants remove nutrients from the soil and air 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 (N) is essential for plant growth and photosynthesis. Without N, plants cannot produce the amino acids which are needed to form proteins, resulting in stunted growth.

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). Soil testing laboratories do not routinely test N. 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 - Plants need phosphorus (P) for nucleic acids (DNA/RNA) and 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, with very little lost via leaching.

Potassium - Potassium (K) is essential for the translocation sugars and forming starch. 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 indicate that low or very low levels. 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 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 still 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 using high-analysis, low-S fertilizers 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. B may be deficient in intensively managed vegetable crop soils. Deficiencies are likely to occur in bulb and root crops, cole crops, and tomatoes. Overapplying of B can be toxic to plant growth, so DO NOT exceed recommended levels.

Chlorine (Cl) deficiencies are quite rare. Chlorine is required for the 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.

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 is 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.
- Cupped leaves.
- Yellowed 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:

- Rosette growth form.
- Fewer flower buds.
- Mottled leaves.

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

Soil
Nutrient
Water

Foliar Fertilization

Plants commonly obtain nutrients from the soil through their roots. Plants can also absorb a limited amount of some nutrients through leaves. 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 crop development, foliar nutrient applications may then be beneficial. Foliar feeding is not recommended for the macronutrients but is commonly used to correct micronutrient 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.

USU EXTENSION FACT SHEET REFERENCES

- *The Fundamentals of Nutrient Management*

Organic Nutrient Sources

For farms focusing on organic production, nutrient management is critical to maintain high levels of productivity. Depleted soils need to be regenerated and rebuilt to sustain crop yield and improve the farm's foundation. 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 nutrients 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 increase soil water storage, decrease runoff, erosion, and leaching as well as improve soil structure and porosity. In the western U.S., soils are low in OM. Soil OM breaks down quickly, particularly when there is

Table 2.2. *Cover Crops or Green Manures for Vegetable Farms*

Crop	Seeding rate (pounds)	Seeding dates[a]	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[a]	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

[a]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*

Nutrient source	Total N	P_2O_5	K_2O
Manures	lb/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	lb/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/sudangrass	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

Note. There are many other sources of organic based nutrients. Always check the nutrient analysis to help determine application rates.

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 various 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, ensure 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. All CC should be incorporated when the foliage is still green so they decompose rapidly and return the greatest amounts of nutrients to the soil. Most unproductive soils 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 green manures should be location-specific as each has different tolerances to cold, heat, or drought (Table 2.2).

For more information on CC and green manures, refer to *Managing Cover Crops Profitably,* from the Learning Center of the Western Sustainable Agriculture Research and Education (https://www.sare.org/resources/managing-cover-crops-profitably-3rd-edition/).

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 humus formation. Most organic materials (manures, crop residues, leaves, sawdust, etc.) can be composted. Finished composts provide relatively low amounts of readily available nutrients. Their nutrient content varies depending on the original source material. Even though most composts don't supply large amounts of nutrients, they help improve soil fertility by increasing OM and slowly releasing nutrients. Compost should be tested for nutrient content and 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 the potential for over or underapplication 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;

- Mixed 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.)
- Manure application timing. (If applied far in advance of the crop, manure can be quite useful. Damage may occur when applied closer to crop planting or at very high rates.)
- Regulations associated with organic certification that require compliance.

For more information on how to improve soil, refer to *Building Soils for Better Crops: Ecological Management for Healthy Soils,* from the Learning Center of the Western Sustainable Agriculture Research and Education (https://www.sare.org/resources/building-soils-for-better-crops/).

USU EXTENSION FACT SHEET REFERENCES

- *Nutrient Management Strategies for Organic Vegetable Production*

Biochar in Vegetable Production

Biochar has proven have long-term benefits for the environment by sequestering carbon in the soil. But for intensive agricultural production, some factors need to be considered in applying biochar to the soil, such as current soil health, the source and production method of the char, and the variable or unknown application rates. In some cases, crop yield may be marginally increased, but this benefit might not outweigh the cost of the biochar itself. Recent studies in the western U.S., including one by USU Extension, have found mixed results for certain vegetable crops.

What Is Biochar?

Biochar is a charcoal-like product made when biomass is slow-burned in the absence of oxygen in a contained system. This technology of burning is called pyrolysis. Biochar contains no petroleum, is made sustainably from biowaste products (herbaceous or woody crop residues, non-salvageable timber and slash, animal manure, and more). For agriculture, biochar is applied to the soil for long-term carbon storage and as an amendment.

It is predicted that at least 50% of the carbon in any piece of waste turned into biochar becomes stable, locking away that carbon into the soil for a period of several to hundreds of years, offsetting its contribution as a greenhouse gas in the form of carbon dioxide.

How Does Biochar Change the Soil?

Biochar works on the soil similarly to organic matter. It does not contain any nutrients; it is the physical properties that provide the benefits. Biochar's negative charge attracts positively charged plant nutrients (calcium, potassium, magnesium, etc.), preventing them from leaching out of the soil and making them readily available to the plant roots. In addition, the high surface area and porosity of biochar attract and hold water and provide a refuge for beneficial organisms.

Possible Benefits in Agriculture

The similarity of biochar to the organic matter found in "terra preta" soils led scientists to theorize that biochar application to other soils could be beneficial. "Terra preta" (dark earth) is a dark and loamy soil found in scattered pockets of the Amazon. Those pockets of soil are widely believed to have been amended or mulched with charcoal waste from pre-Columbian Indian hearths thousands of years ago. Johannes Lehmann at Cornell University showed that the terra preta soils had higher nutrient availability, higher cation exchange capacity, greater water retention, and greater porosity/aeration than the native soil, resulting in improved crop growth.

Since Lehmann's discovery, hundreds of studies have been conducted in the U.S. to try and replicate the results on plant and soil health. Trials in both agricultural soils and potted plants have shown mixed results. Where they occurred, some positive traits listed above were found, as well as increased:

- Fertilizer efficacy.
- Soil pH.
- Beneficial soil microorganisms including helpful rhizobacteria and mycorrhizal fungi.
- Earthworm populations due to improved soil conditions.

Because of the change in soil microflora, studies have examined whether biochar helps plants defend against soilborne diseases. Again, the results have been mixed, with some crop studies showing decreased plant growth. The negative effects may be attributed to temporarily high pH, toxins (resin, tannin, etc.) present on the char surface immediately after production, nutrient imbalances, or simply the crop species.

Biochar Results From a USU Extension Study

From 2015-2017, USU Extension researchers investigated whether biochar as a soil amendment would improve crop yield and root rot-resistance of tomato and melon. For crop-yield comparisons, biochar (beetle-killed pine/375 °C) was soil-applied in 2015 at a rate of 10 tons/acre at the USU Experimental Research Farm in Kaysville. Each year, we compared tomato and melon plant yield after a season grown in either biochar+fertilizer, fertilizer, or no amendment. We saw no statistically significant increase in yield from the biochar application; however, there were trends in the results:

- For the tomatoes in all three years, both average dry weight per plant and fruit yield was highest in the biochar plots, with the greatest increase for both measures in Year 2.
- For the melons, both the average dry weight per plant and fruit yield was highest in the biochar plot in Year 1, but the increase in yield did not continue. In Year 2, dry weight was again highest again in the biochar plots, with yield being second highest behind the fertilized plots. By Year 3, yield was lowest in the biochar plots, and dry weight was highest in the control plots, followed by the biochar plots.

The root rot-resistance comparison was conducted in a greenhouse where we grew tomato and melon transplants in potting soil that was either amended or not amended with the same type of biochar (2% rate by volume). After approximately 6 weeks of growth, half the potted plants were each inoculated with 20 rice grains coated in mycelium of a mix of *Phytophthora capsici*, *P. nicotianae*, *P. cactorum*, and *P. megasperma*. Plants were then grown with normal irrigation and fertilization for an additional 8 weeks. Plants were then rated for disease, weighed, and roots were tested for *Phytophthora* spp. with Agdia test kits. Disease was found on the inoculated plants in both soil types, and no disease was found on un-inoculated plants. This trial was repeated three times. We had hoped to see less incidence of disease on plants growing in the biochar soils, but instead, we found that:

- For both the melons and tomatoes that were inoculated with *Phytophthora*, there were no differences in the number of diseased plants, symptoms (based on individual plant ratings), or average dry plant weight, between the plants grown in biochar and non-biochar media.
- Because of the disparity in positive, negative, and neutral results on plant growth and yield by USU research and beyond, further investigation is needed to properly quantify the effects of biochar application in different climates and cropping systems. You can track all the latest at The International Biochar Initiative (https://biochar-international.org/).

Current Uses of Biochar

- Greenhouse growers are using biochar in potting media to improve water-holding capacity.
- Cacao growers are applying biochar to young trees to shorten the number of years to production by half.
- Nonprofits are creating biochar gardens throughout third world nations where depleted soils can benefit.
- Tree care companies are experimenting with biochar as a remediation tactic on stressed trees.
- Scientists are exploring biochar for soil reclamation and mining remediation due to its sorption characteristics and relatively high pH.
- Foresters in Colorado, Idaho, and Utah are exploring biochar production to turn dead trees (largely beetle kill) into a value-added product and as an alternative to slash and burn.

Obtaining Biochar

If you are interested in trying biochar, note that purchasing commercially-prepared char for large applications is not economically feasible. The cost ranges from $400 to $2,000 per ton. Scaling that down to backyard gardeners is a slightly more acceptable cost, with bagged products ranging from about $25 - $40 per cubic foot (covering 100 ft^2 to 350 ft^2).

As an alternative, some commercial growers are investigating on-site production of their own biochar. There are many YouTube videos online and local workshops.

How to Apply Biochar

Bagged or bulk products sold commercially have been tested and analyzed and will provide application instructions. But for do-it-yourselfers, there are not currently solid application recommendations. If you decide to use your own biochar, note that studies have shown that applying raw biochar alone in poor soil has little benefit to plants and may retard growth for at least 6 months.

- Rinse raw biochar in water and then "charge" it by mixing it almost half and half with compost or with a fertilizer.
- The application rate depends on soil type and cropping system, and ranges from 2 to 22 tons/acre. Therefore, one option is to apply the lower rates over a period of 2-3 years to slowly build up the content in the soil.

Biochar is still a hot topic, as the number of char-related scholarly publications have increased nearly fivefold since 2012. Indications suggest that biochar could play a role in improving sustainability in agriculture. However, the challenges of cost, variability in biochar types and application rates, and how this technique can work with other soil health practices such as no-till, cover cropping, manuring, and mulching still need to be addressed. Certainly, improved recommendations are coming, but a few years down the road.

USU EXTENSION FACT SHEET REFERENCES

- *What Is Biochar and How Is It Used?*

Irrigation

Soil water management is critical for producing 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 rates. 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

Table 2.4. *Effective Root Depth of Selected Vegetables*

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

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 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 determine 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 irrigation method are factors to consider. Cultivation generally increases soil evaporation. Shallow cultivation helps eliminate soil crusts and

Table 2.5. *Critical Vegetable Plant Growth Periods Requiring Adequate Water 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
Leafy greens (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

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.

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%-90% soil moisture). Small frequent irrigations are better than letting the soil moisture get too dry (40%-50% 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 be less efficient than other methods. System design depends on soil type (texture and intake rate), slope, stream size, and length of run. Keep in mind that water distribution 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 one 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 must 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 various 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 using low water quality.

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.
- 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:

- Requires 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.
- Offers 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, and which plants draw the most water.

USU EXTENSION FACT SHEET REFERENCES

- *Drip Irrigation for Commercial Vegetable and Fruit Production*
- *Small Acreage Irrigation System Selection*

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 crops.

One way to determine the soil type and fertilizer need is to have your soil tested.

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.

Applying and incorpporating 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.

Drip 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.

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.

CHAPTER 3: VEGETABLE IPM PRACTICES

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

Growers successfully using IPM combine the following factors:

1. Knowledge of host plants and their associated weeds, pests, and beneficial organisms (including identification, biology, and life cycle).
2. Conduct day-to-day practices to minimize pest problems (such as crop rotation, resistant varieties, composting soil, promotion of beneficial predators, and sanitation).
3. Monitor for pests, symptoms, and beneficial organisms.
4. Chemical use only when pest thresholds are reached.
5. Integrate nonchemical 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, diseases, and 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 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.

When inspecting plants, 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.
- Number of pest insects per plant, or percentage of plant affected by insect feeding or disease.
- 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 earworms, cutworms, armyworms, diamondback moths, cabbage loopers, 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 in the center of the sticky liner.

- "Heliothis" traps are used for corn earworms and include a fabric and mesh cylinder with the lure hung inside.
- 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 indicate of the timing of adult activity and abundance of the species.

Essentials of Pheromone Lures and Traps

Traps are sold as "large plastic delta" or "wing-style." We recommend the delta traps for convenience (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 the name of the insect lure used and not be used 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

- 10x-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

Recommended Field Guides

- *Vegetable Pests of Utah: Disease and Arthropod Pest Identification Guide*
- *Beneficial Insects of Utah Identification Guide*
- *Utah Vegetable Production and Pest Management Guide*
- *Beneficial Insects and Pests of Utah Alfalfa*
- *Greenhouse Biocontrol in Utah: Beneficial Insects*
- *Invasive Insect Field Guide for Utah*

Pest Identification

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

1. Text an image of the insect or disease problem to the Utah Plant Pest Diagnostic Lab (extension.usu.edu/pests/uppdl), phone (385-367-3773). Message and data rates may apply.
2. Send the specimen to the Utah Plant Pest Diagnostic Lab (extension.usu.edu/pests/uppdl) at 5305 Old Main Hill, Logan, UT 84322. A submission form, which is available online, must accompany the specimen. Fees for various services begin at $10 and include identification and management options.
3. Contact your local county extension faculty (extension.usu.edu/locations).
4. Visit the USU Extension integrated pest management website (extension.usu.edu/pests/ipm) to access image galleries, fact sheets, or to subscribe to the seasonal Vegetable Pest 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 treatment cost. 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.

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

- *Asparagus beetle*: treat when 10% of crowns are infested with beetle adults.
- *Corn earworm*: implement treatment (if plants are in silking stage) if two to five moths have been captured in Heliothis traps over 3 consecutive nights.
- *Onion thrips*: treat when there is an average of at least seven thrips per plant.
- *Squash bug*: treat when the average number of egg masses is more than one per plant.
- *Striped cucumber beetle*: treat melons when an average of four to five adults are found per 50 plants.

Treatment Options

Cultural Control

Cultural control options include tilling debris, rotating crops, using cover crops, applying 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.

TRAP CROPS

Trap cropping involves growing plants alongside a target crop that are more appealing to certain pests, thereby protecting the crop. It is an important cultural control method within IPM (Table 3.1) that is not widely used in Utah. But when successfully implemented, trap cropping provides a sustainable, long-term management option.

There are several types of trap cropping, characterized by plant type, where the plants are grown within the farm, and when they are planted.

- *Conventional trap cropping* – A traditional and proven-effective plant is planted around or within the cash crop that is more attractive to a target pest as either a food source or for reproduction.
- *Dead-end trap cropping* – using plants that are attractive to a target pest but on which offspring will not survive. Dead-end trap crops serve as a “sink” and prevent movement of the target pest to a cash crop later in the season. Dead-end trap crops are planted in field borders or edges where they intercept insect pests.
- *Genetically-engineered trap cropping* – plants may be genetically engineered to act as a trap crop. Preventing insect-vectored diseases is one example, where the trap crop is capable of harboring a certain virus but its insect vector cannot acquire it from that plant. In this example, the trap crop helps reduce the insect-vectored pathogen as opposed to the insect itself.
- *Perimeter trap cropping* – planting trap crops around the border of the main crop.
- *Sequential trap cropping* – traps crops that are planted either later or earlier than the main crop to increase the attractiveness to insect pests during certain times of the season.
- *Multiple trap cropping* – planting several trap crop species to manage several pests or controlling a target pest by combining plants whose growth stages enhance attractiveness season-long.
- *Push-pull trap cropping* – a combination system where a trap crop is planted around the perimeter of a crop to attract the target insect pest (pull) and a different plant is inter-cropped to repel (push) the insect away from the cash crop.
- *Biological control-assisted trap cropping* – trap crops that are planted within and around the crop that enhance populations of natural enemies that then help suppress multiple pests.
- *Semiochemical-assisted trap cropping* – using either manually hanging insect semiochemicals (such as pheromone lures) on a perimeter planting, or using genetically modified plants that emit semiochemical lures to attract the target pest.

Table 3.1. *Untested Trap Cropping Options for Utah Vegetable Production*

Cash Crop	Insect Pest	Trap Crop
Broccoli	Potato leafhopper	Various mustards[s]
Cabbage	Cutworms	Chinese cabbage, radish[c, s]
Cabbage	Diamondback moth	Various mustards[c]
Cauliflower	Colorado potato beetle	Chinese cabbage, marigolds, sunflowers[m]
Cruciferous crops	Flea beetles	Various mustards[c]
Cruciferous crops	Cabbage maggot	Chinese cabbage, turnips[c]
Cucurbit crops	Cucumber beetles	Specific varieties of cucurbit crops[c, s]
Sweet potato	Wireworms	Corn, wheat[c, s, sa]
Cucurbit crops	Squash bugs	Hubbard squashes[m, s]
Lettuce	Aster leafhopper	Lettuce[s]
Lettuce	Thrips	Various wildflowers[c]
Sweet corn	Stink bugs	Various mustards[c, p]
Tomato	Colorado potato beetle	Potato[s]
Tomato	Whiteflies	Squash[c]

[C]= Conventional
[M]= Multiple
[P]= Perimeter
[S]= Sequential. Early, and/or late planting
[Sa]= Semiochemical-assisted

Mechanical Control

Options usually involve methods to exclude pests such as applying row covers, disking weeds, and good sanitation practices (keeping tools clean, promptly removing unhealthy plants, etc.).

ROW COVERS

Various cover options are available. Lightweight materials (approximately 0.5 ounces per square yard) are effective as an insect barrier starting in late spring. The material may be non-woven, spun-bond fabric with 90%-95% light transmittance. Heavier fabrics (1.5 ounces to 2 ounces per square yard) are used to extend the growing season by protecting the crop from early or late frosts. These thicker materials allow for 50%-70% light transmittance. A few common brands of the spun bond fabrics include Agribon and Reemay. Ventilated plastic covers are also available for heat retention. Woven materials include thicker fabric or plastic mesh. For example, the Proteknet brand of mesh is available in six grades ranging in sizes from 0.85 mm^2 to 0.85 mm x 1.4 mm (Table 3.2). Ensure the pest being controlled will not be able to pass through the selected mesh grade. Row covers can be purchased online through garden supply and seed companies or may be available at some select garden centers. When selecting the support structure for row covers, consider whether it will be used for a single season or multiple uses. Options include 3/4-inch PVC that can be bent, metal hoops, or small wire hoops.

When constructing your row covers, first decide which crops to cover. Then, identify the purpose of the cover. For example, if the purpose is insect exclusion, be aware that timing is important. Understand when the pests can be most destructive to the crops and plan to leave the covers up for that duration of time. Also consider timing and crop size for row cover height.. The structure can be built over existing beds and rows with plastic mulch and drip line. First, install the PVC, metal, or wire hoops, then lay the cover over the frame and secure with binder clips. A tight seal to the ground is important, but avoid using stakes or anything that could tear the material.

Table 3.2. *Insects Excluded From Various Netting Mesh Opening Sizes*

Species	Netting sizes			
	0.0138″²	0.0335″²	0.05″ x 0.7″	0.19″ x 0.12″
Aphids	X			
Flea beetles	X			
Lacewings	X	X	X	
Ladybugs	X	X	X	
Leafhopper	X	X		
Lygus bug	X	X	X	
Moths	X	X	X	X
Root maggots (flies)	X	X	X	
Stink bugs	X	X	X	X
Spider mites	X			
Squash bugs	X	X	X	X
Thrips	X			
Whitefly	X			

Use shoveled soil or place bricks, rocks, or other heavy objects on the fabric. Regularly monitor the structure to ensure the covers are secure and free of any tears or other damage.

USU EXTENSION FACT SHEET REFERENCES

- *Row Covers*

Biological Control

For greenhouse or high tunnel crops, biological control by releasing 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 organisms through border or edge habitat plantings, applying compost to soil, and reducing pesticide use.

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Natural Enemies and Biological Control*
- *Beneficial Insects: Beetles*
- *Beneficial Insects: Big-Eyed Bugs*
- *Beneficial Insects: Damsel Bugs*
- *Beneficial Insects: Lacewings and Antlions*
- *Beneficial Insects: Mantids*
- *Beneficial Insects: Minute Pirate Bugs*
- *Beneficial Insects: Syrphid Flies*
- *Beneficial Insects: True Bugs*
- *Beneficial Predatory Mites*
- *Reduce Pesticide Poisoning of Bees*

Chemical Control

If you determine 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, you find feeding symptoms but identify no causal insect, a chemical spray is not recommended.

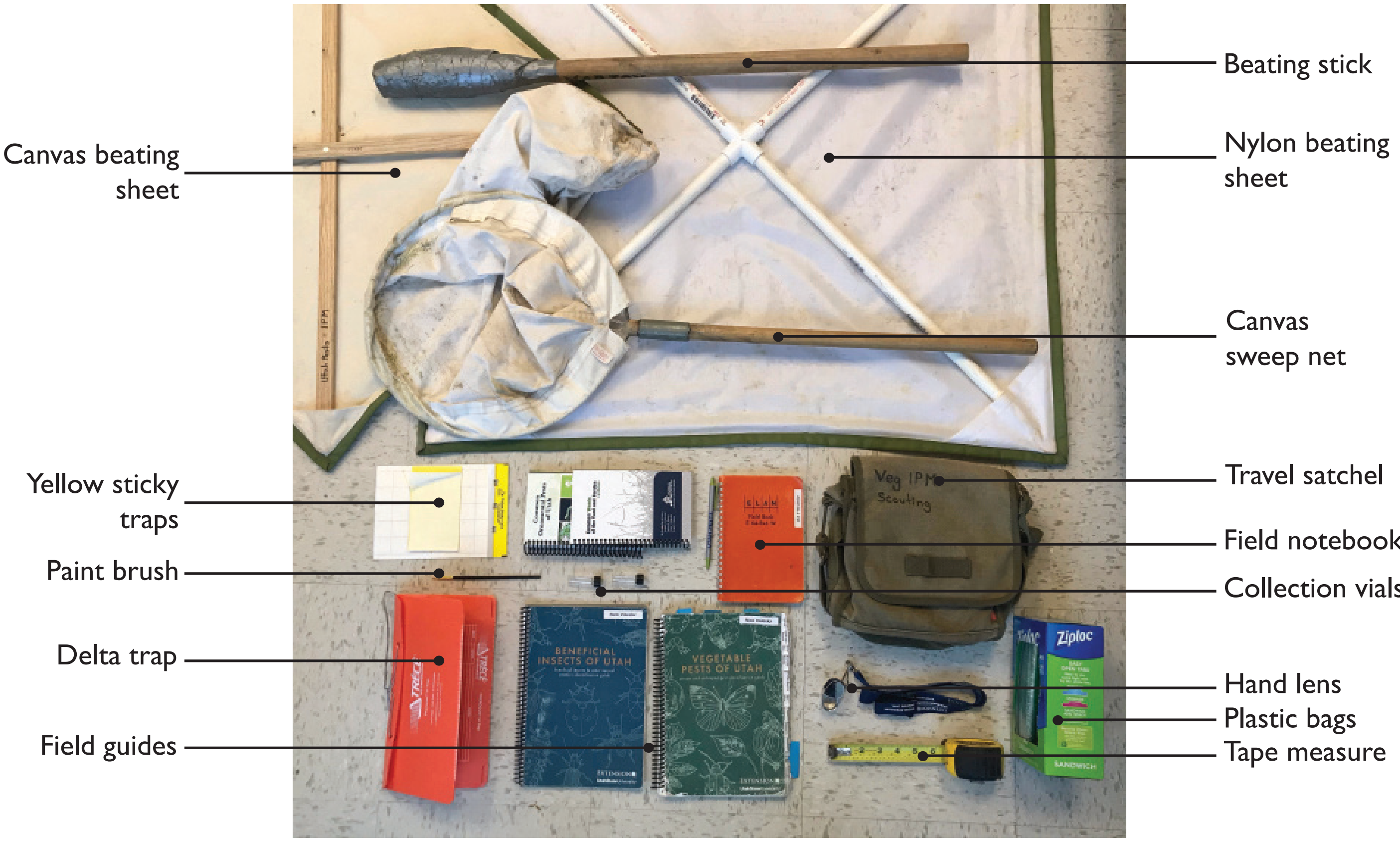
Pesticides are grouped by mode of action (how they kill the target organism), which is usually designated by a group number. Pesticides with similar active ingredients will have the same number. Rotating among pesticides in different group numbers will reduce the likelihood of pest resistance.

For each pest group (insects, diseases, weeds), there are many pesticide options. 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.
- Low toxicity to non-target organisms (birds, fish, plants).
- Low potential for groundwater contamination.
- Low use rates.
- Low pest resistance potential.
- High compatibility with Integrated Pest Management (IPM) practices.

Pest Monitoring Supplies and Methods



Standard supplies used for scouting pests in the field.

Using a hand lens helps in identifying very small insects.

A sweep net is helpful to count mobile insects.

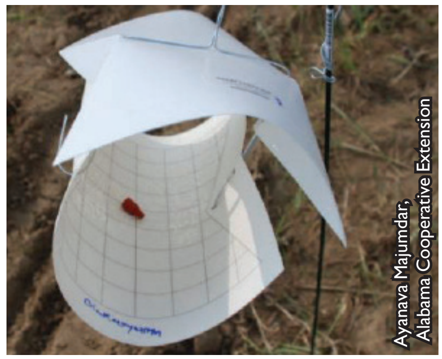
Placing a tray or sheet placed under a shaken plant will aid pest scouting.

Black light traps are used to trap nocturnal moths.

This Delta trap is capuring pests in a tomato greenhouse.

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


Yellow sticky traps are used to monitor pest populations.



This wing-styled pheromone trap is being used in a vegetable field.


Tilling the soil and plant debris can be a form of cultural pest management.


Sorgham grown as a trap crop can deter stink bugs away from cash crop.


These sunflowers are grown as a trap crop along the perimeter of pepper production.


Non-woven, spun-bond fabric is being used as row covers on a vegetable farm.


This plastic mesh insect netting is being used on a vegetable farm.

A slow release satchet of beneficial predatory mites is being used in a tomato greenhouse.

Organic and synthetic pesticide options are available at a garden center.

Ambush Bug (Order Hemiptera, Subfamily Phymatinae)

Western Big-Eyed Bug *(Geocoris pallens)*

Damsel Bug (Order Hemiptera, Family Nabidae)

Adult Lacewing (Order Neuroptera, Family Chrysopidae)

Lacewing Larva


Lacewing Eggs

Lady Beetle Eggs

Lady Beetle Larva

Lady Beetle Pupa


Convergent Lady Beetles *(Hippodamia convergens)*

Multicolored Asian Lady Beetle *(Harmonia axyridis)*


Seven Spotted Lady Beetle *(Coccinella septempunctata)*

Thirteen-spotted Lady Beetle *(Hippodamia tredecimpunctata)*


Transverse Lady Beetle *(Coccinella transversalis)*

Spider Mite Destroyer (*Stethorus punctillum*)

Minute Pirate Bug (Order Hemiptera, Genus Orius)

Rove Beetle (Order Coleoptera, Family Staphylinidae)


European Mantis *(Mantis religiosa)*

Syrphid Fly (Order Diptera, Genus Syrphidae)

Long-legged Flies (Order Diptera, Family Dolichopodidae)

Feather-legged Fly *(Trichopoda pennipes)*

Aphid pararasitized by a parasitic wasp.

Parasitic wasps laying eggs in an aphid.


Aphid killed by the entomopathogenic fungus *Beauveria bassiana.*

CHAPTER 4: BRASSICA PRODUCTION

Varietal Selection

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

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

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

BROCCOLI
Emerald Crown, Gypsy, Hallmark, Marathon, Packman, Premium Crop
BRUSSELS SPROUTS
Atlantic, Calypso, Cross Country, Jackson, Multipik, Napoleon, Pikmaster, Quest, Shenandoah, Vlasset
CABBAGE
Artost, Caraflex, Bronco, Cairo (red), Quisto, Rendero (red), Surprise
CAULIFLOWER
Amazing, Denali, Freedom, Hermon, Minuteman, Synergy, Whistler
KALE
Red Russian, Redbor, Rogue, Starbor, Winterbor
KOHLRABI
Kolibri (red), Konan, Kongo, Early Purple Vienna

Transplant Production

Start transplants in a greenhouse for the earliest planting, in a cold frame/high tunnel for slightly later crops, and in outdoor seedbeds or directly in the field when the weather is warm enough for germination and growth (above 50 °F). For most brassica crops, the minimum temperature for germination and growth is 40°F, the optimum range is 50 °F to 85°F (ideal 75 °F), and the maximum is greater than 90 °F. It takes 6 to 8 weeks for plants to reach transplant size, and 1 oounce of seed will produce about 5,000 transplants.

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

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

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

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

Soil

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

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

Fertility

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

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

Table 4.2. *Phosphorus (P_2O_5) and Potassium (K_2O) Based on Soil Test Results*

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

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

Transplants are "watered in" with a high P starter fertilizer at ¼ to ½ pint per plant. The starter fertilizer is applied in addition to the broadcast of banded fertilizer. Most brassicas need additional magnesium and boron for optimal growth. Be sure to test soil for these minor use nutrients and add them prior to planting.

Nitrogen (N) – Up to 50 lbs N/acre can be applied before planting. High pre-plant soil N levels cause seed or transplant establishment problems, N leaching, and is wasteful since plants use very little N during the first 4 weeks of field growth. An additional 75 pounds to 120 pounds. N/acre is often applied in two sidedress applications. Based on the N uptake pattern in brassicas and extensive research, the first sidedressing is at thinning or 4 weeks after transplanting. The second, if needed, is 4-6 weeks later. Research shows that if pre-sidedress soil nitrate-N concentration is below 20 ppm, the brassicas will respond to additional N. Excessive N applications cause loose, soft heads and splitting in cabbage and Brussels sprouts. For broccoli or cauliflower, excess N contributes to nonuniform, rough, leafy heads and hollow stems (see other production problems on pg. 41). Use less N if the soil had additions of manure, compost, or when brassicas are grown after legumes (beans, alfalfa, etc.).

Planting, Spacing, and Thinning

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

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

Plant and row spacings vary with cultivar grown, plant growth habit, available equipment, irrigation approach, and market requirements. The following spacings in Table 4.3 are common and only provided as recommendations.

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

Table 4.3. *Brassica Row Spacing*

Crop	Between rows (ft.)	Within rows (in.)	Plants/ acre
Brussels sprouts	2.5-3.5	18-30	5,000-12,000
Cabbage, broccoli, cauliflower	1.5-2.5	8-24	8,700-40,000
Kohlrabi, mustards, pak choi, etc.	1-2	6-15	17,500-87,000

Irrigation

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

Monitor soil water status regularly to maintain consistent, uniform water supply. Use soil moisture monitoring sensors and weather-based irrigation scheduling to monitor plant needs. Place sensors at various locations in the field and at several depths in the soil profile to accurately measure soil water content. Start irrigating at 20% to 25% depletion when irrigating by drip and at 35% to 45% depletion for furrow or sprinkler systems. Water extraction estimates, using reference evapotranspiration adjusted with a crop coefficient (kc), are closely related to row canopy cover in the brassicas. The kc is about 0.3 for a crop with 25% row cover, 0.6 for 50% cover, and 1 for 85% cover. Note that irrigation also depends on your soil type (Table 4.4). ATTRA Sustainable Agriculture's publication Soil Moisture Monitoring: Low -Cost Tools and Methods (https://attra.ncat.org/publication/soil-moisture-monitoring-low-cost-tools-and-methods/) contains more suggestions for managing soil moisture.

Table 4.4. *Soil Tension Values for Different Soil Textures*

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

Note. Use in scheduling drip irrigation, based on various percentages of depletion of available water holding capacity (field capacity).

Harvest and Handling

Broccoli - Depending on the variety, it often takes 50-70 days from transplanting till harvest. Mature heads should be compact, uniform in color (no yellowing or flowering), and tight. Cut the center head with 3-4 inches of stem. Side shoots will develop if plants are watered and fertilized. These shoots are harvested as bunching heads over several weeks. For a continuous supply of the main crowns, seed and/or transplant every 2 to 3 weeks from early spring until mid-July.

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

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

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

Greens (Collards, Kale, Mustards) - Depending on the variety, it often takes 50-70 days from planting till harvest. Leaves are commonly hand-harvested. Cut off the whole plant at the base or individually remove older leaves, allowing the plant to continue to growing. Leaves are washed, tied, and packed in cardboard boxes. Fields may be harvested three or four times as maturity time may vary and quality deteriorates with age.

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

Postharvest and Storage

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

For more detail on storing and handleing different brassicas, refer to the specific produce fact sheets available through the University of California - Davis Postharvest Technology website (postharvest.ucdavis.edu). These fact sheets are comprehensive guides to maintaining postharvest quality of the specific crops.

Weed Management

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

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

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

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

Herbicides are applied in the following ways:

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

Physiological Disorders

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

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

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

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

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

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

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

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

Insect and Mite Pest Management

Aphids

Cabbage Aphid *(Brevicoryne brassicae)*

DESCRIPTION

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

LIFE HISTORY

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

DAMAGE

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

MANAGEMENT

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

Cultural:

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

Chemical:

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

Biological:

Natural enemies include lady beetles, lacewings, syrphid flies, and parasitic wasps. These and other predators play a major role in naturally suppressing aphids.

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Pests on Vegetables*
- *Aphid Natural Enemies and Biological Control*
- *High Tunnel Pest Management - Aphids*

Cabbage Looper *(Trichoplusia ni)*

DESCRIPTION

Adult: The brown-colored moth with a silvery figure eight or "U" shape with a circle beneath on the front wings.
Egg: Eggs are yellowish-white to green, dome-shaped with longitudinal ridges, and laid singly or in groups of six to seven on the upper or lower leaf surfaces.
Larva: The green caterpillars are about 38 mm long at maturity, with a white stripe along each side of the body and several narrow lines along the back. Distinguished by their "loop-like" crawling, where the midsection of their body forms a loop as they bring

their back legs (prolegs) toward their front legs.
Pupa: The pupa, about 19 mm long, develops inside a thin white cocoon on the underside of foliage, plant debris, or in soil clods.

LIFE HISTORY

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

DAMAGE

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

MONITORING

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

MANAGEMENT

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

Cultural:

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

Biological:

Insecticides containing *Bacillus thuringiensis var. kurstaki* (Bt) and spinosad (e.g., Entrust) are effective in suppressing cabbage looper larvae. Bt must be applied when larvae are still young (< 12 mm long), and plant coverage is important as Bt must be ingested by larvae to be effective.

Chemical:

When more than one cabbage looper larva is found in 1 of 10 monitored plants (10%), treat just before heading or at Brussels sprout formation. Seedlings only require treatment if medium- to large-sized caterpillars are present, and defoliation (loss of plant tissue) exceeds 10%.

USU EXTENSION FACT SHEET REFERENCES

- *Caterpillar Pests of Brassica Vegetables*
- *High Tunnel Pest Management - Caterpillars*

Diamondback Moth *(Plutella xylostella)*

DESCRIPTION

Adult: Small (8 mm), slender, grayish-brown moths have folded wings that flare outward and upward at the hind end. Male moths have a row of three yellow diamond-shaped spots down the middle of their back.
Egg: Eggs are very small and yellow to white in color; laid singly or in groups of two to three on the underside of lower leaves or stalks.
Larva: Mature larvae are about 9 mm long with a pale yellow-green body that is pointed at both ends. Diamondback larvae are distinguished by their habit of wriggling vigorously or dropping from a plant on a string of silk when disturbed.
Pupa: Pupae are green and develop in a loosely spun, lace-like cocoon that is attached to the leaves or stems.

LIFE HISTORY

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

DAMAGE

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

MONITORING

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

MANAGEMENT

Cultural and Mechanical:

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

Biological:

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

Chemical:

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

USU EXTENSION FACT SHEET REFERENCES

- *Caterpillar Pests of Brassica Vegetables*
- *High Tunnel Pest Management - Caterpillars*

Imported Cabbageworm *(Pieris rapae)*

DESCRIPTION

Adult: White butterflies have a wingspan of about 45 mm and one to four black spots on the wings.
Egg: Eggs are rocket-shaped, and white to cream (eventually turning yellow); laid on the undersides of leaves.
Larva: About 32 mm long at maturity, larvae have a green, velvet-like body, and a yellow-orange stripe down the center of the back.

Pupa: Pupae are green with yellow stripes on the back and sides; there is no outer cocoon.

LIFE HISTORY

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

DAMAGE

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

MONITORING

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

MANAGEMENT

Cultural:

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

Biological:

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

Chemical:

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

USU EXTENSION FACT SHEET REFERENCES

- *Caterpillar Pests of Brassica Vegetables*
- *High Tunnel Pest Management - Caterpillars*

Flea Beetles

Three-Spotted Flea Beetle *(Disonycha triangularis)*
Crucifer Flea Beetle *(Phyllotreta cruciferae)*
Western Black Flea Beetle *(Phyllotreta pusilla)*
Hop Flea Beetle *(Psylliodes punctulata)*

GENERAL DESCRIPTION

Adult: About 3 mm long, adults have small dark metallic bodies and enlarged hind legs that enable them to jump long distances (hence the name "flea"). Some adult flea beetle species are striped.
Egg: Elliptical in shape, and white to yellowish gray, eggs are laid in clusters or singly in the soil at the base of host plants.
Larva: Larvae are small, white, and worm-like with a brown head.
Pupa: Small and cream to white; they pupate in the soil.

GENERAL LIFE HISTORY

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

DAMAGE

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

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

MONITORING

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

MANAGEMENT

Cultural:

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

Chemical:

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

Biological:

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

USU EXTENSION FACT SHEET REFERENCES

Flea Beetles on Vegetables

Brassicas

Root Maggots

Cabbage Maggot *(Delia radicum)*

DESCRIPTION

Adult: These dark gray flies are about half the size of the common house fly.
Egg: Small white, oval-shaped; eggs are typically laid on the soil near the stem of the host plant.
Larva: Small, white, legless maggot have a blunt tail-end and pointed head.
Pupa: They are about 6 mm long and brown.

LIFE HISTORY

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

DAMAGE

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

MONITORING

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

MANAGEMENT

Cultural:

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

Biological:

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

Chemical:

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

Seedcorn Maggot *(Delia platura)*

DESCRIPTION

Adult: Seedcorn maggot adults are about 5 mm long with gray to brown bodies and are similar in appearance to the onion maggot.
Egg: White elongated eggs are deposited in soils rich in organic and decaying matter and on seeds and seedlings.
Larva: Maggots are legless, tapered, about 6 mm long, and yellowish-white. Head-ends are wedge shaped with small black mouth hooks in front.

Pupa: Ova-shaped and dark brown, pupa are about the size of a wheat grain 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 on seeds. Eggs hatch in 2 to 4 days at which point the larvae burrow into seeds and feed on emerging cotyledons and plant roots. Mature larvae pupate in the soil and remain in this stage approximately 7 to 14 days. Seedcorn maggots overwinter as pupae. A complete generation takes about 3 to 4 weeks and about 2 to 3 generations occur per year.

DAMAGE

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

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

MANAGEMENT

Cultural:

- *Apply cultural control methods.* Use the methods listed above in the cabbage maggot management section.
- *Direct-seed when conditions are ideal for rapid seed germination.* Longer germination time results in higher infestation risks.
- *Avoid early season infestations.* Plant susceptible hosts later in the season.

Biological:

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

Chemical:

Apply a preventive seed treatment for optimal control.

Refer to Tables 4.6 and 4.7 for more information on commercial and small-scale insecticide use.

Disease Management

Bacterial Soft Rot *(Pectobacterium carotovorum)*

CAUSAL AGENT

Bacterial soft rot is caused by the bacteria *Pectobacterium carotovorum.* It affects many vegetable crops including brassicas.

SYMPTOMS

Water-soaked lesions on foliage develop early in the season. Cabbage will develop an internal mass of macerated tissue. Slime will ooze from cracks or other openings. Broccoli and cauliflower heads become brown and sunken.

DISEASE CYCLE

It is spread by splashing water, various insects, and pruners and other equipment. The disease thrives in a warm and humid environment. Bacteria enter through plant wounds and can survive in plant debris left in the garden. Bacterial soft rot may also develop within stored produce.

MANAGEMENT

- *Decontaminate knives or other tools used when harvesting and moving from plant to plant.*
- *Remove cull piles near production sites.* Plant debris can harbor bacteria and be a source of infection.
- *Ensure soil is well-draining.* High moisture increases the spread of bacteria.

Turnip Mosaic Virus

CAUSAL AGENT

Turnip mosaic virus (TuMV) is a plant pathogenic virus belonging to the Potyvirus genus and is primarily transmitted by aphids. This virus can infect a wide range of *Brassica* spp. crops causing significant damage to their growth and yield.

SYMPTOMS

Mottled leaves appear with a characteristic light and dark green mosaic pattern, yellowing, stunted growth, and leaf distortion. Severe cases may also exhibit necrotic areas and reduced yields.

DISEASE CYCLE

Aphids serve as the vector and acquire the virus when they feed on infected plants. They subsequently transmit the virus to healthy plants during feeding, leading to infection. The virus multiplies within the host, causing characteristic symptoms, and infected plants serve as sources for further transmission by aphids. TuMV can also survive in plant debris and weed hosts.

MANAGEMENT

- *Use resistant varieties.* Source plant cultivars that are labeled resistant to tolerent of TuMV.
- *Practice sanitation.* Practicing good sanitation is essential. Remove and destroy infected plant material to prevent the virus from persisting in the field. This includes not only the main crop but also any nearby weeds that could act as reservoirs for the virus.
- *Control aphids.* Managing aphid populations, which are the primary vectors of TuMV, is crucial. This can be achieved by using insecticides, promoting beneficial insect predators, and using physical barriers like row covers to prevent aphid access.
- *Use reflective mulches.* In some cases, using reflective mulches can deter aphids from landing on plants, reducing the risk of virus transmission.

Brassica Pesticide Tables for Commercial and Small-Scale Use

Table 4.5. *Herbicides* *Registered for* ***COMMERCIAL*** *Use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.)*

Brand name (Rei/phi)	Active ingredient	Timing and Application Location Relative to crop				Timing relative to weeds		Weed groups controlled			Comments
		Pre- transplanting	Pre-plant incorporate	Post-transplanting	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X	X	X	X		X		X	X	Use shield between rows
Command 3 ME (12hr/45d)	clomazone	X	X			X		X	X	X	Note crop restrictions
Dactha; W75 (12h/30d)	DCPA	X	X	X		X		X			Note crop restrictions
Goal (12hr/14-20d)	oxyflourfen		X			X	X		X	X	Note crop restrictions
Gramaxone Inteon (12hr/30d)	paraquat	X	X				X	X	X	X	Restricted use material
RoundUp & others (12hr/14d)	glyphosate	X	X	X	X		X	X	X	X	Used shield between rows
Prefar 4E (12hr/-)	bensulide	X	X			X		X			
Poast (12hr/14-30d)	sethoxydim			X	X		X	X			
Devrinol (12hr/60d)	napropamide	X	X			X		X	X	X	
Select 2EC (12hr/14-30d)	clethodim			X	X		X	X			
Spartan 4F (12hr/14-20d)	sulfentrazone	X				X			X	X	Cabbage only
Stinger (12hr/30d)	clopyralid			X	X		X		X	X	
Treflan & others (12hr/30d)	trifluralin	X	X	X		X		X	X	X	
Organic Products											
Corn gluten meal		X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 4.6. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Cabbage maggot	Grasshopper	Earwig
carbaryl	Carbaryl 4L, Drexel Carbaryl 4L, Sevin 4F, Sevin XLR Plus	1A	10-14		X	X		X		X	
	Sevin 5 Bait, Carbaryl Cutworm Bait, Drexel Carbaryl 5% Bait				X					X	
	Sevin SL Carbaryl				X	X		X			
methomyl	Corrida 29 SL, Corrida 90 WSP, Lannate LV, Lannate SP, Nudrin LV, Nudrin SP	1A	10-14			X	X	X			
malathion	Drexel Malathion 5EC, Fyfanon 57% EC, Fyfanon Malathion, Malathion 57 EC, Malathion 57%, Malathion 8 Aquamul	1B	5-7	X	X	X	X	X			
	Malathion 5			X			X				
alpha-cypermethrin	Fastac CS, Fastac EC	3A	10-14	X	X	X	X	X		X	
	Afflict 30SG, Anarchy 30SG, Anarchy 70WP, Assail 30SC, Assail 30SG, Assail 70 WP, Intruder Max 70WP, Omni Acetamiprid 30 SG, Omni Brand Acetamiprid 70 WP, Savoy EC			X				X			
	TriStar 8.5 SL				X		X	X			
beta-cyfluthrin	Baythroid XL, Sultrus	3A	14		X	X	X			X	

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O = Organic

Table 4.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Cabbage maggot	Grasshopper	Earwig
bifenthrin	Avenger Max, Batallion 10 WSP, Batallion 2 EC, Bi-Dash 2E, Bifenthrin 2EC, Bifenture EC, Brigade 2EC, Fanfare ES, GCS Bifenthrin 2EC	3A	2-3 wks	X	X	X	X	X		X	
	Batallion LFC, Bifender FC, Capture LFR, GCS Bifenthrin LFC, Lancer FC			X	X	X	X	X	X		
	Brigade WSB, Discipline 2EC, Fanfare 2EC			X	X	X	X				
	Omni Bifenthrin 2EC, Reveal, Tempest, Tundra EC				X	X	X	X			
	Skyraider				X	X	X	X		X	
	Sniper, Sniper Helios				X	X	X	X			
	Sniper LFR				X	X	X	X	X		
	Steed, Swagger				X	X	X	X		X	
	Surrender G				X		X			X	X
	Xpedient Plus								X		
cyfluthrin	Tombstone, Tombstone Helios	3A	10-14		X	X	X			X	
esfenvalerate	Asana XL, S-FenvaloStar	3A	10-14		X	X	X			X	
fenpropathrin	Danitol 2.4 EC	3A	14	X		X	X	X	X		
gamma-cyhalothrin	Declare	3A	10-14	X	X	X	X	X		X	
lambda-cyhalothrin	Crusader 2ME, Drexel L-C, Endigo ZCX, Grizzly Too, Kendo, Kendo 22.8 CS, Lambda Select, Lambda T, Lambda T-2, Lambda-CY AG, Lambda-Cy EC, LambdaStar, LambdaStar 1 CS, LambdaStar Plus, Lamcap II	3A	10-14	X	X	X	X	X		X	
	Lambda-Cyhalothrin 1 EC, Paradigm VC, Province II, Ravage, Ravage 2.0, Roundhouse 1 EC, Serpent 1 EC, Silencer, Tigris Lambda, Warrior II with Zeon Technology, Willowood Lambda 1EC				X	X	X	X		X	
	Willowood Lambda-Cy 1EC, Omni Lambda 1 EC				X	X	X	X			

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Table 4.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Cabbage maggot	Grasshopper	Earwig
permethrin	Arctic 3.2 EC	3A	14	X		X	X	X			
	Perm-UP 3.2 EC, PermaStar AG, Permethrin, Pounce 25 WP				X	X	X	X			
pyrethrins[O]	EverGreen Crop Protection EC 60-6	3A	5-7	X		X	X			X	
	PyGanic Crop Protection EC 1.4 II, PyGanic Crop Protection EC 5.0 II, Tersus				X	X	X	X	X	X	X
	Pyrenone Crop Spray				X	X	X	X		X	X
zeta-cypermethrin	Cortes Maxx Insecticide, Hero EW	3A	10-14	X	X	X	X	X		X	
	Hero			X	X	X	X	X	X	X	
	Mustang				X	X	X	X		X	
	Mustang Maxx				X	X	X	X	X	X	
clothianidin	Belay	4A	10-14	X	X						
dinotefuran	Certador, Scorpion 35SL, Venom	4A	14	X	X						
imidacloprid	Admire Pro , Advise Four, Alias 4F, Imidashot DF, Lada 2F, Macho 2.0 FL, Macho 4.0, Malice 2F, Mallet 2F T&O, Acronyx 4 F	4A	14	X	X						
	Alias 2F			X							
	Brigadier			X	X	X	X	X			
	Kilter			X	X	X	X	X		X	
	Nuprid 2SC, Nuprid 4F Max, Omni Imidacloprid 4F, Prey 1.6, Provoke, Sherpa, Viloprid FC 1.7, Widow, Willowood Imidacloprid 4SC, Midash 2SC, Omni Imidacloprid 2F, Montana 4F				X						
thiamethoxam	Actara	4A	14	X							
	Platinum 75 SG				X						
spinetoram	Radiant SC	5	10-14			X	X	X			
spinosad[O]	Conserve SC, Entrust, Entrust SC, SpinTor 2SC, Success	5	5-7		X	X	X	X			
	Seduce Insect Bait										X

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[O] = Organic

Table 4.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Cabbage maggot	Grasshopper	Earwig
emamectin benzoate	Proclaim	6	7-14			X	X	X			
pyriproxyfen	Senstar	7C	14					X			
pymetrozine	Achiever, Endeavor, Fulfill	9B	7-10	X							
Bacillus thuringiensis^{O}	Agree WG, Leap ES	11A	5-7			X					
	Biobit HP WP, Bioprotec PLUS, BT NOW, Crymax, Deliver, DiPel DF, Javelin WG, Leprotec, XenTari					X	X	X			
methoxyfenozide	Acora, Engame, GCS Methoxy 2F, Inspirato 2 F, Intrepid 2F, Invertid 2F, Troubadour 2F, Vexer, Zylo	18	10-14			X	X	X			
tolfenpyrad	Torac	21A	14		X	X		X	X		
indoxacarb	Avaunt, Avaunt eVo, Comber,	22A	14			X	X	X			
spirotetramat	Kontos, Movento	23	14	X							
chlorantraniliprole	Besiege	28	14	X	X	X	X	X		X	
	Coragen Insect Control					X	X	X	X	X	
	Shenzi 400SC					X	X	X		X	
	Durivo			X	X	X	X	X			
cyantraniliprole	Exirel, Verimark	28	10-14		X	X	X	X			
cyclaniliprole	Harvanta 50SL	28	14-17	X	X	X	X	X			
flonicamid	Beleaf 50 SG	29	14	X							
GS-Omega/Kappa-Hxtx-HV1a^{O}	Spear-LEP	32	5-7		X	X					
azadirachtin^{O}	Atrevia 1.2% SL, Atrevia 3.0% SL, Aza-Direct, Aza-Guard, AzaSol, Azatin O	UN	7-10	X	X				X		
Beauveria bassiana^{O}	BotaniGard 22WP, BotaniGard ES, BotaniGard Optima ES, BoteGHA ES, BoteGHA Optima ES	UN	5-7	X	X	X	X	X		X	
	Mycotrol ESO, Mycotrol Optima ESO, Mycotrol WPO				X	X	X	X		X	
Burkholderia spp.^{O}	Venerate CG, Venerate XC	UN	7-10			X	X	X			
canola oil^{O}	Pycana	UN	3	X	X				X		

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Table 4.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Cabbage maggot	Grasshopper	Earwig
Chromobacterium subtsugae$^{\circ}$	Grandevo, Grandevo CG	UN	5-7	X	X	X	X	X			
	Grandevo WDG			X		X	X	X			
geraniol$^{\circ}$	Brandt Ecotec Plus	UN	3	X	X						X
Isaria fumosorosea$^{\circ}$	Nofly WP	UN	5-7		X					X	
	PFR-97 20% WDG				X						
iron phosphate	Bug-N-Sluggo	UN	2-4 weeks								X
kaolin$^{\circ}$	Surround WP	UN	5-7		X						
mineral oil$^{\circ}$	BioCover MLT, BioCover SS, BioCover UL, Glacial Spray Fluid, PureSpray GREEN, Omni Supreme Spray, SuffOil-X, TriTek	UN	3	X	X						
potassium salts of fatty acids$^{\circ}$	Des-X, Kopa Insecticidal Soap, M-Pede	UN	5-7	X							
sodium tetraborate	Prev-AM, Prev-AM ULTRA	UN	5-10			X	X	X			

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

$^{\circ}$ = Organic

Table 4.7. *Insecticides* for *SMALL-SCALE* use on *Brassicas* (Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)

Active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Root maggot	Grasshopper	Earwig
bifenthrin	Ferti-lome Broad Spectrum Insecticide, Ferti-lome Broad Spectrum Insecticide RTS	3A	2-3 wks	X	X					X	X
	Hi-Yield Vegetable & Ornmental Insect Control Granules								X	X	X
	Bonide Eight Flower & Vegetables Soil Insect Granules										X
	GardenTech Sevin Insect Killer Dust			X	X	X	X	X			
cyfluthrin	BioAdvanced Tomato & Vegetable Insect Killer	3A	14		X	X	X	X		X	
lambda-cyhalothrin	Bonide Eight Garden & Home RTU, GardenTech Sevin RTU, Spectracide Triazicide Insect Killer for Lawns & Landscapes RTU	3A	10-14	X	X	X	X	X		X	
permethrin	Hi-Yield Garden & Farm Insect Control, Hi-Yield Garden, Pet, & Livestock Dust	3A	14			X	X	X			
	Bonide Eight Vegetable, Fruit, & Flower Concentrate, Bonide Eigth Yard & Garden RTS, Bonide Insect Control Garden Dust			X		X	X	X			
pyrethrins[O]	Monterey Bug Buster-O	3A	5-7	X	X	X	X	X	X	X	X
zeta-cypermethrin	GardenTech Sevin Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X	X	X			
pyrethrins[O] + canola oil[O]	Epsoma Organic Insect Control	3A/UN	5-7	X	X	X				X	
pytherins[O] + biperonyl butoxide[O]	Bonide Pyrethrin Garden Spray Concentrate	3A/UN	5-7	X	X	X	X	X			
pyrethrins[O] + potassium salts of fatty acids[O]	Safer Brand Insecticidal Soap + Pyrethrin Concentrate	3/A UN	5-7	X	X	X	X	X			
pyrethrins[O] + neem oil[O]	Ferti-lome Triple Action, Ferti-lome Triple Action Plus RTU	3A/UN	3-5	X	X	X	X	X		X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

[O] = Organic

Table 4.7., continued. ***Insecticides*** *for* ***SMALL-SCALE*** *use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Root maggot	Grasshopper	Earwig
malathion	Hi-Yield 55% Malathion Spray, Spectracide Malathon Insect Spray Concentrate	3B	5-7	X							
	Othro MAX Malathion Insect Spray Concentrate			X	X	X	X		X		
	Bonide Malathion Concentrate			X	X			X			
imidacloprid	BioAdvanced Fruit, Citrus, & Vegetable, Monterey Fruit Tree & Vegetable Systemic Soil Drench	4A	N/A	X							
spinosad°	Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Colorado Potato Beetle Beater, Monterey Garden Insect Spray, Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS	5	7-10		X	X	X	X			
	Bonide Captain Jack's Deadbug Brew Dust					X	X	X			
Bacillus thuringiensis°	Bonide Captain Jack's BT, Bonide Thuricide (BT) Concentrate, Monterey B.T., Monterey B.T. RTU	11	5-7			X	X	X			
Bacillus thuringiensis var. Kurstaki°	Natural Guard Caterpillar Killer Spray with BT, Safer Brand Caterpillar Killer II Concentrate	11	5-7			X	X	X			
	Ferti-lome Dipel Dust					X	X	X			
sulfur° + pyrethrins°	BioAdvanced Fruit & Vegetable 3-in-1Solution Concentrate, BioAdvanced Fruit & Vegetable 3-in-1 Solution RTS, Natria Insect, Disease, and Mite Control RTU, Natria Insect, Disease, and Mite Control RTS	UN/3A	10-14	X	X	X	X	X	X		X
iron phosphate + spinosad°	Monterey Sluggo Plus, Natural Guard Bug, Slug, & Snail Bait	UN/5	2-4 weeks								X

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° = Organic

Table 4.7., continued. ***Insecticides*** *for* ***SMALL-SCALE*** *use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Root maggot	Grasshopper	Earwig
potassium salts of fatty acids[O] + spinosad[O]	Bonide Insecticidal Super Soap RTU, BioAdvanced Organic Tomato, Vegetable, & Fruit RTU, Monterey Garden Insect Spray RTU, Natural Guard Spinosad Soap Concentrate, Natural Guard Spinosad Soap RTU, Natural Guard Spinosad Soap RTS	UN/5	5-7	X	X	X	X	X			X
canola oil[O]	Natural Guard Horticultural Oil Concentrate, Natural Guard Horticultual Oil Concentrate RTS	UN	3	X							
cotton seed oil[O] + clove oil[O] + garlic oil[O]	Bonide Mite X RTU	UN	3	X							
neem oil[O]	Safer Brand Neem Oil Concentrate	UN	3	X	X						
	BioAdvanced Organics Neem Oil RTU, Epsoma Organic Neem Oil 3n1, Monterey 70% Neem Oil, Natria Neem Oil Concentrate, Natria Neem Oil RTU, Natural Guard Neem Oil Concentrate, Natural Guard Neem RTU			X							
potassium salts of fatty acids[O]	BioAdvanced Organics Insecticidal Soap RTU, Bonide Insecticidal Soap RTU, Natria Insecticidal Soap RTU, Natural Guard Insecticidal Soap	UN	3	X						X	X
	Epsoma Organic Insect Soap, Monterey Insecticidal Soap RTU			X							X
potassium salts of fatty acids[O] + neem oil[O]	Safer End All Insect Killer RTU	UN	3	X	X						X
potassium salts of fatty acids[O] + seaweed extract	Safer Insect Killing Soap Spray RTU	UN	3	X							X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

[O] = Organic

Table 4.7., continued. ***Insecticides*** *for* ***SMALL-SCALE*** *use on* ***Brassicas*** *(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, Kohlrabi, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Flea beetle	Imported cabbageworm	Cabbage looper	Diamondback moth	Root maggot	Grasshopper	Earwig
potassium salts of fatty acids + sulfur[o]	Safer 3-in-1 Concentrate, Safer Tomato & Vegetable 3-in-1 Garden Spray, Safer Brand 3-in-1 Garden Spray RTU	UN	5-7	X							X
	Safer Insect Killing Soap Concentrate			X						X	X
silicon dioxide	Natural Guard Diatomaceous Earth Crawling Insect Control	UN	7-14							X	X
	Bonide Diatomaceous Earth			X	X	X	X	X		X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

[o] = Organic


Commercial broccoli production at a farm in Utah County.


Commercial kale production at a farm in Davis County.

Symptoms of nitrogen deficiency in cauliflower.

Brown beading occuring in a broccoli head.

Leaf bracts occuring in a broccoli head.

Blindness in a cabbage plant.

Hollow stem in cauliflower.


Splitting of a cabbage head.

Cabbage Aphids *(Brevicoryne brassicae)*


Cabbage aphid colony on a cabbage plant.


Wild mustard plant infested with cabbage aphids.

Cabbage Looper Moth *(Trichoplusia ni)*


Cabbage Looper

Cabbage Looper Pupa

Diamondback Moth (*Plutella xylostella*)


Diamondback Moth Larva


Diamondback Moth Pupa

Imported Cabbageworm Butterfly *(Trichoplusia ni)*


Imported Cabbageworm Larva

Imported Cabbageworm Pupa

Crucifer Flea Beetle
(Phyllotreta cruciferae)

Western Black Flea Beetle
(Phyllotreta pusilla)

Hop Flea Beetle *(Psylliodes punctulata)*

Flea beetle feeding damage on broccoli foliage.

Cabbage maggot *(Delia radicum)* feeding damage on brocolli roots.

Seedcorn Maggot Fly *(Delia platura)*

Bacterial soft rot *(Pectobacterium carotovorum)* in cabbage.

Turnip Mosaic Virus (TMV) symptoms on kale.

CHAPTER 5: CUCURBIT PRODUCTION

Varietal Selection

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

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

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

Table 5.1. ***Variety Suggestions*** *– Cucumber, Melon, Pumpkins, and Squash*

CANTALOUPE	
Trinity, Edisto Star, Yuma Grande, Top Net, Anita, Sweet East, Western Charm, Olympic Express, Olympic Gold, Western Express, El Camino, Primo, Torreon, Coronado, USAM90000	
CUCUMBERS	
Pickling	*Atlantic, Calypso, Cross Country, Jackson, Multipik, Napoleon, Pikmaster, Quest, Shenandoah, Vlasset*
Slicing	*Centurion, Dasher II, Meteor, General Lee, Marketmore 76, Raider, Slice Nice, Striker, Turbo*
Tunnel	*Unistar, Katrina, Socrates, Iznik, Diva*
MELONS (OTHER)	
Honeydew melons	*Precious Dew, Dewlightful, #252 HQ, Moon Dew, Honeybrew, Snow Mass, USAMX 23000, USAMX 63001, Dulce Nectar*
Casaba-crenshaw-specialty melons	*Juan Coronel, Ananas Hyb EM815, EM850 Galia F1, Casaba Golden Beauty, Tamara, Visa, Lilly*
PUMPKIN	
New England Pie, Munchkin, Small Sugar, Spookie, Autumn Gold, Spirit, Connecticut Field, Howden, Big Max, Atlantic Giant, Polar Bear, Moonshine	
SQUASH	
Summer squash	*crookneck, patty pan, round, straight neck, yellow, green and striped zucchini*
Winter squash	*acorn, banana, buttercup, butternut, delicate, Hubbard, kabocha, spaghetti, turban*
WATERMELONS	
Seeded (diploid) – open pollinated	*Crimson Sweet, Jubilee, Sugar Baby, All Sweet, Cal Sweet, Charleston Grey*
Seeded (diploid) – hybrid	*Sentinel, Sangria, Mara, Sweet Star, Fantasy, Sweet Fashion, EM Scarlet, Carmen, Starbrite*
Seedless (triploid) – red flesh	*Coopertown, Majestic, Fascination, Distinction, Marita, Affirmed, Citation, Millionaire, Ruby, Tiger Eye, Liberty, Freedom*
Seedless (triploid) – yellow flesh	*Yellow Buttercup*
Pollinators	*Gladiator, Polimax, Ace, Wild Card, Sidekick, Accomplice*

Cucurbits

Transplant Production

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

Greenhouse growth temperatures for cucurbits should be approximately 75 °F during the day and 65 °F at night. Allow 4-5 weeks to grow transplants depending on greenhouse growing temperatures. All cucurbit transplants should have two to three mature leaves and a well-developed root system before transplanting to the field. After seeding and watering the trays, expose the seeds to 85 °F to 90 °F temperature conditions for 30-40 hours. You can do this in a dark room with the trays stacked atop each other or use heating pads if only a few trays are needed. Higher tray temperatures after seeding helps create conditions for more uniform germination and plant stands. However, do not allow the seeds to emerge in high heat conditions. Longer exposures times (+48 hours) to high temperatures result in elongated hypocotyls which make the plants grow tall and leggy. These seedlings are then difficult to handle and transplant.

Once seedlings emerge, water regularly and feed twice weekly with a soluble complete fertilizer diluted to 100 ppm nitrogen. Brushing the plants each day, 1 week before planting, helps strengthen the stem. Brushing should be done when the leaves are dry to minimize disease transfer. Transplants can also be hardened or conditioned by exposing them to wind and cooler temperatures to make the plants stocky and strong. Condition or "harden off" transplants for a short time each day by exposing them to cool temperatures (60 °F to 65 °F) starting 1 week before transplanting. Avoid exposing plants to temperatures that are less than 55 °F. Don't over-condition or over-harden the plants, as this will delay establishment and plants will be slow to start growing again.

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

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

Growing seedless watermelon transplants requires a bit more finesse. Since seedless types are less vigorous, slow to germinate, and emerge erratically. Early temperature management after seeding helps improve establishment and uniformity. After seeding and watering the plug trays, expose the seeds to 85 °F to 90 °F temperature conditions for 36-40 hours —but no longer. You can do this in a dark room with the trays stacked on top of each other or use heating pads if only a few trays are needed. Move seeds to cooler growing temperatures after emergence. Longer exposure to high temperatures results in elongated hypocotyls, which make the plants grow tall and leggy. These seedlings are then difficult to handle and transplant.

Water regularly and feed twice weekly with a soluble complete fertilizer diluted to 100 ppm nitrogen after the seedlings emerge. Brushing the plants each day 1 week before planting helps strengthen the stem. Brushing should be done when the leaves are dry to minimize disease transfer. Transplants can also be hardened or conditioned by exposing them to wind and cooler temperatures to make the plants stocky and strong. Condition or "hardened off" transplants for a short time each day by exposing them to cool temperatures (60 °F to 65 °F) starting 1 week before transplanting.

USU EXTENSION FACT SHEET REFERENCES

- *Vegetable Transplant Production*

Soil

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

Most of the cucurbits are quite sensitive to herbicides in soil, so pay special attention to site selection if residual herbicides have been used in the past. Crop rotation is another important consideration. Other cucurbits should not be planted within at least 2 years of related crops (cucumbers, squash, melons, watermelon, pumpkins, or gourds). Plant residue from these related crops serves as a host for plant diseases and insects that may infect or infest the next cucurbit crop. Plant residues from the prior crop should be completely buried at the bottom of the furrow to facilitate decomposition. A well-tilled field will help produce a smooth, fine seedbed for uniform planting and emergence. Several weeks before planting, prepare the field. If soils have drainage issues, create 6 to 8 inch raised beds. A very loose, somewhat dry soil is ideal for transplanting to ensure good soil contact with the transplant root ball or seed.

Table 5.2. *Phosphorus (P_2O_5) and Potassium (K_2O) for Cucumber, Pumpkin, and Squash Based on Soil Test Results*

Phosphorus test results	lb/acre
0-14	100-150
15-29	70-100
30-45	40-70
46-60+	0-30

Potassium test results	lb/acre
0-74	100-150
75-149	50-100
150-199	25-50
200+	0-25

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

Table 5.3. *Phosphorus (P_2O_5) and Potassium (K_2O) for Melons Based on Soil Test Results*

Phosphorus test results	lb/acre
0-14	120-150
15-29	90-100
30-45	60-70
46-60+	30-60
60+	0

Potassium test results	lb/acre
0-74	100-150
75-149	50-100
150-199	25-50
200+	0-25

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

Fertility

Before planting, have the soil tested to determine nutrient needs and deficiencies (Tables 5.2 and 5.3). Soil sampling approaches, forms, test details, and interpretation can be accessed through the Utah State University Analytical Laboratories (www.usual.usu.edu). Organic growers find it is a good idea to incorporate composted organic matter before planting to sustain soil fertility. Initially applying 5 tons per acre of high quality compost of known nutrient analysis may be helpful. This can be broadcast over the whole field or banded and incorporated into the individual rows.

A common practice is to add ⅓ to ½ of the required nitrogen fertilizer and all the phosphorous and potassium prior to planting. This fertilizer is either broadcast or banded. In soils with high P and K levels, broadcasting all of the fertilizer is acceptable. This is done before plowing or disking, then worked into the soil during normal field preparations. Banding is a good method to ensure the fertilizer is near the plant and makes sense for crops like winter squash and pumpkins where wide row spacings are common. Fertilizer bands should be 3 inches beside and 3 inches below the seed or transplant to minimize salt injury during establishment. Often, transplanted cucumbers and summer squash are "watered in" with starter fertilizer containing high P levels applied at ¼ to ½ pint per plant. Apply starter fertilizer in addition to the broadcast or banded fertilizer.

Nitrogen (N) – Apply up to 50 pounds N/acre prior to planting. Higher rates of N at planting may cause seed or transplant establishment problems. An additional 50-100 pounds N/acre is often applied in two applications, the first when vines begin to run and

Cucurbits

again around first flowering. Use the smaller amount if the site has added manure, compost or when cucurbits are grown after a legume crop (beans, alfalfa, etc.).

Planting, Spacing, and Thinning

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

Plant and row spacings vary with cultivar grown, plant growth habit (bush/vine types), available equipment, irrigation approach, and market requirements. Typically, in-row plant spacing ranges from 12-18 inches apart for cucumbers in irrigated plantings. Summer squash are often planted 24-30 inches apart while winter squash are planted 30-48 inches apart. Pumpkin spacing in row is commonly 36-60 inches apart depending on vining habit and expected fruit size. Typical row spacings vary from 3 to 10 feet apart. Cucumbers and summer squash are planted at closer row spacings, while winter squash and pumpkin rows are wider apart.

For melons, in-row plant spacing usually ranges from 18 to 30 inches apart in irrigated land to 36 to 48 inches apart in dry land. Typical row spacings vary from 6 to 10 feet apart. Plant seed of open-pollinated varieties at 1-2 pounds of seed per acre at a depth of ½ to 1½ inches (depending on soil moisture, time of year, and irrigation availability). Higher yields occur with closer spacings but the grower will need to adjust nutrient or water management and fruit size may be smaller when plant densities increase.

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

Transplanting

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

To produce seedless watermelon, it is important to understand that triploid (seedless) watermelon flowers do not produce enough pollen to adequately pollinate themselves. Therefore, a pollen source must be available to achieve acceptable levels of fruit set. A diploid (seeded) cultivar planted within the crop can serve as the pollenizer (see Table 5.4).

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

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Summer Squash Production*

Irrigation

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

Soil water status should be monitored regularly to maintain consistent soil water. Soil moisture monitoring is easily done with a resistance block such as the Irrometer® Watermark sensor. Place sensors at various locations in the field and at several depths in the soil profile to get an accurate measure of soil water content. Sensors typically express soil water content as a tension reading (centibars) that defines the effort required to access available water. Soil water monitoring helps determine when to irrigate next. Field capacity describes a soil at 100% available water holding capacity after excess water has drained away. Start irrigation for the cucurbits at 25%-30% depletion when irrigating by drip systems and at 40%-50% depletion of available water-holding capacity with furrow or sprinkler systems. Note that irrigation depends on your soil type (5.4). Reference 'Soil Moisture Monitoring: Low-Cost Tools and Methods' (https://attra.ncat.org/publication/soil-moisture-monitoring-low-cost-tools-and-methods/) from ATTRA Sustainable Agriculture.

USU EXTENSION FACT SHEET REFERENCES

- *Vegetable Irrigation: Melon*
- *Vegetable Irrigation: Squash and Pumpkin*

Table 5.4. *Soil Tension Values For Different Soil Textures*

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

Note. Use in scheduling drip irrigation, based on various percentages of depletion of available water-holding capacity (field capacity).

Ground Mulch and Row Covers

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

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

Plant and row covers can help protect early plantings from frost or wind-damage and enhance yield and earliness. Hot caps and spun-bonded row covers (known as Reemay) are commonly used. Row covers rest directly atop of plants, but should be weighted down to avoid flapping, which causes leaf damage. Remember that row covers need to be opened or removed as plants outgrow the cover, when the plants begin to flower, or when temperatures under the cover regularly exceed 90 °F. When transplanting, plastic mulches can get very hot, and this can cause stem damage to transplants if they touch the plastic. Be sure to water immediately after planting, or mound some soil around the stem to reduce this problem.

Pollination

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

Harvest and Handling

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

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

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

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

Pumpkins - Pumpkins are mature when fruits have achieved normal size, are fully colored, and when the rind is hard. Stop watering 7-10 days before harvest to help dry out the vine and soil. Fruits should be cut from the vine at maturity, leaving a 3-5-inch-long stem. Generally, growers wait at least 2-3 days after harvest to allow time for the stem to cure. When moving, windrowing, or loading the fruits, do not grasp the stem to avoid breaking it off. Fruits can be windrowed and stacked like winter squash before loading out of the field. Avoid storage in the open to minimize sunburn damage and fruit softening.

Watermelons - Watermelons mature 5-6 weeks after pollination (cultivar and temperature dependent). The indicators of watermelon maturity are rind sheen, strong color differentiation between the stripes, creamy yellow color of the ground spot, and drying of the tendril nearest the fruit. Thumping is less effective, but a dull or muffled sound can indicate over-maturity. Ideally, it is best to cut a few melons in various parts of the field and compare these to other maturity indicators. A refractometer can help determine fruit sugar content, and the BRIX values measured should be above 10. Harvesting and marketing under or over-mature fruits can hurt consumer interest and demand. Fruit sugar content does not increase after harvest, but red color does continue to develop after picking. Fields are often harvested over a period of 2 to 3 weeks and may be picked once or twice a week.

To harvest watermelons, cut fruit from the vine, leaving some stem on the fruit. Watermelons should not be stood on end, as flesh separation (hollow heart) can occur. Also, do not expose the ground spot to the sun to reduce sunburn. Over-stacking fruit piles can lead to bruising and compression injury both in the field and in storage. It is common to create small stacks of fruit in the field at harvest, then to come later and load these into bins, trailers, or trucks. Typically, fruit are bulk-loaded into 1,000-pound cardboard boxes as these are easier to handle during loading, transport, and unloading. Few watermelons are graded here in Utah, though specific markets may request some fruit sizing for their customers.

Cantaloupe, Honeydew, and Other Melons - Harvesting specialty melons like cantaloupe and honeydews is very labor-intensive. Melons need to be picked every few days and fields may be harvested over a period of 2 to 3 weeks. Length of harvest depends on vine quality, number of fruits, variety, and market demands. Fruit maturity takes 4-6 weeks after pollination depending on type, temperature, and season.

Cantaloupe are ready for market when fruits are at “half-slip,” well-netted, and of appropriate color for the variety. Half-slip is when the abscission zone between the stem and the fruit is partially formed and it takes a slight pull to separate the fruit from the vine. Cantaloupe harvested at half-slip allows sufficient time from harvest to market so that fruits do not arrive overripe. Typically, fruit are loaded into 1,000-pound cardboard boxes for transport to markets.
Honeydew melons are cut from the vine at maturity. Honeydews are ripe and ready for market when plants have achieved normal size, when the ground spot turns a creamy or a light-yellow color, when a waxy “bloom” develops on the rind, when the blossom end softens slightly, and when small micro-cracks form near the blossom end. Honeydews do not form an abscission zone where the stem and fruit meet, so other maturity indicators are necessary.

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

Postharvest Handling and Storage

Cucumber, Pumpkin, and Squash - The optimal storage conditions for cucumbers is 50 °F to 55 °F and summer squash is 45 °F to 50 °F at 80%-90% relative humidity. Cucumbers and summer squash stored at these conditions generally keep for 7-10 days before fruit shriveling, yellowing, or decay occurs. Storage or transit temperatures should be kept above 45 °F to minimize chilling injury, which takes as little as 2-3 days to occur. Chilling injury symptoms are water-soaked areas, fruit wall pitting, fruit color changes, and accelerated decay. Chilling injury may be initiated in the field prior to harvest, and then gets progressively worse during storage. Cucumber and summer squash varieties vary considerably in their susceptibility to chilling injury.

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

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

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

Watermelons stored at 55 °F to 60°F and 90% humidity will keep for 10-15 days. Do not store below 50 °F, as fruits are sensitive to chilling injury and disease development. If kept at ambient temperatures, watermelon will hold for about 5-7 days. Cantaloupe are highly perishable and will maintain good quality for about 1 week. Full-slip cantaloupe can be stored at 40 °F, but those harvested at half-slip should not be stored below 45 °F, to ensure they ripen properly.

Never store casaba and other specialty melons at temperatures less than 50°F as they are subject to chilling injury. For more detail on storage, handling and ripening techniques of the different melons, refer to the specific produce fact sheets for the different melons available through the University of California - Davis Postharvest Technology website (http://postharvest.ucdavis.edu).

Weed Management

The cucurbits prefer warm weather conditions to ensure high productivity. Many growers transplant early cucumbers and summer squash or seed cucumber, squash, and pumpkins into bare soil and rely on furrow irrigation. Weed control is critical in bare soil systems as weeds in the planted row and furrow are difficult to manage and often compete with the crop before the plants are large enough to shade out weeds. Weeds in and between the rows are typically controlled with cultivation, hand hoeing, herbicides, or a combination of approaches. More growers are planting through plastic mulches to improve early growth and reduce in-row weed pressure associated with bare soil conditions. Some herbicides can be applied underneath the mulch, but it is the weeds growing along the edge of the plastic that are difficult to control, with cultivation equipment. Directed or shielded herbicide applications on bed edges help with weed control, but use caution as spray drift and residual herbicides left on the plastic may affect crop growth.

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

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

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

Finally, apply herbicides only at times specified on the label and observe the recommended intervals between the time of treatment and time of planting or harvesting the crop. Don't spray in high wind conditions to minimize drift injury to susceptible crops. Work with your neighbors as many herbicides are toxic to other crops growing nearby. Finally, herbicides are just one tool available for weed control; their use should supplement other good weed-management practices.

Herbicides are applied in the following ways:

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

Refer to Table 5.5 for more information on herbicide use.

Cucurbits

Insect and Mite Pest Management

Aphids

GENERAL CUCURBIT APHID INFORMATION

Aphids do not generally attack cucurbits until the vines form runners. Melon and green peach aphids attack cucumber, melon, pumpkin, and squash. Potato aphids only attack cucumber, pumpkin, and squash.

Green Peach Aphid *(Myzus persicae)*

DESCRIPTION

Adult: With soft, pear-shaped bodies and red eyes, adults have tailpipe-like appendages called cornicles on the rear of the body. Wingless adults are yellowish or greenish.

The winged adult has a yellow-green abdomen, with a large dark patch on its back. It has a black head and thorax and is the same size as the wingless form. The oviparous (egg-laying) form is pinkish.
Egg: Eggs are initially yellow or green, eggs become shiny-black as they mature. Eggs measure about 0.5 mm long and 0.25 mm wide. Eggs are usually deposited near buds of *Prunus* spp. trees.
Nymph: Though similar in shape and color to the wingless adult, nymphs are smaller. Nymphs that develop into winged adults may be pinkish.

Melon Aphid *(Aphis gossypii)*

DESCRIPTION

Adult: Soft-bodied, pear-shaped with dark cornicles, melon aphid adults are smaller and have shorter appendages than the green peach aphid. Winged adults are about 1.25 mm long with yellow to dark green bodies. They have a black head and thorax. Wingless adults are about 1 to 1.5 mm long with yellow to dark green bodies.
Egg: Eggs are yellow when first deposited, and turn shiny black when mature.
Nymph: Nymphs resemble adults but are smaller in size, about 0.5 to 1.0 mm long.

Potato Aphid *(Macrosiphum euphorbiae)*

DESCRIPTION

Adult: Potato aphids are larger than the green peach and melon aphids, 2-4 mm long with pink or green bodies.
Egg: They are similar to green peach and melon aphid eggs.
Nymph: Nymphs are a similar color and shape as adults, but smaller.

LIFE HISTORY

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

APHID DAMAGE ON CUCURBITS

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 aphid's feeding secretions, and non-persistent viruses, which are only temporary contaminants of aphid mouthparts, are effectively transmitted by aphids. Green peach aphids cause damage by transmitting plant viruses, including cucumber mosaic virus and watermelon mosaic virus. The melon aphid is one of the chief agents in transmitting cucumber mosaic virus, and the potato aphid may act as a vector for this virus.

APHID MANAGEMENT ON CUCURBITS

Cultural:

- *Avoid excess fertilization.* Aphid densities tend to be higher on plants with excess 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.* Hosts include as peach or nectarine trees.

- *Remove/destroy plant debris.* Disc ing fields immediately after harvest will destroy alternate host plants and reduce available aphid and virus sources.
- *Maintain healthy, vigorous plants.* They are more tolerant to attack by aphids.
- *Plant susceptible crops upwind.* Planting upwind from infested plants decreases aphid migration into the crop since aphids are blown downwind.

Chemical:

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

Biological:

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

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Pests on Vegetables*
- *Aphid Natural Enemies and Biological Control*
- *High Tunnel Pest Management - Aphids*

Cucumber Beetles

Western Spotted Cucumber Beetle
(Diabrotica undecimpunctata undecimpunctata)
Western Striped Cucumber Beetle
(Acalymma trivittatum)

DESCRIPTION

Adult: Spotted cucumber beetle are about 8-9 mm long with a black head, yellow prothorax (segment behind head), and 12 black spots on yellowish green wings with black legs and antennae. Striped cucumber beetle are about 8-9 mm long with a black head, yellow prothorax, and alternating yellow and black stripes on yellow wings.
Egg: Oval-shaped with yellow to orange coloring, eggs are laid near or at the base of cucurbit plants in groups of 200-1,200 and need soil moisture to survive.
Larva: About 8-13 mm long, larvae have a wormlike, white to yellowish-white body, a brown head, and three pairs of brown legs.
Pupa: Pupae are about 6 mm long with white to yellow bodies. Pupation occurs in the soil.

LIFE HISTORY

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

DAMAGE

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

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

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

MONITORING

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

MANAGEMENT

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

Cultural:

- *Choose less susceptible varieties.* Cucumber beetles have a lower preference for some varieties of cucurbits, including:

- *Summer squash:* 'Yellow Crookneck' (crookneck), 'Peter Pan' (scallop), 'Goldbar', 'Seneca Prolific' (straightneck), 'Slender Gold,' 'Sunbar' (yellow)
- *Winter squash:* 'Carnival, 'Table Ace' (acorn), and 'Butternut Supreme', 'Zenith' (butternut)
- *Pumpkin:* 'Baby Pam', 'Jack-Be-Little', 'Jackpot', 'Munchkin', 'Seneca Harvest Moon', 'Tom Fox'

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

Chemical:

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

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

Biological:

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

USU EXTENSION FACT SHEET REFERENCES

- *Cucumber Beetles*

Two-Spotted Spider Mite
(Tetranychus urticae)

DESCRIPTION

Adult: Females are 0.4 mm long and oval; males are slightly smaller with a tapered hind end. They are orange during the winter and early spring, turning 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.
Egg: Eggs are round, 0.5 mm in diameter, and translucent to opaque.
Immature stages: Initially round, translucent to pale green, with three pairs of legs when first hatched, then oval, dark green with black spots on back with four pairs of legs as it matures. Stages include larvae, protonymph, and deutonymph.

LIFE HISTORY

Adult females take on an orange color in the fall as their metabolism slows. They then spend the winter in protected sites on the ground, such as on crop debris and weeds. In the spring, mites crawl to nearby host plants to feed, and can "parachute" on air currents attached to a strand of fine silk. Egg-laying begins a few days after feeding starts. The overwintering females can lay 30 to 50 eggs in a 25-day average life span, while the summer females can lay up to 100 to 150 eggs in a 4- to 6-week period. First generation eggs may take 3 weeks to hatch, depending on temperatures, while egg hatch in the summer may take only 1 to 2 days. A single generation may be completed in as few as 10 to 14 days during the hot summer periods. Eight or more generations occur each year.

DAMAGE

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

MANAGEMENT

Cultural:

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

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Spider Mites*
- *Web-Spinning Spider Mites*

Squash Bug *(Anasa tristis)*

DESCRIPTION

Adult: Adults are about 16 mm long and about one-third as wide. Wings are folded over a flat back, and the body is brown to gray with orange and brown stripes along the edges of the abdomen and underside.
Egg: Clusters of 15 to 40, shiny bronze to red eggs arelocated on the undersides of leaves starting in mid-spring.
Nymph: Five instars range from 5-13 mm long. The 1st instar has a red head, antennae, and legs with whitish to greenish-gray bodies. The 2nd and 3rd instars have black appendages and greenish-gray bodies. The 4th and 5th instars develop wing pads and begin to resemble adults.

LIFE HISTORY

Squash bugs overwinter as adults outdoors in protected sites. In southern Utah, they usually emerge in April, and in northern Utah, they generally emerge in May. After emerging, adults will fly to host plants to feed, mate, and lay eggs. The new adult generation shows up in June to July in northern Utah and 3 to 4 weeks earlier in southern Utah. There is one generation per year in northern Utah and a partial second generation is possible in southern Utah.

DAMAGE

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

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

MONITORING

Monitor in the spring for squash bug adults under plant debris, perennial plants, or near buildings. Look daily for eggs under leaves and watch for plant wilt.

Place wooden boards in susceptible areas. Lift them up every morning and destroy existing eggs and adults.

MANAGEMENT

Cultural:

- *Maintain sanitation.* Remove or till under plant debris at the end of the season and keep fields free of trash or wood that could provide overwintering sites.
- *Employ hand picking.* Physically remove adults and nymphs by hand. Kill and remove egg clusters by squashing, tearing out the leaf section, covering in petroleum jelly, or using duct or packaging tape to "peel" them off. Begin physical removal early in the season and continue every 2 to 3 days to keep population numbers low. This may be more practical for home gardens or small commercial or organic fields.
- *Use trellising.* Trellising vining types of squash and melons can make them less accessible to squash bugs as the bugs prefer to hide under vines and leaves near the soil.
- *Use resistant varieties.* Although there are no cucurbit varieties that are immune to squash bugs, there are some that have lower susceptibility or relative resistance compared to other varieties. Some variety susceptibilities are as follows: butternut and royal acorn (resistant); sweet cheese and green striped cushaw (moderately resistant); pink banana and black zucchini (susceptible); and yellow straightneck, yellow crookneck, and Hubbard pumpkin (highly susceptible and attractive).
- *Plant trap crops.* Along the borders of the field or planting area, plant cucurbit cultivars that will attract overwintering adult squash bugs. Once adults have been lured to the trap crops, apply an insecticide or mechanically destroy the trap crop before eggs begin to hatch. This will reduce squash bug populations that would later attack the main crop. Squash Bugs prefer yellow straightneck and crookneck squash for egg laying compared to acorn, zucchini, butternut, and spaghetti squash.
- *Rotate crops.* To avoid overwintering adult squash bugs, rotate to non-cucurbit crops in alternating years.
- *Add mulches.* Mulches can harbor squash bugs but may also have benefits such as suppressing weeds, reducing soil moisture loss, and attracting beneficial insects. When used in combination with other cultural practices such as row covers, the benefits of mulches may outweigh the negatives.

Chemical:

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

Biological:

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

USU EXTENSION FACT SHEET REFERENCES

- *Squash Bugs*

Flea Beetles

Western Black Flea Beetle *(Phyllotreta pusilla)*
Hop Flea Beetle *(Psylliodes punctulata)*

Reference page 48 for general flea beetle description, life history, monitoring, and management techniques.

USU EXTENSION FACT SHEET REFERENCES

- *Flea Beetles on Vegetables*

Grasshoppers

Differential Grasshopper *(Melanoplus differentialis)*
Red-Legged Grasshopper *(M. femurrubrum)*
Two-Striped Grasshopper *(M. bivittatus)*
Migratory Grasshopper *(M. sanguinipes)*

DESCRIPTION

Adult: Grasshoppers are about 25-50 mm long with robust bodies, hind legs with enlarged femurs for long-distance jumping and relatively short antennae.

Egg: Eggs are about the size as a grain of rice, and are contained in pods of up to 100 eggs in the upper 2 inches of soil.
Nymph: Five nymphal stages or instars occur. Instars grow from around 6 mm (1st instar) to 25 mm (5th instar). Wing pad size gradually increases with each instar until they can fly, indicating adulthood.

LIFE HISTORY

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

DAMAGE

Grasshoppers have chewing mouthparts that leave random, ragged holes in leaves and flowers and can devour entire plants. They generally prefer young green plants of corn, lettuce, beans, carrots, onions, some annual flowers, and melons. Damage occurs in the early summer after rangeland weeds dry up and usually lasts a few weeks.

MANAGEMENT

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

Cultural:

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

Chemical:

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

Biological:

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

USU EXTENSION FACT SHEET REFERENCES

- *Grasshoppers*
- *Community-Wide Grasshopper Control*

Cucurbits

Sowbugs and Pillbugs (Order Isopoda)

DESCRIPTION

Adult: Adults are about 12 to 25 mm long. They have a rounded upper surface and flat lower surface. They are dark gray with armor-like body segments. Sowbugs and pillbugs are not insects, but are soil dwelling crustaceans. They have seven pairs of legs, prominent antennae, and two tail-like appendages.
Egg: Up to 200 eggs are carried in a pouch under the female body.
Young: Young sowbugs and pillbugs look like adults but are paler in color and smaller.

LIFE HISTORY

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

DAMAGE

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

MANAGEMENT

Cultural:

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

Chemical:

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

Thrips

Onion Thrips *(Thrips tabaci)*
Western Flower Thrips *(Frankliniella occidentalis)*

Reference page 172 for descriptions and general life history of onion thrips and western flower thrips.

DAMAGE IN CUCURBITS

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

MONITORING

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

MANAGEMENT

Cultural:

- *Disc in weeds before they flower.* This can reduce attracting thrips to the field. However, disc ing weeds after they have flowered (once thrips are present) can cause thrips to move into crop plants.

Chemical:

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

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Thrips*
- *Onion Thrips*
- *Western Flower Thrips*

Refer to Tables 5.6 and 5.8 for more information on commercial and small-scale insecticide use.

Disease Management

Gummy Stem Blight (Black Rot)
(Didymella bryoniae)

CAUSAL AGENT

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

SYMPTOMS

The disease affects foliage, stems, and fruit. Leaf and stem infections are known as gummy stem blight, appearing as necrotic (dead) spots. Stems sometimes ooze gum. On squash fruit, the disease is called black rot. On butternut squash, the disease may form distinct concentric rings.

DISEASE CYCLE

D. bryoniae is seedborne and soilborne. The fungus can survive on infected plant debris for up to 2 years in the soil. Seedlings can become infected if the seed is contaminated. Optimum conditions for infection range from 65 °F to 75 °F (depending on the crop) and moisture of up to 10 hours. The fungus can produce fruiting structures on decaying tissue after infection, and the spores move to new leaves and neighboring plants through splashing water.

MANAGEMENT

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

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

Powdery Mildew
(Podosphaera xanthii and *Golovinomyces chicoracearum)*

CAUSAL AGENT

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

SYMPTOMS

White powdery spots appear on leaf surfaces when temperatures start to increase. Over time, the entire leaf can be covered. The “powder” on leaves is the fungal mycelium and spores.

DISEASE CYCLE

Powdery mildew overwinters in fruiting structures on plant debris. When temperatures warm in late spring, a secondary spore (conidia) forms and blows to leaf tissue to cause infections. In contrast to many fungi, powdery mildew does not thrive with rainfall. The ideal conditions for infection are 2 or more hours of high humidity or dew on host leaves, which often occurs in cucurbit plantings.

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

MANAGEMENT

- *Monitor plants.* The key to management is to applying fungicides before the disease spreads. Scout fields for new lesions once per week starting in late spring.
- *Plant resistant varieties.* Several resistant varieties are available for squash, cucumber, and pumpkin.
- *Remove or plow under infected plant material after harvest.* This is important to prevent powdery mildew from overwintering.

- *Increase plant spacing.* This can help reduce powdery mildew severity with better air movement that reduces humidity in the plant canopy.

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

USU EXTENSION FACT SHEET REFERENCES

- *Powdery Mildews on Vegetables*

Watermelon Mosaic Virus

CAUSAL AGENT

Watermelon Mosaic Virus (WMV) is in the genus Potyvirus. Spread in a non persistent manner by aphids, it affects summer and winter squash, zucchini, gourds, and pumpkins.

SYMPTOMS

The virus causes mosaic patterns and leaf distortion. The fruit frequently shows color breaking and warts.

DISEASE CYCLE

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

MANAGEMENT

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

Pythium Root and Fruit Rot *(Pythium* spp.)

CASUAL AGENT

Pythium root and fruit rot has been observed in Utah at two separate locations. The rot was caused by two different Pythium species – *Pythium aphanidermatum* and *Pythium ultimum*.

SYMPTOMS

Above ground symptoms consist of plant stunting, wilt, and death, despite wet soils. The fruit rot symptoms start as brown spots on the underside, where the fruit contacts with the ground. Eventually, a cottony mycelium develops and fruit liquefies.

DISEASE CYCLE

Pythium species are soilborne. It can survive indefinitely on organic substrates or as thick-walled oospores. Pythium zoospores are motile. When moisture becomes available, Pythium produces these zoospores and sporangia. Fruit infection occurs via vegetative mycelium, sporangia, zoospores, or oospores. The pathogen is capable of direct penetration. Pre-existing wounds on the plants increase susceptibility.

MANAGEMENT

- *Source disease-free seeds*. Use seeds that have been grown in optimum moisture, temperature, and nutritional conditions.
- *Implement drip irrigation and plastic mulch*. Avoid excessive watering and low, poorly drained areas of the fields.
- *Use staking and mulching*. Prevent fruit contact with the soil.
- *Apply fungicide*. Mefenoxam products used in soil drenches can reduce root rot. These are ineffective against fruit rot.

Cucumber Mosaic Virus

CAUSAL AGENT

Cucumber mosaic virus (CMV) consists of a ribonucleic acid strand (RNA) surrounded by a protein coat.

SYMPTOMS

Symptoms will vary from host plant species and different environmental conditions. Hosts will experience stunted growth. A light green/yellow mosaic pattern will appear on the foliage along with yellow streaking and spotting. The fruits will obtain ring spots or line patterns. Symptoms may be aggravated in high temperatures, herbicides, mineral deficiencies, or insect feeding. Viral diseases often need to be lab tested and can't be based on symptoms alone.

DISEASE CYCLE

This happens mechanically (worker's hand or tools), or through aphid feeding, dodder, or grafting.

MANAGEMENT

- *Employ adequate sanitation*. Disinfect tools used for vegetative propagation.
- *Remove infected plants*. Discard virus-infected plants.
- *Control aphid populations.*
- *Remove weeds*. Weeds may serve as an alternate host for CMV or the aphids that spread them.

Beet Curly Top Virus

CAUSAL AGENT

Beet curly top virus (BCTV) of cucurbits is caused by curtoviruses. This group includes beet curly top virus, beet severe curly top virus, and beet mild curly top virus, among others. They are transmitted by the beet leafhopper (*Circulifer tennellus*).

SYMPTOMS

Curly top symptoms in cucurbits can include plant stunting, stiffness, and shortened internodes. The foliage of young plants turns yellow and may roll upward with a crinkled appearance. The tips of the runners will turn upward. Plants infected in the seedling stage will likely die. Older plants will eventually turn yellow and die.

DISEASE CYCLE AND MANAGEMENT

Reference page 154 for information regarding the disease cycle and management of BCTV.

Fusarium Crown and Root Rot
(Fusarium solani)

CAUSAL AGENT

Fusarium solani is a soilborne fungus that invades a plant's vascular system disrupting water and nutrient transport. It is relatively common in cucurbit cultivation.

SYMPTOMS

Plants wilt and yellow, accompanied by brown discoloration and decay of the lower stem and root tissues. As the disease progresses, affected plants may exhibit stunted growth and eventually succumb to the pathogen.

DISEASE CYCLE

Fusarium solani survives in the soil as chlamydospores or mycelium within infected plant debris between cropping seasons. When conditions are favorable, it germinates and infects plant roots, leading to root damage and the characteristic wilting and yellowing symptoms. The fungus also produces spores disseminated through various means

MANAGEMENT

- *Rotate crops.* Avoid planting cucurbits in the same location for consecutive seasons, as *Fusarium solani* can persist in the soil. Implement a crop rotation plan to reduce the pathogen's build-up in the field.
- *Sterilize soil.* Use soil solarization techniques to kill the pathogen in the soil before planting. These methods can help reduce the initial inoculum.
- *Use resistant cultivars:* Choose cucumber, squash, or pumpkin cultivars that are labeled as resistant to Fusarium crown and root rot. Resistant varieties can provide an effective means of control.
- *Employ adequate sanitation.* Remove and destroy infected plant material to prevent spreading the pathogen. Proper debris disposal is crucial to reduce the disease's persistence.
- *Ensure proper soil drainage.* Well-drained soils prevent waterlogged conditions, as Fusarium crown and root rot thrives in wet environments.

Fusarium Wilt
(Fusarium oxysporum fs. spp. *cucumerinum, cucurbitae, melonis, and niveum)*

CAUSAL AGENT

Fusarium wilt in cucurbits is caused by *Fusarium oxysporum* fs. spp. *cucuerinum*, *cucurbitae*, *melonis*, and *niveum*). The specific strains are adapted to specific hosts.

SYMPTOMS

Wilting is the primary symptom of infection by *F. oxysporum*. Wilting does not occur until several weeks after infection; therefore, young plants can unknowingly be infected. Sometimes, wilting only occurs on one side or portion of the host. Initially, plants may recover in cooler evening temperatures. Older foliage becomes chlorotic and dies. Over time, and especially with hot temperatures, permanent wilting sets, in followed by plant death and sometimes vascular discoloration.

DISEASE CYCLE

Fusarium oxysporum can occur in most soil types across Utah. It survives in the soil or plant residue for multiple years as mycelium or thick-walled resting spores called chlamydospores without a host plant. It may also be present in soil debris on greenhouse benches, irrigation pipes, mechanical equipment, and other field supplies. Fusarium wilt is a disease of warm, wet conditions. In these circumstances, chlamydospores germinate and produce infection hyphae. These hyphae penetrate the root cortex or may enter through wounded or damaged roots. Hyphae then invade the xylem (vascular) tissue, where the pathogen repeatedly sporulates and grows hyphae throughout the plant, essentially clogging the vascular system. If plant defenses cannot prevent the spreading of the pathogen, the plant wilts and dies. Upon plant death, the fungus spreads and grows on the outer, decayed areas of the plant, forming masses of mycelium and subsequent chlamydospores for long-term survival.

MANAGEMENT

Reference page 308 for information on managing fusarium wilt.

USU EXTENSION FACT SHEET REFERENCES

- *Fusarium and Verticillium Wilts in Vegetables*

Verticillium Wilt *(Verticillium dahliae)*

CAUSAL AGENT

Verticillium wilt in cucurbits is caused by the fungus *Verticillium dahliae*.

SYMPTOMS

Symptoms of Verticillium wilt are first seen on the lower foliage that turns chlorotic and necrotic (dead areas). In some hosts, the foliar symptoms are distinct. Decreased photosynthesis reduces the overall fruit quality. In severe infections, plants fully wilt and die with discolored vascular tissue.

DISEASE CYCLE

Verticillium dahliae is potentially found in most soil types across Utah. These fungi can survive several years in the soil as small hard balls of mycelium called microsclerotia. The ideal temperature for *V. dahliae* infection is within 70 °F to 85 °F. Under these temperatures with wet soils, microsclerotia germinate, and the fungus infects plants through intact or damaged roots. From there, hyphae invade the xylem tissue and produce spores that are transported upward throughout the vascular tissue. Eventually, the plant wilts and dies, and the fungus produces microsclerotia that are released into the soil when the plant matter decays.

MANAGEMENT

Since infected plants cannot be treated (and should be removed), it is important to use cultural control practices to prevent introducing of the disease and improve soil health.

Preventing introduction:

- Rotate between different crops to prevent wilt fungi from building up in the soil.
- Source disease-free seed. Though uncommon, uncertified disease-free seeds and tubers may harbor *Verticillium* spp. or *Fusarium* spp.
- When starting seeds and caring for transplants in a greenhouse, sanitation is critical in preventing pathogens like *Fusarium* and *Verticillium* spp. that may eventually get transferred to the field. Sterilize pots and trays by soaking in a 10% to 15% bleach solution for half an hour to an hour or use quaternary ammonium compounds. Pots and trays need to be rinsed well with water afterward to avoid phytotoxicity from residue. Disinfect greenhouse benches and other supplies. If infections do occur, dispose of seedlings along with the potting mix as it may be harboring the pathogens.
- After working in fields, ensure workers clean off soil from their shoes, tools, and mechanical equipment when moving from one field to another.

Where the disease has been diagnosed:

- Plant vegetable cultivars with resistance to Fusarium and Verticillium wilts. Cantaloupes have many varieties available. Note that some cultivars will only have resistance to one of multiple races of the pathogen, and this will be noted on the seed packets.
- Remove all plant residues at the end of the season to reduce the population of overwintering fungal structures.
- Soil solarization could be an option if soil can be heated at significant depths. Review the Soil Solarization for Gardens and Landscapes (https://ipm.ucanr.edu/legacy_assets/pdf/pestnotes/pnsoilsolarization.pdf) literature from the University of California for specific instructions).
- In commercial production, soil fumigation using high concentrations of the fumigants metam sodium, and chloropicrin can reduce microsclerotia populations in the soil. However, this treatment can be hazardous to overall soil health. This method is also not economically viable for Utah farmers.
- Research shows cover crops in the mustard family have some biofumigation properties due to the high presence of glucosinolates. Research on biofumigation is ongoing.

USU EXTENSION FACT SHEET REFERENCES

- *Fusarium and Verticillium Wilts in Vegetables*

Refer to Tables 5.7 and 5.9 for more information and commerical and small-scale fungicide use.

Cucurbit Crop Pesticide Tables for Commercial and Small-Scale Use

Table 5.5. ***Herbicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Cucurbit Crops*** *(Cucumbers, Melons, Winter Squash, Summer Squash, Etc.) in Utah*

		Timing and application location relative to crop				Timing relative to weeds		Weed groups controlled			
Brand name (REI/PHI)	**Active ingredient**	Before transplanting	Pre-emergence	Post-transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	**Comments**
Aim (12hr/0d)	carfentrazone	X		X			X			X	
Command 3me (12hr/45d)	clomazone		X			X		X	X	X	Do not use on pumpkins
Curbit ec (24hr/-)	ethalfuralin		X	X		X					
Dual magnum (12h/30d)	s-metolachlor	X	X	X		X		X	X		Pumpkins only, between rows
Dacthal products (12hr/-)	DCPA			X	X	X		X			Cantaloupe/ watermelon only
Gramaxone (12hr/-)	paraquat	X	X	X			X	X	X	X	Restricted use
League	imazosulfuron			X	X	X	X		X	X	Cantaloupe/ watermelon only
Poast (12hr/14d)	sethoxydim				X		X	X			
Prefar 4-e (12hr/-)	bensulide	X	X			X		X			
Prism (12hr/14d)	clethodim	X	X	X	X		X	X	X	X	
Roundup and others (12hr/14d)	glyphosate	X	X	X	X		X	X	X	X	
Sandea and others (12hr/30 or 57d)	halosulfuron	X	X			X	X		X	X	Should not contact plants
Sinbar (12hr/70d)	terbacil	X	X			X					Watermelon only
Strategy (12hr/45d)	ethalfluralin + clomazone		X	X		X		X	X	X	Not on cantaloupe
Treflan products (12hr/30 or 60d)	trifluralin			X		X		X	X	X	
Organic products											
Corn gluten meal		X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 5.6. *Insecticides* Registered for *COMMERCIAL* Use on *Cucurbit Crops* (Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrip	Armywrm/cutworm	Earwig
carbaryl	Drexel Carbaryl 4L, Sevin 4F, Sevin XLR Plus	1A	7-14		X	X	X	X				
	Drexel Carbaryl 5% Bait				X	X		X			X	
alpha-cypermethrin	Fastac CS	3A	10-14	X	X	X	X				X	
bifenthrin	Brigade WSB, Capture LFR	3A	2-3 wks	X	X	X	X	X	X		X	
	Sniper LFR, Steed			X	X	X	X	X			X	
	Xpedient Plus V				X	X					X	
cyfluthrin	Tombstone	3A	10-14		X	X		X			X	
lambda-cyhalothrin	Crusader 1EC, Silencer VXN	3A	10-14	X								
	Lambda T-2, Lambda T-2, Lambda-CY AG, Ravage			X	X	X	X	X	X	X	X	
permethrin	Arctic 3.2 EC, Perm-UP 3.2 EC	3A	14	X	X	X	X					
	Perm-UP 25DF, Permethrin 3.2 AG			X								
pyrethrins[O]	PyGanic EC 1.4 II, PyGanic EC 5.0 II, Tersus	3A	5-7	X	X	X	X	X		X	X	X
	Pyrol			X								
zeta-cypermethrin	Gladiator, Hero EW, Mustang	3A	10-14	X	X	X	X		X		X	
beta-cyfluthrin	Sultrus	3A	14	X	X	X	X	X	X		X	
dinotefuran	Certador	4A	14	X	X	X	X			X		
imidacloprid	Acronyx 4, Admire Pro, Advise 2FL, Advise 4, Midash 2SC, Montana 4F Nuprid 2SC, Provoke, Tigris Imida 4 F, Willowood Imidacloprid 2SC, Willowood Imidacloprid 4SC, Wrangler	4A	14	X								

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Table 5.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Cucurbit Crops*** *(Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrip	Armywrm/cutworm	Earwig
sulfoxaflor	Transform WG	4C	10-14	X						X		
methoxyfenozide	Engame, GCS Methoxy 2F, Inspirato 2 F, Intrepid 2F, Troubadour 2F Insecticide, Zylo	18	10-14								X	
Bacillus thuringiensis°	Biobit HP WP	11A	5-7								X	
	Crymax, Deliver, Leprotec, XenTari DF				X						X	
bifenazate	Acramite-4SC	20D	14						X			
indoxacarb	Avaunt, Avaunt eVo, Comber	22A	14								X	
chlorantraniliprole	Shenzi 400SC	28	14-17								X	
cyantraniliprole	Exirel, Verimark	28	10-14	X	X	X				X	X	
flonicamid	Beleaf 50 SG	29	14	X						X		
azadirachtin°	Atrevia 1.2% SL, Atrevia 3.0% SL, AzaGuard Azapro, Azatin O, Debug Turbo, Ecozin Plus 1.2% ME, Molt-X, Ornazin 3% EC	UN	7-10	X	X	X				X		
Beauveria bassiana°	BioCeres WP, BotaniGard MAXX	UN	5-7	X	X	X				X		
Chenopodium ambrosioides extracts°	Requiem EC, Requiem Prime	UN	7							X		
Chromobacterium subtsugae°	Grandevo CG	UN	5-7	X	X	X				X	X	
clove oil°	Bemix	UN	3	X					X			
cottonseed oil°	Pest Out	UN	3	X					X			
fats and glyceridic oils of margosa°	Debug ON, Debug Optimo° Debug Tres	UN	7-10	X								
geraniol°	Brandt Ecotec Plus, Furious	UN	3	X	X	X				X		

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

° = Organic

Table 5.6., continued. *Insecticides* *Registered for* ***COMMERCIAL*** *Use on* ***Cucurbit Crops*** *(Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrip	Armywrm/cutworm	Earwig
Isaria fumosorosea^{O}	Nofly WP	UN	5-7	X	X	X		X	X	X		
	PFR-97 10% ES, PFR-9720% WDG			X	X	X			X	X		
kaolin^{O}	Surround	UN	5-7		X	X	X					
Metarhizium spp.^{O}	Lalguard M52 OD, Met 52 EC	UN	7							X		
mineral oil^{O}	BioCover MLT, BioCover SS, BioCover UL	UN	3	X	X	X				X		
	Mite-E-Oil Omni Oil 6 Omni Oil 6E, Sol-Oil 97, Spray Oil 470			X								
	Omni Supreme Spray			X	X	X						
	Glacial Spray Fluid, Ultra-Pure			X	X	X				X		
petroleum oil^{O}	Drexel Damoil	UN	3	X								
potassium salts of fatty acids^{O}	Des-X, Kopa Insecticidal Soap	UN	5-7	X								
potassium silicate^{O}	Carbon Defense, FBS Carbon Defense	UN	7	X								
rosemary oil^{O}	Ecotrol PLUS	UN	3	X					X			
sodium tetraborate^{O}	Prev-AM, Prev-AM ULTRA	UN	7-10	X						X		
soybean oil^{O}	Golden Pest Spray Oil, NanoCrop, Soyote	UN	3	X					X			
sulfur^{O}	Crusade DF	UN	7-10						X			
thyme oil^{O}	Ovex Ovicide	UN	3	X					X			

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^{O} = Organic

Cucurbits

Table 5.7. *Fungicides.* *Registered for* ***COMMERCIAL*** *Use on* ***Cucurbit Crops*** *(Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Gummy stem blight	Pythium root + fruit rot	Powdery mildew
thiophanate-methyl	Omni T-Methyl 4.5 F, Nufarm T-Methyl 70 WSB, Omni T-Methyl 70 Wp, Ovon 4.5, Ovon 70WSB, Talaris 4.5 F, Tesoro 4.5 F	1	10-14	X		X
myclobutanil	Rally 40W	3	14			X
tebuconazole	Willowood Teb 3.6SC	3	7-14	X		X
azoxystrobin	Aframe, Quadris, Tycoon	11	7-14	X		X
fludioxonil	Emblem	12	7-10	X		X
fluazinam	Vantana	29	5-7	X		
allyl isothiocyanate	Dominus	8F	N/A		X	
Bacillus amyloliquefaciens strain D747[O]	Double Nickel 55, Triathlon BA	BM2	7	X		X
Bacillus pumilis strain QST 2808[O]	Sonata	BM2	7			X
Bacillus subtilis strain IAB/BS03[O]	Aviv, Milagrum Plus	BM2	5-7	X	X	X
Bacillus subtilis strain QST 713[O]	Rhapsody, Serenade ASO	BM2	5-7	X	X	X
	Serenade MAX, Cease			X		X
	Serenade Opti WP					X
	Serenade Soil				X	
Clonostachys rosea strain J1446[O]	Lalstop G46 WG	BM2	5-7		X	X
Trichoderma gamsii[O]	Bio-Tam 2.0, Obtego, Tenet WP	BM2	N/A		X	
Trichoderma harzianum Rifai strain T-22[O]	RootShield Granules, RootShield Plus Granules, RootShield Plus WP	BM2	N/A		X	
copper hydroxide	Champ WG, Kocide 3000 Kocide 3000-O	M1	7	X		
copper oxychloride	Badge SC	M1	7	X		
chlorothalonil	Bravo Zn, Drexel Chlorothalonil 720, Echo 720 A, Initiate Zn, Omni Chlorothalonil 720 SC, , Quadris Opti, Zing!	M5	7-14	X		

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[O] = Organic

Table 5.7., continued. ***Fungicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Cucurbit Crops*** *(Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Gummy stem blight	Pythium root + fruit rot	Powdery mildew
hydrogen peroxide[O]	Jet-Ag, OxiPhos	NC	7			X
	OxiDate 2.0, ZeroTol 2.0			X		X
	Jet-Ag 5%				X	X
	OxiDate 5.0			X	X	X
potassium bicarbonate[O]	Kaligreen	NC	5-7			X
potassium salts of fatty acid[O]	Kopa Insecticidal Soap	NC	5-7			X
extract of *Reynoutria sachalinensis*[O]	Regalia CG, Regalia	P5	7-10	X	X	X
mono- and dipotassium salts of phosphorous acid[O]	Rampart, Reliant	P7	7-21	X		X
cyflufenamid[O]	Torino	U6	7-10			X
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM ULTRA	UN	10-14			X
sulfur[O]	Acoidal, Crusade DF, SulfOMEX, Sulfur DF	UN	7-10			X
paraffinic oil[O]	JMS Stylet-Oil	UN	3	X		X
mineral oil[O]	Ultra-Pure Oil	UN	3			X

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[O] = Organic

Cucurbits

Table 5.8. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Cucurbit*** *Crops (Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrips	Armywrm/cutworm	Earwig
bifenthrin	GardenTech Sevin Insect Killer Dust	3A	2-3 wks	X	X	X	X	X		X	X	X
	Bonide Eight Flower & Vegetable Soil Insect Granules										X	X
	Hi-Yield Vegetable & Ornamental Insect Control Granules							X			X	X
	Ferti-lome Broad Spectrum RTS			X		X					X	
zeta-cypermethrin	GardenTech Sevin Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X	X	X		X	X	X
lambda-cyhalothrin	GardenTech Sevin Insect Killer RTU, Spectracide Triazicide Insect Killer for Lawns & Landscapes RTU	3A	10-14	X		X	X	X	X	X	X	X
bifenthrin + zeta-cypermethrin	GardenTech Insect Killer Lawn Granules	3A	2-3 wks	X		X		X	X		X	X
permethrin	Hi-Yield Garden & Farn Insect Control, Bonide Insect Control Garden Dust, Bonide Eight Vegetable, Fruit, & Flower Concentrate, Bonide Eight Yard & Garden RTS, Hi-Yield Garden, Pet, & Livestock Dust	3A	2-3 wks	X	X	X	X				X	
deltamethrin	Ortho Insect Killer Flower & Vegetable Garden Dust	3A	2-3 wks	X	X	X		X		X		X

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O = Organic

Table 5.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Cucurbit*** *Crops (Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrips	Armywrm/cutworm	Earwig
pyrethrins[O]	Monterey Bug Buster-O, Bonide Pyrethrin Garden Spray Concentrate	3A	5-7	X	X	X	X	X		X	X	X
cyfluthrin	BioAdvanced Tomato & Vegetable Insect Killer RTU, BioAdvanced Tomato & Vegetable Insect Killer RTS	3A	14	X	X	X		X		X	X	
pyrethrins[O] + potassium salts of fatty acids [O]	Safer Insecticidal Soap + Pyrethrin Concentrate	3A/UN	5-7	X	X	X			X		X	
pyrethrins[O] + neem oil[O]	Triple Action, Triple Action Plus RTU	3A/UN	5-7	X			X	X	X	X	X	X
malathion	Hi-Yield 55% Malathion Spray, Bonide Malathion Concentrate, Ortho MAX Malathion Insect Spray Concentrate, Spectracide Malathion Insect Spray	3B	5-7	X					X	X		
imiclacloprid	Monterey Fruit Tree & Vegetable Systemic Soil Drench, BioAdvanced Fruit, Citrus, & Vegetable Insect Control Concentrate	4A	N/A	X	X	X				X		

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[O] = Organic

Table 5.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Cucurbit*** *Crops (Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrips	Armywrm/cutworm	Earwig
spinosad[O]	Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS, Monterey Garden Insect Spray, Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Captain Jack's Deadbug Brew Dust, Bonide Colorado Potato Beetle Beater	5	7-10		X							
Bacillus thuringiensis[O]	Monterey B.T., Monterey B.T. RTU, Bonide Captain Jack's Bt, Bonide Thuricide (Bt) Concentrate	11	5-7								X	
Bacillus thuringiensis var. Kurstaki[O]	Safer Caterpillar Killer Spray With Bt, Safer Caterpillar Killer II Concentrate, Natural Guard Caterpillar Killer Spray with Bt RTU, Ferti-lome Dipel Dust	11	5-7								X	
sulfur[O] + pyrethrins[O]	Ortho Insect, Mite, Disease 3-in-1 RTU, Natria Insect, Disease, and Mite Control RTS, Natria Insect, Disease, and Mite Control RTU, BioAdvanced Fruit & Vegetable 3-in-1 Solution RTU, BioAdvanced Fruit & Vegetable 3-in-1 Solution Concentrate	UN/3A	7-10	X	X	X	X		X	X	X	

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[O] = Organic

Table 5.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Cucurbit*** *Crops (Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Cucumber beetle	Flea beetle	Squash bug	Grasshopper	Spider mite	Thrips	Armywrm/cutworm	Earwig
canola oil°	Natural Guard Horticultural Oil Concentrate, Natural Guard Horticultural Oil RTS	UN	3	X					X	X		
mineral oil°	Safer Horticultural & Dormant Spray Oil Concentrate	UN	3	X					X	X	X	
neem oil°	Natural Guard Neem Concentrate, Natural Guard Neem RTU, Monterery 70% Neem Oil, Natria Neem Oil Concentrate, Natria Neem Oil RTU, BioAdvanced Organics Neem Oil RTU, Espoma Organic Neem Oil 3-in-1, Monterey Neem Oil RTU	UN	3	X	X	X			X		X	
potassium salts of fatty acids°	Natural Guard Insecticidal Soap, Monterey Insecticidal Soap RTU, Bonide Insecticidal Soap RTU, Natria Insecticidal Soap RTU, BioAdvanced Organics Insecticidal Soap RTU	UN	5-7	X			X	X	X	X		X
silicon dioxide	Natural Guard Diatomaceous Earth Crawling Insect Control	UN	7-14					X				X
	Bonide Diatomaceous Earth			X	X	X	X		X	X	X	X

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° = Organic

Cucurbits

Table 5.9. *Fungicides* *Registered for **SMALL-SCALE** Use on **Cucurbit Crops** (Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Gummy stem blight	Pythium root + fruit rot	Powdery mildew
copper octanoate	Epsoma Organic Copper Soap RTU, Monterey Liquid Copper RTU, Natural Guard Copper Soap Concentrate	M1	10	X	X	
copper octanoate	Bonide Captain Jack's Liquid Copper Fungicide Concentrate, Bonide Captain Jack's Liquid Copper Fungicide RTS, Bonide Captain Jack's Liquid Copper Fungicide RTU	M1	10		X	
copper sulfate	Bonide Copper Spray/Dust	M1	7	X	X	
sulfur[O]	Bonide Plant Fungicide Dust, GardenTech Sevin Sulfur, Dust 2-in-1 Disease and Insect Control, Safer Garden Fungicide Concentrate, Safer Garden Fungicide RTU	M2	7-10			X
sulfur[O] + pyrethrins[O]	Natria Insect, Disease, & Mite Control RTS, Natria Insect, Disease, & Mite Control RTU	M2/3A	10-14			X
mancozeb	Bonide Mancozeb Flowable w/ Zinc Concentrate	M3	7-10	X		
chlorothalonil	Bonide Fung-onil RTU	M5	7-14	X	suppress	
chlorothalonil	Bonide Fung-onil Concentrate, Ferti-lome Broad Spectrum Landscape & Garden Fungicide, Ferti-lome Broad Spectrum Landscape & Garden Fungicide RTU, GardenTech Daconil Fungicide Concentrate, GardenTech Daconil Fungicide RTU, Hi-Yield Vegetable, Flower, Fruit, and Ornamental Fungicide	M5	7-14	X		
myclobutanil	Ferti-lome F-Stop Lawn & Garden Fungicide Concentrate, Ferti-lome F-Stop Lawn & Garden Fungicide RTS	3	14			X

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[O] = Organic

Table 5.9., continued. ***Fungicides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Cucurbit Crops*** *(Cucumbers, Melons, Winter Squash, Summer Squash, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Gummy stem blight	Pythium root + fruit rot	Powdery mildew
propiconazole	Bonide INFUSE Disease Control Concentrate	3	14			X
pyrethrins[O]	Ferti-lome Triple Action O, Ferti-lome Triple Action RTS, Ferti-lome Triple Action PLUS RTO	3A	5-7			X
Bacillus amyloliquefaciens strain D747[O]	Bonide Revitalize Concentrate, Bonide Bio RTU	MBCA	7			X

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[O] = Organic


Commercial squash production using plastic mulch and drip tape on a farm in Washington County.


Commercial melon production using furrow irrigation on a farm in Emery County.

Nitrogen defiency symptoms in squash.

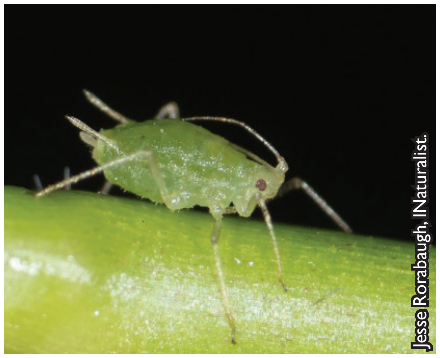
Foliar symptoms of iron chlorosis in squash.


Blossom end rot symptoms.

Harvestable, well-natted cantaloupe at "half-slip" stage.


Flower with male reproductive parts from a squash plant.


Flower with female reproductive parts from a squash plant.



Green Peach Aphid *(Myzus persicae)*

Dark Form Melon Aphid *(Aphis gossypii)*


Light form melon aphid colony on pumpkin foliage.

Potato Aphids *(Macrosiphum euphorbiae)*

Western Spotted Cucumber Beetle *(Diabrotica undecimpunctata undecimpunctata)*

Western Striped Cucumber Beetle *(Acalymma trivittatum)*


Cucumber beetle feeding damage on cantaloupe rind.


Cucumber beetle feeding on watermelon rind.

Two-Spotted Spider Mite *(Tetranychus urticae)*


Squash Bug *(Anasa tristis)*


Squash Bug Eggs


Various instars of squash bug nymphs feeding on a pumpkin.

Red-Legged Grasshopper
(*Melanoplus femurrubrum*)

Differential Grasshopper
(*Melanoplus differentialis*)

Two-Striped Grasshopper
(*Melanoplus bivittatus*)

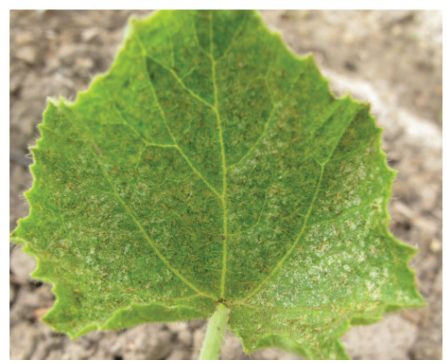
Migratory Grasshopper
(*Melanoplus sanguinipes*)

Pillbug (*Armadillidium vulgare*)

Pillbug feeding on cantaloupe.

Onion Thrips *(Thrips tabaci)*

Western Flower Thrips *(Frankliniella occidentalis)*



Extensive thrips feeding damage on cucurbit foliage.

Cucurbit symptoms of gummy stem blight/black rot (*Didymella bryoniae*).

Fruit symptoms of gummy stem blight/ black rot (*Didymella bryoniae*).

Powdery mildew (*Podosphaera xanthii)* on squash foliage.

Foliar symptoms of watermelon mosaic virus (WMV) on foliage.

Fruit symptoms of water melon mosic virus (WMV) on squash.

Pythium fruit rot (*Pythium* spp.) on a cucumber.

Fruit symptoms of cucumber mosaic virus (CMV).

Beet curly top virus (BCTV) in pumpkin.

Cantaloupe field with fusarium crown and root rot (*Fusarium solani)*.

Fusarium wilt (*Fusarium oxysporum f.sp. niveum*) in watermelon.

Verticillium wilt (*Verticillium dahliae*) in squash.

CHAPTER 6: LEAFY GREENS PRODUCTION

Leafy green vegetables are relatively easy to grow. They come from several different crop families and including:

- Lettuces (bibb/Boston/butterhead, leaf, iceberg, romaine, etc.).
- Spinach (flat leaf and savoy).
- Aster family (endive, escarole, radicchio).
- Brassica crops (arugula, collards, kale, mustard and turnip greens).
- Other leaf crops like Swiss chard, beet greens and parsleys.

Various mixtures of green leafy vegetables ("mesclun") and immature "baby greens" are also very popular.

Table 6.1. ***Variety Suggestions*** - *Commonly Grown Leafy Greens*

ASTERS	
Endive	*Rhodos, Bianca Riccia, Frisan, Lorca*
Escarole	*Eros, Natacha, Salanca*
Radicchio	*Palla Rossa, Rossa di Treviso Precoce, Indigo, Fiero*
BEET GREENS	
Boldor, Merlin, Pacemaker III, Chioggia, Red Ace	
BRASSICAS	
Arugula	*Speedy, Roquette, Sylvetta, Astro*
Collards	*Champion, Hi Crop, Flash, Tiger*
Kale	*Red Russian, Redbor, Rogue, Starbor, Winterbor*
Mustards	*Spicy Green, Dragon Tongue, Scarlet Frills, Green Wave*
LETTUCE	
Bibb	*Optima, Speckles, Carmona, Red Cross, Rex, Adriana*
Romaine	*Winter Density, Outredgeous, Fusion, Salvius*
Iceberg	*Superior 1, Crispino, Crusader, Heatmaster*
Leaf	*Revolution, Encino, Salad Bowl, Tango, Defender,*
SPINACH	
Space, Regiment, Renegade, Bloomsdale, Emperor	
SWISS CHARD	
Rhubarb, Bright Lights, Fordhook Giant, Oriole	

Leafy green mixes (also called mesclun mix, baby greens, or spring mixes) are an assortment of leafy greens harvested in the seedling stage (plants 3 to 4 weeks old). The mixes consist of five to seven types of leafy greens including leaf lettuce and non-lettuce greens from the Brassica or Aster family of crops.

Leafy green crops are mostly cool-season vegetables that grow best in the spring and fall, but there are many heat-tolerant varieties for summer plantings. Many leafy green crops are successfully grown in unheated greenhouses or high tunnels from late January to March and then again from October to December. For cool-weather or winter production, it is best to grow the most cold-hardy greens, such as spinach, arugula, kale, and selected brassicas.

Types and Varietal Selection

Due to the large variety of types and cultivars, spend some time identifying local consumer desires. The following lists are illustrative only and do not include all the wide varieties available. Very few of the varieties listed have been tested in the local marketplace. Most, if not all, can be grown locally, but some may have better adaptation to Utah's varied climatic and environmental conditions.

Soil and Fertility

The leafy green vegetables can be grown on a wide range of different soil types. Heavier soils (silt or clays) produce high yields, while lighter sandier soils are more suitable for early spring, fall, or winter production. Since these crops have high water demands, the soil must have good moisture-holding capacity with excellent drainage. Avoid soils prone to compaction or those that lack good soil structure (crust easily) as these conditions adversely affect seedling emergence or growth.

For fertilizer needs, a soil test is the most accurate guide and helps identify any nutrient limitations. The following recommendations are quite general, and applications should be adjusted based on soil test results.

- Most leafy green vegetables require 75-150 pounds of nitrogen per acre. Overapplication of nitrogen results in rapid, soft growth and can trigger tipburn.
- Ensure the soils have adequate phosphorus (100-200 (P2O5) pounds/acre) and potassium (50-150 (K2O) pounds/acre) based on soil tests.
- These crops grow best when soil pH is maintained at 6.5-7.5.
- Leafy green vegetables respond to banded fertilizer because they all have shallow root systems (most in the top foot of soil).
- Use less nitrogen if soils have had manure/compost additions or when grown after legume cover crops.
- Higher amounts of N and P are commonly applied for late fall and winter plantings.

Planting and Spacing

Most leafy green vegetables will germinate at soil temperatures of 32 °F to 35 °F, with an optimum germination range of 55 °F-70 °F. Soil temperatures above 80 °F cause the seeds of some crops (lettuce, spinach, others) to go dormant and they will not germinate until cooler soil temperatures return. When conditions are cooler, water after seeding and plant later in the day to overcome dormancy effects. Once the crops are established (emerged), high temperatures (80+ °F) cause many to bolt and form a seed head. Since many of these vegetables mature quickly (40 to 60 days), and temperature impacts days to harvest, it is crucial to use sequential plantings to get consistent production. Seeds are commonly planted ¼ - ⅓ inch deep and thus are regularly subjected to warmer soil conditions.

Table 6.2. *Seed Quantities, Field Seeding Rates, and Common Row Spacing for Leafy Green Vegetables*

Leafy green vegetable	Seeds (Per unit weight)		Field seeding (lb/acre)[a]	Row spacing (inches)	
				In row	Between
Arugula[b]	11,000-15,000	oz	1-2	8-12	15-24
Beets	24,000-26,000	lbs	10-15	2-4	12-24
Collards	8,500-9,500	oz	2-4	12-18	24-30
Endive[b]	24,000-26,000	oz	3-4	8-12	15-24
Kale	8,500-9,500	oz	2-4	12-18	24-30
Lettuce[b]	20,000-30,000	oz	1-3	8-15	12-24
Mustard	15,000	oz	3-5	5-10	12-30
Parsley	250,000	lbs	20-40	4-12	12-30
Spinach	45,000	lbs	10-15	2-6	12-30
Swiss chard	25,000	lbs	6-8	12-15	24-30

[a]Lower quantities of seed will be needed if transplanting.
[b]Seeding rates depend on plant type; some are commonly transplanted.

Most of the leafy green crops have similar spacing and seeding requirements (Table 6.2). Growers should purchase the best quality seed available to help ensure germination uniformity, which then leads to more even plant growth. Use modern precision planters when seeding and purchase coated seeds that allow singulation of seed placement. Fungicides should be used (in coatings or applied to raw seed) particularly if establishment issues have been encountered (see the Disease Managment section). Always plant in well-prepared seedbeds to ensure uniform planting depths. Seeds that are primed can help speed up seedling establishment, particularly in harsh (cold or hot) growing environments. These actions help ensure rapid and uniform establishment. It is fairly common to irrigate after seeding to promote more uniform emergence.

Final spacing on heading crops (lettuce, endive, and escarole) varies depending on plant size at harvest. Other types (leaf lettuce, spinach, baby greens, kale, and arugula) are planted at tighter row widths. Regardless of the crop, spacing should allow good air movement around the plants to minimize common diseases like grey mold (*Botrytis*), bottom rot (*Rhizoctonia*), and leaf drop (*Sclerotinia*). Planting on raised beds (3-4 feet wide; 4 inches high; 3-4 rows per bed) helps with air movement and encourages drier soil conditions. As with all crops, rotate planting sites wherever possible.

Transplants are often used for early lettuce production but can be used on most of the leafy green vegetables. Transplants can be used in all production seasons and are particularly suited for very early spring (February-April) or late fall (September-November) plantings in tunnels or the field. Plant transplants when they are 3 to 4 weeks old (grown in 128- or 256- cell trays). Use floating row covers or low tunnels over the beds in combination with early transplanting. Don't over-harden transplants; use a starter fertilizer to reduce transplant shock, and irrigate immediately after planting. Summer transplanting works well when slow-bolting, heat-tolerant varieties are selected. In hot summer conditions, remember to germinate seeds in a cool location before growing out plants in the greenhouse or shade house (pay careful attention to air temperatures).

Leafy green mixes are commonly seeded at very high densities with seeding rates depending on seed size and crop species. Spacing between plants is often less than 1 inch, with rows about 2 to 3 inches apart on beds 30 to 36 inches wide. Seeds can be broadcast on the soil surface and raked in or spread on rows with a hand-operated precision seeder. Because seedling emergence may vary from 3 to 15 days at the optimum germination temperatures (55 °F to 70 °F), each crop of a mix is typically grown separately. Multiple varieties or crops may be grown together; however, different germination times and rates of growth make harvest coordination difficult. Leafy green mixes are very short-season crops (25-40 days). The time from planting to harvest is longer for fall to winter (September-February) plantings than for early spring to summer (March-June).

For all leafy green crops, winter production in Utah is possible. Low light and cold temperatures in winter (particularly December-January) make production times quite long, so cold-hardy species and transplants should be used. Always use low tunnels or row covers in winter since repeated exposure to freezing temperatures will reduce the quality of even the hardiest plants. The best way to determine timing is to experiment in your own system. For a starting point, see the lettuce or spinach high tunnel publications (USU) or consult the Winter Growing Guide (https://www.johnnyseeds.com/growers-library/methods-tools-supplies/winter-growing-season-extension/winter-growing-guide.html) by Johnny's Select Seeds.

Irrigation

Lettuce, spinach, and other leafy vegetables require frequent irrigations for optimal quality. As many as eight to ten irrigations and 10-12 inches of water per acre may be necessary depending on seasonal variation, variety, and planting date. Soil type does not affect the amount of total water needed but dictates the water application frequency. Lighter soils need more frequent water applications but less water applied per application.

If available, use drip irrigation to improve marketable yield and performance and reduce irrigation inefficiencies associated with other methods. Since leafy green vegetables have shallow root systems, drip is often a more efficient way to irrigate. Most of the leafy green vegetables are extremely sensitive to water stress. Critical times when irrigation can aid productivity are during crop establishment (seeding or transplanting), rapid leaf sizing, and right up until harvest. Different irrigation methods are commonly used to irrigate leafy green vegetables, each with different management considerations. Historically, furrow irrigation was common. Furrow irrigation results in large fluctuations in soil moisture, nutrient leaching, and low water use efficiency. Sprinkler irrigation is slightly better than furrow, but not as good as drip.

Plastic mulches conserve water and reduce weeds. Use white-on-black plastic mulch (white on one side and; black on the other) for growing transplanted lettuce and other leafy green vegetables. White-up helps keep the soil temperature several degrees cooler, which can reduce bolting in high temperatures. Black-up may have a place for very early or late season crops and for use in high tunnels in winter when extra heat can help with growth.

USU EXTENSION FACT SHEET REFERENCES

- *Vegetable Irrigation: Leafy Greens*

Weed Management

In conventionally managed fields, weed control is achieved with preplant and/or preemergence herbicides. Postemergence herbicides are applied after the field is cultivated to control broadleaf and grass weeds. Hand hoeing is done as needed.

In organic production systems, preplant irrigation induces weed emergence, which can be killed by tillage, flaming, or mulches (straw, cardboard, etc.). There are OMRI-approved organic herbicides (nonselective, contact) which have limited residual activity. Consult your certifying agent prior to applying organic herbicides.

Users should have a current chemical applicator license, and read and save copies of all labels. Herbicide options are listed in Tables 6.5. Labels change, so always consult a current label to determine (1) if the crop is listed for herbicide use; (2) what precautions are required; and (3) what rates and application methods are allowed. It is a violation of federal law to use any herbicides for purposes other than those specified on the approved label. Always use the recommended amount of product, apply it as stated, and watch reentry intervals (REI) and preharvest intervals (PHI).

Herbicides are applied in the following ways:

- Preplant incorporated into the soil prior to seeding or transplanting the crop.
- Preemergence applied to the soil after planting but before the crop or weeds emerge.
- Post-transplant applied after the crop is transplanted either before weeds emerge or after clean cultivation.
- Postemergence applied to weeds after both weeds and the crop have emerged.

Harvest and Storage

In general, practice good hygiene during harvest, to keep lettuce and other leafy greens clean and free of soil and mud. Lettuce will become bitter and tough if harvest is delayed or if the crop is overmature.

Mixed Leafy Greens - Harvest can start anytime from 3 to 5 weeks after seeding. Leaf flavors and textures change with age, so harvest will depend on yield needs and intended use of the mix. Harvesting is done by hand clipping (1 inch above the soil) or with mechanical harvesters in larger-scale production systems. Careful clipping and variety selection allows regrowth for multiple harvests. After harvest, the mix is washed, dried and cooled before packaging. Leaves are susceptible to bruising, so handle gently, wash in very cold water, and dry using salad spinners (custom or homemade versions) before storing at 32 °F to 35 °F with 98%-100% relative humidity. Mixed greens are usually marketed quickly (only 1-2 days of storage).

Lettuces, Spinach, Escarole, etc. - These are harvested at more mature stages of development and are fragile during harvest. Handle as little as possible during the harvest. Most fresh market greens are hand-cut and trimmed, boxed in the field, and then transported to a central cooling facility. Store at low temperatures (32 °F to 35 °F) and high relative humidity (98%-100%) to prevent wilting for up to 2 weeks. Lettuce and other heading greens are generally not washed before marketing.

Lettuces, Radicchio, and Endives (Heading Crops) - Harvest begins when the heads are full size (about 1-2 pounnds), well formed, and firm. Leave some of the wrapper leaves on each head for protection. In large production areas like California, heads are graded by size, may be wrapped in plastic, and then packed in cartons in the field before cooling prior to shipping. Leaf, bibb, and cos (romaine) types are cut, trimmed, and tied before boxing. Store at 32 °F to 35 °F and 98%-100% relative humidity. Expected yields of iceberg lettuce is approximately 500-700 cartons (40-pound box) per acre (24-30 heads/box), bibb and leaf lettuce approximately 700-1000 cartons (25-pound box) per acre (24-30 heads/box) and romaine approximately 700-900 cartons (25-pound box) per acre (24-30 heads/box).

Turnip, Mustard, Collard, and Kale Greens - Harvest begins when stalks are fairly young and tender. Whole plants or individual leaves may be harvested, and rubber bands (or ties) can be used to group loose leaves. Leaves are bunched, three to five stalks per bunch, prior to washing and cooling. Leaves that are discolored, dying, or unattractive are removed during bunching.

Physiological Problems

Tipburn is a problem in lettuce and other leafy greens. Symptoms include brown leaf margins or spots on the youngest leaves in the heads. It is more visible on open-headed types, but in the head-forming types, it may not be noticed until harvest. Tipburn occurs after a drought period followed by moisture from rain or irrigation and is caused by a localized calcium deficiency in the young, rapidly growing leaves. The deficient part of the leaf collapses, turns brown, and may host secondary rot organisms, which makes the head unmarketable. To reduce the risk of tipburn, maintain adequate soil moisture. Much like blossom end rot of tomato, tipburn occurs due to a lack of water or during adverse conditions (heat, cold, excess nitrogen) rather than a soil calcium deficiency (most Utah soils are high in calcium). Excess nitrogen, root pruning due to cultivation, flooding, or drought are commonly involved in tipburn expression. Some varieties are less likely to get tipburn, so select varieties carefully.

Brown Rib is the occurrence of yellow, brown or black streaks or spots on the midrib of the older outer wrapper leaves of head lettuces. Symptoms often show up as the crop nears harvest. It is more common when day and night temperatures are high, and there is no known varietal resistance.

Spotting on leaves and midribs is associated with several atmospheric gases including air pollutants like ozone, sulfur dioxide, and nitrogen dioxide. The affected tissue is discolored, and leaves often have pits and necrotic spots, making the product less marketable. There is no known resistance and high temperatures and high pressure systems (inversions) seem to aggravate the problem.

Bolting is the term used to indicate a plant that has transitioned from leaf (vegetative) growth to flower (reproductive) formation. The initiation of a flower stalk can occur at any time during growth. Bolting is commonly caused by stresses that slow vegetative growth. Cool-weather crops like lettuce, spinach or mustards often bolt when exposed to hot weather. Long day lengths also trigger bolting, so pay attention to planting dates in the spring. Harvest spring-planted crops as soon as possible to avoid excess heat, long days, and associated bolting. Transplants that are chilled or water-stressed in the greenhouse prior to planting are more susceptible to bolting.

Insect Mite and Pest Management

Aphids

Cabbage Aphid *(Brevicoryne brassicae)*
Green Peach Aphid *(Myzus persicae)*
Melon Aphid *(Aphis gossypii)*
Potato Aphid *(Macrosiphum euphorbiae)*

Reference page 46 for description and life history of cabbage aphids.

Reference page 76 for description and life history of green peach, potato, and melon aphids.

Bean Aphid *(Aphis fabae)*
Lettuce Aphid *(Nasonovia ribisnigri)*
Lettuce Root Aphid *(Pemphigus bursarius)*
Turnip Aphid *(Lipaphis erysimi)*

DESCRIPTION

Adult: They have a soft, pear-shaped body with tailpipe-like appendages called cornicles on the rear of the body. Adults range in color from yellow, green, orange, and pink depending on the species, time of year, and food source. Lettuce root aphid adults have a white powdery wax covering their bodies, short antennae, and their cornicles are undeveloped compared to other aphids found on lettuce. They feed in clusters on lettuce roots.
Egg: Initially yellow or green, eggs become shiny-black as they mature.
Nymph: Similar in shape and color to the wingless adult, nymphs are smaller.

LIFE HISTORY

Most vegetable aphid species have similar life cycles. Each of the following aphids overwinter as eggs. **Lettuce aphid** overwinters on *Ribes* spp. such as blackcurrant and gooseberry bushes, and **lettuce root aphid** overwinters on the bark of Lombardy poplar.

Eggs hatch as all females when leaf buds expand in spring. Adults reproduce asexually, give live birth, and have two to 16 generations during the growing season. Aphids move from overwintering hosts to vegetable crops and/or weeds for the summer. Winged aphids develop when food quality declines, crowding occurs, or when they are seeking new plant hosts. In late summer to fall, aphids lay eggs for overwintering.

DAMAGE

Aphids may contaminate harvested plant parts, leaving them unmarketable. Their feeding may cause stunted, yellowed, distorted, and/or curled leaves and loss of plant vigor. Aphids secrete a sticky, clear substance called honeydew, on which sooty mold fungi may grow. **Lettuce root aphids** feed on roots of host plants. Under heavy attack, plants will wilt during warm temperatures. Developing lettuce heads fail to develop properly, remaining soft and reducing yield. Plants may collapse and die when aphid populations are extremely high over a long period. Masses of white, wooly material along with aphids can be present on the roots. Individual rootlets turn brown and die.

Aphids also vector viruses. The most common aphid-vectored diseases of concern in Utah are alfalfa mosaic virus (tomato, pepper, potato, pea, bean), potato virus Y (potato), and watermelon mosaic virus (cucurbits). Occasionally, other diseases carried by aphids are observed.

LIFE HISTORY

Little is known about the overwintering behavior of turnip aphid. Because its appearance and habits are so similar to cabbage aphid, the two species have often not been distinguished. **Bean aphid** overwinters on Euonymus sp. (burning bush) and Viburnum sp. (snowball bush).

MANAGEMENT

Cultural:

- *Avoid excess fertilization.* Aphid densities tend to be higher on plants that have succulent, vigorous growth.
- *Use mulches or row covers.* Reflective mulches and row covers can help reduce aphid populations on vegetables by interfering with the ability of winged aphids to find plants.
- *Remove and destroy plant debris.* Discing fields immediately after harvest will destroy alternate host plants and reduce available aphid and virus sources.

Chemical:

Many aphid species in other parts of the world have developed resistance to multiple insecticide groups, including some synthetic pyrethroids, carbamates, and organophosphates. In Utah, use these insecticides sparingly; instead, choose products that are less damaging to natural enemies of aphids and non target insects.

Biological:

Natural enemies such as lady beetles, lacewings, syrphid flies, and parasitic wasps play a major role in suppresing aphids.

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Pests on Vegetables*
- *Aphid Natural Enemies and Biological Control*
- *High Tunnel Pest Management - Aphids*

Armyworms

Beet Armyworm *(Spodoptera exigua)*
Bertha Armyworm *(Mamestra configurata)*
Western Yellow-Striped Armyworm *(S. praefica)*

DESCRIPTION

Adult: Armyworm moths have a wingspan of about 31-38 mm and are mottled gray and brown with gray or tan colored markings depending on the species.
Egg: Beet armyworm and western yellow-striped armyworm eggs are pale green to pink, ridged, and are found in a mass covered with a white (beet armyworm) or gray (western yellow-striped armyworm) cotton-like material. Bertha armyworm eggs are white turning black just before hatching and are laid in clusters of 50-100.
Larva: Armyworm larvae are about 31-38 mm long and range from olive green, light green, and yellow, gray with dark markings, and yellow with dark gray or black markings. Bertha armyworm larvae quickly drop from a strand of silk when disturbed
Pupa: Armyworm pupae are about 19 mm long and reddish-brown.

LIFE HISTORY

Armyworms overwinter as pupae in the soil. Adult moths emerge from March to July to mate and lay eggs. Hatched larvae feed for 5 to 8 weeks before pupating in the soil. There are two generations each year. Larval feeding from the second generation may be seen until early October before larvae enter the pupal stage to overwinter.

DAMAGE

Armyworm larvae feed in colonies and cause skeletonized leaves. As they grow, they are more likely to feed on entire leaves or cause irregular patches of feeding damage.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Caterpillars*

Cutworms

Black Cutworm *(Agrotis ipsilon)*
Variegated Cutworm *(Peridroma saucia)*

DESCRIPTION

Adult: Cutworm moths are brown or dark gray with front wings that have irregular bands or spots and lighter-colored hind wings. The average wingspan ranges from 31 to 53 mm.
Egg: Extremely small spherical eggs are white or pale yellow when first laid, changing to brown before hatching. Depending on the species, eggs are laid singly or in irregular clusters of 30-360 eggs on leaves or stems, or near the base of the plant.
Larva: Dull gray to brown caterpillars have black stripes or spots, and up to 50 mm long when full grown. Most cutworms curl into a "C" shape when disturbed and during the day, are usually found in dirt clods or just below the soil surface.
Pupa: Dark brown to orange with two spines on one end, pupae are about 19 mm long.

LIFE HISTORY

Cutworms overwinter as larvae in the soil or under plant debris. In the spring, larvae begin to feed on roots and plant stems. They then pupate in the soil and emerge as adults. Female moths lay eggs on the undersides of leaves; hatched larvae feed on plant foliage, and then pupate in the soil. Both black and variegated cutworms have a second generation (or more during hotter seasons). Larvae that hatch from later generations feed until the weather cools and then enter the soil for overwintering.

DAMAGE

Cutworms feed on a wide range of crops, including potato, winter wheat, corn, tobacco, asparagus, bean, beet, cabbage, castor bean, grape, lettuce, peanut, pepper, radish, spinach, squash, strawberry, and tomato. Most cutworm damage occurs during spring and early summer. Cutworm larvae feed at the soil surface and may cut off the stems of young plants during stand establishment. Later in the season, some species feed on plant foliage, which may cause wilting and possible defoliation when infestations are high.

ARMYWORM AND CUTWORM MONITORING

- *Conduct regular scouting for larvae and damage.* Monitor early, when seedlings emerge, to detect cutworms when larvae are small. Young larvae are easier to control. Cutworms are more commonly found in fields that are planted late or infested with weeds. When injured plants are found, dig about 1-inch-deep around the base of plants to see if live cutworms are present. Look for wilted plants that may indicate stem feeding injury. Later in the season, monitor plants for foliar damage.
- *For black cutworms, use pheromone traps.* A threshold of two black cutworm moths per trap per day indicates heavy egg-laying pressure. Increase field scouting efforts during crop emergence when threshold numbers are met or exceeded.

ARMYWORM AND CUTWORM MANAGEMENT

Cultural:

Weedy fields and field borders and high levels of plant residue provide food sources for armyworms and cutworms. Thoroughly till crop residues and control weeds to reduce armyworm and cutworm overwintering and feeding sites. Remove cool-season weeds along field edges to starve young caterpillars. Lambsquarters and wild mustards are attractive plants for egg-laying. Fall tillage can also help destroy or expose overwintering pupae.

Mechanical:

In small-scale vegetable production, protect seedlings with collars made from plastic or Styrofoam cups or toilet paper rolls cut to size.

Biological:

Many predators, parasites, and diseases attack armyworms and cutworms, but because armyworms and cutworms dwell beneath the soil surface, few of these natural enemies are effective in controlling their populations. *Bacillus thuringiensis* (Bt) products can effectively control young armyworm and cutworm larvae.

Chemical:

The sporadic occurrence of armyworm and cutworm infestations typically doesn't support the use of soil insecticides; however, chronic infestations may require an insecticide incorporated at planting. Alternatively, foliar applications in the spring can protect young plants since larvae at the soil surface will feed on foliage at night

For cutworms, consider treatment options when thresholds reach 2 cuts per 100 seedlings, and 3-7 cuts for older plants (the older the plant the higher the threshold).

USU EXTENSION FACT SHEET REFERENCES

- *Cutworms in Vegetable Production*
- *High Tunnel Pest Management - Caterpillars*

Flea Beetles

Three-Spotted Flea Beetle *(Disonycha triangularis)*
Palestriped Flea Beetle *(Systena blanda)*

Reference page 48 for general flea beetle description, life history, monitoring, and management techniques.

USU EXTENSION FACT SHEET REFERENCES

- *Flea Beetles on Vegetables*

Leafminers

Vegetable Leafminer *(Lyriomyza sativae)*
American Serpentine Leafminer *(L. trifolii)*
Pea Leafminer *(L. langei)*
Spinach Leafminer *(Pegomya hyoscyami)*

DESCRIPTION

Adult: Small, about 1.5-8 mm long, black to gray flies have yellow-green markings, depending on the species.
Egg: About 1 mm long and 0.02 mm wide, eggs are white, elongate, cylindrical and laid singly or in small groups.
Larva: Legless, and initially colorless, it becomes yellowish as it matures with four instars ranging from 5-25 mm long.

LIFE HISTORY

Leafminers overwinter in the soil as pupae and emerge in late May as adults. Females lay eggs on the undersides of host leaves. Eggs hatch in about 2-4 days and small maggots feed between the upper and lower surfaces. One leaf may have several maggots. Larvae emerge from feeding mines to pupate on the leaf surface or just below the soil surface. Adults emerge in 10-25 days and begin to lay eggs for another generation. There are at least three generations each year.

DAMAGE

Larval feeding between the upper and lower leaf surface make distinctive winding, whitish tunnels, or mines in host leaves. These areas may become dry and necrotic as the plant ages and mines enlarge. Leafminer damage can be quite destructive to vegetables grown for edible greens but has little impact on other host vegetables.

Hosts include bean, eggplant, pepper, potato, squash, tomato, watermelon, cucumber, beet, pea, lettuce, spinach, chard, collards, kale, and many other plants. Preferred hosts may depend on the leafminer species.

MONITORING

Regularly check young seedlings for leaf mines. Most mines occur on cotyledons and the first true leaves. It is not necessary to treat leafminers feeding on leaves of root crops such as beets, where the edible portion is unaffected. However, leafminers on spinach or leafy greens may require management.

MANAGEMENT

Cultural:

- *Inspect leaves.* Find egg masses throughout the growing season and crush them.
- *Clip and remove infested leaves.*
- *Gently cultivate the soil.* Uncover pupae around the plants and destroy any that are found.
- *Use adequate irrigation.* This keeps plants healthy.
- *Eliminate alternate hosts.* Destroy weeds and deep-plow or physically remove crop residues which can be food and overwintering sources for leafminers.
- *Encourage parasitic wasps.* Plant flowering plants with nectar and pollen-rich umbel-type flowers with shallow cups, such as yarrow, dill, and fennel.
- *Cultivate the soil in late fall.* Expose overwintering pupae to the colder temperatures that will kill them.

Chemical:

Insecticide applications help prevent adults from laying eggs, but they do not kill larvae that are already feeding within the plant leaves. Choose low-impact insecticides, such as spinosad, when possible to reduce impacts on natural enemies. If insecticides are necessary, the time to treat is on the eggs as they hatch. Make sure to get good coverage on the leaves.

Biological:

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

USU EXTENSION FACT SHEET REFERENCES

- *Leafminers of Vegetable Crops*

Wireworms

Pacific Coast Wireworm *(Limonius canus)*
Sugar Beet Wireworm *(L. californicus)*
Western Field Wireworm *(L. infuscatus)*
Columbia Basin Wireworm *(L. subauratus)*
Great Basin Wireworm *(Ctenicera pruinina)*

GENERAL DESCRIPTION

Adult: Adults are known as click beetles. They are about 6 to 13 mm long, with a hard-shell body that is black to brown. They make a distinctive clicking noises with a "hinge" between the thorax and abdomen and use this clicking mechanism to fling their body to escape threats.
Egg: Small, round, and white, eggs are laid singly or in clusters in the moist soil of grassy areas.
Larva: About 13-38 mm long when mature with a wiry look, larvae are shiny white at first, but become light brown or straw-colored with age.
Pupa: White-colored, a pupa is contained in an earthen cell in the soil.

GENERAL LIFE HISTORY

Adults overwinter in the soil and emerge in late April to early May in northern Utah. Between late May and early June, females lay 50 to 400 eggs in the soil about 6 inches deep. Larvae live in the soil for 1 to 6 years and are closer to the soil surface in spring and fall. During hot summer periods, larvae move deeper into the soil. Some larvae can be found at depths of 1-5 feet.

DAMAGE

Limonius species (Pacific Coast, sugar beet, western field, Columbia Basin wireworms) favor moist conditions while *Ctenicera pruinina* (Great Basin wireworm) prefers dry lands where annual rainfall is less than 15 inches. All crops are susceptible to wireworm attack; however, bean, grain, corn, potato, and other annual crops are preferred hosts.

Wireworms may feed on planted seeds, causing failure to germinate. They can also feed on plant roots, causing the death of young plants. Bare spots in the fields and dead or wilted young plants may indicate wireworm infestation.

In Utah, the Great Basin wireworm has reportedly chewed holes through drip tape.

MONITORING

Inspect the soil surface for wireworms after plowing or disc ing fields. Baits such as carrots, untreated corn or wheat seed, or ground whole wheat flour can also be used to detect wireworms. Place baits 4-6 inches deep in the soil when soil temperatures are at 50 °F. If wireworms are detected, collect soil samples in spring with a 6-inch post hole digger and a shake/sifter to estimate the density of wireworms. Table 6.3 shows a soil sampling guide from the University of California.

Table 6.3. *Wireworm Soil Sampling Guide*

Acres in field	Number of soil samples	Treatment threshold (# Of wireworms)
10	30	1
22	45	2
40	60	2
90	90	4
160	120	5

MANAGEMENT

Wireworms are common in Utah, but do not often cause damage. Once present in a field, wireworms can be difficult to eradicate.

Cultural:

- *Establish a dense plant stand.* Reduce the impact of wireworm damage.
- *Rotate crops.* Fields previously planted to grasses, including grass grains or pasture, are at a higher risk for high wireworm populations. Red and sweet clover and small grains, especially barley and wheat, can increase wireworm populations. Include alfalfa and mustards in crop rotations to reduce wireworm populations over time.
- *Practice sanitation.* Remove dead plants throughout the season and at harvest.
- *Dry the soil.* Sugar beet and Pacific Coast wireworm (*Limonius* spp.) populations prefer moist soil and can be reduced by drying the top 15 inches of the soil for several weeks at midsummer. This will especially kill eggs and young larvae. Soil drying is more effective in light sandy to silt loam soils. Conversely, Great Basin wireworms (*Ctenicera* spp.) prefer dry soil and can be eradicated by converting dryland fields to continual irrigation.
- *Flood the soil.* Thoroughly saturate or flood soils for at least 2 weeks when soil temperatures are above 68 °F to significantly reduce wireworm populations. To increase wireworm mortality, alternate periods of flooding and drying.
- *Use intensive plowing.* Reduce wireworm populations plowing three or more times during late spring and early summer.
- *Maintain soil health.* Maintaining healthy soils with compost, manure, or green manures, may reduce wireworm damage.
- *Place drip tape atop of the soil rather than covering it with soil.* This avoids holes created by chewing larvae.

Chemical:

Chemical options for wireworm control are few. Organophosphate chemicals are most effective and consistent when applied at preplant as a broadcast treatment, or at planting time as a furrow application.

Biological:

Birds may feed on wireworms in recently plowed fields but will not reduce populations below economic levels in seriously infested areas. There are no known biological insecticides.

USU EXTENSION FACT SHEET REFERENCES

- *Wireworms*

Cabbage Maggot *(Delia radicum)*

Reference page 50 for general cabbage maggot description, life history, monitoring, and management techniques.

Diamondback Moth *(Plutella xylostella)*

Reference page 46 for general diamondback moth description, life history, monitoring, and management techniques.

Imported Cabbageworm *(Pieris rapae)*

Reference page 47 for general imported cabbageworm description, life history, monitoring, and management techniques.

USU EXTENSION FACT SHEET REFERENCES

- *Caterpillar Pests of Brassica Vegetables*
- *High Tunnel Pest Management - Caterpillars*

Cucumber Beetles

Western-Spotted Cucumber Beetle
(Diabrotica undecimpunctata undecimpunctata)
Western-Striped Cucumber Beetle
(Acalymma trivittatum)

Reference page 77 for general cucumber beetle description, life history, monitoring, and management techniques.

USU EXTENSION FACT SHEET REFERENCES

- *Cucumber Beetles*

European Earwig *(Forficula auricularia)*

DESCRIPTION

Adult: Their elongate brown body with a red-brown head is 12 to 16 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, holding prey, and for the males to grasp females during mating. Male cerci are strongly curved while females are straighter but curve slightly towards the tip.
Egg: Elliptical, pearly white, eggs are 1 mm 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 and similar in appearance to adults, but smaller.

LIFE HISTORY

Adults overwinter in the soil as brooding pairs or aboveground 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 crops when it feeds on the leaves, causing numerous irregular holes or chewed edges. This damage can resemble caterpillar damage. Earwigs also congregate within the plant and contaminate it with their presence and frass. Earwigs can be confirmed as a pest by viewing them at night with a flashlight when they are active.

MANAGEMENT

Since European earwigs can be both beneficial (eat other pest insects) and detrimental to crops, apply control measures only if there is unacceptable crop damage.

Cultural:

- *Use traps.* Trapping earwigs can be an effective way to monitor and reduce earwig numbers. Various types of traps that can be used include:
  - Corrugated cardboard rolled and tied to stakes along field borders or dispersed throughout the field.
  - Rolled or crumpled moistened newspaper.
  - Grooved wood placed together.
  - Tuna cans or yogurt or sour cream containers (punch holes in the container sides just below the lid). Bait containers with smelly oils such as fish or clam oil, bacon grease, and wheat bran or wheat germ, and then bury the container's bottom 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:

Apply insecticides in the late evening just before earwigs come out to feed. Target sites on plants wher injury appears and where earwigs congregate (sites where females brood their young).

Biological:

Earwigs emit a foul-smelling chemical that is distasteful to many predators; however, natural predators such as toads, songbirds, chickens, ducks, and turkeys will eat earwigs. A parasitic tachinid fly will also attack the European earwig.

USU EXTENSION FACT SHEET REFERENCES

- *European Earwig*

Loopers

Alfalfa Looper *(Autographa californica)*
Cabbage Looper *(Trichoplusia ni)*

Reference pages 152 and 46 for looper description, life history, monitoring, and management techniques.

USU EXTENSION FACT SHEET REFERENCES

- *Caterpillar Pests of Brassica Vegetables*
- *High Tunnel Pest Management - Caterpillars*

Slugs and Snails

DESCRIPTION

Adult: Small soft-bodied mollusks, slugs and snails are closely related, except snails have a hard shell and slugs do not. Mucus or slime is secreted and left behind as they travel. As the mucus dries, it forms a shiny white silvery trail, indicating their presence.
Egg: Small, round, pearl-like, and translucent when young, the eggs turn white as they mature and are covered in a layer of mucus. Laid in groups of about 25-120 under residue on the soil surface if the soil is moist or in sheltered cavities near the soil surface.

LIFE HISTORY

Slugs and snails are hermaphroditic. Each individual has both male and female sex organs and is capable of laying 300 eggs. Eggs may hatch in about 1 month under favorable conditions. After hatching, the young start feeding and can reach sexual maturity in 3-5 months (some snails may take up to 2 years to reach maturity). Many slugs and snails that hatch in the spring can begin laying eggs in the fall. Younger slugs and snails tend to stay close to their hatching site and return there each morning. Slugs and snails need moisture to thrive but survive in reasonably dry conditions by hiding in protected areas.

DAMAGE

Slugs and snails feed on a wide variety of plants and are particularly damaging to new seedlings and maturing vegetables that touch the soil. They feed on leaves with chewing mouthparts resulting in irregular holes with smooth edges. Look for the silvery mucous trails as other chewing pests (earwigs, caterpillars) may cause similar damage.

MANAGEMENT:

Although salt will kill slugs and snails quickly, it is not recommended because it will damage plants.

Cultural:

- *Practice sanitation.* Remove boards, stones, and any debris that shelters slugs and snails.

- *Use handpicking.* Though it may not be practical for large commercial productions, but can be an effective method of controlling slugs and snails when done regularly. Daily removal is most effective, but after initially reducing the population, handpicking once a week will keep the numbers down. Water the garden in the afternoon to encourage slugs and snails to come out after dark when you can pick them up and drop them in a bucket of soapy water or seal them in a plastic bag. Do not crush slugs and snails in the garden as any eggs remaining in their carcass will hatch even after the parent is dead.
- *Use barriers.* Slugs and snails avoid irritating barriers. Barriers only work if slugs and snails have other desirable places to feed or hide. Mesh copper screens or sheeting 8 inches wide make effective barriers. Barriers are not lethal but divert the pests to other nearby vegetation.
- *Use traps*. They can be used to lure and destroy slugs and snails. Types of traps include:
    - One-inch lumbar strips nailed as runners on the underside of a 12 x 12 inch board. Slugs and snails crawl underneath the board as a hiding place each day. Turn the trap over once a day and destroy the pests.
    - Bait traps using a pie plate or deeper container (deeper is more effective as it prevents pests from escaping) filled with beer, yeast water, or plain water will attract and destroy slugs and snails. Remove and dispose of the pests each morning to maintain the trap's appeal.
    - Inverted melon rinds and other produce scraps are also attractive to slugs and snails.

Biological:

Natural slug and snail enemies include geese, ducks, and other birds. These predators may damage young seedlings or cause problems with their droppings. Some ground beetles, rove beetles, and certain flies are natural snail enemies, as are toads and snakes. The predacious decollate snail is a voracious predator of the common garden snail but is not recommended for garden situations because it may feed on seedlings, small plants, and flowers once other snails are controlled.

Chemical:

Slug and snail baits can be used in severe cases and can be effective when combined with the cultural control methods already listed. Baits composed of iron phosphate are nontoxic to nontarget animals. Use bait stations to keep bait dry and avoid attracting pets, birds, or other nontarget animals. Effective bait stations include:

- Small piles of bait covered with a board trap (already describer in "Use traps" in Cultural section). The covered area remains somewhat moist, so slugs and snails tend to congregate there.
- Milk cartons (containing bait) with small "doorways" cut in the side. The accessible bait is protectes from rain or irrigation and does not touch the soil.
- Similar bait stations can be made from other food containers, such as cottage cheese cartons. Cut slots around the sides big enough for slugs and snails to enter, and bury the trap so the slots are level with the soil. Place the bait inside the containers and put the lid on. Remove and renew the bait when pests are killed.

Commercial baits are more attractive to slugs and snails when they are slightly moistened with apple or orange juice. If they become too wet, they are ineffective.

Diatomaceous earth can protect vulnerable plants from slugs and snails. Sprinkle diatomaceous earth on plant leaves and on the surrounding ground. Diatomaceous earth becomes ineffective when wet, so reapply as needed.

USU EXTENSION FACT SHEET REFERENCES

- *Controlling Slugs and Snails in Utah*

Garden Symphylan *(Scutigerella immaculata)*

DESCRIPTION

Adult: Slender, elongated, and "centipede-like," symphylans are white with prominent antennae and 15 body segments with 10-12 pairs of legs.
Egg: Eggs are pearly-white and spherical with hexagonal shaped ridges.
Nymph: Similar in appearance to adults but smaller with six pairs of legs, nymphs add an additional pair of legs with each molt.

Leafy Greens

LIFE HISTORY

Adults overwinter in the soil, and eggs, adults, and nymphs can be found together in the soil throughout most of the year. The greatest numbers of eggs are usually deposited in the spring and fall. Eggs incubate 25-40 days when temperatures are 50 °F to 70 °F, and 12 days when temperatures reach 77 °F. First instars emerge from the eggs and go through seven molts before reaching adulthood. There are one to generations each year.

DAMAGE

Symphylans feed on sprouting seeds and underground plant parts. Feeding damage causes root death on younger roots and a gnarled appearance with corky tissues forming around wound sites on older roots. Damage also includes reduced stands, general stunting, and susceptibility to soilborne plant pathogens. Moderately to highly susceptible crops include broccoli, squash, spinach, and cabbage. More tolerant crops include potato, bean, and small grains, where feeding may not lead to significant damage, even at considerably high population densities. Commonly damaged crops include broccoli, other cole crops, spinach, beets, onions, and squash.

MONITORING

Garden symphylans tend to occur in "hotspots" of a few square feet to several acres. Soil sampling, bait sampling, and indirect sampling are the three main sampling methods used to identify damage and inform management decisions.

Soil Sampling is the standard method used for estimating how many garden symphylans are present in a field and is typically done when symphylans are believed to be in the top 6-12 inches of the root zone. Sample units are usually placed on a piece of dark plastic or cloth, where the aggregates are broken apart and symphylans are counted. This method uses variable sample unit sizes including:

- 1-foot cube.
- 6-inch square, 1-foot deep.
- "A shovelful."
- Cores 3-4 inches in diameter and 4-12 inches deep.

Bait sampling is typically much faster than soil sampling but has more variable results. Half of a potato or beet is placed on the soil surface and sheltered with a protective cover (e.g., a white pot or a 4-inch PVC cap). After 1-3 days, lift the bait and count first the garden symphylans on the soil and second the garden symphylans on the bait. During cooler conditions, check baits after 3-5 days. During warm and dry conditions, check baits after 1-2 days.

Indirect sampling refers to using plant growth as an indirect measure of garden symphylan populations and assessing their spatial patterns. Healthy plants sometimes indicate low symphylan populations, while unhealthy plants sometimes indicate high garden symphylan populations. These measurements help to assess overall infestation patterns, but should not be used in place of soil or bait sampling.

MANAGEMENT

Sampling (as discussed above) is important in determining management decisions because in most cases, once damage is noticed, little can be done without replanting.

Cultural:

- *Till the soil.* This physically crushes garden symphylans, thus reducing their populations.
- *Rotate crops.* Garden symphylan populations decrease significantly in potato crops, even allowing subsequent plantings of susceptible crops in rotation.
- *Use transplants instead of direct seeding.* This, or increasing transplant size, decreases plant susceptibility (not effective for broccoli and eggplant).

Chemical:

Noticeable damage often occurs if garden symphylans exceed an average of 5-10 per shovelful in moderately to highly susceptible crops such as broccoli, squash, spinach, and cabbage. In conventional cropping systems, two to three garden symphylans per square foot is commonly used as a treatment threshold.

Biological:

Although little is known about their effect on symphylan populations, many organisms prey on symphylans, including true centipedes, predatory mites, predaceous ground beetles, and various fungi.

Springtail (Order Collembola)

DESCRIPTION

Adult: These minute, soil-dwelling (primitive) insects that have a bi-forked appendage called a furcula that is folded underneath their body and used, by snapping downward, to propel them through the air when disturbed. Body color ranges from white to pale brown to red to purple.

Egg: Tiny spherical eggs are laid singly or in clusters.

LIFE HISTORY

Springtails are most common in heavy, organic soils during very wet, cool spring conditions. They overwinter primarily as resting adults below the soil surface.

DAMAGE

Collembola (springtails) can be a pest of young greens in moist grow boxes and tunnels, especially if there is a high level of organic matter. They cause reduced stands and loss of vigor in surviving plants as they feed on germinating seeds or roots of small plants.

Hosts include multiple vegetables, but spinach and beets are most commonly damaged.

MANAGEMENT

Cultural:

- *Reduce moisture and excess organic matter.*
- *Avoid planting in fields with high levels of organic matter.*
- *Till soil before and after planting to facilitate soil drying and discourage collembola populations.*
- *Select greens varieties with a more upright growth habit to reduce contact between the leaves and soil.*

Chemical:

Insecticides are not generally necessary for springtail management, but there are home and commercial options available.

Biological:

Natural enemies of springtails include rove beetles and predatory mites.

Refer to Tables 6.6 and 6.8 for more information on insecticide use.

Disease Management

Damping-off

CAUSAL AGENTS

Damping off is caused by several soil fungi, including *Pythium*, *Fusarium* and *Phytophthora* species, and *Rhizoctonia solani*

SYMPTOMS

Seedlings affected by damping-off may fail to emerge (can be mistaken for poor seed germination). Aboveground symptoms of seedlings include brown water soaked areas at the base of stems, which causes the seedling to fall over and die. Roots of these seedlings are rotten.

DISEASE CYCLE

Damping-off pathogens are soilborne and are ubiquitous even in small amounts of soil and dirt. They can be found in dirt stuck to reused seed trays and benches. After planting in reused trays infected with damping-off, fungal spores (mycelium) will start to colonize the soil in the trays and subsequently the seedlings. Chances of damping-off in seedlings increase when seedlings are kept very wet. Some damping-off pathogens, like Pythium, have motile spores that can swim in a film of water. If seedling trays are standing in water, the spores can move through the water to other seedlings.

MANAGEMENT

The two most important management options are sanitation and seed treatments with fungicides.

- *Sterilize reused pots and trays.* If pots and trays are re-used they should be sterilized with a 10%-15% bleach solution for one hour and then rinsed with clean water to remove chloride residue.
- *Clean and disinfect greenhouse benches.* Benches should be cleaned and disinfected with bleach.
- *Place plastic under pots and trays that are on the floor.* If trays or pots are placed on a dirt floor, put plastic under the pots to prevent contamination from damping-off pathogens on the ground.
- *Treat seeds with fungicides. This* reduces the chance of young seedlings becoming infected with damping-off pathogens.

USU EXTENSION FACT SHEET REFERENCES

- *Damping-off*

Downy Mildew

(Peronospora farinosa f. sp. *spinaciae* and *Bremia lactuacae)*

CAUSAL AGENTS

The first documented case of spinach downy mildew in Utah occurred in spring 2017 in a greenhouse. Lettuce downy mildew in Utah has only been confirmed in grocery store produce.
On spinach: Downy mildew of spinach is caused by *Peronospora farinosa* f. sp. *spinaciae*. There are 16 known races of spinach downy mildew.
On lettuce: Downy mildew of lettuce is caused by *Bremia lactucae*. At least six races are known in the western United States.

SYMPTOMS

Yellow to brown angular spots appear on leaves during cool wet weather, with white fuzz on the undersides. Over time, lesions turn brown and dry up.

DISEASE CYCLE

Spinach downy mildew survives in living and dead spinach plants, and spores are dispersed by wind. Spinach downy mildew can survive a wide range of temperatures from near freezing to very hot temperatures. Downy mildew can also be seedborne, but the importance of this type of inoculum is unknown.

Lettuce downy mildew can overwinter on crop residue left in the field and can be windborne. Windborne spores can be blown in from hundreds of miles away. Lettuce downy mildew develops best during cool moist weather with temperatures ranging from 41 °F to 75 °F with an optimum temperature of 68 °F.

MANAGEMENT

Resistant varieties are available for both spinach and lettuce downy mildew. However, they are not resistant to all races (see Table 6.4 for spinach cultivar resistance). Lettuce varieties are more selective to areas they can be grown in, and therefore no variety recommendations are made.

- *Use drip irrigation instead of overhead irrigation.* This minimizes dew development on leaves and reduces disease incidence.
- *Some fungicides are effective for lettuce downy mildew, especially as a preventative.* Apply fungicides during environmental conditions that are ideal for infection.

Table 6.4. *Spinach Varieties With Known Resistance to Specific Downy Mildew Races*

Variety	High resistance	Intermediate resistance
3665 (F1)	Races 1-5, 8, 9, 11-12, 14	
Anna (F1)	Races 1, 3, 5	
Baker (F1)	Races 1, 3, 5, 8, 9, 11, 12, 14	
C2-606 (F1)	Races 1-9, 11-16	
C2-608 (F1)	Races 1-7, 9, 11, 13, 16	
Carmel (F1)	Races 1-11,13	
Corvair (F1)	Races 1-12, 13	
Emperor (F1)	Races 1-10	
F91-415 (F1)	Races 1-2	
Flamingo (F1)	Races 1-11	Races 12-13
Gazelle (F1)	Races 1-13	
Kookaburra (F1)	Races 1-13, 15	
Persius (F1)	Races 1-3, 5, 8, 9, 11, 12, 14, 16	
Red Kitten (F1)	Races 1-13, 15	
Reflect (F1)	Races 1-11	
Seaside (F1)	Races 1-12	Race 14
Space (F1)	Races 1- 3, 5-6, 8, 11-12	
Viceroy (F1)	Races 1-2	
Woodpecker (F1)	Races 1-15	

Verticillium Wilt *(Verticillium dahliae)*

CAUSAL AGENT

Verticillium wilt is caused by *Verticillium dahliae* which affects both lettuce and spinach.

SYMPTOMS

Foliar symptoms include necrotic lesion that can be angular. In head lettuce, outer leaves die by remaining folded on the head. Vascular tissue discoloration can be seen by cutting through the main stem. As the lettuce matures the fungus colonizes the center of the head and kills the plant.

DISEASE CYCLE

Verticillium dahliae is a soilborne pathogen that infects many plant species, including several vegetables and alfalfa. Infection occurs through the roots and grows through the vascular tissue up into the plant. The first symptoms usually occur 6-8 weeks after infection. 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. Survival structures of this disease (microsclerotia) can survive many years in the soil.

MANAGEMENT

Managing *Verticillium* is difficult. The best option is avoiding its introduction into fields by only using certified, disease-free seed and cleaning equipment after use in other fields. Crop rotation is ineffective due to the pathogen's large host range. No chemical treatment options are available for this disease.

- *Use disease-free seed to avoid introduction into fields.* Some lettuce varieties have resistance to Verticillium race 1 but not to race 2.
- *Use disease-free seeds for other rotating vegetables*. Verticillium may colonize seeds of other vegetables.

USU EXTENSION FACT SHEET REFERENCES

- *Fusarium and Verticillium Wilt in Vegetables*

Drop (Sclerotinia Rot) *(Sclerotinia sclerotiorum)*

CAUSAL AGENT

Drop or Sclerotinia rot is caused by *Sclerotinia sclerotiorum.*

SYMPTOMS

Drop or sclerotinia rot infect through the roots and foliar infections. Initial symptoms from root or crown infections occur as outer leaves wilt due to damaged roots. Under cool conditions with wet soil, infected plants collapse within 2 days. The rapid decline of the plants is what gave the disease the name "drop." Dead leaves may lay flat on the soil, while inner leaves of the head are still green. Eventually a soft rot sets in. Symptoms from foliar infections are like root infections except that they occur on aboveground plant parts instead of the roots. Infected plants will be colonized by white, cottony mycelium on which the fungus produces survival structures called sclerotia.

The mycelium usually grow on parts of the plant that have high moisture. A fruiting structure called an apothecium (a small, cup-like structure that contains spores) is sometimes produced on the ground.

DISEASE CYCLE

Sclerotinia sclerotiorum is a soilborne pathogen whose survival structures (sclerotia) can survive for many years in the soil. Susceptible plants are colonized through the roots or leaves laying on the ground that come into contact with mycelium or sclerotia. If the fungus produces apothecia with spores, airborne infections can occur. The spores can be shot at least 5 feet into the air and land on leaves that they can then colonize. Once the tissue is decayed, the fungus survives on plant debris until the next suitable host is planted.

MANAGEMENT

Managing *Sclerotinia* is difficult.

- *Apply fungicides at the rosette stage to reduce disease incidence.*
- *Use subsurface drip irrigation.* This fungus prefers wet soil, so switching irrigation to subsurface drip irrigation can be even more effective than fungicide applications by helping to keep the top 3 inches of soil dry.
- *Flood fallow fields for 1 or 2 months to drown sclerotia in the soil.* This technique has been used in some parts of the country and can result in very good control of drop. However, this control method may not be feasible in many parts of Utah.

Leafy Greens

Beet Curly Top Virus

CAUSAL AGENT

Curly top disease is caused by curtoviruses transmitted by beet leafhoppers.

SYMPTOMS

Plants are stunted and leaves are yellow and wrinkled. This should not be mistaken for some spinach varieties that naturally have crinkled leaves. Depending on the infection severity, entire spinach or beet fields can be lost.

DISEASE CYCLE

In the spring and summer, beet leafhoppers migrate from their overwintering sites into vegetable fields. They can acquire the virus by feeding on infected weeds and subsequently spread it to susceptible vegetables, such as spinach, beets, chard, tomato or pepper. Once acquired, beet leafhoppers will carry and transmit the virus for the rest of their lives.

MANAGEMENT

Once a plant is infected there is no cure. There are currently no resistant beet, chard, or spinach varieties available.

- *Maintain good weed control in areas close to host crops to help remove virus reservoirs.*

Leaf Spots
(Stemphylium botryosum f. sp. *spinacia* and *Cladosporium variabile)*

CAUSAL AGENTS

Leaf spots are caused by *Stemphylium botryosum* f. sp. *spinacia* (spinach) and *Cladosporium variabile* (spinach and chard).

SYMPTOMS

Stemphylium and *Cladosporium* are of minor importance in spinach and chard production.

On spinach: *Stemphylium* causes small spots that are initially gray-green. The spots enlarge over time and eventually dry up and become tan and papery in texture. *Cladosporium* initially causes tiny necrotic, sunken spots on the leaves (the spots could be mistaken for spray damage). Eventually, the lesions turn dark brown and the leaf dies.
On chard: *Cladosporium* on chard causes the same foliar symptoms as on spinach.

DISEASE CYCLE

Stemphylium and *Cladosporium* on spinach cause most damage at high humidity (80%) between 59 °F to 68 °F and 65 °F to 74 °F, respectively.. The spores are splashed from volunteer spinach or plant debris on the soil surface by rain or irrigation onto the leaves of new plants. The spores can also be windborne and, in the case of *Stemphylium*, seedborne.

MANAGEMENT

There are no effective chemical controls.

- *Remove crop debris.* This minimizes inoculum for crops grown in the following year.

Phoma Leaf Spot and Root Rot
(Phoma betae)

CAUSAL AGENT

This disease is caused by *Phoma betae.*

SYMPTOMS

Phoma leaf spot and root rot can cause damping-off in *Beta* sp. such as beets and chard. It can also cause light brown leaf spots that may contain concentric rings of tiny round fruiting bodies containing spores. The fungus can also cause root rot resulting in plant wilting.

DISEASE CYCLE

Phoma betae is seedborne and can overwinter on plant debris. Seedborne inoculum leads to damping-off. In spring, spores developing in fruiting bodies on plant debris are blown by wind onto new plants, causing spots on leaves and stems. The spores developed in new lesions are moved to uninfected plants by splashing water, equipment, and foot traffic during wet weather. The ideal conditions for infection and disease development are 57 °F to 65 °F and high humidity.

MANAGEMENT

- *Use certified disease-free seed.*
- *Reduce incidence by rotating crops.* Allow 3 years to pass before an area is planted with *Beta* genus crops again.
- *Seed treatments.* The only chemical management option is seed treatment with products such as Thiram.

Tomato Spotted Wilt Virus (TSWV)

CAUSAL AGENT

Tomato spotted wilt virus (TSWV) is transmitted by thrips. TSWV is frequently seen in Utah on tomatoes and peppers but thus far has not been confirmed on lettuce.

SYMPTOMS

Symptoms on lettuce leaves are like to symptoms on tomato leaves. Initially, infected leaves show bronzing, and small brown lesions begin to develop along the veins. Lesions expand over time and may merge, causing large necrotic areas on leaves. Lettuce plants may die if infected at a young age.

DISEASE CYCLE

Plants are infected when thrips carrying the virus feed on a healthy plant depositing virus particles. The first symptoms often appear 7-10 days after infection. In some cases, the virus remains localized to the area where thrips feeding occurred. However, plants often become systemically infected, and the virus spreads from the original infection point throughout the entire plant. Once a plant is infected there is no cure. If thrips are reproducing on the plant, it can serve as an inoculum source for neighboring plants.

MANAGEMENT

There is no cure for an infected plant. Remove and destroy dsiseased plants. The best management strategy is to prevent an infection. There are no resistant lettuce varieties.

- *Scout for and manage thrips populations*.
- *Remove and destroy infected plants.*
- *Plant lettuce upwind from susceptible crops*. Thrips are often blown to other plants by wind.
- *Maintain good weed control.* Weeds can be a host TSWV and reservoir. Good weed control on field edges and in backyards can reduce the chance of infections.

Powdery Mildew *(Erysiphe polygoni* and *E. betae)*

CASUAL AGENT

Powdery mildew is a prevalent problem in beet production throughout the western United States. It is well adapted to semiarid locations with warm, dry climates. The fungal species that cause powdery mildew on beets are *Erysiphe polygoni* and *Erysiphe betae*.

SYMPTOMS

Small, circular white patches of mycelium appear on the undersides of older leaves. They spread rapidly throughout the foliage. Eventually, leaves may turn yellow and purplish-brown before completely dying off.

DISEASE CYCLE

The conidia (asexual spores) of *E. polygoni* and *E. betae* are short-lived and unable to overwinter in northern Utah. Ascospores (sexual spores) produced later in the season can overwinter on plant debris. Also, the fungus is reintroduced annually from windborne conidia from the south. Germinating conidia produce hyphae that penetrate the epidermal plant cells, allowing the fungus to continually grow mycelium covering leaf surfaces.

MANAGEMENT

Early detection is critical for good control.

- *Balance irrigation.* Too much surface irrigation may leave the soil saturated and increase humidity which allows the fungus to spread. Nevertheless, drought-stressed plants are more susceptible to plant damage.
- *Plant resistant varieties of beets.*
- *Apply fungicide when the first spots are detected.*

USU EXTENSION FACT SHEET REFERENCES

- *Powdery Mildews on Vegetables*

Refer to Tables 6.7 and 6.9 for more information on fungicide and bactericide use.

Leafy Greens Pesticide Tables for Commercial and Small-Scale Use

Table 6.5. *Herbicides* *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah*

Brand name (REI/PHI)	Active ingredient	Application relative to crop				Application relative to weeds		Weeds controlled			Comments
		Pretransplanting	Preplant incorporate	Post-transplanting	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X	X	X	X		X		X	X	Use shielded
Dactha; W75 (12h/30d)	DCPA	X	X	X		X		X			
Devrinol (12hr/60d)	napropamide	X	X			X		X	X	X	
Gramaxone Inteon (12hr/30d)	paraquat	X	X				X	X	X	X	Restricted use; collards only
Poast (12hr/14-30d)	sethoxydim			X	X		X	X			
Prefar 4E (12hr/-)	bensulide	X	X			X		X			
RoundUp & others (12hr/14d)	glyphosate	X	X	X	X		X	X	X	X	Use shielded
Select 2EC (12hr/14-30d)	clethodim			X	X		X	X			
Stinger (12hr/30d)	clopyralid			X	X		X		X	X	
Treflan & others (12hr/30d)	trifluralin	X	X	X		X		X	X	X	
Organic Products											
Corn gluten meal		X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 6.6. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Imported cabbageworm,/ diamondback moth,/cabbage looper	Leafminer	Flea beetle	Earwig	Thrips	Snail/slug
acephate	Acephate 90 Prill, Acephate 90 WDG, Acephate 97 UP, Acephate 97 WDG, Bracket 97, Bracket 97 WDG, Livid 90 Prill, Livid 97 Prill, Orthene 97, Tide Acephate 90WDG	1B	7	X	X	X					
permethrin	Arctic 3.2 EC, Perm-UP 3.2 EC, PermaStar AG	3A	14				X	X			
	Permethrin, Pounce 25 WP			X	X	X	X	X			
pyrethrins[O]	Azera, PyGanic Crop Protection EC 1.4 II, PyGanic Crop Protection EC 5.0 II, Tersus	3A	5-7				X	X	X		
	Pyrenone Crop Spray			X	X	X	X	X	X	X	
	EverGreen Crop Protection EC 60-6							X	X		
	Pyrus TR			X				X		X	X
zeta-cypermethrin	Gladiator	3A	10-14	X			X	X			
acetamiprid	TriStar 8.5 SL	4A	10-14	X			X				
clothianidin	Belay	4A	10-14	X			X		X		
dinotefuran	Scorpion 35SL, Venom	4A	14				X			X	
imidacloprid	Dominion	4A	14	X						X	
	Lada 2F, Leverage 360, Malice 2F, Mallet 2F T&O, Mallet 75 WSP, Marathon 1% Granular, Marathon II, Mineiro 2 F Flex, Omni Imidacloprid 2F T&O, Omni Imidacloprid 4F, Viloprid FC 1.7, Widow, Willowood Imidacloprid 4SC,			X				X		X	
thiamethoxam	Platinum 75 SG	4A	14				X				
flupyradifurone	Altus	4D	10-14	X							
spinetoram	Radiant SC	5	10-14				X				
spinosad[O]	Entrust, Entrust SC, Success, SpinTor 2SC, Conserve SC.	5	7-10				X				
	Seduce Insect Bait				X				X		

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[O] = Organic

Table 6.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Imported cabbageworm,/ diamondback moth,/cabbage looper	Leafminer	Flea beetle	Earwig	Thrips	Snail/slug
abamectin	Abacus V, Abacus V6, Abamex, Abba Ultra, Agri-Mek SC, Averland FC, Enterik 0.7 SC, Minecto Pro, Timectin 0.15 EC Ag, Willowood Abamectin 0.15LV, Enterik 0.15 LV, Reaper 0.15 EC, Reaper Advance, Reaper ClearForm	6	14-21				X				
emamectin benzoate	Proclaim	6	7-14				X				
pyrifluquinazon (greenhouse only)	Rycar	9B	7	X							
*Bacillus thuringiensis ssp. kurstaki*ᴼ	Bioprotec Plus, BT Now, Leprotec	11A	5-7		X	X					
	Bioprotec PLUS, Deliver Biological Insecticide				X						
cyromazine	Citation, Trigard, Trignata WSP	17	7				X				
spirotetramat	Movento	23	14	X			X				
chlorantraniliprole	Coragen, Durivo, Shenzi 400SC	28	10-14	X			X				
cyantraniliprole	Verimark, Exirel	28	10-14	X	X	X	X				
cyclaniliprole	Harvanta 50SL	28	14-17	X			X				
flonicamid	Beleaf 50 SG	29	7-10	X							
GS-omega/kappa-Hxtx-Hv1aᴼ	Spear-LEP	32	5-7		X			X			
	Spear-T Liquid Concentrate			X						X	
allyl isothiocyanate	Dominus	UN	N/A		X			X			X
azadirachtinᴼ	Atrevia 1.2% SL, Aza-Direct	UN	7-10				X				
	Atrevia 3.0% SL			X	X		X	X		X	
	AzaGuard, AzaSol, Azatin O			X	X	X	X	X		X	
Burkholderia spp.ᴼ	Venerate CG	UN	7-10				X				
canola oilᴼ	Captiva Prime	UN	3							X	
	Pycana						X		X		
Chenopodium ambrosioides extractᴼ	Requiem EC, Requiem Prime	UN	7				X				

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ᴼ = Organic

Table 6.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Imported cabbageworm,/ diamondback moth,/cabbage looper	Leafminer	Flea beetle	Earwig	Thrips	Snail/slug
cinnamon oil^{O}	Cinnerate	UN	3	X						X	
clove oil^{O}	Bemix	UN	3	X							
garlic oil^{O}	Captiva	UN	3							X	
geraniol^{O}	Brandt Ecotec Plus	UN	3	X				X		X	
	Wrath			X	X						
Isaria fumosorosea strain FE 9901^{O}	Nofly WP	UN	5-7	X				X		X	
iron phosphate	Bug-N-Sluggo	UN	2-4 weeks						X		X
	First Choice Sluggo Snail and Slug Bait, Leaf Life Sluggo Snail and Slug Bait, Sluggo										X
kaolin^{O}	NovaSource Surround WP	UN	5-7					X			
Metarhizium anisopliae strain F52^{O}	Lalguard M52 OD	UN	7	X						X	
	Met 52 EC									X	
metaldehyde	Deadline Bullets, Deadline GT, Durham Metaldehyde Granules 3.5, Durham Metaldehyde Granules 7.5, Deadline M-PS Mini Pellets, Deadline Ornamental	UN	3-4 weeks								X
mineral oil^{O}	BioCover MLT, BioCover SS, BioCover UL, PureSpray Green	UN	3	X				X		X	
	Glacial Spray Fluid, Omni Supreme Spray, Suffoil-X, TriTek, Ultra-Pure Oil			X						X	
neem oil^{O}	EcoWorks EC, Rango, Trilogy	UN	3	X						X	
potassium salts of fatty acids^{O}	Des-X, Kopa Insecticidal Soap	UN	5-7	X							
	M-Pede			X			X			X	
potassium silicate	Carbon Defense	UN	7	X							
sodium ferric	Despot Snail & Slug Bait	UN	2-4 weeks								X

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^{O} = Organic

Table 6.7. ***Fungicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Downy mildew	Sclerotinia rot	Leaf spot	Phoma leaf spot	Powdery mildew
triflumizole	Procure 480SC, Trionic 4SC	3	14					X
mefenoxam	Oxem 4ME Select, ReCon Bold SL, Ridomil Gold GR, Ridomil Gold SL, Subdue Maxx, Thrive 4M, Ultra Flourish, Ultra Flourish XHL	4	14	X				
boscalid	Pageant Intrinsic, Pompa	7	7-14	X	X		X	
	Bonafide						X	
fluopyram	Velum Prime	7	5					X
cyprodinil	Xuvance, Xuvia	9	7-10		X			X
azoxystrobin	Acadia LFC, Aframe, Atticus Acadia 2 SC, A-Zox 25SC, Azoxy 50WDG Select, AzoxyStar, Azoxyzone, Azterknot, Azteroid FC 3.3, Cadera, Drexel Azoxystrobin SC, GCS Azoxy 2SC, Heritage, Heritage SC, Mazolin, Mazolin 50WDG, Mika SC, Quadris, Satori, Tetraban, Tigris Azoxy 2 SC, Topguard EQ, Trevo	11	10-14	X				
famoxadone	Tanos	11	5-7	X				
fenamidone	Reason 500 SC	11	5-7	X				
pyraclostrobin	Cabrio EG, Innliven Elite, Priaxor Xemium	11	7-10	X				
	Empire			X	X		X	
	Merivon Xemium			X			X	
fludioxonil	Alterity 62.5 WG, Switch 62.5WG, Cannonball WG	12	7-10		X			
	Emblem, Spirato GHN				X			X
	Miravis Prime				X	X		
polyoxin D zinc salt	OSO 5%SC	19	5-7	X				
cyazofamid	Ranman 400SC Fungicide, RenaZ SC, Zilker SC	21	14	X				
tolfenpyrad	Torac	21A	14	X				
cymoxanil	Tanos	27	5-7	X				

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^{O} = Organic

Leafy Greens

Table 6.7., continued. ***Fungicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Downy mildew	Sclerotinia rot	Leaf spot	Phoma leaf spot	Powdery mildew
propamocarb hydrochloride	Previcur Flex	28	7-14	X				
aluminum tris	Aliette WDG, Linebacker WDG	33	10	X				
dimethomorph	Forum	40	7-10	X				
mandipropamid	Micora, Revus	40	7-10	X				
fluopicolide	Presidio	43	7-14	X				
ametoctradin	Zampro	45	7	X				
corn oil[O]	PureCrop1	BM1	3	X				
extract of *Swinglea glutinosa*[O]	Ecoswing	BM1	5-7	X				
geraniol[O]	Zayin	BM1	3	X				X
soybean oil[O]	Bionatrol-M	BM1	3	X				X
thyme oil[O]	Guarda	BM1	3	X				
cinnamon oil[O]	Cinnerate	BM1	3					X
	Cyclops			X				
neem oil[O]	EcoWorks EC, Rango, Trilogy	BM1	3	X				X
Bacillus amyloliquefaciens strain D747[O]	Double Nickel 55, Double Nickel LC, Triathlon BA	BM2	7	X				
Bacillus amyloliquefaciens strain F727[O]	Stargus	BM2	7	X		X		
Bacillus amyloliquefaciens strain MBI 600[O]	Serifel	BM2	7	X				
Bacillus mycoides isolate J[O]	LifeGard LC	BM2	7	X				X
	LifeGard WG			X		X		
Bacillus pumilus strain QST2808[O]	Sonata	BM2	5-7	X				X
Bacillus subtilis strain AFS032321[O]	Theia	BM2	5-7	X				
Bacillus subtilis strain IAB/BS03[O]	Aviv, Milagrum Plus	BM2	5-7	X				
Bacillus subtilis strain QST 713[O]	Cease, Rhapsody, Serenade ASO, Serenade Max	BM2	5-7	X				X
Bacillus subtilis var. amyloliquefacien strain FZB24[O]	Taegro 2	BM2	5-7	X				

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Table 6.7., continued. ***Fungicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Downy mildew	Sclerotinia rot	Leaf spot	Phoma leaf spot	Powdery mildew
Clonostachys rosea strain J1446[O]	Lalstop G46 WG	BM2	5-7		X			
Pseudomonas chlororaphis strain AFS009[O]	Howler, Howler EVO	BM2	7	X				
Streptomyces lydicus WYEC 108[O]	Actinovate AG	BM2	5-7	X				X
basic copper sulfate	Basic Copper 53, Cuproxat FL	M1	7	X				
copper hydroxide[O]	Champ Dry Prill, Champ Formula 2 Flowable, Champ WG, ChampION++, Kocide 3000, Kalmor, Kocide 50DF, Kocide HCu, Mankocide, Nu-Cop 30 HB, Nu-Cop 50 DF, Nu-Cop HB, Previsto, Ridomil Gold Copper	M1	7	X				
	Camelot O, Cueva Fungicide Concentrate, Grotto	M1	7	X				X
copper oxychloride	Badge X2, Badge SC, C-O-C-S WDG	M1	7	X				
copper sulfate pentahydrate	ET-F, MasterCop	M1	7	X				
mancozeb	Dithane M45, Roper DF, Roper DF Rainshield	M3	7-10	X		X	X	
hydrogen peroxide	Jet-Ag, OxiDate 2.0, OxiPhos	NC	7	X				X
mineral oil[O]	PureSpray Green, Ultra-Pure Oil	NC	3					X
peroxyacetic acid	Rendition	NC	7	X				
	Jet-Ag 5%, OxiDate 5.0, ZeroTol 2.0			X				X
potassium bicarbonate[O]	Carb-O-Nator	NC	5-7	X				
	MilStop B, MilStop SP			X				X
potassium salts of fatty acids	Des-X, Kopa Insecticidal Soap, M-Pede	NC	5-7					X
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM Ultra	NC	10-14	X				
chitosan	Warhammer	P	2-8 weeks	X				X

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Leafy Greens

Table 6.7., continued. ***Fungicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Downy mildew	Sclerotinia rot	Leaf spot	Phoma leaf spot	Powdery mildew
extract of *Reynoutria sachalinensis*[O]	Regalia CG, Regalia	P5	7-10	X				
mono- and di-potassium phosphite	Resist 57, Valley-Phite, Rampart 6.8, Fungi-Phite, Reliant	P7	7-21	X				
	Fosphite			X				X
mono-and di-basic sodium, potassium, and ammonium phosphites	Phostrol	P7	7-21	X				
potassium phosphite	Viathon	P7	7-21	X				
mono potassium phosphate	Phorcephite	P7	7-21	X				
mono- and dipotassium salts of phosphorous acid	K-Phite 7LP	P7	7-21	X				X
	Rampart			X				
paraffinic oil[O]	JMS Stylet-Oil	UN	3					X
sulfur[O]	Sulfomex, Yellow Jacket Wettable Sulfur II	UN	7-10					X

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[O] = Organic

Leafy Greens

Table 6.8. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Imported cabbageworm, diamondbaxk moth, cabbage looper	Leafminer	Flea beetle	Earwig	Thrips	Snail/slug
pyrethrins° + potassium salts of fatty acids°	Safer Brand Insecticidal Soap + Pytherin Concentrate	3A/UN	5-7	X	X	X	X	X	X	X	
pyrethrins° + neem oil°	Ferti-lome Triple Action, Ferti-lome Triple Action Plus RTU	3A/UN	5-7	X	X	X	X	X	X	X	
sulfur° + pyrethrins°	BioAdvanced Fruit & Vegetable 3-in-1 Solution RTU, BioAdvanced Fruit & Vegetable 3-in-1 Solution Concentrate	3A/UN	10-14	X	X	X	X	X	X	X	
malathion	Hi-Yield 55% Malathion Spray	3B	5-7		X	X		X		X	
	Bonide Malathion Concentrate, Ortho MAX Malathion Insect Spray Concentrate,			X	X	X		X		X	
	Spectracide Malathion Insect Spray Concentrate			X	X	X				X	
imiclacloprid	BioAdvanced Fruit, Citrus, & Vegetable Insect Control, Monterey Fruit Tree & Vegetable Systemic Soil Drench	4A	N/A	X							
spinosad°	Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Colorado Potato Beetle Beater, Monterey Garden Insect Spray, Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS	5	7-10		X	X	X			X	
	Bonide Captain Jack's Deadbug Brew Dust				X		X				
Bacillus thuringiensis°	Bonide Captain Jack's BT, Bonide Thuricide (BT) Concentrate, Monterey B.T., Monterey B.T. RTU	11	5-7		X	X					
Bacillus thuringiensis var. Kurstaki°	Natural Guard Caterpillar Killer Spray with BT, Safer Brand Caterpillar Killer II Concentrate	11	5-7			X	X				
	Ferti-lome Dipel Dust Biological Insecticide					X	X				

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° = Organic

Leafy Greens

Table 6.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Imported cabbageworm, diamondbaxk moth, cabbage looper	Leafminer	Flea beetle	Earwig	Thrips	Snail/slug
neem oil○	BioAdvanced Organics Neem Oil RTU, Epsoma Organic Neem Oil 3n1, Monterey 70% Neem Oil, Monterey Neem Oil RTU, Natria Neem Oil Concentrate, Natria Neem Oil RTU, Natural Guard Neem RTU, Safer Brand Neem Oil Concentrate	UN	3	X							
cotton seed oil○+ clove oil○ + rosemary oil○	Monterey All Natural Snail & Slug Spray RTU	UN	3	X						X	X
	Bonide Mite X RTU			X						X	
iron phosphate	Bonide Captain Jack's Slug Magic Granules, Monterey Sluggo, Monterey Sluggo MAXX	UN	2-4 weeks								X
	Bonide Captain Jack's Bug & Slug Killer, Natural Guard Bug, Slug, & Snail Bait, Monterey Sluggo Plus				X				X		X
mineral oil○	Safer Brand Horticultural & Dormant Spray Oil Concentrate	UN	3	X						X	
potassium salts of fatty acids○	Natural Guard Insecticidal Soap	UN	5-7	X				X		X	
	Bonide Insecticidal Soup RTU, Epsoma Organic Insect Soap, Monterey Insecticidal Soap RTU, Natria Insecticidal Soap RTU			X					X	X	
	BioAdvanced Organic Tomato, Vegetable, & Fruit, RTU, Bonide Insecticidal Super Soap RTU, Monterey Garden Insect Spray RTU, Natural Guard Spinosad Soap RTS, Natural Guard Spinosad Soap Concentrate			X	X	X	X	X	X	X	
potassium salts of fatty acids○ + neem oil	Safer Brand End ALL Insect Killer RTU	UN	5-7	X			X	X			
potassium salts of fatty acids○ + seaweed extract○	Safer Brand Insect Killing Soap RTU Spray	UN	5-7	X				X		X	

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○ = Organic

Table 6.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Imported cabbageworm, diamondbaxk moth, cabbage looper	Leafminer	Flea beetle	Earwig	Thrips	Snail/slug
potassium salts of fatty acids^O + sulfur^O	Safer Brand 3-in-1 Concentrate, Safer Brand 3-in-1 RTU Garden Spray, Safer Brand Insect Killing Soap Concentrate, Safer Brand Tomato & Vegetable 3-in-1 Garden Spray	UN	5-7	X					X	X	
silicon dioxide	Bonide Diatomaceous Earth	UN	7-14	X	X	X	X	X	X	X	X
	Natural Guard Diatomaceous Earth Crawling Insect Control								X		X
potassium salts of fatty acids^O + spinosad^O	Natural Guard Spinosad Soap RTU	UN/5	5-7	X	X	X			X	X	

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^O = Organic

Table 6.9. ***Fungicides and Bactericides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA).*

Active ingredient	Brand name	MoA	Residual days	Downy mildew	Drop (sclerotinia rot)	Leaf spos	Phorna leaf spot + root rot	Powdery mildew
copper octanote	Bonide Captain Jack's Liquid Copper Fungicide Concentrate, Bonide Captain Jack's Liquid Copper Fungicide RTS, Bonide Captain Jack's Liquid Copper Fungicide RTU, Monterey Liquid Copper Fungicide RTU, Natural Guard Copper Soap Fungicide Concentrate, Natural Guard Copper Soap Fungicide RTU	M1	7	X		X		
	Epsoma Organic Copper Soap RTU			X		X		X
copper sulfate	Bonide Copper Fungicide Spray/ Dust	M1	7	X		X		
sulfur[O]	Bonide Plant Fungicide Dust, GardenTech Sevin Sulfur Dust 2-in-1Disease and Insect Control, Safer Garden Fungicide Concentrate, Safer Garden Fungicide RTU	M2	7-10					X
sulfur[O] + pyretherins[O]	Natria Insect, Disease & Mite Control RTS, Natria Insect, Disease, & Mite Control RTU	M2/ 3A	10-14					X
chlorothanonil	Bonide Fung-onil Concentrate, Bonide Fung-onil RTU, Ferti-lome Broad Spectrum Landscape & Garden Fungicide, GardenTech Daconil Fungicide Concentrate, GardenTech Daconil Fungicide RTU, Ferti-lome Broad Spectrum Landscape & Garden Fungicide RTU, Hi-Yield Vegetable, Flower, Fruit, and Ornamental Fungicide	M5	14			X	X	
myclobutanil	Ferti-lome F-Stop Lawn & Garden Fungicide Concentrate, Ferti-lome F-Stop Lawn & Garden Fungicide RTS	3	14			X	X	

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[O] = Organic

Leafy Greens

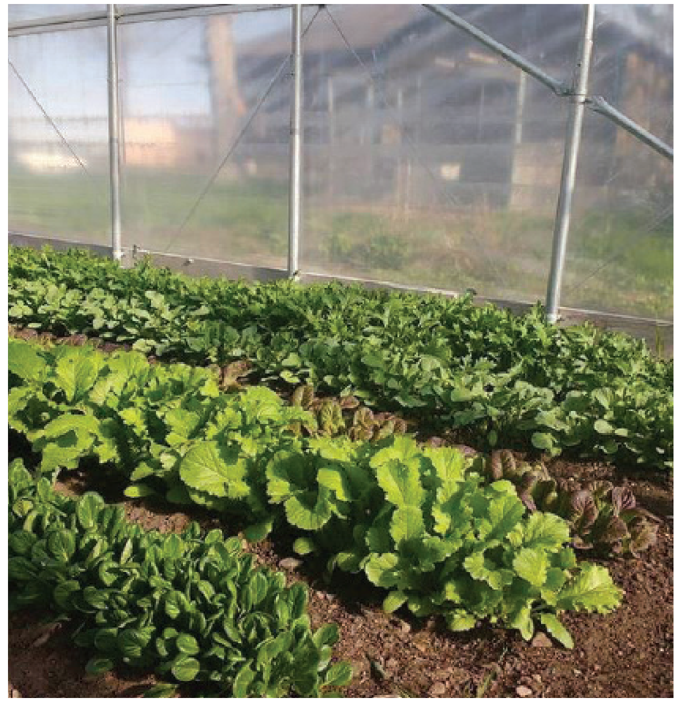
Table 6.9., continued. ***Fungicides and Bactericides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Leafy Greens*** *(Lettuces, Spinach, Chard, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Downy mildew	Drop (sclerotinia rot)	Leaf spos	Phorna leaf spot + root rot	Powdery mildew
propiconazole	Bonide INFUSE Disease Control Concentrate	3	14			X	X	
pyrethrins°	Ferti-lome Triple Action O, Ferti-lome Triple Action RTS, Ferti-lome Triple Action Plus RTU	3A	5-7					X
Bacillus amyloliquefaciens strain D747°	Bonide Revitalize Bio Fungicide Concentrate, Bonide Revitalize Bio Fungicide RTU	MBCA	7	Sup-pression		X		X
mineral oil°	Monterey Horticultural Oil O, Monterey Horticultural Oil O RTS, Safer Horticultural + Dormant Spray Oil Concentrate	UN	3					X
neem oil°	BioAdvancedd Organics Neem Oil RTU, Epsoma Organic Neem Oil 3-n-1, Monterey Neem Oil RTU, Natural Guard Neem Concentrate O, Natural Guard Neem RTU, Safer Neem Oil Concentrate, Safer Neem Oil RTU	UN	3					X
	Natria Neem Oil Concentrate, Natria Neem Oil RTU			X				X
potassium salts of fatty acids° + sulfur°	Safer Tomato & Vegetable 3-in-1 RTU O	UN	5-7					X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

° = Organic

Lettuce field at a commercial vegetable farm in Utah county.



High tunnel leafy greens production at a vegetable farm in Cache county.

Symptoms of nitrogen deficiency in lettuce.

Symptoms of nitrogen deficiency in spinach.

Tip burn in lettuce.

Heat-induced bolting occurring in lettuces.

Brown rib occurring in lettuce head.

Hail damage in Swiss chard.

Black Bean Aphid *(Aphis fabae)*

Turnip Aphid *(Lipaphis erysimi)*

Lettuce Aphid *(Nasonovia ribisnigri)*

Lettuce Root Aphid
(Pemphigus bursarius)

Colony of lettuce aphids on lettuce leaf.

Beet Armyworm Moth
(Spodoptera exigua)

Beet Armyworm

Bertha Armyworm Moth
(Mamestra configurata)

Bertha Armyworm

Western Yellow-Striped Armyworm
Moth *(Spodoptera praefica)*

Yellow-Striped Armyworm

Black Cutworm Moth *(Agrotis ipsilon)*

Black Cutworm

Variegated Cutworm Moth *(Peridroma saucia)*

Variegated Cutworm

Three-Spotted Flea Beetle *(Disonycha triangularis)*

Pale-Striped Flea Beetle *(Systena blanda)*

Flea beetle feeding damage on kale foliage.

American Serpentine Leafminer Fly *(Liriomyza trifolii)*

Pea Leafminer Fly *(Liriomyza langei)*

Spinach Leafminer Fly *(Pegomya hyoscyami)*

Vegetable Leafminer Fly *(Liriomyza sativae)*

Leafminer Eggs on Spinach

Leafminer maggot and feeding tunnel.

Extensive leafminer feeding damage in Swiss chard.

Leafminer feeding damage in spinach.

Alfalfa Looper Moth *(Autographa californica)*

Alfalfa Looper *(Autographa californica)*

Wireworm feeding damage on lettuce

Western spotted cucumber beetle feeding on lettuce.

European Earwig *(Forficula auricularia)*

European earwig damage and frass on lettuce head..

Snail (Phylum Mollusca, Class Gastropoda)

Slug (Phylum Mollusca, Class Gastropoda)

Garden Symphylan *(Scutigerella immaculata)*

Springtails captured in bait trap.

Springtail feeding damage on kale seedlings.

Damping-off in spinach seedlings.

Downy mildew *(Peronospora farinosa* f.sp. *spinaciae)* on spinach.

Downy mildew *(Bremia lactucae)* on lettuce.

Beet greens infected with beet curly top virus (BCTV).

Stemphylium leaf spot *(Stemphylium botryosum* f. sp. *spinacia)* on spinach.

Cladosporium leaf spot *(Cladosporium variabile)* on spinach.

Symptoms of phoma leaf spot *(Phoma betae).*

Verticillium wilt *(Verticillium dahliae)* in lettuce.

Sclerotinia rot or drop *(Sclerotina sclerotiorum)* in lettuce.

Tomato spotted wilt virus (TSWV) symptoms on lettuce.

Powdery mildew *(Erysiphe polygoni)* on Swiss chard.

CHAPTER 7: LEGUME PRODUCTION

Varieties

Variety selection can be challenging given the large number of choices available. Consider the length of the growing season, soil type, climate conditions, and production practices when selecting varieties. For information on variety options, talk to your seed salesperson. Most varieties will grow and produce in Utah but not all may be suited to your location. Heirloom (open-pollinated) varieties generally lack disease resistance and are more prone to cosmetic defects.

Table 7.1 displays a few suggested varieties. Exclusion from the list does not imply the variety lacks merit Most have not been tested in Utah. When evaluating a new variety, compare it to what you already grow, and evaluate it based on earliness, growth habit, market needs, and disease resistance. On-farm testing is the best way to identify varieties suited to your farm's unique conditions.

Table 7.1. *Variety Suggestions -* *Commonly Grown Legumes*

BEAN	
Bush	*Colter, Goldilocks (y), Jade, LaSalle, Provider, Rocdor (y) , Royal Burgundy, Tavera*
Pole	*Fortex, Kentucky Pole, Monte Gusto (y), Seychelles*
Dry	*kidney, navy, pinto, black, and white beans*
BROAD BEAN	
Improved long pod	
LIMA BEAN	
Bridgeton, Cangreen, Eastland, Fordhook 242	
PEA	
Shelling	*Knight, Miragreen, Premium, Strike, Utrillo*
Edible pod	*Sugar Ann, Super Sugar Snap*
Snow	*Avalanche, Golden Sweet (y), Oregon Giant, Royal Snow*

Planting and Spacing

Legume crops are both cool-season (fresh or dry peas, broad bean) and warm-season(snap or dry beans, lima bean) vegetables. The cool-season legumes germinate in cool soils (below 60 °F), while the warm-season legumes germinate best in warm soils (above 65 °F). Peas grow best when the mean daily temperatures are 60 °F to 70 °F, while beans prefer temperatures of 70 °F to 85 °F. Temperatures significantly warmer than the ideal for the crop results in slow growth and may affect fruit set. Split-set, pod curvature, and stringy pods occur when legumes are exposed to high growing temperatures during flowering (see the Production Problems section).

Planting dates vary widely in Utah depending on local climate conditions. Planting may begin in March in southern Utah (St. George) and may be as late as early June in the cooler mountain areas of northern Utah. Plant the cool-season legumes several weeks before and the warm-season legumes around the frost-free date for the location. Local average last freeze dates can be accessed through the Utah Climate Center (climate.usu.edu).

Plant and row spacing varies with cultivar grown, plant growth habit (bush, pole, or vining types), available equipment, irrigation approach, and market requirements.

Legumes are always direct-seeded. Plant seeds ½ to ¾ inches deep (depending on seed size, soil moisture, time of year, and irrigation availability). Sequential plantings (every 10 days) are possible to provide continuous harvest for bush types. Pole or vining cultivars are trellised on horticultural netting and often grow 5 to 8 feet tall without much training.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Green Bean Production*

Table 7.2. *Legume Seed Requirements (lb/acre) for Different Between and In-Row Spacing*

	Row spacing (ft)	Seed spacing (seeds/row ft)	Seed needs (lb/acre)	Seeds/lb
Beans (fresh, dry, lima)	1.5-3.0	2-7	25-90	500-2,000
Pea (fresh, dry)	2.0-3.0	3-8	80-250	1,500-2,500
Broad bean	2.0-4.0	1-2	60-80	300-800

Soil and Fertility

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

The legume crops may be sensitive to residual herbicides from the previous crop, so pay attention to prior cropping patterns and use crop rotation when required.

Before planting, have the soil tested to determine nutrient needs and deficiencies. Soil sampling approaches and interpretation of the tests are found on the Utah State University Analytical Laboratories website (http://www.usual.usu.edu). Organic growers should incorporate composted organic matter before planting to improve soil fertility. If you regularly apply compost or manure, periodic soil testing is critical. Regularly adding organic fertilizers can result in the buildup of salts and excess levels of some nutrients. Initially applying 5 tons per acre of high-quality compost of known nutrient analysis can provide all nutrient needs. Broadcast the compost over the whole field or band it on the planting row before incorporating it into the soil.

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

Nitrogen (N) – Apply up to 20-30 pounds N/acre for peas and 30-50 pounds for beans prior to planting. Base legume N needs on prior cropping history, residual soil N levels, and prior additions of compost or manures. Be sure to inoculate legume seeds with the appropriate rhizobium for the crop. Inoculated legumes then produce their own nitrogen, so no sidedress N is required. Some legumes are prone to zinc, iron, or manganese deficiency, particularly if grown in soils with pH over 8.0. Use soil testing to identify if these trace minerals are required, and then add them to the broadcast or sidedressed fertilizer applications.

Table 7.3. *Phosphorus (P_2O_5) and Potassium (K_2O) Based on Soil Test Results*

Phosphorus test results	lb/acre	Potassium test results	lb/acre
0-10	100-150	0-125	100-150
10-19	50-100	125-250	50-100
20-29	25	250-400	25-50
30-60+	--	400+	--

Irrigation

All legumes require regular, uniform watering during the growing season. Wet or waterlogged soils during establishment can limit seed germination, cause root rot problems, and poor or nonuniform stands. Inconsistent watering around flowering can cause misshapen pods, split set, poor seed fill or sizing, and stringy pods. Overwatering encourages root rots and foliar diseases. Sprinklers can be used to germinate seeds, then after the first cultivation, switch to furrow or drip irrigation. For small production areas, use drip irrigation.

Monitor soil water status to maintain consistent, uniform water supply. Use soil moisture monitoring sensors and weather-based irrigation scheduling to monitor plant needs. Place sensors at various locations in the field and at several depths in the soil profile to accurately measure of soil water content. Start irrigating at 20%-25% depletion when irrigating by drip and at 35%-45% depletion for furrow or sprinkler systems. Water extraction estimates using reference evapotranspiration adjusted with a crop coefficient (kc) are closely related to row canopy cover. The kc is about 0.4 for a legume crop with 25% row cover; 0.8 for 50% cover; 1.1 during flowering and pod growth; and 0.8 during the late season seed maturity (dry bean/pea) period. Find low-cost tools and methods to monitor soil water at ATTRA Sustainable Agriculture (https://attra.ncat.org/publication/soil-moisture-monitoring-low-cost-tools-and-methods/).

Weed Management

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

In organic production systems, manage weeds by encouraging weed emergence with irrigation, then kill these weeds with tillage, flaming, or mulches (straw, cardboard, etc.). There are OMRI-approved organic herbicides that can assist in weed management. These herbicides are nonselective, contact herbicides, and are applied to growing, green weeds. Most organic herbicides have limited residual activity and are used in combination with tillage, hoeing, and mulches. Consult your certifying agent prior to applying organic herbicides to ensure you stay in compliance.

For any herbicide application, keep a copy of the label, and ensure you have read it carefully. Different companies market similar products under different trade names, so use the chemical name (active ingredient) to ensure the proper material is applied. Only one representative trade name is listed in the Table 7.4. Herbicide labels change, so always consult a current label to determine: (1) if the crop is listed for herbicide use; (2) what precautions are required; and (3) what rates and application methods are allowed. It is a violation of federal law to use any herbicides for purposes other than those specified on the approved label. Off-label applications are hazardous to the environment, to people using the product, and can severely injure the crop.

Use the recommended amount of product and apply it as stated. Pay attention to re-entry intervals (REI) and preharvest intervals (PHI). Don't spray in high wind conditions. Work with your neighbors, as many herbicides are toxic to other crops growing nearby. Finally, herbicides are just one tool available for weed control, and their use should supplement other good weed management practices.

Herbicides are applied to legumes in the following ways:

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

Refer to Table 7.4 for more information on commercial herbicide use.

Harvest and Storage

Fresh Pea (Green, Podded, or Snow) - Depending on the variety or type grown, it takes 60-70 days from planting until harvest. Green peas are commonly machine harvested (once-over pass), and the machine shells the peas. With edible-podded or snow pea, harvests occurs every few days once plants start producing pods of the desirable size. Peas are highly perishable. To maintain quality, cool immediately to 35 °F and store under high humidity for 7-10 days.

Broad Bean - It often takes 90-120 days from planting until harvest. To maintain quality, cool immediately to 35 °F and store under high humidity for 7-10 days.

Fresh Bean (Bush or Pole) - Depending on the variety, it takes 60-80 days from planting until harvest. Harvests occurs every few days once plants start producing pods of the desirable size. With pole beans, picking generates more flowers and pods. Bush beans are commonly machine picked (once-over harvest), where all the pods are stripped off the plants. To maintain quality, cool immediately to 40 °F to 45 °F and store under high humidity for 7 days.

Lima Bean - Depending on the variety, it often takes 70-100 days from planting until harvest. Harvest for fresh pod when the seeds are full size. Pod maturity is variable due to different flowering times. Harvest about once per week. To maintain quality, cool immediately to 40 °F to 45 °F and store under high humidity for 7 days.

Dry Bean or Pea - It often takes 80-120 days from planting until harvest for beans or 80-100 days for peas. Use a once-over harvests approach to gather all pods when they are dry. Machine harvest in the morning when plants are more hydrated to avoid pod shatter. When pods and seeds are very dry, seed damage may occur during harvest.

Physiological Disorders

Incomplete pod fill (green pea and dry bean): When pods develop under stressful conditions (high temperatures, low soil moisture), some of the seeds growing in the pod may not set or fill properly. The seed voids cause variable pod growth, which gives them a curved or nonuniform appearance. Maintain uniform soil water conditions to minimize the problem.

Pod dehiscence (dry bean or pea): As pods dry out, the vascular bundles lose their connectedness. If the pod is very dry, they often shatter when pickled, causing the seeds to scatter. Varieties vary greatly in their expression of the problem. Picking when it is more humid or in the morning helps limit shattering and seed loss.

Pod curvature (fresh bean): When bush beans grow poorly, flowers may be set too close to the soil. As the pods grow, they bend when they meet the soil and this causes pod curvature. Some curvature is normal, but when it is excessive, pods may be less marketable (due to appearance or if stained by the soil). Ensure plants are fertilized and watered properly so growth in not restricted, which minimizes the problem.

Split set (all legumes): In most legumes, plants flower over extended times. Split set occurs when some of the flowers abort (drop off) resulting in variable pod maturity. The combination of high temperatures (+90 °F day/75 °F nights) and low relative humidity or soil moisture stress favors flower drop. Cultivars vary in their sensitivity to weather conditions, and good irrigation practices helps minimize the problem.

Stringiness (fresh bean or pea): When pods develop under high temperatures and/or low soil moisture, the vascular bundles in the pods may lignify prematurely. Pods consist of two halves, and the vascular bundles help connect them. Stringiness makes the pods tough, so maintain uniform soil water conditions to minimize the problem. Heirloom varieties are more prone to string development.

Insect and Mite Pest Management

Aphids

Pea Aphid *(Acyrthosiphon pisum)*

DESCRIPTION

Adults: Pea aphids are relatively large, at 3mm long. They have long legs and are pale-green with black tips on the long cornicles or “tail pipes”. There also may be yellow-brown forms. Host plants include crops in the legume family (alfalfa, beans, peas, etc.).

LIFE HISTORY

Pea aphids reach maturity and start reproducing 10-22 days after birth. They overwinter as eggs on perennial legume hosts.

DAMAGE

Pea aphids cause direct feeding injury by sucking plant sap from the leaves, stems, and blossoms at all growth stages. Pea aphids have also been documented to transmit over 30 different plant viruses, including watermelon mosaic virus and zucchini yellow mosaic virus.

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.* Metallic/reflective mulches and row covers can help reduce aphid populations on vegetables by interfering with the ability of winged aphids to find plants.
- *Choose planting locations carefully.* Don’t plant vegetable crops near overwintering hosts, such as rangeland or alfalfa fields.
- *Remove and destroy plant debris*. Discing fields immediately after harvest will destroy alternate host plants and reduce available aphid and virus sources.
- *Plant susceptible crops upwind.* Planting upwind from infested plants decreases aphid migration into the crop since aphids are blown downwind.

Chemical:

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

Biological:

Natural enemies include lady beetles, lacewings, syrphid flies, and parasitic wasps. These play a major role in natrually supressing aphids.

USU EXTENSION FACT SHEET REFERENCES

- *Aphids in Alfalfa*
- *Aphid Pests on Vegetables*
- *High Tunnel Pest Management - Aphids*

Armyworms

Reference page 111 for a general armyworm description and life history.

DAMAGE

Armyworm larvae feed in colonies and cause skeletonized leaves. As they grow, they are more likely to feed on entire leaves or cause irregular patches of feeding damage.

MANAGEMENT

Cultural:

- *Use traps.* Include blacklight and/or pheromone traps to detect moth’s presence.
- *Scout plants.* When moths are detected, look for armyworm eggs and larvae.
- *Plant early and plant early-maturing varieties.* Late-planted legumes are more susceptible to larval feeding injury because more plants are in the seedling stage when larval feeding occurs.

Chemical:

Apply insecticides when larvae are in the early instars group. Apply insecticides early or late in the day, when armyworm larvae are most active.

Biological:

Numerous species of parasitoids and generalist predators affect armyworms. The most common species that parasitize armyworms include braconid wasps and tachinid flies. Predators include various

Legumes

ground beetles, spined soldier bug, the insidious flower bug, and vertebrates such as birds, skunks, and rodents.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Caterpillars*

Cutworms

Reference page 111 for a general cutworm description and life history.

DAMAGE

Cutworms feed on a wide range of crops, including legume crops. Most cutworm damage occurs during spring and early summer. Cutworm larvae feed at the soil surface and may cut off the stems of young plants during stand establishment. Later in the season, some species feed on plant foliage which may cause wilting and possible defoliation when infestations are high.

MONITORING

- *Conduct regular scouting for larvae and damage*. Monitor early, when seedlings emerge, to detect cutworms when larvae are small. Young larvae are easier to control. Focus on fields with an early season weed infestation and those planted late. Cutworms preferentially attack these types of fields. When injured plants are found, dig about 1 inch deep around the base of plants to see if live cutworms are present. Look for wilted plants that may indicate stem feeding injury. Later in the season, monitor plants for foliage damage.
- *For black cutworms (Agrotis ipsilon), use pheromone traps*. A threshold of 2 moths per trap per day indicates significant egg-laying pressure. Increase field scouting efforts during crop emergence when threshold numbers are met or exceeded.

MANAGEMENT

Cultural:

Weedy fields and field borders, and high levels of plant residue provide food sources for cutworms. Thoroughly till crop residues and control weeds to reduce cutworm overwintering and feeding sites. Remove cool-season weeds along field edges to starve young caterpillars. Lambsquarters and wild mustards are attractive host plants for egg-laying. Fall tillage can also help destroy or expose overwintering pupae.

Biological:

Many predators, parasites, and diseases attack cutworms, but because cutworms dwell beneath the soil surface, few of these natural enemies are effective in controlling their populations. *Bacillus thuringiensis* (Bt) products can be effective in controlling young cutworm larvae.

Chemical:

The sporadic occurrence of cutworm infestations typically doesn't support the use of soil insecticides; however, if chronic cutworm infestations occur or large numbers of overwintering cutworms are observed, insecticides incorporated at planting provide a good preventive strategy. Young larvae at the soil surface will feed on foliage at night; thus, foliar applications in the spring can protect young plants.

USU EXTENSION FACT SHEET REFERENCES

- *Cutworms in Vegetable Production*
- *High Tunnel Pest Management - Caterpillars*

Grasshoppers

Reference page 80 for a general grasshopper description, life history, damage, monitoring, and management.

USU EXTENSION FACT SHEET REFERENCES

- *Grasshoppers*
- *Community-Wide Grasshopper Control*

Mexican Bean Beetle *(Epilachna varivestis)*

DESCRIPTION

Adult: Adult beetles are a bright red color (sometimes orange or brown) with a hemispherical shape and 16 black spots on their back. They are 8 mm long and 6 mm wide.

Egg: Eggs are laid in clusters of 40-60 on the underside of host leaves. They are elliptical-shaped and yellow-orange.

Larva: Upon hatching, larva are yellow and covered with dense branched spines. They develop through four instars before pupating.

Pupa: Pupae are yellow-orange and bear brown-black lines. Pupation lasts 8-10 days.

LIFE HISTORY

Mexican bean beetles are related to lady beetles and have one to three generations per season in Utah. Adults overwinter in woody areas near legume production.

DAMAGE

Both Mexican bean beetle adults and larvae cause lacy defoliation by feeding and stripping away the lower layer of leaf tissue. Eventually, this leads to skeletonization and total defoliation.

MANAGEMENT

Cultural:

- *Search for egg masses on host crops and crush them by hand.* One egg mass per 1 foot is the standard insecticide threshold for fields.
- *Grow early-maturing bean varieties*. Avoid peak Mexican bean beetle damage in late July and August.
- *Plant resistant bean varieties.* Non-waxy varieties such as 'Regal' and 'Idaho Refugee' snap beans, and 'Baby Fodhook' and'Baby White' lima beans are more resistant compared to waxy varieties.

Biological:

The beneficial parasitoid wasp *Pediobius faveolatus* is a natural enemy of the Mexican bean beetle.

Seedcorn Maggot *(Delia platura)*

Reference page 50 for a general seedcorn maggot description and life history.

MANAGEMENT

Practices that speed up germination and plant emergence will reduce crop losses from maggots.

Cultural

- *Handle seeds carefully.* 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.* Shallowly planting 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.
- *Plant during fly-free periods determined by monitoring (see above).*
- *Don't overwater.* Seedcorn maggots thrive in moisture.
- *Use row covers.* Row covers placed over transplants at the time of planting excludes egg-laying.
- *Sanitize fields*. Removr and destroy plant residues.
- *Rotate crops each season.* Maggot populations are generally higher after legumes (e.g., beans and peas) 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 preventive 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 seedcorn maggot larvae and reduce populations.

Two-Spotted Spider Mite *(Tetranychus urticae)*

DESCRIPTION

Reference page 78 for a description of the two-spotted spider mite.

LIFE HISTORY

The mites overwinter in non-crop and weedy areas, such as grassy banks along irrigation ditches and roadsides, on weeds, in fallowing fields, and in pastures. Spider mite populations increase in mid to late summer, spread onto entire corn plants. Mites can complete their development (one generation) in as quickly as 1 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. 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. This pattern occurs especially along the field borders or near grassy areas within fields.

MANAGEMENT

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 suppress mites.
- *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 foliage.

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.

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.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Spider Mites*
- *Web Spinning Spider Mites*

Thrips

Onion Thrips *(Thrips tabaci)*
Western Flower Thrips *(Frankliniella occidentalis)*

Reference page 172 for general thrips description, life history, damage, monitoring, and management.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Thrips*
- *Onion Thrips*
- *Western Flower Thrips*

Slugs and Snails

Reference page 116 for general snail and slug description, life history, damage, monitoring, and management.

USU EXTENSION FACT SHEET REFERENCES

- *Controlling Slugs and Snails in Utah*

Flea Beetles

Reference page 48 for general snail and slug description, life history, damage, monitoring, and management.

USU EXTENSION FACT SHEET REFERENCES

- *Flea Beetles on Vegetables*

Pea Weevil *(Bruchus pisorum)*

DESCRIPTION

Adult: Adult pea weevils are brown with patches of white, gray, and black. They have a triangular white patch on the prothorax. Their antennae and legs are black. They are oval-shaped, measuring 4.5-6 mm long.
Egg: Eggs are oval and 1.5 mm long. They are a yellow-orange and laid in small clusters on pea pod surfaces.
Larva: Larvae develop through four instars growing to 6-7 mm long.

LIFE HISTORY

Pea weevils have one generation per season. Adults overwinter in plant debris in the soil or stored dry peas. In spring, adults lay their eggs on pea pods, and hatched larvae bore directly into the pods. At maturity, they will have consumed all the content of the seed. Pupation takes about 2 weeks.

DAMAGE

Larvae cause the primary damage by feeding within the pea seeds, making them undesirable for human consumption.

MANAGEMENT

Management should begin right after pea bloom.

Cultural

- *Monitor using a sweep net in commercial fields.* The sampling threshold is one weevil per 25 sweeps, indicating a possible infestation.
- *Till or disc the soil to reduce overwintering adults.*
- *Destroy crop residue at the end of the season.*
- *Remove volunteer plants in the spring.*
- *Plant and harvest early.*

Chemical

Apply insecticides to kill adults before they lay their eggs on the pods.

Pea Leaf Weevil *(Sitona lineatus)*

DESCRIPTION

Adult: Adults are 4.5 mm long, slender, gray-brown and have a broad snout.
Egg: Eggs are white when laid but gradually turning black before hatching.
Larva: White with a dark brown head capsule. Legless and curls in a "C" shape when disturbed. Ranges from 3mm-6mm in length.

LIFE HISTORY

Adult pea leaf weevils overwinter in alfalfa and other perennial legumes. Adults emerge in spring and feed on host crops (alfalfa, beans, peas, and other legumes). After mating, females lay thousands of eggs singly near the soil surface of host plants. After two to three weeks, the newly hatched larvae burrow into the soil and feed on the nitrogen-fixing root nodules of the host legumes. They develop through five instars in four to eight weeks. The mature larvae pupate in the soil before the new generation of adults emerge in mid-summer.

DAMAGE

Adults feed on new foliage, causing notched shapes along the margins. This feeding typically doesn't result in yield loss. The larvae feeding on nitrogen-fixing root nodules can reduce soil nitrogen which may affect current and future crop yields.

MANAGEMENT

Cultural

- *Scout crops.* Begin scouting when legume crops are nearly emerged and look for the leaf-notch feeding damage on the lower foliage.
- *Plant later in spring.* Avoid feeding damage from the early peak emergence and dispersal of first generation adults.
- *Plant trap crops.* Early spring-planted faba beans or winter peas have been used as a trap crop to deter pea leaf weevils from the cash crop.

Chemical

If populations reach an economically damaging threshold, consider foliar insecticide sprays. These should be applied before the adult females lay eggs.

Alfalfa Looper *(Autographa californica)*

DESCRIPTION

Adult: The wingspan of moths measures 35-45mm. Front wings are gray with various brown patches. There is a prominent silvery white or yellow mark at the center of each forewing. The edge of the front and hind wings have a series of dark spots.

Egg: Eggs are pale yellow, hemispherical, with thin vertical ridges.

Larva: Larvae are green with distinct white stripes along each side and three abdominal prolegs. They develop through five instars growing to 25-35 mm long.

Pupa: Larvae spin a loose, whitish-silk cocoon. Pupae are a black-brown color and 18-20 mm long.

LIFE HISTORY

Alfalfa loopers overwinter as pupae in the soil. Adult moths emerge in late spring and can have up to four generations (a generation lasting 30-40 days) throughout the growing season.

DAMAGE

Larvae initially feed by chewing irregular holes in the foliage. This can eventually skeletonize leaves.

MANAGEMENT

Cultural

Weedy fields, field borders, and high levels of plant residue provide food sources for alfalfa loopers. Thoroughly till crop residues and control weeds to reduce overwintering looper and feeding sites. Remove cool-season weeds along field edges to starve young caterpillars. Fall tillage can also help destroy or expose overwintering pupae.

Biological

Many predators, parasites, and diseases attack alfalfa loopers. *Bacillus thuringiensis* (Bt) products can effectivly control young larvae.

Refer to Tables 7.5 and 7.7 for information about using insecticides for edible beans and peas in commercial and small-scale operations.

Disease Management

Bacterial Brown Spot
(Pseudommonas syringae pv. *syringae)*

CASUAL AGENT

Bacterial brown spot is caused by the bacteria *Pseudommonas syrigae* pv. *syringae*.

SYMPTOMS

Small, necrotic lesion with a yellow-green halo develop in young leaves. Once lesions enlarge and merge, the dead tissue can fall out, giving the leaves a tattered appearance. On bean pods lesions have a water-soaked appearance. As lesions age they become brown and sunken. Occasionally, bacteria will ooze from lesions.

DISEASE CYCLE

P. syringae pv. *syringae* has a wide host range and is found on leaves of many crops and weeds without causing disease. It can also survive in plant debris and can be found on bean seed (Schwartz, 2011; Schwartz et al, 2005). The bacteria are splashed onto bean plants by rain or overhead irrigation. They enter leaves or bean pods through wounds and natural openings. Bacterial brown spot is most severe at high humidity (95% or higher) and temperatures of less than 80 °F.

MANAGEMENT

To manage bacterial brown spot, use resistant varieties when available and certified disease-free seed. Incorporate bean residue into the soil. The bacteria cannot survive in the soil once the bean residue is decomposed. Crop rotation for at least 2 years to non-legume crops reduces inoculum in the field. Copper-based bactericides can reduce inoculum on bean foliage and reduce the spread to bean pods.

Common Bacterial Blight
(Xanthomonas axonopodis pv. *phaseoli)*

CASUAL AGENT

Common bacterial blight is caused by the bacteria *Xanthomonas axonopodis* pv. *phaseoli*.

SYMPTOMS

On leaves, the initial symptoms are small water-soaked lesions that enlarge over time and turn dry and brown with a yellow halo. The symptoms on pods consist of large water-soaked lesions that get pitted and turn a rusty-red color. Affected seeds often have poor germination, yellow or brown spots on the seed coat, and in severe cases, may be shriveled.

DISEASE CYCLE

The bacteria survive on seed, which can be a major infection source. Another source of inoculum is plant debris left on the soil surface. The bacteria can also survive on nonhost plants such as weeds or other crops. Disease is most severe at temperatures between 82 °F to 86 °F (Schwartz et al, 2005). The bacteria can be splashed by rain or irrigation water onto susceptible bean plants as well as being spread by soil, humans, and insects. After infection, it takes 10-14 days for bacteria to build and be spread as secondary inoculum.

MANAGEMENT

It is very important to plant only pathogen-free seed. Good weed control can reduce inoculum from these hosts. A crop rotation of at least 2 years eliminates inoculum from plant debris left on the soil surface. when available. Chemical control must be applied before symptoms appear. Follow the label and use copper-based products on bean foliage.

Halo Blight
(Pseudomonas syringae pv. *phaseolicola)*

CASUAL AGENT

Halo blight is caused by the bacteria *Pseudomonas syringae* pv. *phaseolicola*.

SYMPTOMS

The initial leaf symptoms appear as small water-soaked lesions on the underside of leaves. The lesions quickly turn necrotic and are sometimes surrounded by a halo. In cases of severe infections, the entire plant may turn chlorotic. The chlorosis is due to a toxin produced by bacteria at temperatures between 64 °F and 73 °F. During these temperatures, chlorosis of plants can occur. It will not be noticed at higher temperatures. On bean pods, rust-colored, water-soaked lesions are seen. If infections include sutures, bean seed may be discolored and shriveled.

DISEASE CYCLE

As with other bacterial bean diseases, contaminated seed and leftover plant debris are sources of inoculum. Splashing rain, irrigation water, or soil blown by wind can spread the bacteria to susceptible host plants. The bacteria enter the plant through natural openings like stomates or through wounds and colonize the plant. The disease is most severe during cooler temperatures of less than 73 °F.

MANAGEMENT

Managing halo blight is very similar to managing other bacterial bean diseases. Using clean, disease-free seed and crop rotation for at least 2 years to nonhost crops will significantly reduce inoculum. Since the bacteria can survive on the leaves of nonhost plants or volunteer beans, good weed control is essential. Allow no cultivation work or field walk-throughs if foliage is wet to avoid spreading bacteria from infected to healthy plants. Follow the label and apply copper-based bactericides in the late vegetative or early flowering state.

Beet Curly Top Virus

CASUAL AGENT

Curtovirus transmitted by beet leafhopper causes beet curly top virus (BCTV).

SYMPTOMS

Plants are stunted and leaves are yellow. Later, leaves become thick and brittle and may turn dark green. Few if any pods develop, and plants drop flowers and senesce early.

DISEASE CYCLE

In spring and summer, beet leafhoppers migrate from their overwintering sites into vegetable fields. They can acquire the virus during feeding on weeds and then spread it to susceptible vegetables, including beans. The leafhopper will carry and transmit the virus its entire life.

MANAGEMENT

Once a plant is infected, there is no cure. Good weed control to remove virus reservoirs in the vicinity of fields can help. There are currently no resistant bean varieties available.

Damping-off

CASUAL AGENT

Damping-off is caused by *Pythium*, *Fusarium* and *Phytophthora* species, *Rhizoctonia solani.*

SYMPTOMS

If seedlings are killed before they emerge, bare spots are left in rows. This symptom can be mistaken for a poor germination rate of seed. After seedlings emerge, the stems turn brown at the base and the seedlings fall over and die. The roots of these seedlings rot.

DISEASE CYCLE

Damping-off pathogens are soilborne and are ubiquitous even in small amounts of soil and dirt. They can be found in dirt adhering to reused seed trays and benches. After planting, spores or mycelium colonize the soil in the trays, and subsequently, the seedlings. Chance of seeing damping-off increases when seedlings are kept very wet. For example, a field's gradient can lead to water pooling at one end. Some damping-off pathogens like Pythium have motile spores that can swim in a film of water.

MANAGEMENT

The most important management option to prevent damping-off in peas or beans is seed treatment with a fungicide. Cleaning tools and equipment that come in contact with soil minimizes damping-off pathogens moving from one field to the next. If damping-off has occured in the past, using smooth-seeded peas instead of wrinkle-seed pea varieties can reduce disease incidence. Cultural practices to reduce incidence include shallow planting in well-drained soils, reducing compaction, and minimizing irrigation (shortly after planting).

USU EXTENSION FACT SHEET REFERENCES

- *Damping-off*

Powdery Mildew *(Erysiphe polygoni* and *E. pisi)*

CASUAL AGENT

Several Erysiphe species cause powdery mildew on beans and peas. It is currently not known which species are present in Utah.

SYMPTOMS

The leaves show white, powdery spots that enlarge and eventually cover the entire leaf. Leaves may turn yellow and drop.

DISEASE CYCLE

Infections occur in early summer from spores released from fruiting structure in plant debris, overwintering legumes, or spores blown in by 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 spread 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 the fungus starts growing on the plant surface. 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 worker's clothes going through the rows.

MANAGEMENT

Powdery mildew must be controlled early on when the first lesion is seen. Once the fungus covers the entire leaves or the leaves are yellow, it is too late to control the disease. Remove infected plant debris from fields before planting a new crop and remove weeds in the legume family. There are resistant pea varieties for *E. pisi*. They are not resistant to other powdery mildews infecting peas. It is therefore necessary to identify the species present in Utah. Fungicide applications following the label may be necessary.

USU EXTENSION FACT SHEET REFERENCES

- *Powdery Mildews on Vegetables*

Bean Common Mosaic Virus

CASUAL AGENT

Bean common mosaic virus (BCMV) is a Potyvirus that infects various bean species.

SYMPTOMS

Symptoms include puckering, blistering, and foliar distortion. Downward curling and rolling may also be present. Plants infected early may end up stunted and distorted.

DISEASE CYCLE

The virus is spread season to season through infected seeds, aphid vectors, mechanical transmission and, occasionally, pollen.

MANAGEMENT

- Source certified disease-free seed.
- Grow bean plants that are labeled resistant to the virus.
- Manage aphid populations on bean plants.

Refer to Tables 7.6 and 7.8 for information on using fungicides and bacteracides on edible beans and peas in commercial and small-scale operations.

Legume Pesticide Tables for Commercial and Small-Scale Use

Table 7.4. *Herbicides* *Registered for* ***COMMERCIAL*** *Use on* ***Legumes*** *in Utah*

Brand name (REI/PHI)	Active ingredient	Timing and application location relative to crop				Timing relative to weeds		Weed groups controlled			Comments
		Pre-plant & stale beds	Pre-plant incorporate	Pre-emerge soil	Post-emergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/-d)	carfentrazone	X			X		X	X	X	X	Hooded; directed to row middles
Aquesta (12hr/-d)	sulfentrazone			X		X		X	X		Peas only
Assure II (12hr/15d)	quizalofop p-ethyl				X		X	X			Bean/pea
Basagran 5L (48hr/30d)	bentazon				X	X			X		Bean/pea
Command 3ME (12hr/45d)	clomazone	X		X		X		X	X		Bean/pea
Dual Magnum (24hr/-d)	s-metolachlor	X	X	X		X		X	X		Bean/pea
Eptam 7E/20G (12hr/-d)	EPTC		X	X	X	X		X	X		Beans only
Far-Go (12hr/14d)	triallate	X	X			X		X			Peas only
Gramaxone Inteon (24hr/7d)	paraquat	X					X	X	X	X	
Poast (12hr/15d)	sethoxydim				X		X	X			Bean/pea
Raptor (4hr/30d)	imazomox				X		X	X	X		Bean/pea
RoundUp & others (12hr/14d)	glyphosate	X					X	X	X	X	
Sandea (12hr/30d)	halosulfuron-methyl			X	X	X	X		X		Bean/pea; injury possible
Select Max (24hr/21d)	clethodim				X		X	X			Bean/pea
(various names) (24hr/-d)	pendimethalin		X			X		X	X		Peas only
Thistrol (24hr/-d)	MCPB				X		X		X		Peas only; for thistle control

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 7.4., continued. ***Herbicides*** *Registered for* ***COMMERCIAL*** *Use on* ***Legumes*** *in Utah*

Brand name (REI/PHI)	Active ingredient	Timing and application location relative to crop: Pre-plant & stale beds	Pre-plant incorporate	Pre-emerge soil	Post-emergence	Timing relative to weeds: Preemergence	Postemergence	Weed groups controlled: Annual grass	Small-seeded broadleaves	Broadleaves	Comments
Treflan & others (12hr/-d)	trifluralin		X			X		X	X		Bean/pea
Organic products											
Corn gluten meal					X	X		X	X	X	
Summerset Alldown	acetic/citric acid	X		X			X	X	X	X	Will injure/kill crop
Weed Zap (others)	cinnamon/clove oil	X		X			X	X	X	X	Will injure/kill crop
Avenger (other products)	citrus oil	X		X			X	X	X	X	Will injure/kill crop

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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).

Legumes

Table 7.5. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Legumes*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm	Cutworm	Grasshopper	Mexican bean beetle	Seed-corn maggot	Spider mite	Thrips	Flea beetle	Pea weevil	Pea leaf weevil	Alfalfa looper
carbaryl	Sexin XLR Plus	1A	10-14		X	X		X			X	X	X	X	X
methomyl	Lannate	1A	10-14	X	X	X					X				X
malathion	Drexel Malathion 5EC, Fyfanon 57%,	1B	5-7	X			X	X		X			X		
beta-cyfluthrin	Baythroid XL, Tombstone Helios	3A	10-14	X	X	X	X	X					X	X	
esfenvalerate	Asana	3A	10-14	X	X	X	X								
fenpropathrin	Danitol	3A	10-14	X	X	X				X	X		X	X	X
lambda-cyhalothrin	Crusader 2ME, RAVAGE 2.0, Warrior II	3A	10-14	X	X	X	X	X		X	X	X	X		X
bifenthrin	Capture, Lancer, Sniper	3A	2-3 wks	X	X	X	X	X		X	X	X	X	X	X
zeta-cypermethrin	Mustang, Mustang Maxx	3A	10-14	X	X	X	X	X	X		X		X	X	X
zeta-cypermethrin + bifenthrin	Hero	3A	2-3 wks	X	X	X	X	X	X		X	X	X	X	X
acetamiprid	Assail 30SG	4A	14	X				X			X				
imidacloprid	Admire Pro, Prey, Gaucho	4A	14-17	X							X				
thiamethoxam	Cruiser 5FS	4A	10-14	X				X	X					X	
sulfloxaflor	Transform WG	4C	14-17	X							X				
flupyradifurone	Sivanto	4D	10-14	X											
spinetoram	Radiant	5	10-14		X						X				
spinosad^{O}	Entrust	5	7-10		X						X				
abamectin	Agri-Mek SC, MinectoPro	6	14-21							X	X				
sodium tetraborohydrate decahydrate	Prev-Am	8D	10-14	X	X					X	X				
Bacillus thuringiensis^{O}	Javelin	11A	5-7		X										X
novaluron	Rimon .83	15	10-12		X			X			X				X
methoxyfenozide	Intrepid	18	10-12		X										X
spirotetramate	Movento HL	23	14-21	X						X	X				
Beauveria bassiana^{O}	Mycotrol ESO	UN	5-7	X	X		X			X	X	X			X
insecticidal soap	M-Pede	UN	3	X						X	X				

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

^{O} = Organic

Legumes

Table 7.6. ***Fungicides and Bacteriacides*** *Registered for* ***COMMERCIAL*** *Use on* ***Legumes*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Bacterial brown spot	Common bacterial blight	Halo blight	Powdery mildew
copper oxychloride	Badge SC	M1	7	X	X	X	X
copper hydroxide	Champ WG	M1	7	X	X	X	X
	Nu-Cop, Previsto				X	X	X
basic copper sulfate	Cuprofix Ultra 40	M1	7		X	X	
copper octanoate	Cueva	M1	10	X	X	X	X
Reynoutria sachalinensis[O]	Regalia	P5	7-10		X		X
difenoconazole + benzovindiflupy	Aprovia Top	3/7	10-14				X
boscalid	Endura	7	7-14				X
polyoxin D zinc salt[O]	OSO 5%	19	5-7				X
streptomycin sulfate	AS-50 Agricultural stremptomycin	25	3-4			X	
potassium bicarbonate[O]	Kaligreen	NC	5-7				X
Bacillus amyloliquefaciens[O]	Amplitude	UN	7		X		
Bacillus pumilus[O]	Sonata	UN	7				X
Saccharomyces cervisiae[O]	Romeo	UN	7				X
sulfur[O]	Microthiol Disperss	UN	7-10				X
Swinglea glutinosa[O]	Ecoswing	UN	5-7				X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Legumes

Table 7.7. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Legumes*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	Moa	Residual days	Aphid	Armyworm	Cutworm	Grasshopper	Mexican bean beetle	Seed-corn maggot	Spider mite	Thrips	Flea beetle	Pea weevil	Pea leaf weevil	Alfalfa looper
malathion	Ortho Malathion, Yi-Yield 55% Malathion, Spectracide Malathion Insect Spray, Bonide Malathion Insect Control	1B	5-7	X				X	X	X	X				
zeta-cypermethrin	Garden Tech Sevin Insect Killer Concentrate	3A	10-14		X	X	X	X	X	X	X	X	X	X	X
pyrethrins^O^	Bonide Pyrethrin Garden Insect Spray Ferti-lome Triple Action	3A	5-7	X				X							
lambda-cyhalothrin	Spectracide Triazicide Insect Killer, GardenTech Sevin RTU	3A	10-14												
bifenthrin	Ferti-lome Broad Spectrum Insecticide, GardenTech Sevin Insect Killer Dust	3A	2-3 wks	X	X	X				X		X			X
sulfur^O^ + pyrethrins^O^	Ortho Insect, Mite, & Disease 3-in-1, BioAdvanced Fruit & Vegetable 3-in-1 solution	UN/3A	10-14	X	X	X				X	X				X
imidacloprid	BioAdvanced Fruit, Citrus, & Vegetable Insect Color	4A	7-10	X							X				
spinosad^O^	Bonide Captain Jack's Deadbug Brew, Bonide Colorado Potato Beetle Beater, Natural Guard Spinosad	5	7-10		X	X					X				X
spinosad^O^+ potassium salts of fatty acids^O^	Natural Guard Spinosad Soap Concentrate	5/UN	5-7	X	X	X				X	X				X
Bacillius thuringensis^O^	Bonide Captain Jack's Bt, Natural Guard Caterpillar Killer Spray with Bt	11A	3		X										
mineral oil	Safer Horticultural & Dormant Spray Oil	UN	3	X	X					X	X				

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

^O^ = Organic

Table 7.7., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Legumes*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	Moa	Residual days	Aphid	Armyworm	Cutworm	Grasshopper	Mexican bean beetle	Seed-corn maggot	Spider mite	Thrips	Flea beetle	Pea weevil	Pea leaf weevil	Alfalfa looper
plant-based oils[O]	Bonide Mite X, Safer Neem Oil, Natural Guard Neem, Monterey 70% Neem Oil	UN	3	X						X	X				
potassium salts of fatty acids[O]	Bonide Insecticidal Super Soap, Safer EndALL, Safer Insect Killing Soap, Safer 3-in-1 Ready to Use Garden Spray, Natural Guard Insecticidial Soap Concentrate	UN	5-7	X	X					X	X				X
sulfur[O]	GardenTech Sevin Sulfur Dust	UN	7-10							X	X				
iron phosphate + spinosad[O]	Bonide Captain Jack's Bug & Slug Killer	UN/5	2-4 wks			X									

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Table 7.8. ***Fungicides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Legumes*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Bacterial brown spot	Common bacterial blight	Halo blight	Powdery mildew
copper octanoate	Bonide Captain Jack's Deadbug Copper Fungicide Concentrate, Natural Guard Copper Soap Concentrate	M1	10	X	X	X	X
sulfur° + pyrethrin°	Ortho Insect, Mite, & Disease 3-in-1	UN + 3A	10-14				X
pyrethrin°+ neem oil°	Ferti-loam Triple Action	3A+ UN	3-5	X			X
sulfur°	GardenTech Sevin Sulfur Dust	UN	7-10				X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

° = Organic


Rows of trellised peas in Salt Lake County.


Commercial soybean field in Cache County.

Symptoms of nitrogren deficiency in beans.

Symptoms of phosphorus deficiency in beans.

Symptoms of potassium deficiency in beans.

Symptoms of iron deficiency in peas.

Incomplete pod fill in a pea.

Pod curvature in beans.

Pea Aphid *(Acyrthosiphon pisum)*

Armyworm feeding on bean foliage.

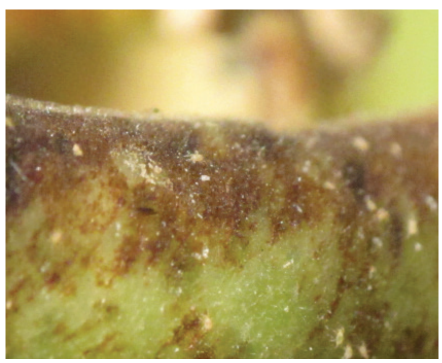
Cutworm feeding damage on bean pods and foliage

Grasshopper feeding on bean foliage.

Mexican Bean Beetle *(Epilachna varivestis)*

Mexican bean beetle larva.

Seedcorn maggot *(Delia platura)* damage on bean seedling.

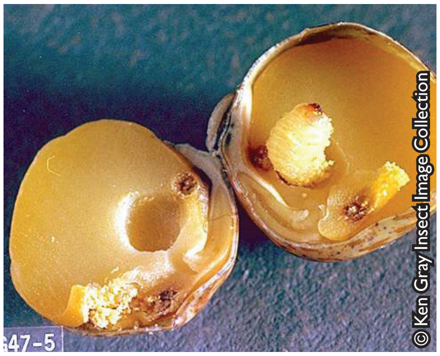

Spider mite damage on bean pod.


Thrips feeding damage on bean foliage.


Snail on pea plant.


Flea beetle feeding damage.

Pea Weevil *(Bruchus pisorum)*



\Pea weevil larval damage.

Pea Leaf Weevil *(Sitona lineatus)*


Pea leaf weevil feeding damage on pea seedlings.

Symptoms of bacterial brown spot on bean foliage *(Pseudommonas syrigae* pv. *syringae)*.

Symptoms of common bacterial blight on bean foliage *(Xanthomonas axonopodis* pv. *phaseoli)*.

Symptoms of halo blight on bean pods *(Pseudomonas syringae* pv. *phaseolicola)*.


Bean infected with beet curly top virus (BCTV).

Damping-off in bean seedlings.


Powdery mildew on peas *(Erysiphe pisi)*.


Bean Common Mosaic Virus (BCMV)

CHAPTER 8: ONION PRODUCTION

Onion *(Allium cepa)* is a cool-season annual crop grown commercially on over 1,600 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 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 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), 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.

Selecting appropriate onion varieties for a location and market is an important decision. There are many 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. Reference the USU Extension Production Horticulture website for onions (https://extension.usu.edu/productionhort/vegetables/onions) for more information.

Seedbed Preparation

Onion seeds need firm, finely textured soil in the seedbed for good germination and stand establishment. Onions grow best in soil with good organic matter and a pH between 6.0 and 7.8. Seedbed 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, the beds are smoothed with a bed-shaped harrow or roller and planted. Because some onion diseases will carry over in the soil, most fields should be planted with onions only once every 5-7 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 requirement) and cause seedling growth to slow. Irrigation water is generally unavailable 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, leading to reduced final bulb size.

Onions may be grown from sets, seeds, or transplants. An onion set is a small, dormant bulb that will produce a larger bulb once planted. Onion transplants are started from seed in a greenhouse or are field-grown (in the southwest U.S.), and then shipped to growers prior to planting in the field. Growers looking to produce onions for niche markets like farmers markets, roadside stands, and community-supported agriculture (CSA) shares 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 seedbed, 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 application rates. 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, place it 2 inches to the side and 2 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 widths, depending on the cropping system and the individual grower's equipment. 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 have a major influence on bulb size and are critical to a good stand establishment. Plant seeds 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 inches), large jumbo (3.5-4.0 inches), and colossal (4+ inches) 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

Spring weather can bring heavy rainstorms that can lead to crusting in seedbeds 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 setup 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.

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.

The critical period for irrigation is from the plant establishment through bulb expansion stage. Soil type usually does not affect the total water needed during a growing season but does dictate the water application frequency. Lighter soils need more frequent water applications but a smaller amount per application. Heavier soils need less frequent irrigation and a greater amount of water applied per irrigation set. It is important to maintain moisture near the soil surface for good root generation. Research has shown that onion roots generate at the stem plate only when moisture is present. Proper moisture management is also important for general root health, bulb growth, and vigor. Terminate watering after bulbs reach full size and tops begin to senesce (at least 2 weeks prior to lifting).

USU EXTENSION FACT SHEET REFERENCES

- *Vegetable Irrigation: Onion*

Harvesting

For spring-seed onions, harvest starts near the end of August and continues through early October, with the main harvest in September. The average yield of onions in Utah is approximately 1,2001,500 bags/acre (600-750 cwt/A), with higher yields reaching 2,000 bags/acre (1,000 cwt/A).

Research has shown that the optimum harvest time is when onion foliage is still partially erect and long before attaining maximum yield (when tops are completely down and dry). Yields can increase 30%-40% between the stage when tops begin to go down and 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 early fall's lower daytime temperatures. 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. Leaving bulbs in the field too long may sacrifice quality 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%-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.

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, topped/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 2-3 weeks, depending upon the weather.

Onion bulbs intended for immediate sale (farmers markets, CSA shares, 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 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 headwall.

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 °F 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 must 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-pound sacks or in consumer packs of 2-, 5-, and 25-pound 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 2 inches in diameter, with bulbs greater than 3 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 preemergents. 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. There are also OMRI-approved organic herbicides that can assist in weed management in these operations.

These organic herbicides primarily contact the weeds' green tissue. Use contact herbicides carefully to avoid getting the chemical 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 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.

Important Considerations for Herbicide Use

- Carefully read and follow all label directions.
- Use herbicides only on crops for which they are approved and recommended on the label.
- Use the recommended amount of product and apply it as stated. (Too much material may damage the crop and make it unsafe for consumption.)
- Apply herbicides only at times specified on the label and observe the recommended intervals of the time of planting and the time between treatments.
- Follow re-entry intervals (REI) and preharvest 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 Environmental Protection Agency (EPA) has the authority to seize any agricultural commodity that carries a pesticide residue beyond 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.

•**Preemergence:** applied to the soil after planting but before onions or weeds emerge.

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

•**Postemergence:** applied to weeds after both weeds and onions have emerged.

•**Directed postemergence:** applied as a directed or shielded spray after emergence on small weeds in rows of taller crops or in row middles. When using a postemergence herbicide, the entire weed must be covered for maximum control.

For more information on using herbicides in commercial operations, see Table 8.1.

Onions

Insect and Mite Pest Management

Thrips

Onion Thrips *(Thrips tabaci)*

DESCRIPTION

Adult: Adults are about 1.5 mm long. Their yellow and brown bodies are elongated with two pairs of fringed (hairy) wings. They have beak-like mouthparts, gray eyes, and seven-segmented antennae.
Larva: Early larvae, instars I and II (0.5-1.0 mm in length), are active feeding stages. Larvae are white to pale yellow, have an elongated 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 (1.0-1.2 mm long), are inactive, nonfeeding 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.
Egg: White to yellow, kidney-bean-shaped, and microscopic, eggs develop within leaf tissue with one end near the leaf surface.

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 3 weeks. A complete generation requires 3 to 4 weeks during the summer months, and five to eight 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. Thrips prefer to feed on the newly emerged leaves in the center of onion necks. When feeding injury is severe, leaves take on a silvery cast and can wither. Tiny black “tar” spots of excrement are evident on leaves with heavy feeding injury. Damaged plants are prone to water stress, resulting in reduced growth. Onions are most sensitive to thrips injury during the rapid bulb enlargement phase that occurs in July and early August (in northern Utah). Accelerated plant maturity and senescence due to thrips injury may shorten the bulb growth period resulting in reduced bulb size. If thrips are present on stored bulbs, they may continue to feed, causing scars that reduce the quality and aesthetic appearance of bulbs.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Thrips*
- *Onion Thrips*

Western Flower Thrips *(Frankliniella occidentalis)*

DESCRIPTION

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

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 causing much less onion crop damage.

THRIP MANAGEMENT

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*. Alfalfa harbors overwintering thrips.
- *Plant younger fields upwind from older fields.* 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.* We recommend applying no more than 200 pounds of nitrogen per acre. Moderate, consistent nitrogen availability has been associated with a healthy onion crop and reduced onion thrips densities.
- *Mulch with straw or other materials*. Mulch placed on the plant bed may reduce onion thrips populations and improve onion growth. Mulches suppress thrips populations by enhancing predator populations, creating barriers that prevent the resting stage larvae from accessing the soil, and lowering soil temperatures, slowing thrips development and population increase.
- *Use trap crops.* Plant small strips or patches of an alternate crop (buckwheat, carrot, crucifer, cucurbits, and some flowers, such as phacelia, are highly attractive to onion thrips) within an onion field to attract thrips. These alternate crops can then be disked under or sprayed with an insecticide when thrips populations increase.
- *Use overhead sprinkler irrigation.* Sprinklers can reduce thrips populations by physically washing thrips from plants and forming a crust on the soil surface, reducing thrips' ability to seek shelter there.
- *Plant onion varieties that are more tolerant to thrips injury.* Varieties with tolerance to thrips injury require fewer insecticide applications. Using less insecticide can result in lower control costs, slower development of resistance, and preservation of natural enemies. Onion varieties with an open neck growth and dark, glossy leaves are less attractive to thrips than varieties with tight necks and lighter green leaves. Studies conducted in Colorado showed relative susceptibilities of some onion varieties:
    - *Highly tolerant:* 'White Keeper'
    - *Moderately tolerant:* 'El Charro', 'Snow White', 'Vega', 'X201', 'Zapotec'
    - *Susceptible:* 'Blanco Duro', 'Brown Beauty', 'Brown Beauty 20', 'Colorado 6', 'Sweet Perfection', 'Tango', 'Valdez', 'White Delight'
    - *Highly susceptible:* 'Early Red Stockton', 'Mambo', 'Red Baron', 'Redman'

Chemical:

The high frequency of insecticide use for managing onion thrips, as high as eight applications per season, rapidly developing resistance to several insecticide classes, 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 onion thrips enemies include the banded thrips (Aeolothrips spp.), 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.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Thrips*
- *Western Flower Thrips*

Seed, Root, and Bulb Maggots

Onion Maggot *(Delia antiqua)*

DESCRIPTION

Adult: Onion maggot flies are about 6.35 mm with brownish-gray bodies and large wings. They resemble houseflies but have longer legs, are more slender, and overlap their wings at rest.
Egg: Eggs are white, elongated, and about 8 mm long. They are deposited in or on the soil, near young leaves, necks, or bulbs.
Larva: Maggots are legless, tapered, about 8 mm long, and creamy-white. They have hooked mouthparts for rasping their way into plant tissue, and require 2 to 3 weeks to complete development.

Pupa: Chestnut brown and about 8 mm long, pupae may be found 1-6 inches deep in soil.

Onions

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 unharvested onions and culls before emerging as adults 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 second and third 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.

Seedcorn Maggot *(Delia platura)*

DESCRIPTION

Adult: Seedcorn maggot adults are about 5 mm long with gray to brown bodies and are similar in appearance to the onion maggot.
Egg: Eggs are white and elongated. They are deposited in soils rich in organic/decaying matter and on seeds and seedlings.
Larva: Maggots are legless, tapered, about 6 mm long, and yellowish-white. Head-ends are wedge-shaped with small black mouth hooks.

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

LIFE HISTORY

Adult flies emerge in April and May and begin mating within 2 to 3 days. Females lay eggs in or on soils and 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 for approximately 7 to 14 days. Seedcorn maggots overwinter as pupae. A complete generation takes about 3 to 4 weeks, and about two to three 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.

MAGGOT MANAGEMENT

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; eliminate them before the current season's crop emerges.
- *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 third-generation larvae.
- *Handle seeds carefully to avoid cracking the seed coat.* A cracked seed coat provides entry points for maggots and other diseases.

- *Avoid planting in soils that are high in undecomposed organic matter.*
- *Plant during fly free periods* determined by monitoring.
- *Use sticky traps.* Yellow sticky cards serve as a monitoring tool to assess pest infestation levels around fields and may serve as a control measure by reducing the amount of adult populations before egg laying occurs.
- *Use row covers in small-scale production sites (impractical for large fields).* Row covers placed over transplants at planting time 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 inches on each side of the seed row. Remove covers when plants are big enough to tolerate damage.

Chemical:

Seed or furrow treatments with insecticides are effective for preventive measures. An insecticide applied to the soil at planting protects seedlings from damage by first 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:

Onion maggot enemies 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 seedcorn maggot larval populations. Predation by spiders, ants, and birds upon adults may also occur. Selective insecticides, such as seed treatments, allow natural enemies to supplement maggot control.

Leafminers

Pea Leafminer *(Liriomyza huidobrensis)*
Vegetable Leafminer *(L. sativae)*
American Serpentine Leafminer *(L. trifolii)*

Reference page 112 of descriptions and general life history for the pea leafminer, vegetable leafminer, and American serpentine leafminer.

DAMAGE

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

MANAGEMENT

Reference page 112 for general leaminer managment.

USU EXTENSION FACT SHEET REFERENCES

- *Leafminers of Vegetable Crops*

Two-Spotted Spider Mite (*Tetranychus urticae*)

Reference page 78 for general two-spotted spider mite life history, damage, monitoring, and management.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Spider Mites*
- *Web Spinning Spider Mites*

Bulb Mites

DESCRIPTION

Adult: Creamy-white, bulb-shaped adults are about 0.8 mm long. Wingless, with four pairs of short, brown legs, they are often described as tiny pearls with legs.
Egg: White and minute, eggs are laid singly on bulbs.
Immature Stages: White to brown, oval, 0.15 to 0.4 mm long, with three pairs of legs initially, then four pairs as they mature. Stages include larva, protonymph, and deutonymph.

LIFE HISTORY

Onions

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 occurs 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 soilborne 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 the 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 the 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 mite population build-up.
- *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:

Use preplant soil fumigation to control mites found in the soil prior to planting bulbs. 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.*

For more information on insecticide use in onion production, see Tables, 8.2 and 8.4.

Onions

Disease Management

Iris Yellow Spot Virus

Iris yellow spot virus (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 transmit it to healthy plants. Once thrips larvae have acquired the virus, they will transmit it for the rest of their lives. The virus has several known hosts related to onion, including shallots and garlic. The virus has also been reported in other parts of the world in iris and Lisianthus cut flower production. More recently, several weeds such as prickly lettuce, sowthistle, green foxtail, and saltbush have been reported as hosts. Common mallow has been identified as a potential host for the virus but has not been confirmed. Not all susceptible weeds show virus symptoms.

SYMPTOMS

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

DISEASE CYCLE

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

MANAGEMENT

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

- *Control thrips.* (see “Thrips” in the Insect and Mite Management).
- *Practice 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.

USU EXTENSION FACT SHEET REFERENCES

- *Iris Yellow Spot Virus in Onions*

Pink Root *(Phoma terrestris)*

CASUAL AGENT

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. 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, pink root’s aboveground symptom is stunting. 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 disease susceptibility. 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 °F to 85 °F. Visible symptoms on onions usually appear 7 to 21 days after infection has occurred. Open wounds are unnecessary 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 other plants’ roots 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.

USU EXTENSION FACT SHEET REFERENCES

- *Pink Root Disease of Onions*

Purple Blotch *(Alternaria porri)* and Stemphylium Leaf Blight *(Stemphylium vesicarium)*

CASUAL AGENT

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. When *Alternaria* is the causal agent, the brown lesions will eventually turn purple as fungal spores develop. Lesions caused by *Stemphylium* often appear dark brown to black as it produces 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 °F to 85 °F for *Alternaria* and 65 °F 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 inoculum present and disease incidence.
- *Avoid excessive nitrogen.* Applications can increase disease severity.
- *Bury or dispose culls and other plant debris.* Culls and plant debris can be a source for both pathogens and insects that cause wounding on new onion plants. Debris can be buried or disposed of in the trash.
- *Use fungicides.* There are several fungicides available to control both pathogens.

Botrytis Neck Rot *(Botrytis aclada* and *B. allii)*

CASUAL AGENT

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

SYMPTOMS

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

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 that can survive for several years until a suitable host (onion) is planted again. It also produces spores on plant debris that are blown by wind to the onion fields from miles away.

Occasionally, the disease can be seedborne. Leaf tissue and bulbs can be infected in the field from soil or seedborne inoculum without showing any symptoms during the growing season. Most infections occur when onions are harvested before the leaves and necks are dry. The fungus infects the green neck area after the leaves are cut off. Symptoms usually don't develop until onions have been in storage for 1-2 months.

MANAGEMENT

- *Store onions with dry, well cured necks.* The fungus is unable to penetrate and infect a dry neck.
- *Ensure proper curing.* Achieved proper curing by undercutting onions at maturity, severing all roots, refraining from applying any nitrogen fertilizer once bulbs have been initiated, and planting at the correct plant density in the field. If it is difficult to dry onions due to environmental conditions, forced air

(93 °F) at 0.06 m^3 per minute per 0.03 m^3 of bulbs can reduce losses to neck rot.

- *Maintain proper storage conditions.* The best storage conditions include air movement, temperatures between 33 °F to 34°F, and 70%-75% relative humidity. Air movement must be monitored to avoid condensation on bulbs.

USU EXTENSION FACT SHEET REFERENCES

- Botrytis Neck Rot of Onion

Fusarium Basal Rot
(Fusarium oxysporum f. sp. *cepae)*

CASUAL AGENT

Fusarium Basal Rot is caused by the fungus *Fusarium oxysporum* f. sp. *cepae*. It is a soilborne disease present worldwide. The disease affects all allium species but is most damaging in onion and garlic production.

SYMPTOMS

The fungus infects onions and garlic at any growth stage through the wounds and scars at the base of the bulb. Initial symptoms include leaf curling, yellowing, and dieback. Red-brown discoloration and rot forms along the root-basal plate margin. When cut open, the bulb tissue will appear brown. Symptoms may not be visible in the field, as they tend to develop during storage.

DISEASE CYCLE

F. oxysporum f. sp. *cepae* overwinters in the soil as chlamydospores (thick-walled survival spores) within the soil. When temperatures reach 77 °F to 84 °F, chlamydospores germinate and invade onions through existing tissue wounds. Rotational crops (corn, tomato, sunflower, oats, and sudangrass) support fungal growth but are asymptomatic.

MANAGEMENT

- *Plant resistant cultivars*.
- *Implement crop rotation*. Rotate out of onion, garlic, and leeks for 3-4 years.
- *Avoid planting in fields with a history of Fusarium basal rot problems.*
- *Store onion bulbs at 39 °F and relatively low humidity (70%) to prevent losses, if possible.*

USU EXTENSION FACT SHEET REFERENCES

- *Fusarium and Verticillium Wilts in Vegetables*

Bacterial Soft Rot
(Pecobacterium carotovorum)

CASUAL AGENT

Bacterial soft rot in onions is caused by the bacterium *Pectobacterium carotovorum*. The bacteria mainly affects onions in storage.

SYMPTOMS

Bacterial soft rot of onions usually goes unnoticed until after harvest. The pathogen spreads from the neck down into the bulb. The water-soaked tissue later disintegrates into pulp. Decay does not spread readily from scale to scale, rather it completely rots a few scales while the rest of the bulb remains intact. It can be detected by squeezing the bulb until watery fluid is exuded. A foul odor is typically associated with the liquid.

DIESEASE CYCLE

Soft rot begins in the field before the onion harvest. P. carotovorum enters through existing wounds and aged tissue during moist conditions. Onion maggots contribute to disease spread by creating wounds on the bulb. The bacteria may also persist in the onion maggot larva's intestinal tract and can be moved to a different site during the adult stage. Wound entry also occurs from hail damage, sunscald, freezing, and mechanical damage from harvesting equipment. *P. carotovorum* thrives in moist conditions.

MANAGEMENT

- *Control onion maggots.* Onion maggots contribute to bacterial infection by creating wounds.
- *Allow the tops and necks of the onions to dry out before topping.* When using mechanical toppers, aim to prevent as much bruising as possible. This will prevent bacterial movement
- *Cure bulbs thoroughly.* This allows outer scales and neck tissue to completely dry.

Black Mold *(Aspergillus niger)*

CASUAL AGENT

Black rot in onions is caused by the fungus *Aspergillus niger*. The fungus mainly affects onions in storage.

SYMPTOMS

Black discoloration in the neck area. Dark lesions with spores develop under the outer scales, yielding overall bulb rot.

DIESEASE CYCLE

Aspergillus spores are airborne, soilborne, and seedborne. The fungus can survive on plant debris. Infection usually occurs from wounds in the bulb.

The disease is worse under warm conditions, especially during storage. Optimum growing conditions are 82 °F to 93 °F. Harvested onions should be stored at cool temperatures as soon as possible. If long-distance transport occurs under warm conditions, the fungus will resume growth, even if onions have been stored in cool conditions.

MANAGEMENT

- *Prevent wounding or bruising of bulbs.*
- *Store and transport bulbs below 59 °F.*

Refer to Table 8.3 and Table 8.5 for funigcide and bactericide recommendations.

Onion Pesticide Tables for Commercial and Small-Scale Use

Table 8.1. ***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
		Preemergence	Delayed preemergence	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/-)	carfentrazone	X	X	X		X	X	X	X	Use with shields between rows
Dacthal (12hr/-)	DCPA	X	X		X		X	X	X	
Fusilade (12hr/-)	fluazifop		X	X		X	X			
GoalTender, plus others 12hr/45d)	oxyfluorfen			X		X	X	X	X	After 2-leaf stage; Do not use on stressed onions
Gramaxone Inteon 12hr/60d)	paraquat	X	X			X	X	X	X	Restricted use product
Nortron SC (12hr/30d)	ethofumesate	X	X	X	X		X	X	X	
Outlook (12 hr/30d)	dimethenamid-P			X	X		X	X	X	Apply after 2-leaf stage

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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).

Onions

Table 8.2. *Insecticides* Registered for *COMMERCIAL* Use on *Onions* in Utah, Organized by Mode of Action (MoA)

Primary Active Ingredient	Brand Name	MoA	Residual Days	Thrips	Maggot	Leafminer	Spider Mite
malathion	Malathion 5	1B	5-7	X			
deltamethrin	Delta Gold	3	14	X			
pyrethrins°	Pyrenone Crop Spray	3A	5-7	X		X	X
	EverGreen Crop Protection EC 60-6, Pyrus TR			X			
acetamiprid	Assail 30SG	4A	14	X			
imidacloprid	Admire Pro, Acronyx 4 F	4A	14	X			
tolfenpyrad	Torac	21A	14	X			
azadirachtin°	Atrevia 1.2% SL, AzaSol	UN	5-10	X		X	
	Atrevia 3.0% SL, AzaGuard			X		X	X
	Azatin O			X	X	X	
Beauveria bassiana strain GHA°	BotaniGard 22WP, BotaniGard ES, BoteGHA ES, Mycotrol ESO, Mycotrol WPO	UN	5-7				X
canola oil°	Captiva Prime	UN	3	X			
cinnamaldehyde°	Seican	UN	3	X			X
cinnamon oil°	Cinnerate	UN	3	X			
clove oil°	SNS PC+AG	UN	3			X	
fats and glyceridic oils of margosa	Debug ON, Debug Optimo, Debug Tres, Debug Turbo	UN	3			X	X
garlic oil°	Alluma	UN	3			X	
	Gemsei						X
	Captiva			X			
geraniol°	Brandt Ecotec Plus	UN	3	X		X	
	Wrath				X		
Isaria fumosorosea apopka strain 97°	PFR-97 20% WDG	UN	5-7	X		X	X
Isaria fumosorosea strain fe 9901°	Nofly WP	UN	5-7	X			X
kaolin°	Surround WP	UN	5-7	X			
Metarhizium anisopliae strain f52	Lalguard M52 OD, Met 52 EC	UN	7	X			

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

° = Organic

Onions

Table 8.2., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Onions*** *in Utah, Organized by Mode of Action (MoA)*

Primary Active Ingredient	Brand Name	MoA	Residual Days	Thrips	Maggot	Leafminer	Spider Mite
mineral oil[O]	Mite-E-Oil, Omni Oil 6, Omni Oil 6E	UN	3			X	
	Omni Supreme Spray, Omni Supreme Spray, SuffOil-X, TriTek			X		X	
neem oil[O]	EcoWorks EC, Rango	UN	3	X		X	X
	Trilogy			X			
peppermint[O]	SNS PC	UN	3			X	
potassium salts of fatty acids [O]	M-Pede	UN	5-7	X		X	
rosemary[O]	SNS-209 Organic Systemic Pest Control	UN	3			X	
	SNS Systemica		3			X	X
soybean oil[O]	NanoCrop, Soyote	UN	3	X			X
thyme oil[O]	KeyPlex AWP	UN	3	X			X
sodium tetraborate [O]	Prev-AM, Prev-AM Ultra	UN	7-10	X			

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[O] = Organic

Table 8.3. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Onions*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Stemph blight	Botrytis neck blight	Bacterial soft rot	Black mold
propiconazole	Omni Propiconazole 41.8% EC	3	14	X			
cyprodinil	Vangard WG	9	7-10	X			
pyraclostrobin	Cabrio EG, Innliven Elite, Innliven P	11	7-10	X			
polyoxin D zinc salt[O]	OSO 5% SC	19	5-7	X	X		
cinnamon oil[O]	Cinnerate	BM1	3			X	X
neem oil[O]	Trilogy, EcoWorks EC, Rango	BM1	3				X
thyme oil[O]	Huma Gro Promax, Slam Org	BM1	3				X
Bacillus amyloliquefaciens strain D747[O]	Double Nickel 55, Triathlon BA	BM2	5-7	X	X		
Bacillus subtilis strain QST 713[O]	Serenade ASO, Serenade Max, Serenade Opti WP	BM2	7	X	X		
Clonostachys rosea strain J1446[O]	Lalstop G46 WG	BM2	5-7				X
Pseudomonas chlororaphis strain AFS009[O]	Zio	BM2	7-14				X
Streptomyces lydicus WYEC 108[O]	Actinovate	BM2	7				X
Streptomyces sp. strain K61[O]	Lalstop K61 WP	BM2	7				X
basic copper sulfate[O]	Basic Copper 53, Cuprofix Ultra 40 Disperss, Cuproxat FL	M1	7	X			
copper hydroxide[O]	Champ Dry Prill, Champ Formula 2 Flowable, Champ WG, ChampION++, Kalmor, Kocide 2000, Kocide 3000, Kocide 50DF, Nu-Cop 30 HB, Nu-Cop 50 DF, Nu-Cop HB, Previsto	M1	7	X			
copper octanoate	Camelot O, Cueva, Grotto	M1	10	X		X	
copper oxychloride	Badge SC, Badge X2, C-O-C-S WDG	M1	7	X			
copper sulfate pentahydrate	CS 2005, ET-F	M1	7	X			
	MasterCop			X		X	X
hydrogen peroxide	OxiDate 2.0	NC	7			X	
	Jet-Ag, Jet-Ag 5%, TerraClean 5.0						X
	OxiDate 5.0			X		X	
potassium bicarbonate[O]	Carb-O-Nator	NC	5-7	X			
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM Ultra	NC	10-14	X			

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[O] = Organic

Table 8.3., continued. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Onions*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Stemph blight	Botrytis neck blight	Bacterial soft rot	Black mold
Ulocladium oudemansii strain U3[O]	BotryStop	NC	7		X		
mono- and dipotassium salts of phosphorous acid[O]	OxiPhos	P7	1-3 wks			X	
	K-Phite 7LP			X			X

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[O] = Organic

Onions

Table 8.4. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Onions*** *in Utah, Organized by Mode of Action (MoA).*

Active ingredient	Brand name	MoA	Residul days	Thrips	Maggot	Leafminer	Bulb mite	Spider mite
bifenthrin	Ferti-lome Broad Spectrum Insecticide, Ferti-lome Broad Spectrum Insecticide RTS	3A	2-3 wks	X		X		X
deltamethrin	Hi-Yield Multi-Use Dust	3A	14	X	X	X		
	Ortho Insect Killer Flower & Vegetable Garden			X	X	X		X
lambda-cyhalothrin	Bonide Eight Garden & Home RTU, GardenTech Sevin Insect Killer RTU, Spectracide Trazicide Insect Killer for Lawns & Landscapes RTU	3A	10-14	X	X	X		
pyrethrins[O]	Monterey Bug Buster-O	3A	5-7	X	X	X	X	
zeta-cypermethrin	GardenTech Sevin Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X		
pyrethrins[O] + neem oil[O]	Ferti-lome Triple Action, Ferti-lome Triple Action Plus RTU	3A/UN	5-7	X	X	X	X	X
pyrethrins[O] + canola oil[O]	Espoma Organic Insect Control	3A/UN	5-7	X	X	X	X	X
malathion	Hi-Yield 55% Malathion Spray	3B	5-7		X	X		
	Ortho MAX Malathion Insect Spray Concentrate, Bonide Malathion Concentrate			X	X	X		
spinosad[O]	Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS, Monterey Garden Insect Spray, Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Colorado Potato Beetle Beater	5	7-10					
sulfur[O]	Garden Tech Sevin Sulfur Dust	UN	7-10				X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Table 8.4., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* **Onions** *in Utah, Organized by Mode of Action (MoA).*

Active ingredient	Brand name	MoA	Residul days	Thrips	Maggot	Leafminer	Bulb mite	Spider mite
sulfur[O] + pyrethrins[O]	Ortho Insect, Mite & Disease, 3-in-1 RTU, Natria Insect Disease, and Mite Control RTU, Natria Insect, Disease, and Mite Control RTS, BioAdvanced Fruit and Vegetable 3-in-1 Solution RTS, BioAdvanced Fruit and Vegetable 3-in-1 Solution Concentrate	UN/3A	10-14	X	X	X	X	X
neem oil[O]	Safer Brand Neem Oil Concentrate, Natural Guard Neem Concentrate, Natural Guard Neem RTU, Monterey 70% Neem Oil, Monterey Neem Oil RTU, Natria Neem Oil Concentrate, Natria Neem Oil RTU, BioAdvanced Organics Neem Oil RTU, Espoma Organic Neem Oil 3n1	UN	3	X			X	X
potassium salts of fatty acids[O] + seaweed extract[O]	Safer Brand Insect Killing Soap RTU Spray	UN	5-7	X			X	X
potassium salts of fatty acids[O]	Natural Guard Insectidcal Soap, Monterey Insecticdal Soap RTU, Bonide Insecticidal Soap RTU, Natria Insecticial Soap RTU, BioAdvanced Insecticidal Soap RTU, Espoma Organic Insect Soap	UN	5-7	X			X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Onions

Table 8.4., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Onions*** *in Utah, Organized by Mode of Action (MoA).*

Active ingredient	Brand name	MoA	Residul days	Thrips	Maggot	Leafminer	Bulb mite	Spider mite
potassium salts of fatty acids[O] + spinosad[O]	Natural Guard Spinosad Soap RTU, Natural Guard Spinosad Soap Concentrate, Natural Guard Spinosad Soap RTS, Monterey Garden Insect Soap RTU, Bonide Insecticidal Super Soap RTU, BioAdvanced Organic Tomato, Vegetable, and Fruit	UN/5	7-10	X			X	X
potassium salts of fatty acids[O] + sulfur[O]	Safer Brand 3-in-1 Concentrate, Safer Brand 3-in-1 RTU Garden Spray, Safer Brand Insect Killing Soap Concentrate	UN	7-10	X			X	X
silicon dioxide	Bonide Diatamaceous Earth	UN	7-14	X	X	X	X	X

Onions

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Table 8.5. ***Fungicides and Bactericides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Onions*** *in Utah, Organized by Mode of Action (MoA).*

Active ingredient	Products	MoA	Residul days	Purple blotch + stemphylium leaf blight	Botrytis neck rot	Bacterial soft rot	Black mold
copper octanoate	Epsoma Organic Copper Soap RTU	M1	10			X	
	Monterey Liquid Copper Fungicide RTU			X		X	
	Natural Guard Copper Soap Fungicide Concentrate, Natural Guard Copper Soap RTU			X	X	X	
copper sulfate	Bonide Copper Fungicide Spray/Dust	M1	7	X		X	
mancozeb	Bonide Mancozeb Flowable w/ Zinc Concentrate	M3	7-10	X	X		X
chlorothalonil	Bonide Fung-onil Concentrate, Bonide Fung-onil RTU, GardenTech Daconil Fungicide Concentrate, GardenTech Daconil Fungicide RTU	M5	7-14	X	X		X
	Ferti-lome Broad Spectrum Landscape & Garden Fungicide, Ferti-lome Broad Spectrum Landscape & Garden Fungicide RTU, Hi-Yield Vegetable, Flower, Fruit, and Ornamental Fungicide			X	X		
myclobutanil	Ferti-lome F-Stop Lawn & Garden Fungicide Concentrate, Ferti-lome F-Stop Lawn & Garden Fungicide RTS	3	14	X	X		X
propiconazole	Bonide INFUSE Disease Control Concentrate	3	14	X	X		X
Bacillus amyloliquefaciens strain D747[O]	Bonide Revitalize Bio Fungicide Concentrate, Bonide Revitalize Bio Fungicide RTS	MBCA	5-7	X	X	X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Commercial onion harvest in Davis County.

Commercial storage facility for onions in Davis County.

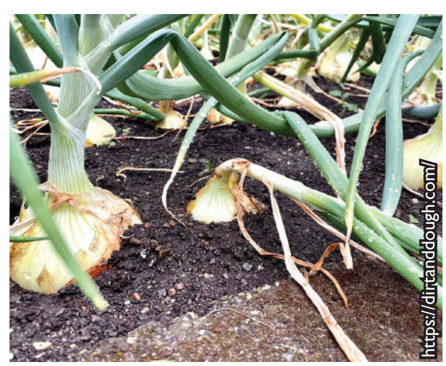
Symptoms of nutrient deficiencies in an onion plant.

Onions being undercut mechnaically in the field.

Onions being topped mechanically in the field.

Poor onion stand due to poor soil conditions.

Hail-damaged onions.

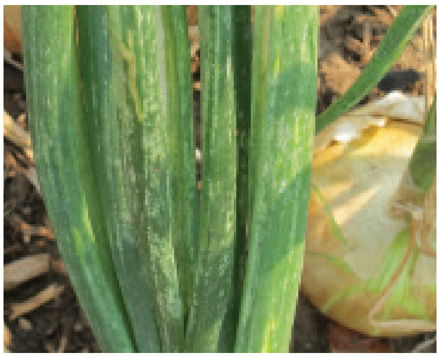


Onions can be harvested when foliage is still partially erect.

Thrips Egg (Family Thripidae)

Thrips Nymphs


Adult onion thrips on onion.


Thrips feeding damage on onion.

Adult Onion Maggot *(Delia antiqua)*

Onion maggot damage on onion bulb.


Leafminer damage on onion.

Spider mite damage on onion.

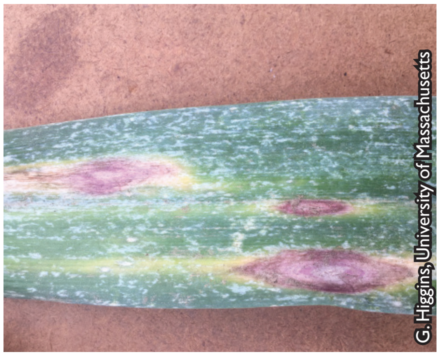
Bulb Mite *(Rhizoglyphus* spp.*)*

Bulb mites on onion.

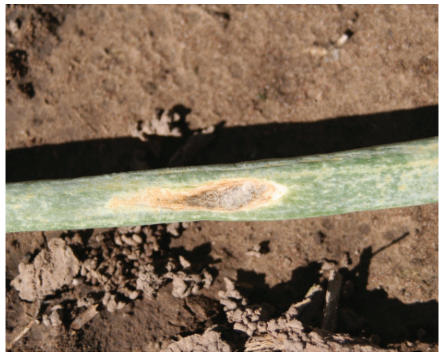

Onion with symptoms of iris yellow spot virus (IYSV).


Pink root in onions *(Phoma terrestris)*.

Onions



Purple Blotch *(Alternaria porri)*


Stemphylium Leaf Blight *(Stemphylium vesicarium)*


Botrytis Neck Rot *(Botrytis aclada* and *Botrytis allii)*

Fusarium Basal Rot *(Fusarium oxysporum* f. sp. *cepae)*

Bacterial Soft Rot *(Pectobacterium carotovorum)*

Black Mold *(Aspergillus niger)*

CHAPTER 9: POTATO PRODUCTION

Varietal Selection

Potato variety selection can be challenging given the number of choices available. Consider the length of the growing season, soil type, climate conditions, and production practices when selecting varieties. Little testing of potato varieties has been done in Utah, but with our proximity to Idaho, selecting varieties successful in Idaho is reasonable.Remember, most varieties will grow and produce tubers, but not all may be suited to your location. When selecting a new variety, compare it to existing varieties grown on your farm. Evaluate new varieties based on earliness, vine growth habit, and disease resistance. If viruses and fungal diseases have been problems, look for varieties with some resistance to these issues. Heirloom varieties, while popular, generally lack disease resistance and are more prone to cosmetic defects.

Table 9.1. ***Variety Suggestions*** *- Commonly Grown Potatoes*

Fruit types	Varieties	Tuber characterstics
Early	*CalWhite*	white skin; white flesh
	Irish Cobbler	buff skin; white flesh
	Russett Norkotah	russet skin; white flesh
	Dark Red Norland	dark red skin; white flesh
	Norland	red skin; white flesh
Mid-season	*French Fingerling*	pink skin; yellow flesh
	Gold Rush	russet skin; white flesh
	NorValley	white skin; white flesh
	Chieftain	red skin; white flesh
	Red La Soda	deep red skin; white flesh
	Red Pontiac	red skin; white flesh
Late-season	*Bannock Russet*	russet skin; white flesh
	Katahdin	whitish skin & flesh
	Russet Burbank	russet skin; white flesh
	Yukon Gold	yellow; buff skin; yellow flesh
	Ida Rose	red skin; white flesh
	Russian Banana	yellow skin; yellow flesh
	Western Russet	russet skin; white flesh

Note. Variety recommendations are from the University of Idaho Commercial Potato Production in North America.

We recommend that growers regularly test new varieties and compare them to what they already grow. On-farm testing is the best way to identify varieties that are most suited to local farms and unique conditions.

Potato Seed Handling and Treatment

Always plant foundation or certified seed. Tubers or seed-pieces showing decay should not be planted. Store seed potatoes at 38 °F to 40 °F and 95% relative humidity until planting, then warm tubers to 50 °F to 55 °F for 2 weeks prior to cutting or planting. Cut seed can be planted immediately. If conditions after cutting delay planting, store seed stock in sacks or crates to allow air movement about them and keep in a humid environment for 2 or 3 days. Cut seed pieces should be blocky, have at least one eye, and weigh 1.5-2 ounce per piece. Seed pieces of uniform size and weight are easier to plant, so try to be consistent when cutting.

The ideal seedbed conditions for planting potatoes is warm soil, moderately moist, and of uniform particle size. Soils should be 50 °F to 60 °F, which encourages cut seed wound healing and rapid sprouting and emergence. Seed piece decay is more common when planted in cool (< 45 °F) wet soils.

Seed pieces can be pre-sprouted (called green sprouting or chitting), which accelerates plant emergence and speeds tuber development. Green sprouting combined with close plant spacing (about 6 inches) can lead to an earlier harvest by 7-14 days. Plants are commonly harvested when tubers are small and marketed as small new potatoes.

To green sprout seed, about 6 weeks prior to planting spread out seed tubers one layer deep with the eyes up. Seed should be chitted warm (~ 70 °F) and at medium light intensities (bright shade—not direct sunlight). The warm stimulates strong shoots while the bright light keeps the shoots short. The sprouts should be about 1 inch long at planting. Do not cut the seed before green sprouting as this encourages desiccation.

Soil

Deep sandy to loamy soil with a pH of 6.5 to 7.5 is ideal for early potatoes. Heavier soils, while more productive, should be used for main-season production. Most soils in Utah are suitable for potatoes, provided they are well-drained and fertile. Practice good crop rotations, remembering that potatoes are related to eggplant, peppers, and tomatoes and most insects and diseases are common to all solanaceous vegetables. Note: plant residue from these related crops serves as a host for plant diseases and insects that may infect or infest the next crop. Completely bury plant residues from the prior crop at the bottom of the furrow to facilitate decomposition.

When green manure or cover crops are part of the production system, incorporate these early and allow sufficient breakdown time of crop residues so they do not tie-up nutrients or interfere with planting. Some residues (straw, corn stalks, grassy sod, or grain stubble) require additional nitrogen to enhance breakdown. Manures are also beneficial in providing extra nutrients and maintaining organic matter. Prior to planting, be sure to incorporate green manures, cover crops, residues, composts and manures.

Potato fields should be well tilled to create a smooth, firm seedbed for uniform planting and emergence. Several weeks before planting, prepare the field to create a loose, moist seedbed which ensures good soil-seed piece contact. Overworking the seedbed encourages soil crusting and compaction.

Potatoes

Planting and Spacing

Planting dates in Utah vary depending local climate conditions. Planting often begins in late March in southern Utah and may be as late as early June in cooler areas of northern Utah. Planting is recommended after frost danger passes. Local freeze dates can be accessed through the Utah Climate Center (climate.usu.edu).

Potato seed requirements depend on between and in-row spacing (Table 9.2), variety, and local conditions. Close spacing (6 - 8 inches) are used to reduce tuber size and increase the number of tubers set. Closer spacings also reduce hollow heart and growth cracks.

Seed pieces should be planted 2 - 4 inches deep. For more rapid emergence, plant shallow. If soils are dry, plant a bit deeper. Rapid emergence is necessary to reduce soil-borne diseases such as Rhizoctonia.

Table 9.2. *Potato Seed Requirements (pounds per acre) for Different Between and In-Row Spacing*

Seed piece spacing (in.)	32 inch row spacing		36 inch row spacing		40 inch row spacing	
	1.5 oz pieces	2 oz pieces	1.5 oz pieces	2 oz pieces	1.5 oz pieces	2 oz pieces
6	3060	4085	2725	3630	2450	3270
8	2300	3065	2040	2725	1840	2450
10	1835	2450	1630	2180	1470	1960
12	1535	2040	1360	1810	1225	1635
16	1150	1535	1020	1360	920	1225

Fertility

Prior to planting, have the soil tested to determine nutrient needs and deficiencies (Table 9.3). Soil sampling approaches, forms, test details, and interpretation can be accessed through the Utah State University Analytical Laboratories (usual.usu.edu). Organic growers find it is a good idea to incorporate composted organic matter before planting to sustain soil fertility. An initial application of 5 tons per acre of high quality compost of known nutrient analysis may be helpful. This can be broadcast over the whole field or banded and incorporated into the individual rows.

A common practice is to add ¼ to ⅓ of the required nitrogen fertilizer and all the phosphorous and potassium prior to planting (See Table 9.3). In soils with high P and K levels, broadcast applications are acceptable, then work the fertilizer into the soil during normal field preparations. Banding is a good method to ensure the fertilizer is near the plant and makes sense where wide row spacings are common. Fertilizer bands should be 3 inches beside and 3 inches below the seed to minimize salt injury.

Nitrogen (N) – Nitrogen fertilizer is most efficiently used in split applications. Apply up to 50 pounds N/acre prior to planting with an additional 100-150 pounds N/acre applied in two or three applications. The first side-dressing occurs when stolons start to form, the next around flowering, and the last during early bulking. Use the smaller amount if the site has added manure, compost, or when potatoes are grown after a legume crop (beans, alfalfa, etc.). Nitrogen is particularly suited for application by sprinkler or drip irrigation. In these systems, it is common to apply 20-30 pounds N/A every 10-14 days. Nitrogen management can be greatly improved through tissue testing.

Table 9.3. *Phosphorus (P_2O_5) and Potassium (K_2O) Based on Soil Test Results*

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

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

Weed Management

Weed control is critical for potatoes, as weeds in the planted row and furrow compete with the crop before the plants are large enough to shade out weeds. Weeds in and between the rows are typically controlled with cultivation, herbicides, or a combination of approaches. An effective weed control program identifies the weeds common to the farm, assesses cultivation practices used, reviews available herbicides, and determines the competitive ability of the potato varieties grown. If herbicides are used, tailor them to present in-field weeds.

In organic production systems, mulches (such as straw, cardboard, etc.) can provide good weed control if applied in a thick mat. There are OMRI-approved organic herbicides that can assist in weed management in organic operations. Most organic herbicides have limited residual activity, so use a combination of controls like tillage, hoeing, and mulches in addition to herbicides.

Many herbicides are manufactured by different companies under different trade names. Table 9.6 lists chemical names (active ingredient) along with one representative trade name. Herbicide and pesticide labels change, so growers must always consult a current label to determine (1) if the crop is listed for herbicide use; (2) what precautions in use are required; and (3) what rates and application methods are allowed. Off-label applications are hazardous to the environment, to people using the product, and can severely injure the crop.

Use herbicides only for those crops for which they are approved and recommended. Use the recommended amount of product and apply it as stated. Pay attention to reentry intervals (REI) and preharvest intervals (PHI). The EPA has the authority to seize any agricultural commodity that carries a pesticide residue beyond the established tolerance. In addition, if residues of unlabeled chemicals are detected on fresh produce, they could be traced back to your farm.

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

Herbicides are applied in the following ways:

- **Before planting:** incorporated into the soil prior to seeding or transplanting the crop.
- **Preemergence:** applied to the soil after planting but before the crop or weeds emerge.
- **At or after hilling:** applied to the soil after transplanting the crop is either before weeds emerge or after clean cultivation. In some cases, sprays are directed to row middles and shielded from application to the crop.
- **Directed or Shielded:** applied as a directed or shielded spray postemergence on small weeds in rows of taller crops or in row middles. When using a postemergence herbicide, the entire weed must be covered for maximum control.
- **Postemergence:** applied to weeds after both weeds and the crop have emerged.

See Table 9.6 for more information about herbicides for potato production.

Cultivation and Hilling

Cultivation operations often begin after potatoes begin to emerge. The purpose of cultivation is to maintain soil aeration, shape the beds to maximize tuber growth and reduce tuber greening, establish irrigation furrows, and control weeds. Complete hilling before plants fill half of the row, being careful to minimize foliar, stolon, and/or root damage. Hilling allows for shallow planting depth to speed emergence while providing the soil depth necessary for proper tuber development and protection from sunlight. Discs, hilling listers, and rolling cultivators are commonly used. Hills should be broad with flatter tops rather than narrow and peaked. Cultivation during hilling provides weed control and incorporates soil-applied herbicides.

Irrigation

Potatoes require regular, uniform watering during the growing season for optimal productivity. Potatoes are sensitive to water shortages due to the plant's shallow root system and large leaf area. Water shortages during establishment can limit emergence and early vine growth. Inconsistent watering at flowering impacts stolon initiation and number. Water deficits during tuber bulking limits size, shape, and contributes to reduced tuber quality (necrosis, black spot, hollow heart, heat sprouting). Overwatering encourages foliar and root diseases, impacts tuber quality, delays senescence and skin set, and interferes with harvest.

Common irrigation methods include furrow, sprinkler, and in some areas, drip irrigation. Regardless of the system used, the goal of soil water management is to maintain adequate soil moisture while avoiding extreme or excessive fluctuations. The amount of water applied during an irrigation event depends of the infiltration rate and water-holding capacity of the soil. Specific guidelines on irrigation depend on soil type, stage of growth, and local conditions (temperature, relative humidity, wind). Regularly monitor soil water status to maintain consistent soil water using a resistance block such as the Irrometer Watermark sensor. Place sensors throughout the field and at several depths to get an accurate measure of soil water content. Start irrigations at 15%-25% depletion during vegetative growth. During tuber initiation and tuber bulking, soil should be maintained at 80%-90% of available soil water (10%-20% depletion) for optimal production.

Vine Removal and Desiccation

In preparation for harvest, it may be necessary to remove potato vines prior to harvesting the tubers. Remove vines mechanically (flail beaters, rotary choppers) or by applying chemical vine-killers. Mechanical beaters effectively remove potato tops but should be adjusted to remove the tops without injuring any tubers near the soil surface. Organic growers prefer this method of top-killing.

When potatoes have excessive top growth, use a chemical vine-killer first, followed by mechanical removal to shred tops. This combination provides effective vine kill. Potato vines should be chemically killed approximately 21 days prior to harvest. This provides time to ensure good skin set. Note that rapid vine desiccation (either chemical or mechanical) can cause stem-end discoloration in tubers.

With chemical vine-killers, use the lower application rates if plants are stressed (see the label). Good spray coverage is important for these chemicals to work effectively, and the speed of vine desiccation varies greatly between the different chemicals.

CAUTIONS: When using chemical vine-killers, always follow the label instructions. The information provided below is very general and does not provide full label instructions regarding the application or full use of the materials.

- carfentrazone (Aim): 3.2 to 5.8 ounces/acre (7 dh; REI 12h) and spray adjuvant (NIS, MSO, or COC) is required (1%-2% v/v). Suitable for seed and storage potatoes. Thorough coverage is essential. May be tank mixed or used sequentially with other desiccants (see labels for restrictions).
- diquat (Reglone): 1 to 2 pints/acre (7 dh; REI 12h) and always use a spray adjuvant (0.1-0.5% v/v NIS). Suitable for seed and storage potatoes.
- glufosinate-ammonium (Rely): 3 pints/acre (9 dh; REI 12h). Do NOT use on seed potatoes.
- paraquat (Firestorm or Parazone 3SL): 0.7 to 1.3 pints/acre (9 dh; REI 24h) and always use either NIS (0.125% v/v) or COC (1.0% v/v). NOTE: paraquat is NOT registered as a vine desiccant for storage or seed potatoes. May ONLY be used for Fresh Market Potatoes. Potatoes must be harvested promptly and processed or consumed immediately.

- pyraflufen-ethyl (Vida): 2.75 to 5.5 ounces/acre (7 dh; REI 12h). Apply when vines are starting to senesce for best results. May be tank-mixed in sequence with other desiccant products.

Harvest and Handling

Harvest potatoes for storage when tuber temperatures are between 45 ° to 60 °F. At warmer soil temperatures (above 60 °F), field heat contributes to tuber quality deterioration before cooling can occur in storage. When tubers are cold (below 45 °F), potatoes bruise easily during harvest. If days are warm, harvest early in the day; conversely, if it's cold, start harvest later in the day and continue into the evening. The ideal temperature during harvest is 60 °F to 70 °F.

Bruising can be further reduced by controlling fertilizer and irrigations late in the season. Initiate better skin set through vine killing, controlling late season nutrient/water management, ensuring harvesters (chain and forward speed ratios) are adjusted properly, and keeping harvester chains filled. Potatoes should not drop more than 4-6 inches and equipment surfaces should be properly padded. Premature harvesting results in reduced yields and low specific gravity. When harvesting is delayed, frost and diseases can cause serious storage losses.

Potatoes intended for long-term storage are often treated with sprout inhibitors (pre or postharvest) to extend storage life. Use maleic hydrazide (MH-30) preharvest (one application; 1-1.33 gal/A [REI 12h]), 4-6 weeks before potatoes are mature and ready for harvest. Potatoes treated with MH-30 cannot be used for seed. Chlorpropham (CIPC) is the most effective postharvest sprout inhibitor registered. CIPC requires licensed commercial applicators to apply the aerosol formulation while, the emulsifiable concentrate (EC) formulation can be applied as a direct spray during the fresh packing operation. CIPC can be applied any time after wound healing but before tubers break dormancy or sprouts start to grow.

For organic growers, some essential oils (peppermint, spearmint, and clove oils) have been shown to reduce sprouting in potatoes. These alternative compounds are not true "sprout inhibitors" like CIPC but are "sprout suppressors" since they physically damage developing sprouts. Because of their high volatility, these oils leave behind little or no residue. However, new sprouts continue to develop, so repeat applications are required every 2-3 weeks. Timing is critical with all the sprout suppressors. They are most effective when applied before sprouts are 1/8 inch long. Organic growers should check with their certification agency and the National Organic Standards Board (https://www.ams.usda.gov/rules-regulations/organic/nosb) for current regulations regarding alternative sprout control products.

Postharvest Handling and Storage

An important aspect of potato quality control is to provide a pathogen-free storage environment. Clean and disinfect all storage and potato handling equipment surfaces before placing the crop into storage. Surfaces should be well moistened by the disinfectant spray. Spray bin walls until there is a slight runoff. Several disinfectant materials are available including quaternary ammonium compounds (Prosan and Ster-Bac), sodium hypochlorite products (Agclor), and hydrogen dioxide products (Storox). Consult the labels for specific directions. Once the storage environment is clean and sterilized, it is ready for potatoes.

Healing of cuts and bruises that occur during harvest is most rapid in storage when:

- The environment has a high relative humidity (95%).
- Tubers are at an appropriate temperature (50 °F to 60 °F).
- When adequate ventilation is provided throughout the pile.

These conditions should be provided for 2 to 3 weeks at the beginning of storage and helps the tubers suberize. Effective suberization reduces tuber water loss and prevents rot organisms from entering damaged tubers. After suberization the temperature should be gradually lowered to 40 °F (table stock or seed potatoes) or maintained at 50 °F (chipping potatoes). When rot potential is high (field frost, late blight, or ring rot is present), eliminate the curing period, drop the temperature immediately, and increase ventilation. Crops with these issues should be used as soon as possible.

Storage temperature control is best achieved with forced air ventilation. Storage relative humidity should be kept as high as possible without causing condensation on the storage walls and ceilings. Good insulation properly protected with a vapor barrier reduces the danger of condensation.

Once potatoes reach the long-term storage temperature, ventilate several hours per day or just enough to maintain pile temperature. Continuous ventilation is not necessary unless condensation or rot development occurs within the storage area or pile. Constant ventilation increases tuber weight loss and influences quality. A relative humidity of 95% is desirable for long term storage to maintain quality and minimize shrinkage.

For more detail on storage, handling, and maintaining postharvest potato quality, reference the resources and fact sheets from the Postharvest Research and Extension Center, University of California, Davis (postharvest.ucdavis.edu).

Potatoes are susceptible to various noninfectious disorders that affect the shape, function, and appearance of the plants or tubers. These are called physiological disorders since they are often caused by abiotic, nonpathogenic, nonparasitic, or noninfectious maladies that have nothing to do with diseases or pests. Physiological disorders growth or appearance changes, which contribute to economic losses since the tubers may not make grade standards. Table 9.4 names some of the more important disorders and plant part affected and describes ways to minimize or control the problem. Most physiological disorders develop slowly, may only be observed very late in the crop's growth cycle, are difficult to correctly identify, and thus make it hard to determine when the problem started. Most occur erratically in time (not evident each year) and location (field to field).

Physiological Disorders

Table 9.4. *Potato Physiological Disorders*

Name	Plant part affected	Cause, control or management
Frost damage	Leaves/foliage	Injury occurs when the leaf temperature falls below freezing. Tissue turns dark and dries out after warm up. Leaves/stems may turn yellowish and be distorted.
Hail damage	Leaves/foliage	Foliage shows tears, ragged holes, or complete defoliation. Stems may have gray- to white-colored impact injuries or bruises.
Lighting damage	Leaves/foliage	Circular areas in the field have dead plants in the centers with stunting of plants as one moves further away from the strike site.
Cracking	Tubers - external	Growth cracks are shallow to deep fissures in the tuber surface. These are commonly caused by uneven watering. Dry, then wet conditions result in changes in growth rate that cause the tuber to split. Maintain more constant water supply.
Enlarged lenticels	Tubers - external	Lenticels are small pores on the surface of the tubers. When tubers are oxygen-starved (waterlogged soils) or in dry, compacted soils, lenticels enlarge, giving the tuber a warty, scab-like appearance. Maintain constant water supply and provide good field drainage.
Freezing/chilling	Tubers - external	When tubers are exposed to cold temperatures (32 °F to 38 °F), they become chilled. They appear wrinkled, feel soft, and may have a blackish coloration just below the skin. Tubers that have been frozen (<31 °F) become soft, watery, and disintegrate when rewarmed.
Greening	Tubers - external	Exposure to light (sunlight or artificial light) enhances the development of chlorophyll by the tubers. Control light by providing good tuber cover in the field and keeping storage facilities dark.
Malformation	Tubers - external	Deformities are also called bottlenecks, chains, dumbbells, heat sprouts, and knobby, or pointed tubers. Tubers have multiple areas of growth and are oddly shaped. The severity of deformity depends on the stage of tuber growth, the severity of stress, and size of the tuber.

Insect and Mite Pest Management

Aphids

Green Peach Aphid *(Myzus persicae)*

Reference page 76 for green peach aphid description and life history.

DAMAGE

The green peach aphid is the most important vector of potato leaf roll virus (PLRV). It also vectors potato virus Y (PVY). Both diseases are particularly damaging viruses in solanaceous crops such as potato. See the diseases section of this chapter for more information on PLRV and PVY.

Potato Aphid *(Macrosiphum euphorbiae)*

Reference page 76 for potato aphid description and life history.

DAMAGE

The potato aphid may act as a vector for potato virus Y (PVY) and cucumber mosaic virus (CMV). See the "Disease Management" section of this chapter for more information on PVY.

APHID MANAGEMENT

Reference pages 76 for general aphid management.

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Natural Enemies and Biological Control*
- *Aphid Pests on Vegetables*
- *High Tunnel Pest Management - Aphids*

Colorado Potato Beetle *(Leptinotarsa decemlineata)*

DESCRIPTION

Adult: This beetle is a similar size (9 mm long) and shape as a lady beetle but with yellow and black stripes.
Egg: Small, bright yellow to orange oval-shaped eggs are laid in clusters of about 20-45 on the underside of leaves.
Larva: Larvae are about 12 mm long when mature. Small bulbous larvae are reddish with two rows of black spots alongside of the body.
Pupa: Pupa are oval in shape and cream to orange.

LIFE HISTORY

Overwintering adults emerge from under plant debris and in the soil around May in northern Utah. Females lay egg clusters on the undersides of leaves of potato, tomato, pepper, eggplant, nightshade, and other solanaceous plants. Larvae feed for 10-30 days, and then pupate in the soil. There are two to three generations per season.

DAMAGE

Colorado potato beetle (CPB) adults and larvae feed on foliage and can defoliate plants if not controlled. The last (4^{th}) instar larva causes most of the feeding damage. Potatoes in the vegetative stage can usually tolerate up to 30% defoliation, but when tubers start to bulk, plants can tolerate no more than 10% defoliation. Thus, it is crucial to manage CPB soon after flowering, as this is when tuber bulking begins. Other CPB hosts include eggplant, tomato, pepper, and other nightshade or solanaceous plants.

MONITORING

Start monitoring fields at crop emergence for the presence of CPB. Larvae prefer to feed at the tops of plants, making it simple to scout by checking these areas when walking through fields. Because small populations are easier to manage than large ones, the goal is to limit population growth and spread.

MANAGEMENT

Cultural:

- *Rotate crops and maintain sanitation.* Crop rotation delays and reduces infestations. If potatoes follow potatoes, overwintering CPB will immediately infest the new crop. Destroy any solanaceous plant residues that may provide alternate food sources.

Biological:

Damsel bugs and big-eyed bugs feed on eggs and young larvae; predatory stink bugs will attack larvae. Two bioinsecticides are effective on young larvae: the bacterium, *Bacillus thuringiensis* var *tenebrionis* (Bt), and the fungus, *Beauveria bassiana.*

Chemical:

CPB has developed resistance to nearly every class of chemicals. Thus, it is critical to carefully rotate insecticide modes of action. In spring, wait until eggs have hatched for the first application. Border sprays may provide a more economical choice, especially early in the season before populations increase and spread throughout fields.

Several economic treatment thresholds have been developed. One adult or larva per plant early in the season generally warrants control. After flowering/ tuber bulking, treat when there are an average of 1.5 large larvae or adults per plant.

Cutworms

Pale Western Cutworm *(Agrotis orthogonia)*
Glassy Cutworm *(Crymodes devastator)*
Army Cutworm *(Euxoa auxiliaris)*
Black Cutworm *(A. ipsilon)*
Variegated Cutworm *(Peridroma saucia)*

GENERAL DESCRIPTION

Adult: Moths are brown or dark gray with front wings that have irregular bands or spots and lighter-colored hind wings. Average wingspan ranges from 32 to 38 mm.
Egg: Extremely small spherical eggs are white or pale yellow when first laid, changing to brown before hatching. Depending on the species, eggs are laid singly or in irregular clusters of 30-360 on leaves or stems of plants or near the base of the plant.
Larva: Dull gray to brown, these caterpillars have black stripes or spots, and are up to 50 mm long when full grown. Most cutworms curl into a "C" shape when disturbed, and during the day, are usually found in dirt clods or just below the soil surface.
Pupa: Pupae are dark brown to orange in color with two spines on one end. Sizes range from 12 to 24 mm long.

GENERAL LIFE HISTORY

Cutworms overwinter as larvae in the soil or under plant debris. In the spring, larvae become active and begin to feed on roots and plant stems. Larvae then pupate in the soil and emerge as adults. Female moths lay eggs on the undersides of leaves, and hatched larvae feed on plant foliage and then pupate in the soil. Some species of cutworms will have a second generation of adults (or more during hotter seasons) that emerge and deposit eggs. Larvae that hatch from these eggs feed until the weather cools and then enter the soil for overwintering. Black and variegated cutworms usually have two overlapping generations per year. Army, pale western, and glassy cutworms usually have one generation per year.

DAMAGE

Cutworms feed on a wide range of crops. Some plant hosts include: potato, winter wheat, corn, tobacco, asparagus, bean, beet, cabbage, castor bean, grape, lettuce, peanut, pepper, radish, spinach, squash, strawberry, and tomato. Cutworm larvae feed at the soil surface and may cut off the stems of young plants during stand establishment. Later in the season, some species can be found feeding on plant foliage, which may cause wilting and possibly complete defoliation when infestations are high. Larvae can feed on tubers, causing gouged-out cavities. Tubers exposed by soil cracks or those set very shallow in the soil may be more susceptible.

MONITORING

- *Conduct regular scouting for larvae and damage.* Monitor early, when seedlings emerge, to detect cutworms when larvae are small. Young larvae are easier to control. Focus on fields with an early season weed infestation and those planted late. Cutworms preferentially attack these types of fields. When injured plants are found, dig about 1 inch deep around the base of plants to see if live cutworms are present. Look for wilted plants that may indicate stem feeding injury. Later in the season, monitor plants for foliage damage.
- *For black cutworms, use pheromone traps.* A threshold of two black cutworm moths per trap per day indicates significant egg-laying pressure. Increase field scouting efforts during crop emergence when threshold numbers are met or exceeded.

MANAGEMENT

Cultural:

Weedy fields and field borders and high levels of plant residue provide food sources for cutworms. Thoroughly till crop residues and control weeds to reduce cutworm overwintering and feeding sites. Remove cool-season weeds along field edges to starve young caterpillars. Lambsquarters and wild mustards are attractive host plants for egg-laying. Fall tillage can also help destroy or expose overwintering pupae.

Biological:

Many predators, parasites, and diseases attack cutworms, but because cutworms dwell beneath the soil surface, few of these natural enemies are effective in controlling their populations. *Bacillus thuringiensis* (Bt) products can be effective in controlling young cutworm larvae.

Chemical:

The sporadic occurrence of cutworm infestations typically doesn't support using soil insecticides; however, when experiencing chronic cutworm infestations or observing large numbers of overwintering cutworms, insecticides incorporated at planting provide a good preventive strategy. Young larvae at the soil surface will feed on foliage at night; thus, foliar applications in the spring can protect young plants.

Consider treatment options when thresholds reach two cuts per 100 seedlings, and three to seven cuts for older plants (the older the plant, the higher the threshold).

USU EXTENSION FACT SHEET REFERENCES

- Cutworms in Vegetable Production
- High Tunnel Pest Management - Caterpillars

Flea Beetles

Reference page 48 for a general flea beetle description and life history.

DAMAGE

Adults will chew holes in leaves and larvae can reduce plant health by feeding on roots and fine root hairs, but both of these types of injuries do not usually cause economic loss. However, some species, such as the tuber flea beetle, may cause significant damage in potato tubers. Tuber flea beetle larvae feed on roots, underground stems, and tubers. Tuber feeding results in small brown tunnels in the tuber and a pimpled surface. Severe tuber feeding can leave potatoes unmarketable for the fresh and processing markets. Tunnels will be filled with insect frass (excrement) that may stain the potato skin and flesh.

MANAGEMENT

Cultural:

- *Avoid planting susceptible crops after potatoes.* Crop rotations are generally ineffective against flea beetles because of their extreme mobility; however, potato tuber flea beetle populations tend to be greater in areas where potatoes were previously planted. Thus, it is important to avoid planting highly susceptible crops after potatoes.

USU EXTENSION FACT SHEET REFERENCES

- Flea Beetles on Vegetables

Potato Psyllid *(Bactericera cockerelli)*

DESCRIPTION

Adult: Less than 3 mm long with clear wings that rest like a tent over the body, they are related telated to aphids and leafhoppers and resemble small cicadas. Black with white markings and a white inverted "V" on the back, they readily jump when disturbed.
Egg: Extremely small (just larger than potato leaf hairs), football-shaped eggs are orange to yellow color, supported individually by a short stalk, and laid in the upper canopy of plants on the undersides and edges of leaves.
Nymph: Flat, green (yellowish-green to orange when newly hatched) nymphs have red eyes, and an oval-shaped body with spines around the edge. Nymphs resemble immature soft scale insects or whiteflies but differ in that they readily move when disturbed.

LIFE HISTORY

Potato psyllids do not overwinter in northern Utah; they migrate north on air currents from warmer areas. Psyllid population dynamics and dispersal are greatly dependent on temperatures. Movement and dispersal increases at or above 92 °F.

In the Pacific Northwest, potato psyllids are typically first detected in early July, although it is possible they may colonize potato fields around mid-June (possibly later in Utah). Each female lays about 200 eggs that hatch in 6 to 10 days. Early hatching will occur with warmer temperatures; however, temperatures above 90 °F reduce reproduction and survival. Nymphs complete five instars (molts) in 13-24 days. Under optimal conditions, potato psyllids can complete a generation in less than a month. Multiple generations occur each season, depending on temperatures and when the psyllids arrive. Adults lay eggs over an extended period, resulting in overlapping generations.

DAMAGE

Adult potato psyllids vector the bacterium *Candidatus Liberibacter solanacearum* that causes zebra chip disease (ZC). ZC significantly impacts potato production. Adults and nymphs acquire the bacterium by feeding on an infected plant and will carry the bacterium for the rest of their life. Some eggs laid by infected adults will also become carriers of the bacterium. See the "Disease Management"section of this chapter for more details on ZC.

All stages of potato psyllids feed on potato foliage with needle-like mouthparts that suck out plant juices. Toxins from their saliva are injected into the plant as they feed. This causes "psyllid yellows" which turns leaves yellow or purple. Psyllid yellows also results in fewer, smaller, or misshapen tubers.

MONITORING

Sampling and monitoring programs are a critical component of making management decisions.

- *Use yellow sticky cards.* Hang sticky cards when potato seedlings emerge from the soil, and replace them weekly. Early in the season, place sticky cards on field edges to detect immigrating psyllids. As the season progresses, distribute sticky cards evenly throughout the field. Place at least five sticky cards per field to enhance psyllid detection.
- *Visually inspect leaves for psyllid eggs and nymphs.* Collect 10 mature leaves from the middle of the plant at 10 locations among the outer rows of the field. A hand lens is needed to see nymphs on the undersides of leaves and eggs on leaf edges and undersides. Note that by the time psyllids are detected in the field, if any individuals are carrying the ZC bacterium, infection will likely have already occurred.

MANAGEMENT

Cultural:

There are currently no effective nonchemical controls for potato psyllids.

Chemical:

If potato psyllids have caused ZC disease or psyllid yellows in past years, or if nearby fields are experiencing these problems, several insecticide applications may be required to reduce psyllid populations.

Biological:

Because potato psyllid is a non-native pest, natural enemies have not been very effective to date. Predators that feed on psyllids include lady beetles, lacewing larvae, and minute pirate bugs.

Wireworms

Pacific Coast Wireworm *(Limonius canus)*
Sugar Beet Wireworm *(L. californicus)*
Western Field Wireworm *(L. infuscatus)*
Columbia Basin Wireworm *(L. subauratus)*
Great Basin Wireworm *(Ctenicera pruinina)*

DESCRIPTION

Reference page 113 for a general wireworm description and life history.

DAMAGE

Wireworms are uncommon, but there have been a few cases in Utah. *Limonius* species (Pacific Coast, sugar beet, western field, Columbia Basin wireworms) favor moist conditions, while *Ctenicera pruinina* (Great Basin wireworm) prefers dry lands where annual rainfall is less than 15 inches. All crops are susceptible to wireworm attack; however, bean, grain, corn, potato, and other annual crops are preferred hosts.

In potato, wireworms will feed on seeds and roots of young plants. Larvae can cause severe damage to potato by creating tunnels in tubers as they feed. Infestations do not spread rapidly from one field to another because female beetles are poor flyers.

MONITORING

Inspect the soil surface for wireworms after plowing or disking fields. Baits can also be used to detect wireworms. Baits include: carrots, untreated corn or wheat seed, or ground whole wheat flour. Place baits 4-6 inches deep in the soil when soil temperatures are at 50 °F. If wireworms are detected, collect soil samples in spring with a 6-inch post hole digger and a shake/sifter to estimate the density of wireworms.

Table 9.5 shows a soil sampling guide from the University of California, Davis.

MANAGEMENT

Although wireworms are generally uncommon in Utah, there have been a few cases reported. Once present in a field, wireworms can be difficult to eradicate.

Cultural:

- *Establish a dense plant stand to reduce the impact of wireworm damage.*
- *Rotate crops.* Fields previously planted to grasses, including grass grains, or pasture are at a higher risk for high wireworm populations. Red and sweet clover and small grains, especially barley and wheat, can increase wireworm populations. Include alfalfa and mustards in crop rotations to reduce wireworm populations over time.
- *Maintain sanitation.* Remove dead plants and tubers throughout the season and at harvest. Wireworm damage typically peaks at mid-season (showing up at harvest as scabbed-over holes in the tubers), and tubers of dead plants can be reinfested, resulting in increased in wireworm population. Thus, it is important to avoid prolonged periods between vine death and harvest.
- *Allow soil drying.* Sugar beet and Pacific Coast wireworm (*Limonius* spp.) populations prefer moist soil and can be reduced by drying the top 15 inches of the soil for several weeks at midsummer. This will especially kill eggs and young larvae. Soil drying is more effective in light sandy to silt loam soils. Conversely, Great Basin wireworms (*Ctenicera* spp.) prefer dry soil and can be eradicated by converting dryland fields to continual irrigation.
- *Flood soils.* Thoroughly saturating or flooding soils for at least 2 weeks when soil temperatures are above 68 °F will significantly reduce wireworm populations. To increase wireworm mortality, alternate periods of flooding and drying.
- *Schedule intensive plowing.* Wireworm populations can be reduced by plowing three or more times during late spring and early summer.
- *Use resistant varieties.* There are some resistant varieties that may be worth testing if wireworms are a potential problem. A study in Oregon found a range of potato varietal susceptibility to wireworms. These varieties are shown in Table 9.5.
- *Manage soil health.* Maintaining healthy soils with compost, manure, or green manure may reduce wireworm damage.

Chemical:

Chemical options for wireworm control are few. Organophosphate chemicals are the most effective and consistent when applied at preplant as a broadcast treatment, or planting time as a furrow application.

Biological:

Birds may feed on wireworms in recently plowed fields but will not reduce populations below economic levels in seriously infested areas. There are no known biological insecticides.

USU EXTENSION FACT SHEET REFERENCES

- *Wireworms (Click Beetles)*

See Tables 9.7 and 9.9 for more information about insecticide use for potato production.

Table 9.5. *Percentage of Wireworm Infected Tubers for Various Potato Varieties*

Variety	Percent Infected
AC9531	1%
VC1009	1%
Cherry Red	3%
Ozette	13%
Yukon Gold	15%
Colorado Rose	16%
Austrian Crescent	17%
Red LaSoda	17%
Satina	20%
Mountain Rose	20%
Nicola	24%
POR01PG22	24%
Sangre	27%
Huckleberry	28%
Jacqueline Lee	30%

Disease Management

Alfalfa Mosaic Virus

CAUSAL AGENT

Alfalfa mosaic virus (AMV) is in the genus Alfamovirus and is spread by aphids.

SYMPTOMS

Yellow mosaic or calico patterns occur on the foliage. Some AMV strains can cause severe stunting of plants and tuber necrosis. Sometimes corky or brown areas will develop in potato tubers.

DISEASE CYCLE

The virus is commonly found in alfalfa. Aphids feed on infected alfalfa, acquire the virus, and transmit it to healthy potato plants. Aphids need to feed on another infected plant to spread the disease again. The virus is not seedborne in potatoes.

MANAGEMENT

Insecticides to control aphids will be of limited help. The best management option is to avoid planting potatoes close to alfalfa fields.

Late Blight *(Phytophthora infestans)*

CAUSAL AGENT

Phytophthora infestans is a fungal-like organism that causes late blight.

SYMPTOMS

Phytophthora affects potato foliage, stems, and tubers. Initially, foliar lesions are greasy-appearing, with a light yellow halo around them. They quickly enlarge and turn black-brown. Infected tubers decay either in the soil or in storage.

DISEASE CYCLE

Phytophthora overwinters in the soil and in decaying potato tubers or cull potato/tomato piles. It produces spores that are blown by wind or splashed by rain onto new host tissue. The disease occurs when temperatures range from 50 °F to 78 °F and relative humidity is above 90%.

MANAGEMENT

- *Remove cull piles.*
- *Allow plants with infected foliage to dry for 2-3 weeks before harvest to ensure Phytophthora has died.* It cannot survive on dry, dead plant material.
- *Apply a fungicide.* Options are: azoxystrobin, chlorothalonil, pyraclostrobin, famoxadone, cymoxanil, dimethomorph, fenamidone, propamocarb hydrochloride or mefenoxam + chlorothalonil.

Potato Virus Y

CAUSAL AGENT

Potato virus Y is in the genus Potyvirus. There are three strains: PVYO, PVYN, and PVYNTN. This virus is transmitted by aphids.

SYMPTOMS

Symptoms vary depending on the strain. PVYO causes mosaic symptoms on the leaves and no symptoms on tubers. PYVN causes necrotic spots on leaves and tubers. PVYNTN causes necrotic lesions on leaves and necrotic ringspots on the tuber surface that extend into flesh.

DISEASE CYCLE

The virus is most frequently introduced into a field on infected seed pieces. It can be spread within a field and beyond by aphids and farm equipment. When aphids feed on an infected plant, they can then transmit the virus to a single healthy plant. They have to feed on another infected plant to transmit the virus again. This type of transmission is called "nonpersistent." The virus overwinters in infected seed pieces and solanaceous weeds, such as nightshade or ground cherry.

MANAGEMENT

There are no resistant potato varieties; however, some are more susceptible than others, depending on the strain. For example, Yukon Gold is very susceptible to tuber necrosis. The best option is to use certified seed potatoes. Unfortunately, these potatoes will not be certified as 100% disease-free, and small amounts of PVY may still be introduced. Therefore, scouting for infected plants and removing them from the fields is important for early detection.

Remove alternative hosts by controlling weeds. Since the virus is transmitted in a nonpersistent manner, insecticides used to control aphids will have negligible effects.

Verticillium Wilt *(Verticillium albo-atrum)*

CAUSAL AGENT

Verticillium albo-atrum is a soilborne fungus that infects many hosts.

SYMPTOMS

Infected plants initially show wilting of the lower leaves during the hot part of the day, with recovery in the evening. Eventually, the plants permanently wilt. The vascular tissue of the main stem will be discolored. Diseased plants may also show early senescence. Occasionally, the vascular tissue inside the tubers discolors as well.

DISEASE CYCLE

Verticillium infects through plant roots, and the fungus grows through the vascular tissue up into the main stem. The wilting is caused by the fungal growth clogging the xylem and the plant trying to stop the movement of the fungus by blocking the colonized vascular tissue.

Verticillium produces an overwintering structure called a microsclerotium, which is a hard black ball of fungal tissue. The microsclerotia germinate when a suitable host is planted and then infect the plant. Microsclerotia can survive in the soil for up to 10 years, depending on environmental conditions, while it waits for a suitable host. If root-feeding nematodes are present in high numbers in the soil, they can increase the severity of the disease by creating wounds on roots during feeding.

MANAGEMENT

Managing verticillium wilt is very difficult and can be prevented with careful crop rotations. There are no resistant potato varieties. If crop rotation is not possible and verticillium is present, the field should be planted with grass, cereals, or legumes for several years to reduce the number of microsclerotia in the soil. In severe cases, fumigation with 1,3-dichloropropene (e.g., Telone II) may be necessary. Telone II is a restricted product with application requirements.

USU EXTENSION FACT SHEET REFERENCES

- *Fusarium and Verticillium Wilt of Vegetables*

Zebra Chip Disease

CAUSAL AGENT

Zebra chip disease is caused by the bacterium *Candidatus* Liberibacter solanacearum. The bacteria are transmitted when potato psyllids feed on susceptible hosts. The bacteria colonize the vascular tissue in the plant and tubers.

SYMPTOMS

There are no aboveground symptoms specific to zebra chip disease. When psyllids feed, they cause pink to reddish discoloration of the foliage (sometimes mistaken for nutrient deficiency). If psyllids are detected along with the discolored foliage, there is a high chance that the bacteria are present as well.

Belowground symptoms on potato tubers are only visible when they are cut. The vascular tissue in the tuber has a brown discoloration. The discoloration is even more pronounced when the potatoes are fried.

DISEASE CYCLE

The bacteria are acquired by potato psyllids and then transmitted during feeding, where they then colonize the vascular tissue in the plant and tubers. Seed pieces from infected plants either do not sprout or produce only small, weak plants.

MANAGEMENT

Management options are very limited.

- *Control potato psyllids early in the season.* Detecting potato psyllids early is important.
- *Use yellow sticky cards.* They will attract adult psyllids.
- *Look for psyllids on the underside of the leaves.* A hand lens helps to see them.
- *There are no resistant potato varieties.* Once the potatoes are infected, there is no cure.

USU EXTENSION FACT SHEET REFERENCES

- *Zebra Chip Disease of Potato*

See Tables 9.8 and 9.10 for more information about fungicides for potato production.

Potato Pesticide Tables for Commercial and Small-Scale Use

Table 9.6. *Herbicides* *Registered for* ***COMMERCIAL*** *Use on* ***Potato*** *in Utah*

Brand name (REI/PHI)	Active ingredient	Timing and application location relative to crop					Timing relative to weeds		Weed groups controlled			Comments
		Before planting	Preemergence	At/after hilling	Between rows, directed/ shielded	Postemerge over crop	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/0d)	carfentrazone	X			X			X		X	X	
Chateau (12h/-)				X			X			X	X	
Dual Magnum (12h/30d)	s-metolachlor	X	X	X	X		X		X	X		
Eptam (12h/45d)		X					X		X			
Gramaxone Inteon (12hr/30d)	paraquat	X	X		X			X	X	X	X	Restricted use product
League (12h/45d)	imazosulfuron		X	X		X	X	X		X	X	
Linuron (12h/-)	linuron		X				X	X	X	X	X	
Matrix (4h/60d)	rimsulfuron		X	X			X	X	X	X	X	
Metribuzin (12h/60d)	metribuzin		X			X	X		X	X	X	
Outlook (12h/40d)	dimethenamid-p		X				X		X	X		
Pendimethalin (12h/-)	pendimethalin		X			X	X		X	X		
Poast (12hr/14-20d)	sethoxydim	X	X	X		X		X	X			
Reflex (12h/70d)	fomesafen		X				X			X	X	
RoundUp, others (12hr/14d)	glyphosate	X	X		X			X	X	X	X	
Select Max, others (12h/30d)		X	X	X		X		X	X			
Treflan, others (12hr/-)	trifluralin		X		X		X		X	X		
Organic Products												
Corn gluten meal		X	X				X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X				X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X				X	X	X	X	
Worry Free	citrus oil	X	X	X				X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 9.7. *Insecticides* *Registered for* *COMMERCIAL* *Use on* *Potato* *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
carbaryl	Carbaryl 4L, Drexel Carbaryl 4L, Sevin 5 Bait, Carbaryl Cutworm Bait, Drexel Carbaryl 5% Bait, Sevin 4F, Sevin XLR Plus	1A	10-14		X	X	X			X	
methomyl	Corrida 29 SL, Corrida 90 WSP, Lannate LV, Lannate SP, Lanveer LV, Nudrin LV, Nudrin SP	1A	10-14	X	X	X	X				
oxamyl	Vydate C-LV, Return XL, ,Vy-King 42, Vypera C-LV	1A	14-18	X		X	X				
malathion	Drexel Malathion 5EC, Fyfanon 57% EC, Fyfanon Malathion Insecticide, Malathion 5	1B	5-7	X						X	
	Malathion 57%, Malathion 8 Aquamul			X							
phosmet	Imidan 70-W	1B	2-3 wks			X	X	X			
alpha-cypermethrin	Fastac CS, Fastac EC	3A	2-3 wks	X	X	X	X			X	
bifenthrin	Avenger Bold S3, Avenger Max, Skyraider, Swagger, Tempest	3A	2-3 wks	X		X	X	X		X	
	Batallion 2 EC, Batallion LFC, Bi-Dash 2E, Bifender FC, Bifenthrin 2EC, Bifenture EC, Bifenture EC, Bifenture LFC, Bifenture LFC, Brigade 2EC, Capture LFR, Discipline 2EC, Ethos XB, Fanfare 2EC, Fanfare EC, Fanfare ES, GCS Bifenthrin 2EC, GCS Bifenthrin LFC, Lancer FC, Omni Bifenthrin 2EC, Reveal, Sniper, Sniper Helios, Sniper LFR, Suro LFC, Tepera Plus, Tundra EC, Xpedient Plus					X	X				
	Steed			X	X	X	X			X	
cyfluthrin	Tombstone, Tombstone Helios	3A	10-14	X		X	X	X			
deltamethrin	Delta Gold 100	3A	14	X	X	X	X				
esfenvalerate	Asana XL, S-FenvaloStar	3A	10-14	X	X	X	X	X		X	

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O = Organic

Potatoes

Table 9.7., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Potato*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
gamma-cyhalothrin	Declare	3A	10-14	X	X	X	X	X	X	X	
lambda-cyhalothrin	Crusader 2ME, Drexel L-C, Endigo ZCx, Grizzly Too, Kendo, Kendo 22.8 CS, Kilter, Labamba, Lambda Select, Lambda T, Lambda T-2, , Lambda-Cy AG, Lambda-Cy EC, LambdaStar, LambdaStar 1 CS, LambdaStar Plus, Lamcap II, Lunge, Omni Lambda 1 EC, Paradigm VC, Province II, Ravage, Ravage 2.0, Ravage II, Roundhouse 1 EC, Serpent 1 EC, Silencer, Tigris Lambda, Warrior II with Zeon Technology, Willowood Lambda-Cy 1EC	3A	10-14	X	X	X	X	X	X	X	
permethrin	Arctic 3.2 EC, Perm-UP 3.2 EC, Pounce 25 WP	3A	14	X	X	X	X	X			
	PermaStar AG, Permethrin			X	X	X	X				
pyrethrins[O]	BotaniGard Maxx, EverGreen EC 60-6, PyGanic EC 1.4 II, PyGanic Crop Protection EC 5.0 II, Pyrenone, Tersus	3A	5-7	X	X	X	X		X	X	X
	Pyrethrum TR, Pyrus TR			X		X	X		X		
zeta-cypermethrin	Cortes Maxx, Gladiator, Hero, Hero EW, Mustang, Mustang Maxx	3A	10-14	X	X	X	X			X	
	Gladiator			X	X	X	X	X		X	
beta-cyfluthrin	Baythroid XL, Sultrus	3A	14	X		X	X	X			
acetamiprid	Afflict 30SG, Anarchy 30SG, Anarchy 70WP, Assail 30SC, Assail 30SG, Assail 70 WP, Assail 70 WP, Intruder Max 70WP, Omni Acetamiprid 30 SG, Omni Acetamiprid 70 WP, Savoy EC, Verso 30SG, Verso 70WP	4A	14	X		X	X	X			
clothianidin	Belay	4A	10-14	X		X	X	X			

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[O] = Organic

Potatoes

Table 9.7., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Potato*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
dinotefuran	Certador, Venom	4A	14	X		X	X				
	Scorpion 35SL			X		X	X	X			
imidacloprid	Acronyx 4F, Admire Pro, Advise Four, Alias 2F, Alias 4F, Imidashot DF, Macho 2.0 FL, Macho 4.0, Malice 2F, Midac FC, Montana 2F, Montana 4F, Nitro Shield IV, Nuprid 2SC, Nuprid 4F Max, Nuprid 4.6F Pro, Omni Imidacloprid 4F, Prey 1.6, Provoke, Sherpa, Viloprad FC 1.7, Widow, Willowood Imidacloprid 4SC, Wrangler	4A	10-14	X		X	X	X			
	Brigadier			X		X	X	X		X	
	Lada 2F			X			X	X	X		
	Marathon 1% G, Omni Imidacloprid 2F			X				X	X		
	Mallet 75 WSP			X							
	Marathon II, Mineiro 2 Flex			X					X		
thiamethoxam	Actara, Cruiser 5FS, CruiserMaxx Vibrance Potato	4A	14	X							
	CruiserMaxx Potato Extreme, Legend 5L ST			X		X	X				
	Platinum 75 SG			X		X	X	X			
sulfoxaflor	Transform WG	4C	10-14	X				X	X		
flupyradifurone	Sivanto 200 SL, Sivanto HL, Sivanto prime	4D	10-14	X		X	X	X			
spinetoram	Delegate WG, Radiant SC	5	10-14		X			X	X		
spinosad[O]	Entrust Naturalyte, Entrust SC Naturalyte, Success, Blackhawk, SpinTor 2SC	5	7-10		X				X		
	Seduce Insect Bait				X						X
	Conserve SC								X		

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[O] = Organic

Potatoes

Table 9.7., continued. *Insecticides* *Registered for* COMMERCIAL *Use on* Potato *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
abamectin	Abacus V, Abacus V6, Abamex, AbbA Ultra, Agri-Flex, Agri-Mek SC, Averland FC, Enterik 0.7 SC, Agri-Flex, Minecto Pro, Timectin 0.15 EC Ag, Willowood Abamectin 0.15LV, Willowood Abamectin 0.7SC, Enterik 0.15 LV, Reaper 0.15 EC, Reaper Advance, Reaper ClearForm	6	14-21			X	X	X	X		
	Minecto Pro			X	X	X	X	X	X		
avermectin	Athena	6	14-21	X	X	X	X		X	X	
pyriproxyfen	Senstar	7C	14	X							
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM Ultra	8D	10-14	X	X				X		
pymetrozine	Achiever, Fulfill, Seville	9B	7-10	X							
pyrifluquinazon	PQZ	9B	7	X							
afidopyropen	Sefina Inscalis	9D	7	X				X			
hexythiazox	Hexamite, Onager, Onager Optek, Proneva EC	10A	N/A					X			
Bacillus thuringiensis aizawai strain GC-91°	Agree WG, Biobit HP WP, Bioprotec Plus, BT Now, Crymax, Deliver, DiPel DF, Javelin WG, Leprotec, Trident, Xentari DF	11A	5-7		X	X	X				
fludioxonil	CruiserMaxx Potato	12	7-10	X		X	X				
cyromazine	Trigard, Trignata WSP	17	7-14			X	X				
tolfenpyrad	Torac	21A	14	X		X		X	X		
indoxacarb	Avaunt eVo, Avaunt, Comber	22A	14			X	X				
spiromesifen	Oberon 2 SC, Oberon 4 SC	23	7-14					X			
spirotetramat	Movento	23	14	X					X		
chlorantraniliprole	Coragen, Elevest, Shenzi 400SC, Vantacor	28	7-14		X	X	X			X	
	Verimark, Exirel			X	X	X	X	X			
cyclaniliprole	Harvanta 50SL	28	14-17	X	X	X	X	X	X		
flonicamid	Beleaf 50 SG, Carbine 50WG	29	14	X				X			

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° = Organic

Potatoes

Table 9.7., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Potato*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
gs-omega/kappahxtx-hv1a	Spear-LEP	32	5-7		X	X	X				
	Spear-T Liquid Concentrate			X				X	X		
allyl isothiocyanate	Dominus	UN	7-10			X	X				
azadirachtin^{O}	Atrevia 1.2% SL, AzaGuard	UN	7-10	X		X	X		X		
	Atrevia 3.0% SL, Aza-Direct, AzaSol			X	X	X	X		X	X	
	Azatin O			X	X	X	X	X	X	X	
Beauveria bassiana strain ANT-03^{O}	BioCeres WP	UN	5-7	X					X		
Beauveria bassiana strain GHA^{O}	BotaniGard ES, BotaniGard Optima ES, BotaniGard 22WP, BoteGHA ES, BoteGHA Optima ES, Mycotrol ESO, Mycotrol Optima ESO, Mycotrol WPO	UN	5-7	X		X	X	X	X		
Burkholderia spp. strain A396^{O}	VENERATE CG	UN	7-10	X	X				X		
	Venerate xC			X	X						
canola oil^{O}	Captiva Prime, Pycana	UN	3						X		
Chenopodium ambrosioides extract^{O}	Requiem EC, Requiem Prime	UN	3-5					X			
Chromobacterium subtsugae^{O}	Grandevo	UN	5-7	X	X						
	Grandevo WDG			X	X	X	X	X			
cinnamaldehyde^{O}	Seican	UN	3	X					X		
cinnamon oil^{O}	Cinnerate	UN	3	X					X		
garlic oil^{O}	Captiva	UN	3						X		
geraniol^{O}	Wrath	UN	3								X
	Brandt Ecotec Plus			X			X		X		
iron phosphate	Bug-N-Sluggo	UN	2-4 weeks								X
Isaria fumosorosea Apopka strain 97^{O}	PFR-97 10% ES, PFR-97 20% WDG	UN	5-7	X		X	X		X		
Isaria fumosoroseus strain FE 9901^{O}	Nofly WP	UN	7-10	X		X	X		X	X	
kaolin^{O}	NovaSource Surround WP Agricultural Crop Protectant	UN	5-7			X	X				

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

^{O} = Organic

Potatoes

Table 9.7., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Potato*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
mineral oil[O]	BioCover MLT, BioCover SS, BioCover UL, Glacial Spray Fluid, PureSpray Green, SuffOil-x, TriTek Ultra-Pure Oil	UN	3	X					X		
neem oil[O]	EcoWorks EC, Rango Trilogy	UN	3	X				X	X		
	Trilogy			X					X		
potassium salts of fatty acids[O]	Des-x, Kopa Insecticidal Soap, M-Pede	UN	5-7	X					X		
potassium silicate[O]	Carbon Defense, Sil-Matrix LC	UN	7	X							

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Table 9.8. *Fungicides* *Registered for* ***COMMERCIAL*** *Use on* ***Potato,*** *Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Late blight
fludioxonil	Startup Fludi, Dyna-Shield Fludioxonil, Fludioxonil 4L ST, Maxim 4FS, Spirato 480 FS	12	7-10	X
polyoxin d zinc salt	Ph-D	19	5-7	X
neem oil[O]	EcoWorks EC	BM1	3	X
Bacillus amyloliquefaciens strain D747[O]	Double Nickel 55	BM2	5-7	X
Streptomyces sp. strain K61	Lalstop K61 WP	BM2	7	X
hydrogen peroxide	Jet-Ag, Jet-Ag 5%	NC	7-10	X

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[O] = Organic

Potatoes

Table 9.9. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* **Potato,** *Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
acephate	Bonide Systemic Insect Control	1B	7	X							
bifenthrin	Ferti-lome Broad Spectrum Insectide, Ferti-lome Broad Spectrum Insecticide RTS, Hi-Yield Vegetable & Ornamental Insect Control	3A	2-3 wks	X	X	X	X	X	X	X	X
cyfluthrin	BioAdvanced Tomato & Vegetable Insect Killer RTU, BioAdvanced Tomato & Vegetable Insect Killer RTS	3A	14	X	X	X	X	X	X	X	X
deltamethrin	Hi-Yield Multi-Use Dust	3A	14	X	X	X	X				
	Ortho Insect Killer Flower & Vegetable Garden Dust			X	X	X	X	X	X	X	X
permethrin	Bonide Insect Control Garden Dust, Bonide Eight Vegetable, Fruit, & Flower Concentrate, Bonide Eight Yard & Garden RTS, Hi-Yield Garden & Farm Insect Control, Hi-Yield Garden, Pet, & Livestock Dust	3A	14	X	X	X	X	X	X	X	X
zeta-cypermethrin	GardenTech Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X	X	X	X	X	X
bifenthrin + zeta-cypermethrin	GardenTech Insect Killer Lawn Granules	3A	2-3 wks	X	X	X	X	X	X	X	X
pyrethrins[O] + potassium salts of fatty acids[O]	Safer Brand Insecticidal Soap + Pyhrethrin Concentrate	3A/ UN	5-7	X	X	X	X	X	X	X	X
pyrethrins[O] + neem oil[O]	Ferti-lome Triple Action, Ferti-lome Triple Action Plus RTU	3A/ UN	3-5	X	X	X	X	X	X	X	X
pytherins[O] + piperonyl butoxide	Bonide Pyrthein Garden Spray Concentrate	3A/ UN	5	X	X	X	X	X			
pyrethins[O] + canola oil[O]	Espoma Organic Insect Control	3A/ UN	5	X	X	X	X	X	X	X	X

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[O] = Organic

Table 9.9., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* **Potato***, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
pyrethrins° + sulfur°	BioAdvanced Fruit & Vegetable 3-in-1 Solution Concentrate, BioAdvanced Fruit & Vegetable 3-in-1 Solution RTU, Natria Insect, Disease, and Mite Control RTU, Natria Insect, Disease, and Mite Control RTS, Ortho Insect, Mite, & Disease 3-in-1 RTU	3A/ UN	7-10	X	X	X	X	X	X	X	X
malathion	Hi-Yield 55% Malathion Spray	3B	5-7	X	X						
	Ortho MAX Malathion Insect Spray Concentrate, Bonide Malathion Concentrate, Spectracide Malathion Insect Spray Concentrate			X	X	X	X	X	X	X	X
imiclacloprid	Bonide Systemic Insect Spray	4A	N/A	X							
spinosad°	Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Captain Jack's Deadbug Brew Dust, Bonide Colorado Potato Beetle Beater, Monterey Garden Insect Spray, Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS	5	7-10		X	X			X		X
spinosad° + iron phosphate	Bonide Captain Jack's Bug & Slug Killer, Monterey Sluggo Plus, Natural Guard Bug, Slug, & Snail Bait	5/ UN	2-4 wks		X						X
spinosad° + potassium salts of fatty acids°	BioAdvanced Organic Tomato, Vegetable, & Fruit RTU, Bonide Insecticidal Super Soap RTU, Monterey Garden Insect Spray RTU, Natural Guard Spinosad Soap Concentrate, Natural Guard Spinosad Soap RTS, Natural Guard Spinosad Soap RTU	5/ UN	5-7	X	X	X	X	X	X		X

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° = Organic

Table 9.9., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Potato****, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
Bacillus thuringiensis[O]	Bonide Captain Jack's BT, Bonide Thuricide (BT) Concentrate, Monterey B.T., Monterey B.T. RTU	11	5-7		X						
Bacillus thuringiensis var. Kurstaki[O]	Natural Guard Caterpillar Killer Spray with BT RTU	11	5-7		X						
	Ferti-lome Dipel Dust Biological Insecticide				X						
canola oil[O]	Natural Guard Horticultural Oil Concentrate, Natural Guard Horticultural Oil Concentrate RTS	UN	3	X				X	X		
cotton seed oil[O] + clove oil[O] + garlic oil[O]	Bonide Mite X RTU	UN	3	X					X		
mineral oil[O]	Safer Brand Horticultural & Dormant Spray Oil Concentrate	UN	3	X				X	X		
neem oil[O]	BioAdvanced Organics Neem Oil RTU, Espoma Organic Neem Oil 3n1, Monterey 70% Neem Oil, Natria Neem OIl Concentrate, Natria Neem Oil RTU, Natural Guard Neem Concentrate, Natural Guard Neem RTU	UN	3	X				X	X		
potassium salts of fatty acids[O]	Bonide Insecticidal Soap RTU, Epsoma Organic Insect Soap, Natural Guard Insecticidal Soap	UN	5-7	X				X	X		
	Natria Insecticidal Soap RTU			X				X	X		X
potassium salts of fatty acids[O] + neem oil	Safer Brand RTU End ALL Insect Killer	UN	5-7	X				X	X		

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[O] = Organic

Table 9.9., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Potato****, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/cutworm	Colorado potato beetle	Flea beetle	Potato psyllid	Thrips	Grasshopper	Earwig
potassium salts of fatty acids[O] + seaweed extract[O]	Safer Brand Insect Killing Soap RTU Spray	UN	5-7	X				X	X		
potassium salts of fatty acids[O] + sulfur[O]	Safer Brand 3-in-1 Concentrate, Safer Brand 3-in-1 RTU Garden Spray	UN	7-10	X	X	X	X		X		X
	Safer Brand Insect Killing Soap Concentrate			X				X			
	Safer Brand Tomato & Vegetable 3-in-1 Garden Spray			X				X	X		
silicon dioxide	Bonide Diatomaceous Earth	UN	7-14	X	X	X	X	X	X	X	X
	Natural Guard Diatomaceous Earth Crawling Insect Control									X	X
sulfur[O]	GardenTech Sevin Sulfur Dust	UN	7-10	X							

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[O] = Organic

Potatoes

Table 9.10. *Fungicides* Registered for *SMALL-SCALE* Use on *Potato*, Organized by Mode of Action (MoA)

Active ingredient	Brand name	MoA	Residual days	Blights
Bacillus subtilis strain QST 713	Serenade Garden Disease Control	44	5-7	X
copper	Natural Guard Copper Soap, Monterey Liqui-Cop, Bonide Copper Fungicide	M1	5	X
chlorothalonil	Fertilome Broad Spectrum Landscape & Garden Fungicide, Hi Yield Vegetable Flower Fruit & Ornamental Fungicide, Ortho Max Garden Disease Control	M5	7-14	X

Potatoes

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O = Organic

Commercial seed potato harvest in Cache County.

Seed potatoes being loaded for export in Cache County.

Symptoms of nitrogen deficiency in potatoes.

Symptoms of phosphorus deficiency in potatoes.

Symptoms of potassium deficiency in potatoes.

Hail damage amongst potatoes.

Potatoes with enlarged lenticels.


Tuber malformation in potatoes.

Potato aphids (Myzus persicae) feeding on potato foliage.

Colorado potato beetle eggs *(Leptinotarsa decemlineata).*

Colorado potato beetle larvae and feeding damage.

Colorado Potato Beetle

Tobacco Flea Beetles *(Epitrix hirtipennis)*

Western Potato Flea Beetle (*Epitrix subcrinita*)

Flea Beetle Larva

Flea beetle larval feeding damage on potato tuber.

Potato Psyllid Nymph *(Bactericera cockerelli)*

Adult Potato Psyllid

Army Cutworm Moth *(Euxoa auxillaris)*

Army Cutworm

Pale Western Cutworm Moth *(Agrotis orthogonia)*

Pale Western Cutworm *(Agrotis orthogonia)*

Glassy Cutworm Moth *(Apamea devastator)*

Glassy Cutworm *(Apamea devastator)*

Adult Pacific Coast Wireworm (Click Beetle) *(Limonius canus)*

Adult Sugar Beet Wireworm (Click Beetle) *(Limonius californicus)*

Adult Western Field Wireworm (Click Beetle) *(Limonius infuscatus)*

Adult Columbia Basin Wireworm (Click Beetle) *(Limonius subauratus)*

Adult Wireworm (Click Beetle) *(Ctenciera* spp.*)*

Wireworm Larva

Wireworm feeding damage on sweet potatoes.

Potato plant infected with alfalfa mosaic virus.

Late blight *(Phytophthora infestans)* symptoms on potato foliage.

Potato virus Y symptoms on tuber.

Potato plants with verticillium wilt symptoms.

Zebra chip disease foliar symptoms (*Candidatus* Liberibacter solanacearum).

Zebra chip disease tuber symptoms.

CHAPTER 10: ROOT CROP PRODUCTION

Root vegetables are relatively easy to grow with few production problems. They come from several different crop families and include crops like carrot and parsnip (Parsley Family); radish, rutabaga, and turnip (Mustard Family); and other crops like beets (Goosefoot Family).

Root crops are mostly cool-season vegetables that grow best in the spring and fall, but there are heat-tolerant varieties for summer plantings. Some are successfully grown in unheated greenhouses or high tunnels, planted in January or February and then again in October or November. This allows harvest either early in the spring or through the winter to supply local or specialty markets.

Types and Varietal Selection

Due to the large variety of types and cultivars, it is important to identify local consumer wants or needs. The following list is illustrative only (Table 10.1). There are too many varieties to list, and most have not been tested locally. Individual or on-farm testing of new varieties allows growers to find cultivars adapted to the local climatic and environmental conditions found throughout Utah. Always compare a new variety to your existing variety. Seed dealers can provide other options.

Table 10.1. *Variety Suggestions* - *Commonly Grown Root Vegetables*

CARROT
Adelaide, Bolero, Cordoba, Danvers, Fuerta, Imperator, Ingot, Neptune, Romance
PARSNIP
Albion, All American, Javelin, Pacific
RADISH
Champion, Cherry Belle, Crunchy Crimson, French Breakfast, Sparkler, Whitella, Winner
RUTABAGA
Helenor, Laurentian
TURNIP
Bella Luna, Purple White Top, Royal Crown, Shogoin, White Lady
BEET
Cylindra, Detroit, Early Wonder, Falco, Red Ace, Touchstone

Note. These varieties are mostly untested, and this is not a complete list.

Soil and Fertility

Root vegetables tolerate a wide range of different soil types. Heavy soils (silt or clays) produce high yields, while light sandy soils are more suitable for early spring, fall, or winter production. Root crops have high water demands, require deep, loose, friable soils, and soils with good moisture-holding capacity with excellent drainage. Avoid soils prone to compaction, those with lots of stones, or those that lack good soil structure (crust easily), as these conditions affect seedling emergence, root growth, or make harvest difficult.

For fertilizer needs, use a soil test to identify nutrient limitations. The following recommendations are general, and applications should be adjusted based on soil test results.

- Most root vegetables require 50-150 pounds of nitrogen per acre. Overapplying of nitrogen results in excessive leaf growth at the expense of root sizing. Apply one-third to one-half this amount preplant, then side-dress with the remainder at 4 and 8 weeks after emergence. Use the lowest amount on radish.
- Use less nitrogen if soils have had manure/compost additions or when grown after legume cover crops.
- Soils should have adequate phosphorus (50-150 (P_2O_5) pounds/acre) and potassium (50-150 (K_2O) pounds/acre). Adjust levels based on soil tests.
- Apply higher amounts of phosphorus in cold soil conditions (early spring, late fall, or winter plantings).
- These crops grow best when soil pH is 6.5-7.5.
- Root vegetables can be damaged by banded fertilizer. Place fertilizer to the side of the planting row.

Planting and Spacing

Root vegetables start to germinate at soil temperatures of 40 °F, with optimum germination between 55 °F to 70 °F. High temperatures (over 80 °F) can cause heat-induced seed dormancy, poor root development (off-shapes), poor root quality (poor color and coarse texture), and reduce root sugar levels. Root vegetables mature quickly (30 to 100 days), and temperature influences the days to harvest. Use sequential plantings (about every 10 days) to get consistent production. Plant seeds ¼ - ⅓ inches deep in rows spaced 12-24 inches apart.

Purchase the best quality seed available to help ensure uniformity of germination and plant growth. Seed weight information can help plan seed purchases (Table 10.2). Use modern precision planters when seeding. A fungicide seed treatment should be used if establishment issues have been encountered. Always plant in well-prepared seedbeds to ensure uniform planting depths and rapid establishment. Water after seeding to promote even emergence. Carrot and parsnip are very slow to emerge, particularly in cold soils.

Regardless of the crop, proper plant spacing allows good air movement around the plants to minimize common diseases. Planting on raised beds (3-4 feet wide; 4 inches high; 3-4 rows per bed) helps with air movement and encourages drier soil conditions. Rotate planting sites wherever possible, each year.

Table 10.2. *Seed Quantities, Field Seeding Rates, and Common Row Spacing for Root Vegetables*

Crop	Seeds/lb (Per unit weight)	Field (lb/Ac)	Row spacing (in.)	
			In row	Between
Beet	24 - 26,000	10-15	2-4	12-24
Carrot	300 - 400,000	2-4	1-3	15-24
Parsnip	185 - 200,000	3-5	2-4	18-30
Radish	40 - 50,000	10-20	1/2 - 1	8-15
Rutabaga	150 - 200,000	1-2	4-8	15-30
Turnip	150 - 200,000	1-2	2-6	12-30

Note. Field seeding rates depend on plant type, germination percentage, plant population, and seasonal field conditions at planting.

Irrigation

Root vegetables require frequent irrigations for optimal quality. As many as 8-10 irrigations and 10-12 inches of water per acre may be necessary depending on seasonal variation, variety, and planting date. Soil type does not affect the amount of total water needed but does dictate frequency of water application. Lighter soils need more frequent water applications but less water applied per application.

Drip irrigation will improve marketable yield and performance and reduce irrigation inefficiencies associated with other irrigation methods. Root vegetables are sensitive to water stress. Critical times when irrigation can improve productivity include during establishment (seeding), during rapid leaf growth, and as the roots size. Different irrigation methods are used to irrigate root vegetables, each with different management considerations. Use sprinkler irrigation to help establish the crops, then switch over to furrow or drip irrigation. Irrigate when about 40% of the soil's available water is depleted. Root crops require approximately 1-2 inches of water per week. Excessive irrigation can cause root splitting, cracking, and poor color development.

Weed Management

In conventionally managed fields, control weeds with preplant and/or preemergence herbicides. Apply postemergence herbicides after the field is cultivated to control broadleaf and grass weeds. Hand-weed or mechanically cultivate as needed.

In organic production systems, apply a preplant irrigation to induce weed emergence. Weeds can then be killed by tillage, flaming, or OMRI-approved organic herbicides (nonselective, contact, limited residual activity). Consult your certifying agent prior to applying organic herbicides.

Users should have a current chemical applicator license, and read and save copies of all labels. Herbicide options are listed in Table 9.3. Herbicide labels change regularly, so always consult a current label to determine (1) if the crop is listed for herbicide use; (2) what precautions are required; and (3) what rates and application methods are allowed. It is a violation of federal law to use any herbicide for purposes other than those specified on the approved label. Always use the recommended amount of product, apply it as stated, and watch reentry intervals (REI) and preharvest intervals (PHI).

Herbicides are applied in the following ways:

- **Preplant:** incorporated into the soil prior to seeding the crop.

•**Preemergence:** applied to the soil after planting but before the crop or weeds emerge.

•**Postemergence:** applied to weeds after both weeds and the crop have emerged.

Harvest and Storage

Root vegetable harvest is not determined by defined maturity characteristics. Timing depends on plant growth rates, root size and quality criteria, and market demands. Roots are harvested with or without the tops attached. In smaller plantings, harvest is done by hand, but it is more common to use some type of harvester or harvest aid.

Beet - Harvest any time after bulb sizing begins. Harvest by hand when bunches are desired. Beet roots require clipping (1 inch above the bulb) with mechanical harvesters in larger production systems or by hand. Wash beets in cold water and bag before storing at 32 °F to 35 °F with 98%-100% relative humidity. Bunched beets are usually marketed quickly (5-7 days of storage; leaves cause water loss), while bagged roots (without tops) can be stored for 3-4 months.

Carrot and Parsnip - Harvest any time after root sizing begins. In small operations, hand-dig or use a small potato harvester to lift the roots. Large mechanical harvesters undercut the root, grasp the leaves and lift roots out of the soil. Some machines remove or leave the foliage attached to the root. Wash roots and bag before storing at 34 °F to 36 °F with 98%-100% relative humidity. Bunched carrots are usually marketed quickly (5-7 days storage; leaves cause water loss), while bagged roots (without tops) can be stored for many months.

Radish, Rutabaga, and Turnip - Harvest radish when roots reach desired size. Bunch (with tops) or trim and sell bulbs only. Wash, sort, cool, and pack in plastic bags. Store at 32 °F to 34 °F with 95%-100% relative humidity for 2-3 weeks. Rutabaga and turnip can be machine- or hand-harvested. Most are topped, but bunches are common when direct-marketed. Wash roots before bagging. Roots may be waxed to reduce water loss. Store at 32 °F to 35 °F and 95%-100% relative humidity for 2-6 months.

Physiological Disorders

Bitterness can be an issue in carrots or radishes. Bitterness occurs by formation of natural compounds when exposed to stress. In carrot, these compounds form when plants are heat-stressed (preharvest) or if exposed to ethylene in storage. In radish, high temperatures during growth increase the “hotness/ bitterness” in the bulbs.

Black heart/spotting can be an issue in beet or rutabaga. Symptoms include strap-like leaves, or dark spots on the leaves, and hard black spots in the bulb. A localized boron deficiency causes the disorder, whichcan occur in high pH soils. It is managed by treating with 10-30 pounds of borax per acre.

Bolting is the term used to indicate a plant that has transitioned from leaf (vegetative) growth to flower (reproductive) formation. Flower stalks can occur at any time during growth. Cool-weather crops like beet, carrot, parsnip, rutabaga, and turnip often bolt when planted early or overwintered. Plants exposed to several weeks of cool temperatures (<50 °F) trigger the response. Long days and hot temperatures trigger bolting in radish.

Cracking is a problem in carrot, parsnip, and radish. Cracking occurs in older roots and is associated with poor irrigation practices. Keep soils moist to ensure steady growth, especially in sandy or drought-sensitive soils. When irrigation is erratic, roots take in more water and the root expands quickly and may crack. Large-rooted cultivars (or older roots) are more prone to split than small (younger) ones. Splitting or shattering can also occur at harvest, particularly if roots are very cold when dug.

Forking (fanging) can be a problem in carrot. Dense, compact soils, root obstructions (rocks, etc.), or other factors can deflect root growth. When the taproot is damaged, secondary roots grow and fill, giving it the forked look. Fertilizer placement, insect/disease damage, excess nitrogen, and using fresh manures also injure the root, resulting in branching.

Insect Mite and Pest Management

Carrot Rust Fly *(Psila rosae)*

DESCRIPTION

Adult: Adults are 5 mm long, with a slender, black abdomen and thorax, orange-colored head, and yellow legs. Wings are a dark and transparent color and 12 mm wide in full span. The abdominal tip for females is pointed, and rounded on males.
Egg: Eggs are white, 0.6-0.9 mm long, and 0.15 mm wide.

Nymph: Nymphs are yellow-brown and 5 mm in length.

LIFE HISTORY

Carrot rust flies overwinter as pupae in the soil near the host plant or sometimes as larvae within carrot roots. Adults emerge during May and June in favorable, cool, moist conditions. Females lay up to 40 eggs on the soil surface near the base of plants in clusters of one to three eggs. When hatched, the larvae feed on the roots for a few weeks, and eventually pupate in the soil for approximately 25 days. The carrot rust fly has one to three generations per year in Utah, with the second generation emerging in August. Not all generations cause damage because of the timing matchup of the host and larvae, the damaging stage.

DAMAGE

In Utah, carrot rust flies are sporadic but can cause significant damage to crops when present. The larva is the damaging stage, and feeds on umbelliferous species, mainly carrots, but also targets celery, celeriac, chervil, parsnips, and parsley. Newly hatched larvae enter through the root surface and mine the lower portion of the carrot roots (upper portion in parsnips), which causes scarring on older plants or kills younger plants. The tunnels created in carrots turn a red rusty color and may become colonized by fungi or bacteria. Aboveground symptoms include wilting and plant stunting.

MANAGEMENT

To identify the carrot rust fly population and determine when adults are active in a field, place at least two yellow sticky traps near the soil level.

Cultural:

- *Exercise timely harvest.* Harvest all carrots in blocks (rather than selectively) as soon as they are ready. This will prevent larvae from spreading from plant to plant within the soil.
- *Delay planting.* Planting carrots after mid-June will avoid the peak egg-laying period.
- *Avoid planting near other host plants and weeds.* Carrot rust flies attack both umbelliferous crop and weed species, such as wild carrot (*Daucus carota*) and water hemlock (*Conium maculatum*).
- *Rotate crops.* Rotating to non-susceptible hosts every year will break the carrot rust fly life cycle and prevent the population from building.
- *Remove crop residue.* Remove all carrots and related host crops from the ground at the end of the growing season to prevent overwintering populations.
- *Use floating row covers*. Where practical, row covers prevent flies from landing near host plants and laying eggs.

Chemical:

Granular insecticides are usually best when incorporated into the furrow at planting to prevent larval attack on the roots.

Biological:

Natural enemies of carrot rust flies include the parasitoids *Chorebus gracilis*, *Eutrias tritoma*, and *Aleochara sparsa* which target the early larval and pupa stages of the carrot rust fly.

Aphids

Green Peach Aphid *(Myzus persicae)*

Reference page 76 for green peach aphid description and life history.

Willow-Carrot Aphid *(Cavariella aegopodii)*

DESCRIPTION

Adult: Wingless aphids are pale green with dark legs, cornicles, and cauda (tail structure). Compared to other aphids, they are medium in size and have elongated oval-shaped bodies. Winged forms have a black head and pale green abdomen with darker areas on each side.

Egg: Eggs are metallic black.
Nymph: A rusty color in spring and green in summer, nymphs measure up to 12 mm in length.

LIFE HISTORY

The willow-carrot aphid requires two hosts to complete its life cycle. It overwinters as eggs near buds of willow trees (*Salix* spp.). Eggs hatch in early spring, and new aphids feed on willow foliage for a few weeks. In early summer, winged aphids migrate to umbelliferous crops and weeds such as carrot, celeriac, celery, and parsnip, and feed until early fall. They then migrate back to willow trees, reproduce as males and females, mate, and lay eggs.

DAMAGE

Willow-carrot aphids cause direct feeding damage on foliage, turning it yellow to red. As they feed, they excrete sticky honeydew that covers the plant.

Willow-carrot aphids vector multiple viruses, such as parsnip yellow fleck virus, Anthriscus yellow virus, or carrot motley dwarf virus (none have been reported in Utah).

Bean Aphid *(Aphis fabae)*

DESCRIPTION

Adult: Both winged and wingless forms are dark green-black. They have a dull matte appearance (not to be confused with the cowpea aphid, which are shiny).
Egg: Eggs are initially green, then turn to a metallic black.
Nymph: Nymphs are dark green, with four pairs of white stripes on the surface of the abdomen.

LIFE HISTORY

Bean aphids overwinter as eggs inside the cracks of bark and bud axils of *Euonymus* and *Viburnum* spp. Eggs hatch in early spring and produce one to two generations of wingless parthenogenetic females, followed by a generation of winged females which migrate to umbelliferous crops, such as carrot, celeriac, celery, parsnip or related weed species such as lambsquarter and curly dock. In early fall, bean aphids return to host shrubs to lay eggs for overwintering.

DAMAGE

Many roots crops are affected by bean aphids. Feeding symptoms include curling and yellowing leaves. The bean aphid vectors multiple viruses to host plants, notably beet yellows virus.

Honeysuckle Aphid *(Hyadaphis foeniculi)*

DESCRIPTION

Adult: Wingless aphids are about 1 mm long, with a dark yellow head and gray-green antennae, legs, and cornicles. The body appears dusted with a white wax. Winged forms have a green abdomen with a darker green patch around the base of each cornicle.
Egg: Initially green, eggs eventually turn black. They are oval-shaped and less than half a millimeter.

LIFE HISTORY

Honeysuckle aphids overwinter as eggs on woody hosts in the Caprifoliaceae family (honeysuckle). During the summer months, honeysuckle aphids are found on both woody and herbaceous hosts, including carrot. Sexual forms of the aphids are found in all seasons.

DAMAGE

Honeysuckle aphid populations may occasionally build up on umelliferous crops; however, injury resulting in crop loss is rare. Most damage comes from vectored viruses, such as celery crinkle leaf mosaic virus.

APHID MANAGEMENT

Cultural:

- *Inspect transplants before field-planting.* Prevent introducing new populations to a site.
- *Remove weeds.* Reduce the amount of umbelliferous weeds in and near the growing site, as they serve as alternative hosts.
- *Avoid excessive fertilization.* Aphid densities tend to be higher on vigorously growing plants that have received excess nitrogen.
- *Foliage pruning.* If the population is identified on a few leaves, they can be pruned out.
- *Treat nearby woody hosts with horticultural oil at bud burst.*

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Natural Enemies and Biological Control*
- *Aphid Pests on Vegetables*
- *High Tunnel Pest Management - Aphids*

Flea Beetles

Pale-Striped Flea Beetle *(Systena blanda)*

DESCRIPTION

Adult: Adults are 4 mm long, with broad white stripes along each brown wing. The hind legs are enlarged for jumping.

Egg: Eggs are white-yellow and elliptical shaped.

Larva: Larvae are small, white, and wormlike with a brown head, found exclusively in the soil.

Pupa: Pupae are small and cream-colored.

LIFE HISTORY

Pale-striped flea beetles overwinter as adults in areas protected by soil clods, weeds, or plant debris. They emerge mid to late spring, and mated females lay their eggs in the soil near the base of host plants. Once hatched, larvae move into the soil to feed on roots for about 18 days, followed by pupation in the soil. Up to three generations can occur each season. First generation adults occur during May through July, and the second generation is active from mid-July until September.

DAMAGE

Adults are more destructive than larvae. They feed on the underside of foliage, leaving irregular-sized holes. Damage can be severe if populations are high, especially on young transplants. Larval feeding on the carrot roots contribute to reduced yield. Other hosts include cole crops, edible greens, tomatoes, eggplants, peppers, beets, potatoes, melons, and various weed species.

MANAGEMENT

Cultural:

- *Select sites carefully.* Adult pale-striped flea beetles migrate (or jump) into crops from nearby vegetation or weedy areas. Therefore, planting crops away from those refuge areas can reduce infestation.
- *Use trap crops.* Plant a trap crop that is highly favored by flea beetles, such as cole crops or edible greens two weeks earlier than the main crop. Flea beetle adults are attracted to the earliest and then can be controlled.
- *Use floating row covers.* Apply row covers in spring to prevent adults from laying their eggs.

Biological:

Natural enemies of flea beetles include the parasitic wasp *Microtonus vittatae*, entomopathogenic nematodes, white muscadine (fungal pathogen), and generalist predators, such as lacewing larvae, adult big-eyed bugs, and damsel bugs.

USU EXTENSION FACT SHEET REFERENCES

- *Flea Beetles on Vegetables*

Armyworms

Beet Armyworm *(Spodoptera exigua)*

DESCRIPTION

Adult: Moths are gray-brown, with a 25 mm wingspan.
Egg: Eggs are ribbed, circular-pointed, and covered by fluff pulled from adult wings.
Larva: 32 mm long larvae have light stripes along their sides, without hairs or spines.
Pupa: Pupae are 13 mm long and light brown.

LIFE HISTORY

In southern Utah, beet armyworms overwinter as pupae, emerging in spring. Females lay several hundred eggs, placed singly on the underside of leaves near blossoms and branch tips of woody hosts. After 2-5 days, the caterpillars hatch and feed for 3 weeks. When mature, the caterpillar pupates near the soil surface. During summer, pupation takes 5-8 days until the adult emergence. Several generations can occur each season. In northern Utah, beet armyworm pupae do not survive the cold winters, so moths are re-introduced each summer from southern locations.

DAMAGE

Feeding caused by beet armyworm is a concern for a variety of vegetable crops, notably beets. They feed on foliage, shred leaves, make irregular holes, and in extreme cases, defoliation. The time of greatest concern is from mid-July through harvest.

MANAGEMENT

Cultural:

- *Till the soil.* In southern Utah, tilling the soil at the end of the season will disrupt the beet armyworm's overwintering pupation stage, which occurs only a few centimeters below the surface.

Root Crops

- *Use floating row covers.* Apply row covers on seedlings or transplants in spring for 5-8 weeks to exclude adults from laying eggs on the crop.

Biological:

The ichneumonid wasp (*Hyposoter exiguae*) is a parasitoid that lays eggs inside young beet armyworm larvae.

USU EXTENSION FACT SHEET REFERENCES

- High Tunnel Pest Management - Caterpillars

Cutworms

Black Cutworm *(Agrotis ipsilon)*

DESCRIPTION

Adult: Moths have a wingspan of 38 mm. The forewings are dark brown and the hind wings are white and gray.
Egg: Spherical, 0.5 mm wide, eggs are initially white, then turn brown with maturity.
Larva: The head is brown with dark spots, and the body color ranges from a light gray to black, reaching 50 mm long at maturity.
Pupa: Pupae are dark brown and about 1 inch long.

LIFE HISTORY

Black cutworms overwinter as pupae 1 to 5 inches below the soil surface. Adult females emerge in spring and may deposit up to 1,900 eggs during their life span. Eggs are laid on foliage of various vegetables, including carrots and beets. After 3-6 days, larvae hatch and develop through six to seven instars over a period of 20-40 days. Later-instar larvae hide in the soil during the day. In Utah, two to four generations may occur each season.

DAMAGE

Host crops include a wide variety of vegetables, including carrots and beets. Larvae will feed at soil level, often severing the stem.

Variegated Cutworm *(Peridroma saucia)*

DESCRIPTION

Adult: Moths have a wingspan of 38 mm. Front wings are a dark mix of gray, brown, and red. Hind wings are white with brown veins and shading. The head, thorax, and abdomen are brown.
Egg: Spherical, 0.5 mm wid, eggs are white and then turn brown.
Larva: The larva grows up to 43 mm and ranges from brown-gray to gray-black. The main characteristic is a yellow-white spot on each of the four abdominable segments.
Pupa: Pupae are mahogany brown color, less than 25 mm long.

LIFE HISTORY

Cutworms overwinter as pupae in the soil, with moths emerging in the spring. Females lay clusters of up to 100 eggs on leaves and stems, and up to 1,400 eggs in their lifespan. Depending on the weather, eggs hatch occurs within 10 days. There are normally six instars throughout the larval development. When the larva reaches maturity, it pupates near the soil surface for 13-33 days. In Utah, two to four generations occur each year.

DAMAGE

Larvae kill young seedlings by severing the plant at the soil surface and by defoliation. Larger larvae hide underneath leaves during the day and feed in the evening. Variegated cutworms are also known to invade greenhouse and high tunnel production.

GENERAL CUTWORM MANAGEMENT

Cultural:

- *Monitor crops.* Scout crops in multiple locations by examining upper leaves of the host plants and looking for eggs, larvae, and feeding damage. Moths can be monitored with pheromone traps.
- *Till the soil.* Tilling the soil at the end of the season will disrupt the cutworm's overwintering pupation stage, which occurs only a few centimeters below the surface.
- *Manage weeds.* Reduce the amount of weeds near the growing site as they serve as an alternate host.
- *Use floating row covers, where practical.* This prevents adult moths from laying eggs near host plants.
- *Use light traps.* Black light traps are effective to monitor or kill adult moths in the summer and fall; however, later generations are less of a threat to crops. This method can also be used to monitor adult populations.

- *Protect seedlings.* Consider using a protective barrier such a waxed paper container, can, or aluminum foil around the plant stem or base of seedlings.

Biological:

Variegated cutworms are vulnerable to attack by various entomopathogenic nematodes, such as those in the Steinernematidae and Heterorhabditidae families. Nematodes are more effective in higher-moisture soils.

Chemical:

Generally, persistent insecticides are effective toward both black and variegated cutworms. Early application is especially beneficial to younger plants to prevent stem-cutting damage and early defoliation.

USU EXTENSION FACT SHEET REFERENCES

- *Cutworms in Vegetable Production*
- *High Tunnel Pest Management - Caterpillars*

Leafminers

Beet Leafminer *(Pegomya betae)*

DESCRIPTION

Adult: Flies are hairy, and measure 7 mm long, are gray-brown, and have long silvery-white hairs, a dark stripe on the abdomen, and transparent wings.
Egg: Eggs are elongated, oval-shaped, and bright white. They are less than 1 mm wide and have hexagonal patterning along the surface.
Larva: Larvae are cylindrical and tapered to a point at the end. Coloration changes from transparent to yellow through three instars.
Pupa: Puape start off brown and then turn black.

LIFE HISTORY

Beet leafminers overwinter as pupae. Adult flies emerge in April and May. Each female lays up to 70 egg clusters on the undersides of leaves. Eggs hatch within 3-6 days, and larvae immediately begin mining within the leaves. Typically, only two to three larvae can survive on a single leaf. The larva stage lasts 7-12 days. Once larvae reach maturity, they drop to the soil to pupate for 10-20 days. In Utah, two to four generations can occur per year, and each generation lasts about 30-40 days.

DAMAGE

Beet leafminer can attack beets, spinach, Swiss chard, and other leafy greens. Damage occurs in both the upper and lower epidermis of the leaves, where the mining causes blotching and brittle leaves. For root crops, this feeding damage will decrease root development.

MANAGEMENT

Reference page 112 for leafminer management.

USU EXTENSION FACT SHEET REFERENCES

- *Leafminers of Vegetable Crops*

Refer to Tables 10.4 and 10.6 for more information on insecticides for use in root crops commercial and small-scale production.

Disease Management

Cottony Soft Rot (White Mold)
(Sclerotinia sclerotiorum)

CAUSAL AGENT

Cottony soft rot is a white mold caused by the fungus *Sclerotinia sclerotiorum*. The wide host range includes succulent plants, ornamentals, and several vegetable crops. For root crops, carrots are most susceptible.

SYMPTOMS

Sclerotinia causes infection during any growth stage of the carrot. Extensive root decay will lead to wilt and collapse the aboveground portion of the plant. The "cottony" white mycelium appears on infected tissue, usually at the base of the plant. Inside this mycelium are black, irregular-shaped structures called sclerotia (hard balls of mycelium), which range in size from 0.1-0.4 inches wide.

DISEASE CYCLE

During late summer/early fall, *S. sclerotiorum* produces sclerotia that germinates and produces hyphae directly on the surface or inside of infected plant tissue. The following spring, these structures sometimes produce fruiting bodies called apothecia, which have thin stalks with small, cup-like structures. Eventually, the ascospores are released and carried by the wind to susceptible hosts where they cause new infections. The optimal conditions for infection are cool temperatures (60 °F to 70 °F).

MANAGEMENT

- *Till the soil.* Turning over the soil can bury the sclerotia, which reduces the chance of disease infection the following season.
- *Rotate crops.* Rotating crops from carrots to non-susceptible hosts such as grains and corn will prevent the disease from building up.
- *Supply adequate ventilation.* Spacing crops apart can reduce humidity and prevent spread.
- *Flood the site.* Emerging the site underwater for several weeks can "drown" the sclerotia.

Powdery Mildew
(Erysiphe heraclei and *E. polygoni)*

CAUSAL AGENTS

Powdery mildew is a disease that affects many types of ornamental plants, fruits, and vegetables. Most powdery mildew fungal species are host-specific. *Erysiphe heraclei* infects carrots, parsley, and parsnips, while *Erysiphe polygoni* will infect beets.

SYMPTOMS

Both *E. heraclei* and *E. polygoni* form a thin layer of mycelium and spores on their host plant's foliage, which appear as a white "powder." Over time, the infected foliage turns yellow and may die. Infected plants will have reduced yields.

DISEASE CYCLE

Erysiphe heraclei inoculum overwinters in fruiting bodies (chasmothecium) in plant debris. In spring, when temperatures warm to above 70 °F and there is high humidity, the chasmothecium release airborne ascospores, which germinate on host plant tissue. Both *E. heraclei* and *E. polygoni* grow and spread with minimal humidity and moisture.

MANAGEMENT

- *Plant resistant varieties.* Resistant variety examples include 'Bolero F1', 'Black Knight', 'Cumbre', 'Honeysnax', 'Indigo Winter', and 'Notable'.
- *Supplu adequate ventilation.* Spacing crops apart reduces humidity and prevents foliage from touching.

USU EXTENSION FACT SHEET REFERENCES

- *Powdery Mildews of Vegetables*

Damping-Off

CAUSAL AGENTS

Damping-off is a common problem when greenhouse or field seedlings are grown in wet or infected soils. Damping-off is caused by various soilborne pathogens, such as *Pythium*, *Phytophthora*, *Rhizoctonia* and *Fusarium* species.

SYMPTOMS

Infected plants typically fail to emerge from seed, or seedlings collapse and die soon after germination.

Stems will turn black and shrivel at the soil line. *Pythium* spp. can also cause root dieback in carrots later in the season.

DISEASE CYCLE

Damping-off typically occurs during times of cool and wet weather. Soilborne pathogens thrive in moist soils, ideally around 6.8 pH. *Pythium* overwinters in the soil as survival structures called oospores, which then become active as the soil temperature warms. Under saturated conditions, *Pythium* forms swimming zoospores, which cause infection.

MANAGEMENT

- *Maintain uniform soil moisture at seed depth.* Prevent over or under watering. *Pythium* requires free water to spread, and allowing soil to dry between waterings will help prevent infection. Avoid planting seeds too deep.

USU EXTENSION FACT SHEET REFERENCES

- Damping-Off

Nematodes

Root-Knot Nematodes *(Meloidogyne* spp.*)*
Stubby Root Nematode *(Trichodorus obtusus)*
Needle Nematode *(Longidorus elongatus)*
Lesion Nematode *(Pratylenchus* spp.*)*

CAUSAL AGENTS

Nematodes are microscopic plant-parasitic roundworms that live in the soil and plant tissues. Root-knot nematodes occur occasionally throughout Utah. They are a cause for concern for root vegetables and ornamental plantings. They can be a threat throughout the growing season but control measures are most effective before or shortly after planting.

SYMPTOMS

Root-knot nematode's parasitic activity in the carrot causes the root to become forked, distorted, or stunted. This eventually leads to stand and yield reductions. Nematodes feed by releasing chemicals that cause plant cell nuclei to divide without cell division, developing massive feeding cells. These appear as gall formations on the roots. This is a key indicator of root-knot nematode presence. Aboveground, foliage will become chlorotic and stunted. Needle and stubby root nematodes cause similar symptoms in the field.

DISEASE CYCLE

Root-knot nematodes infect plants through the roots. Wormlike, second-stage juveniles (J2) enter the root tip. They migrate in the root until they find a suitable location to establish a feeding site, where they stay for the rest of their lives. They inject hormones that increase nucleus and cell division. The increased cell division causes gall formation. The adult nematode becomes lemon-shaped and eventually breaks through the root/tuber. It produces egg masses that are released into the soil. Stubby root, lesion, and needle nematodes are free-living nematodes. They migrate in the soil and feed on roots, creating wounds that allow other pathogens to enter.

MANAGEMENT

- *Crop rotation does not help.* It is ineffective due to nematodes' wide host range.
- *Use cover crops and biofumigation.* The mustard 'Caliente rojo' can be grown as a cover crop. Incorporate 20 minutes from cutting as a biofumigant.
- *Till the soil*. Till fallow areas once every 3-4 weeks during the hot, dry summer months.
- *Remove all weeds*. Weeds can serve as an alternate host.
- *Use tolerant or resistant cultivars when available*.
- *Fumigate soil in commercial fields*. Products may be difficult to obtain in Utah along with fumigation equipment.
- *Plant early*. Some species of root-knot nematodes found in southern Utah (*Meloidogyne incognita* and *Meloidogyne arenaria*) are unable to infect roots at soil temperatures below 50 °F to 64 °F. Consider planting root crops when the temperature is below this level.

Cavity Spot *(Pythium sulcatum* and *P. violae)*

CAUSAL AGENTS

Cavity spot is caused by the fungi, *Pythium sulcatum* and *P. violae*. These pathogens favor cool temperatures and grow best around 58 °F. Though prominently

Root Crops

found on carrots, *Pythium* spp. can cause lesions on alfalfa roots, celery, beets, and other host plants.

SYMPTOMS

Cavity spot causes oval-shaped, depressed lesions along mature carrot taproots. The lesions are large and measure around an inch in diameter. Infections occur in the upper third of the root.

DISEASE CYCLE

Both *P. violae* and *P. sulcatum* occur during cool and wet weather. They thrive in moist soils, ideally around a 6.8 pH. *Pythium* overwinters as oospores in soil, then becomes active as the soil temperature warms, forming zoospores in free water to cause new infections.

MANAGEMENT

- *Rotate crops.* Rotate away from carrots with a non-susceptible crop every 3 years.
- *Avoid overhead irrigation.* Opt for drip irrigation to maintain even soil moisture.
- *Harvest carrots soon after maturity.* Carrots become more susceptible to cavity spot as they mature.

Scab *(Streptomyces scabies)*

CAUSAL AGENTS

Scab is caused by *Streptomyces scabies*, a bacterial pathogen present in soils where potato is the predominant crop. Other root crops, such as beets, turnips, parsnips, radishes, and carrots may be affected if grown in these soils.

SYMPTOMS

S. scabies can cause a variety of symptoms on root crops, including both pitted and raised lesions on the root portion of the plant. There are no symptoms displayed aboveground.

DISEASE CYCLE

S. scabies causes infections when the air temperature reaches 80 ^{0}F. It is unusual bacterium in that is has filamentous growth, similar to fungi. The filaments can break off, forming survival structures in plant debris in the soil. *S. scabies* infects the plants by growing in between and through the plant cells of the host.

MANAGEMENT

- *Use tolerant or resistant cultivars when available.*
- *Use certified, disease-free seed.*
- *Rotate crops.* Implement crop rotation between potatoes, carrots, radishes, and turnips with non-susceptible crops such as corn, alfalfa, and small grains.

Beet Curly Top Virus

Reference page 154 for the causal agents, symptoms, and management of beet curly top virus (BCTV).

Carrot-Aster Yellows

CAUSAL AGENTS

Carrot-aster yellows is a disease caused by a bacterium-like organism called a phytoplasma. It can affect hundreds of species of broadleaf herbaceous plants, but primarily those in the aster family, as well as carrots. Aster-yellows is vectored by the aster leafhopper (*Macrosteles quadrilineatus*).

SYMPTOMS

New leaves may turn yellow, reduce in size, and appear deformed. Older leaves will turn a purple/red color. The dormant buds on the crown may also develop a "witches' broom" appearance.

DISEASE CYCLE

The aster leafhoppers are active during summer, and when they feed on the phloem of infected host plants, they pick up the phytoplasma and spread it to new hosts with their piercing-sucking mouthpart (stylet).

MANAGEMENT

- *Remove infected plants.* Remove infected plants as soon as they are detected.
- *Control aster leafhoppers.* Management should focus on aster leafhopper control.

Refer to Tables 10.5 and 10.7 for more information on fungicides and bactericides for use in root crops commercial and small-scale production.

Root Crop Pesticide Tables for Commercial and Small-Scale Use

Table 10.3. *Herbicides* *Registered for* **COMMERCIAL** *Use on* **Root Crops** *(Beets, Carrot, Radish, Parsnip, Turnip, and Rutabaga)*

		Application relative to crop				Application for weeds		Weed groups controlled			
Brand name (REI/PHI)	**Active Ingredient**	**Pre-seeding**	**After seeding before emergence**	**Postemergence between rows**	**Postemergence**	**Preemergence**	**Postemergence**	**Annual grass**	**Small-seeded broadleaves**	**Broadleaves**	**Crops covered**
Aim (12hr/0d)	carfentrazone			X			X		X	X	B, C, P, R, T
Caparol (12hr/30d)	prometryn		X		X	X	X			X	C
Fusilade DX or 2E (12hr/45d)	fluazifop-P				X		X	X			C
Gramoxone (12hr/14-30d)	paraquat	X	X				X	X	X	X	C, R
Nortron SC (12hr/-)	ethofumesate	X	X		X	X	X	X	X		B
Poast (12hr/14-60d)	sethoxydim				X		X	X			B, C, P, R, T
Prowl (12hr/60d)	pendimethalin		X	X		X		X	X		C
Ro-Neet (12hr/ -)	cycloate	X				X		X			B
RoundUp and others (12hr/14d)	glyphosate	X		X			X	X	X	X	B, C, P, R, T
Select Max (12hr/15-30d)	clethodim				X		X	X			B, C, P, R, T
Sencor (12hr/60d)	metribuzin				X		X		X	X	C
Spin-Aid (12hr/60d)	phenmedipham				X		X		X	X	B
Stinger (12hr/30d)	clopyralid				X		X		X	X	B, T
Treflan and others (12hr/-)	trifluralin					X		X	X		C, R
Upbeet (12hr/30d)	trisulfuron				X		X			X	B
Organic Products											
Corn gluten meal	corn endosperm	X	X			X			X	X	B, C, P, R, T
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	B, C, P, R, T
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	B, C, P, R, T
Worry Free	citrus oil	X	X	X			X	X	X	X	B, C, P, R, T

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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).

B= Beets C= Carrots P= Parsnips R = Radish T = Turnip

Table 10.4. *Insecticides* *Registered for* ***COMMERCIAL*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
carbaryl	Carbaryl 4L, Drexel Carbaryl 4L, Sevin 5 Bait, Carbaryl Cutworm Bait, Drexel Carbaryl 5% Bait, Sevin 4F, Sevin XLR Plus	1A	10-14		X		X	
methomyl	Corrida 29 SL, Corrida 90 WSP, Lannate LV, Lannate SP, Lanveer LV, Nudrin LV, Nudrin SP	1A	10-14		X		X	
malathion	Drexel Malathion 5EC, Fyfanon 57% EC, Fyfanon Malathion Insecticide, Malathion 5, Malathion 57 EC, Malathion 57%, Malathion 8 Aquamul	1B	5-7	X				
alpha-cypermethrin	Fastac CS, Fastac EC	3A	10-14	X	X		X	
bifenthrin	Batallion 10 WSP, Batallion 2 EC, Batallion LFC, Bi-Dash 2E, Bifender FC, Bifenthrin 2EC, Bifenture EC, Bifenture EC, Brigade 2EC, Brigade WSB, Discipline 2EC, Fanfare 2EC, Fanfare EC, Fanfare ES, GCS Bifenthrin 2EC, GCS Bifenthrin LFC, Lancer FC, Omni Brand Bifenthrin 2EC, Reveal, Sniper, Sniper Helios, Sniper LFR, Tundra EC	3A	2-3 wks	X			X	
	Steed, Suro LFC			X	X		X	
deltamethrin	Delta Gold 100	3A	14	X	X		X	
pyrethrins[O]	PyGanic EC 1.4 II, PyGanic EC 5.0 II, Pyrenone, Tersus	3A	5-7	X	X	X	X	X
	EverGreen EC 60-6			X	X		X	X
	Pyrethrum TR Pyrus TR			X			X	
zeta-cypermethrin	Cortes Maxx, Hero, Hero EW, Mustang, Mustang Maxx	3A	10-14	X	X		X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Root Crops

Table 10.4., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
imidacloprid	Acronyx 4 F, Admire Pro, Advise Four, Alias 2F, Alias 4F, Dominion Fruit Tree & Vegetable, Imidashot DF, Macho 2.0 FL, Macho 4.0, Malice 2F, Midash 2SC, Montana 2F, Montana 4F, Nuprid 2SC, Nuprid 4.6F Pro, Nuprid 4F Max, Omni Imidacloprid 2F, Omni Imidacloprid 4F, Prey 1.6, Provoke, Sherpa, Viloprid FC 1.7, Widow, Willowood Imidacloprid 4SC, Wrangler	4A	14	X			X	
thiamethoxam	Actara, Platinum 75 SG	4A	14	X			X	
sulfoxaflor	Transform WG	4C	10-14	X				
flupyradifurone	Altus, Sivanto 200 SL, Sivanto HL, Sivanto Prime.	4D	10-14	X				
spinetoram	Radiant SC	5	10-14		X	X	X	
spinosad°	Entrust Naturalyte, Entrust SC Naturalyte, Success, Blackhawk, SpinTor 2SC, Conserve SC	5	7-10		X	X	X	
	Seduce							X
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM Ultra	8D	10-14	X	X			
Bacillus thuringiensis°	Agree WG, Biobit HP, Bioprotec PLUS, BT NOW, Crymax, Deliver, DiPel DF, Javelin WG, Leprotec, XenTari DF	11A	5-7		X			
methoxyfenozide	Acora Insecticide, Engame, GCS Methoxy 2F, Inspirato 2 F, Intrepid 2F, Invertid 2F, Troubadour 2F, Vexer, Zylo	18	10-14		X			
indoxacarb	Avaunt eVo, Avaunt, Comber, DuPont	22A	14		X			
chlorantraniliprole	Coragen, Shenzi 400SC, Vantacor	28	7		X			
	Elevest			X	X		X	

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° = Organic

Table 10.4., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
cyantraniliprole	Exirel	28	10-14	X	X		X	
flonicamid	Beleaf 50 SG	29	14	X				
GS-omega/kappa-Hxtx-Hv1a[O]	Spear-LEP	32	5-7		X		X	
	Spear-T			X				
azadirachtin[O]	Atrevia 1.2% SL	UN	7-10	X		X	X	
	Atrevia 3.0% SL, Aza-Direct, AzaGuard, AzaSol, Azatin O			X	X	X	X	
heat-killed *Burkholderia* spp.[O]	Venerate CG, Venerate XC	UN	7-10	X	X			
iron phosphate	Bug-N-Sluggo	UN	2-4 wks					X
potassium salts of fatty acids[O]	Des-X, Kopa Insecticidal Soap	UN	5-7	X				
	M-Pede			X		X		
Chromobacterium subtsugae strain PRAA4-1[O]	Grandevo, Grandevo CG, Grandevo WDG	UN	5-7	X	X			
canola oil[O]	Pycana	UN	3	X				
cinnamaldehyde[O]	Seican	UN	3	X				
cinnamon oil[O]	Cinnerate	UN	3	X				
neem oil[O]	EcoWorks EC, Rango	UN	3	X				
	Trilogy			X	X	X	X	
Beauveria bassiana strain ANT-03[O]	BioCeres WP	UN	5-7	X				
Beauveria bassiana strain GHA[O]	BotaniGard 22WP, BotaniGard ES, BotaniGard Optima ES, Botegha ES, Botegha Optima ES, Mycotrol ESO, Mycotrol Optima ESO, Mycotrol WPO	UN	5-7	X	X		X	
Isaria fumosorosea Apopka strain 97[O]	PFR-97 20% WDG	UN	5-7	X		X	X	
kaolin[O]	Surround WP	UN	5-7				X	
mineral oil[O]	BioCover MLT, BioCover SS, BioCover UL, Glacial Spray Fluid, Omni Supreme Spray, Omni Supreme Spray, PureSpray Green, Ultra-Pure Oil	UN	3	X				

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[O] = Organic

Root Crops

Table 10.5. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Scab	Cottony soft rot	Powdery mildew
difenoconazole	Quadris Top	3				X
mefentrifluconazole	Cevya	3				X
propiconazole	Atticus Aquila XL, Avaris 2XS, Bumper, Bumper 41.8 EC, Bumper ES, Colcha XL, Cover XL, Fitness, Marazo, MiCrop, Omni Propiconazole 41.8% EC, PPZ 41.8 Select, Propicon EC, Propiconazole 3.6 EC, PropiMax EC, Shar-Shield PPZ, Slant, Slant EC, Tide Propiconazole 41.8EC, Tigris Prop 41.8%, Tilt, Topaz, Vigil, Willowood Propicon 3.6EC, Propi-Star EC	3	14			X
pyraclostrobin	Cabrio EG, Empire, Innliven Elite, Merivon Xemium, Pristine	3	7-10			X
Trichoderma asperellum	Tenet WP	4			X	
boscalid	Bonafide, Endura	7	7-14			X
fluxapyroxad	Tesaris	7				X
penthiopyrad	Fontelis	7				X
cyprodinil	Inspire Super, Xuvance	9	7-10			X
azoxystrobin	Aframe, Aframe Plus, Acadia ESQ, Acadia LFC, Atticus Acadia 2 SC, Avaris 2XS, A-Zox 25SC, AzoxyStar, Azoxyzone, Azterknot, AZteroid FC 3.3, Cadera Drexel Azoxystrobin SC, GCS Azoxy 2SC, GCS Azoxyprop, Mazolin, Propaz, Quadris, Quilt Xcel, Satori, Tetraban, Tigris Azoxy 2 SC, Tigris AzoxyProp, Trevo, Trevo DCZ, Trevo P, Tycoon, Xiphosin	11	10-14			X
trifloxystrobin	Flint, Flint Extra, Gem 500 SC,	11				X
fludioxonil	Alterity 62.5 WG, Switch 62.5WG	12	7-10			X
polyoxin D zinc salt	OSO 5%SC	19	5-7			X
canola oil[O]	Pycana	BM1	3			X
neem oil[O]	EcoWorks EC, Rango, Trilogy	BM1	3			X

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[O] = Organic

Table 10.5., continued. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Scab	Cottony soft rot	Powdery mildew
extract of *Reynoutria sachalinensis*°	Regalia, Regalia CG	BM1	7-10			X
extract of *Swinglea glutinosa*	EcoSwing	BM1	5-7			X
soybean oil°	Bionatrol-M	BM1	3			X
tea tree oil°	Timorex Act	BM1	3			X
thyme oil°	Guarda	BM1	3			X
Bacillus amyloliquefaciens strain D747°	Double Nickel 55, Double Nickel LC, Triathlon BA	BM2	7			X
Bacillus amyloliquefaciens strain F727°	Stargus	BM2	7	X	X	X
Bacillus amyloliquefaciens subspecies plantarum strain FZB42°	Bexfond	BM2	7	X	X	
Bacillus subtilis strain AFS032321°	Theia	BM2	5-7			X
Bacillus subtilis strain IAB/BS03°	Sonata	BM2	5-7			X
	Aviv, Milagrum Plus	BM2	5-7	X		X
Bacillus subtilis strain QST 713°	Minuet	BM2	5-7	X		
	Serenade ASO			X		X
	Serenade MAX					X
Clonostachys rosea strain J1446°	LALSTOP G46 WG	BM2	5-7		X	X
Streptomyces lydicus WYEC 108°	Actinovate	BM2	5-7			X
Ulocladium oudemansii strain U3°	BotryStop	BM2	7		X	
sulfur	Acoidal, Crusade DF, Drexel Sulfur 80 WDG, Sulfomex THAT, Thiolux, Cosavet DF Edge, Microthiol Disperss, Sulfur Dry Flowable, Yellow Jacket Wettable Sulfur II	M2	7-10			X
mono- and dipotassium salts of phosphorus acid	Sparra, Fosphite, OxiDate 2.0, OxiPhos, Rampart	P7				X
	K-Phite 7LP				X	X
chitosan	WarHammer	UN	2-8 wks		X	X
hydrogen peroxide	Jet-Ag	UN	7	X		X
	OxiDate 5.0					X

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° = Organic

Root Crops

Table 10.5., continued. *Fungicides and Bactericides* *Registered for* ***COMMERCIAL*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Scab	Cottony soft rot	Powdery mildew
potassium bicarbonate[O]	Carb-O-Nator, Kaligreen, MilStop SP	UN	5-7			X
potassium methyldithiocarbamate	K-Pam HL, Metam KLR 54%,	UN			X	
potassium salts of fatty acids[O]	Des-X, Kopa, M-Pede	UN	5-7			X
potassium silicate	Sil-Matrix LC	UN	7			X
sodium methyldithiocarbamate	Sectagon 42, Vapam HL	UN			X	
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM Ultra	UN	10-14			X

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[O] = Organic

Root Crops

Table 10.6. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
acephate	Bonide Systemic Insect Control	1B	7	X				
bifenthrin	Bonide Eight Flower & Vegetable Soil Insect Granules, Hi-Yield Vegetable & Ornamental Insect Control Granules	3A	2-3 wks		X			X
	GardenTech Sevin Insect Killer Dust			X	X	X	X	
	Ferti-lome Broad Spectrum Insecticide, Ferti-lome Broad Spectrum Insecticide RTS			X	X	X	X	X
cyfluthrin	BioAdvanced Tomato & Vegetable Insect Killer RTU, BioAdvanced Tomato & Vegetable Insect Killer RTS	3A	10-14	X	X	X	X	X
deltamethrin	Hi-Yield Multi-Use Dust, Ortho Insect Killer Flower & Vegetable Garden Dust	3A	14	X	X	X	X	
lambda-cyhalothrin	GardenTech Sevin RTU	3A	10-14	X	X	X	X	
	Bonide Eight Garden & Home RTU, Spectracide Trizicide Insect Killer for Lawns & Landscapes RTU	3A		X	X	X	X	X
permethrin	Bonide Eigth Vegetable, Fruit, & Flower Concentrate, Bonide Eight Yard & Garden RTS, Bonide Insect Control Garden Dust, Hi-Yield Garden & Farm Insect Control, Hi-Yield Garden, Pet, & Livestock Dust	3A	14	X	X	X	X	X
pyrethrins[o]	Monterey Bug Buster-O, Natria Snail and Slug Killer Bait Granules	3A	5-7	X	X	X	X	X
zeta-cypermethrin	GardenTech Sevin Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X	X	
bifenthrin + zeta-cypermethrin	GardenTech Insect Killer Lawn Granules	3A	2-3 wks	X	X	X	X	X
pyrethrins[o] + canola oil[o]	Epsoma Organic Insect Control	3A/ UN	5-7	X	X	X	X	X
pyrethrins[o] + neem oil[o]	Ferti-lome Triple Action, Ferti-lome Triple Action Plus RTU	3A/ UN	5-7	X	X	X	X	X
pyrethrins[o] + piperonyl butoxide	Bonide Pyrthein Garden Spray Concentrate	3A/ UN		X	X	X	X	X

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[o] = Organic

Root Crops

Table 10.6., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
pyrethrins[o] + potassium salts of fatty acids[o]	Safer Brand Insecticidsal Soap + Pyrehrin Concentrate	3A/ UN	5-7	X				
malathion	Bonide Malathion Concentrate, Hi-Yield 55% Malathion Spray, Ortho MAX Malathion Insect Spray Concentrate, Spectracide Malathion Insect Spray Concentrate	3B	5-7	X	X	X	X	
imiclacloprid	Bonide Systemic Insect Spray, BioAdvanced Fruit, Citrus, & Vegetable Insect Control Concentrate	4A	N/A	X				
	Monterey Fruit Tree & Vegetable Systemic Soil Drench			X			X	
spinosad[o]	Bonide Colorado Potato Beetle Beater, Monterey Garden Insect Spray, Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS	5	7-10		X	X		X
	Bonide Captain Jack's Deadbug Brew Concentrate				X	X	X	X
	Bonide Captain Jack's Deadbug Brew Dust				X		X	X
Bacillus thuringiensis[o]	Bonide Captain Jack's BT, Bonide Thuricide (BT) Concentrate, Monterey B.T., Monterey B.T. RTU	11	5-7		X	X		
Bacillus thuringiensis var. Kurstaki[o]	Natural Guard Caterpillar Killer Spray, Natural Guard Caterpillar Killar Spray with BT RTU	11A	5-7		X			
	Safer Brand Caterpillar II Concentrate				X	X		
	Ferti-lome Dipel Dust Biological Insecticide				X			
sulfur[o]	GardenTech Sevin Sulfur Dust	UN	7-10	X				
sulfur[o] + pyrethrins[o]	BioAdvanced Fruit & Vegetable 3-in-1 Solution Concentrate, BioAdvanced Fruit & Vegetable 3-in-1 Solution RTU, Natria Insect, Disease, and Mite Control RTU, Natria Insect Disease, and Mite Control RTS	UN/ 3A	10-14	X	X	X	X	X

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[o] = Organic

Table 10.6., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
canola oil[o]	Natural Guard Horticultural Oil Concentrate, Natural Guard Horticultural Oil Concentrate RTS	UN	3	X				
neem oil[o]	BioAdvanced Organics Neem Oil RTU, Epsoma Organic Neem Oil 3n1, Monterey 70% Neem Oil, Natural Guard Neem Concentrate, Natural Guard Neem RTU, Natria Neem Concentrate, Natria Neem Oil RTU	UN	3	X				
	Monterey Neem Oil RTU	UN		X	X	X	X	
cotton seed oil[o] + clove oil[o] + garlic oil[o]	Bonide Mite X RTU	UN	3	X				
cotton seed oil[o] + clove oil[o] + rosemary oil[o]	Monterey All Natural Snail & Slug Spray RTU	UN	3	X				
iron phosphate	Bonide Captain Jack's Slug Magic Granules	UN	2-4 wks					X
potassium salts of fatty acids[o]	BioAdvanced Organics Insecticidal Soap RTU, Epsoma Organic Insect Soap, Natria Insecticidal Soap RTU, Natural Guard Insecticidal Soap	UN	3	X				
	Bonide Insecticidal Soap	UN		X				X
potassium salts of fatty acids[o] + neem oil[o]	Safer Brand RTU End ALL Insect Killer	UN	5-7	X				X
potassium salts of fatty acids[o] + seaweed extract[o]	Safer Brand Insect Killing Soap RTU Spray	UN	5-7	X				X
iron phosphate + spinosad[o]	Bonide Captain Jack's Bug & Slug Killer, Monterey Sluggo Plus, Natural Guard Bug, Slug, & Snail Bait	UN/5	2-4 wks		X			X
potassium salts of fatty acids[o] + spinosad[o]	Bonide Insecticidal Super Soap RTU, BioAdvanced Organic Tomato, Vegetable, & Fruit RTU, Monterey Garden Insect Spray RTU, Natural Guard Spinosad Soap Concentrate, Natural Guard Spinosad Soap RTU, Natural Guard Spinosad Soap RTS	UN/5	5-7	X	X	X	X	X

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[o] = Organic

Table 10.6., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworm/ cutworm	Leafminer	Flea beetle	Earwig
potassium salts of fatty acids[o] + sulfur[o]	Safer Brand Insect Killing Soap Concentrate, Safer Brand Tomato & Vegetable 3-in-1 Garden Spray, Safer Brand 3-in-1 Concentrate, Safer Brand 3-in-1 RTU Garden Spray	UN	7-10	X				
mineral oil[o]	Safer Brand Horticultural & Dormant Spray Oil Concentrate	UN	3	X				
silicon dioxide	Bonide Diatomaceous Earth	UN	7-14	X	X	X	X	X
	Natural Guard Diatomaceous Earth Crawling Insect Control	UN						X

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[o] = Organic

Table 10.7. *Fungicides and Bactericides* *Registered for* ***SMALL-SCALE*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Powdery mildew	Scab
copper octanoate	Espoma Organic Copper Soap RTU	M1	10	X	
sulfur[o]	Bonide Plant Fungicide Dust, GardenTech Sevin Sulfur Dust 2-in-1 Disease and Insect Killer, Safer Garden Fungicide RTU, Safer Garden Fungicide Concentrate, Safer Tomato & Vegetable 3-in-1 RTU O	M2	7-10	X	
sulfur[o] + pyrethrins[o]	Natria Insect, Disease, and Mite Control RTU, Natria Insect, Disease, and Mite Control RTS	M2/3A	10-14	X	
mono-and dipotassium salts of phosphorous acid[o]	Monterey Garden Phos Concentrate	M3	1-3 wks	X	
clorothalonil	Hi-Yield Vegetable, Flower, Fruit, & Ornamentals Fungicide, Ferti-lome Broad Spectrum Landscape & Garden Fungicide, Ferti-lome Broad Spectrum Landscape & Garden Fungicide RTS, Bonide Fung-onil Concentrate, Bonide Fung-onil RTU, GardenTech Daconil Fungcide RTU, GardenTech Daconil Fungicide Concentrate	M5			X
myclobutanil	Ferti-lome F-Stop Lawn & Garden Fungicide Concentrate, Ferti-lome F-Stop Lawn & Garden Fungicide RTS,	3	14	X	X
propiconazole	Bonide Infuse Disease Control Concentrate	3	14		X

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[o] = Organic

Root Crops

Table 10.7., continued. ***Fungicides and Bactericides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Root Crops*** *(Beets, Carrot, Radish, Parsnip, and Turnip) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Powdery mildew	Scab
pyrethrins[o]	Ferti-lome Triple Action Plus RTU O, Ferti-lome Triple Action O	3A	5-7	X	
Bacillus amyloliquefaciens strain D747[o]	Bonide Revitalize Biofungicide Concentrate, Bonide Revitalize Biofungicide RTU	MBCA	5-7	X	Suppress
neem oil[o]	BioAdvanced Organics Neem Oil RTU, Monterey Neem Oil RTU, Natria Neem Oil Concentrate, Natria Neem Oil RTU, Natural Guard Neem Concentrate O, Natural Guard Neem RTU, Safer Neem Oil Concentrate, Safer Neem Oil RTU	UN	3	X	
mineral oil[o]	Monterey Horticultural Oil O, Monterey Horticultural Oil O RTS, Safer Oil O RTS, Safer Horticultural + Dormant Spray Oil Concentrate	UN	3	X	
potassium salts of fatty acids[o] + sulfur[o]	Safer Tomato & Vegetable 3-in-1 RTU O	N/A + M2	7-10	X	

Root Crops

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[o] = Organic

Farmers market display of root crops in Utah County.


Small-scale radish production.

Symptoms of phosphorus deficiency in beets.

Symptoms of nitrogen deficiency in carrots.

Healthy radish compared to iron deficient radish.

Black heart occurring in a rutabaga.

Carrots in bolting stage.

Forking occurring carrots.

Carrot Rust Fly *(Psila rosae)*

Carrot rust fly maggot

Carrot rust fly maggot feeding damage.

Willow-Carrot Aphid *(Cavariella aegopodii)*

Honeysuckle Aphid *(Hyadaphis foeniculi)*

Aphids feeding on carrot.

Beet armyworms *(Spodoptera exigua)* feeding on sugar beet foliage.

Cutworm feeding on radish.

Beet Leafminer Adult *(Pegomya betae)*

Root Crops

Leafminer feeding damage on beet greens.

Cottony soft rot *(Sclerotinia sclerotiorum)* also known as white mold on carrots.

Powdery mildew *(Erysiphe heraclei)* on carrots.

Powdery mildew *(Erysiphe polygoni)* on beets.

Damping-off in beet seedling

Nematode damage to carrots.

Nematode damage to beet roots.

Cavity spot *(Pythium* spp.*)* on carrot.

Scab *(Streptomyces scabies)* on carrot.

Beet root with symptoms of beet curly top virus (BCTV).

Aster Leafhopper *(Mascrosteles squadrilineatus)*

Carrot Aster-Yellows

CHAPTER 11: 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.

Classes of Sweet Corn

Standard Sugary - Standard sugary is the oldest and most vigorous class of sweet corn. Example varieties include 'Earlivee', 'Honey & Cream', 'Jubilee', and 'Silver Queen'. This class is often used in processing and sometimes sold fresh from heirloom and organic operations. A limitation of standard sweet corn is that the kernels contain less sugars and they convert sugars to starch within a few days after harvest, so it must be consumed or processed quickly.

Sugar Enhanced - Sugar enhanced corn is also commonly known as sugary enhancer or EH sweet corn (e.g., 'Sugar Buns', 'Bodacious', 'Fantasia', 'Luscious', 'Miracle', 'Temptation'). It is primarily grown for direct retail sale or wholesale market. It offers a more tender and creamy texture than other sweet corn classes. Kernels have more sugar than the standard types, so storage life is extended a few days over less sweet types.

Shrunken-2 - Shrunken-2 sweet corn gets its name from the seed having a wrinkled appearance and is also referred to as shrunken, super sweet, ultra sweet, or extra sweet (e.g., 'Devotion', 'How Sweet It Is', 'Obsession', 'Vision', 'Xtra-Tender' series). Up to 90% of corn sold for fresh consumption is the shrunken-2 variety. Sugar levels in this class of corn are up to twice that of other sweet corn types. Additionally, the conversion of sugar to starch within the kernels occurs at a slower rate, so varieties can be stored for 5 to 10 days. A common complaint, especially about older varieties, is that the skin covering the kernels is tough. Kernels of newer shrunken-2 varieties are less tough. Seeds may germinate poorly in cold soils and should be planted after soil temperatures are optimal.

Synergistic and Others - Synergistic and other new varieties (e.g., 'Cameo', 'Gourmet Sweet', 'Vitality') are continually being released. They are bred using combined genetics of other sweet corn types to enhance quality. Recent reports from the Midwest indicate many newer varieties perform reasonably well and are of good quality. However, some varieties, especially some of the initial introductions, have limitations including:

- Poor germination, especially at temperatures below 60 °F.
- Brittle seed that can be easily damaged with rough handling.
- Smaller seed that may not work with seeding equipment.
- Poor vigor in cold conditions.
- Poor ear tip cover on some varieties.
- Lodging (wind blowing cornstalks over).
- Low yields.

Isolation is necessary to maintain kernel sweetness and color. All sweet corn varieties should be isolated from field corn by 250 feet or 14 days' difference in pollen shed (tasselling dates). Isolate shrunken-2 varieties from standard and sugar enhanced types to minimize starchy kernels. While isolation of sugar enhanced from standard types is not necessary, it does ensure full expression of the different sweetness characteristics of the variety.

To maintain kernel color, white varieties need to be isolated from yellow or bicolor corn. Yellow is the dominant color, so pollen from yellow corn will cause fewer white kernels in both bicolor and white varieties. However, white pollen does not influence color formation in yellow or bicolor varieties.

Soil Requirements

Sweet corn can be grown in most Utah soil types that are suitable for growing other vegetable crops. Soil electrical conductivity (EC, or measure of salinity) should be below 1.7 decisiemens per meter (ds/m). Yields become detrimentally affected above this point.

Soil should be plowed deeply and free of clods and other debris but not overworked. 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 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 (www.usual.usu.edu).

Nitrogen (N) - Both urea and ammonium sulfate are acceptable nitrogen 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.

Phosphorus (P) and Potassium (K) - 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.

USU EXTENSION FACT SHEET REFERENCES

- *The Ten Most Common Mistakes in Using No-Till*
- *The Potential for Reducing N Fertilizer Inputs for Corn Production in the First Year Following Alfalfa*

Planting

Sweet corn is a warm-weather vegetable. Germination and growth start at 55 °F, and the optimum temperature range is 70 °F to 86 °F. To avoid seed rot and maximize germination, soil temperatures at planting time should be at least 60 °F. When soil temperatures at planting are below 75 °F, use seed pretreated with a fungicide to reduce seed loss due to rots.

USU EXTENSION FACT SHEET REFERENCES

- *Corn Silage Variety Performance*

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.

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 unfurrows.
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 (maximum/minimum) 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 ˚F and the low was 56 ˚F.

[(84 + 56) / 2] – 50 = 20 GDU

Example 2

The daily maximum temperature was 96 °F and daily minimum was 48.

[(86+50] / 2] – 50 = 18

Note: Substitute max and min temperatures were used because the daily high exceeded 86 °F and the daily low was below 50 °F.

Example 3

The daily maximum temperature was 54 °F and the low was 34 °F.

[(54 + 34) / 2] – 50 = 0

Note: GDUs 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 1,400 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, Utah, plant corn on April 20, and expect to harvest the corn for 4 days, then you need to calculate the total GDUs during this 4-day period. The 4-day average daily maximum/minimum temperature for July 20-23 in Layton is 91 °F/63 °F.

GDU = [(86 + 63) / 2] – 50 = 25.

When Should You Plant Your 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 4 days.
3. Monitor maximum/minimum 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. Plant Field 2 when spring conditions accumulate 100 GDUs.
6. Repeat for subsequent plantings or other varieties.

Using Different Varieties

Another option to provide mature sweet corn over an extended period is to plant several varieties with different ripening dates at the same time. For example, 'Early Sun Glow' (standard) matures in approximately 63 days, 'Honey and Pearls' (shrunken-2) matures in approximately 76 days, and 'Serendipity' (shrunken-2) matures in 82 days.

Irrigation

Sweet corn requires 18 to 28 inches of water per acre, depending on weather conditions throughout the growing season. Maintain soils 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.

Plasticulture

Depending on the cost of plastic mulch, equipment availability, early market opportunities, and field installation systems, growing corn using plasticulture may be economically viable. Potential benefits include improved weed control, warmer soils, increased soil moisture retention, earlier first harvest, and increased yields. One study from Iowa State University using 'Temptation' sweet corn found that clear plastic mulch shortened the first harvest date by 4 days. Additionally, all the various colors of plastic mulch tested increased yield by 5% to 12% compared to the bare ground control. Other studies have reported earlier ripening times of up to 7 days.

When considering using plastics, plant in furrows with clear plastic installed over the rows (low tunnel) or lay plastic first, and then plant the seeds through the plastic. The second system requires either specialized plastic planters or planting is done by hand.

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.

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.

USU EXTENSION FACT SHEET REFERENCES

- Chopping and Storing Quality Corn Silage

Postharvest Care

Postharvest temperature management is imperative to maintain ear quality. Ears will be 15 °F 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 types lose sweetness in just a few days. In fact, half of the sugar in standard sugary kernels is lost within 24 hours when stored above 86 °F. When kept near freezing, only 8% of the sugar is lost each day. Extra sweet and super sweet types remain sweet for a longer period, but cooling the harvested ears is still critical to maintain quality.

When sweet corn is shipped or stored for more than 2 to 3 days, maintain the corn at 32 °F. Cooling with air is common but not as effective as other options because it often takes 24 to 48 hours for ears to become sufficiently chilled.

Larger operations often use hydrocooling (soaking or sprinkling ears in chilled water) and then top-icing is 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, 1 gallon of water is needed for every 4 pounds of corn.

Hydrocooling 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 pound of ice for every five pounds of pre-chilled corn in the shipping containers. Contact the local health department or government food safety administrator for potential restrictions, building codes, and other safety issues.

If using an air refrigeration system, immerse sweet corn ears in tanks of pre-chilled water to lower their temperature quickly. After the initial bath, store the ears in the cooler at approximately 98% humidity to maintain ear quality.

Weed Management

Weeds compete with sweet corn for sunlight, water, and nutrients. Historically, cultivation was used as the primary weed control option. This necessitated wider rows and limited production per acre. Herbicides are now the primary choice for weed management.

Many pre and postemergent herbicides are available that control troublesome grassy and broadleaf weeds (lambsquarter and various pigweed species). Researchers from Iowa State University reported achieving 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 preemergent herbicides, or that the three products could be applied soon after seeding. They concluded that weed control at the preplant and early postplant 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 its 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 11.2, 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 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 preharvest 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 beyondthe 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 :

- **Preplant incorporated:** incorporated into the soil prior to seeding or transplanting onions.
- **Preemergence:** applied to the soil after planting but before onions or weeds emerge .
- **Post-transplant:** applied to the soil after the crop is transplanted, either before weeds have emerged or after clean cultivation.
- **Postemergence:** applied to weeds after both weeds and onions have emerged.
- **Directed postemergence:** applied as a directed or shielded spray postemergence on small weeds in rows of taller crops or in row middles. When using a postemergence herbicide, the entire weed must be covered for maximum control.

Refer to Table 11.2 for additional herbicide information.

Insect and Mite Pest Management

Seedcorn Maggot *(Delia platura)*

DESCRIPTION

Adult: Seedcorn maggot adults (flies) are about 0.2 inches (5 mm) long with gray to brown bodies. They resemble houseflies but are about half their size and overlap their wings at rest.
Egg: White and elongated, eggs are deposited in soils rich in organic and decaying matter and on seeds and seedlings.
Larva: Maggots are legless, tapered, about 0.25 inches (6 mm) long, and yellowish-white. Head-ends are wedge-shaped with small black mouth hooks in front.
Pupa: Oval-shaped, dark brown, and about the size of a grain of wheat, pupae are found in the soil.

LIFE HISTORY

Adult flies emerge from overwintering pupae in April and May and begin mating within 2 to 3 days. Females lay eggs in or on soil and/or on seeds. Eggs hatch in 2 to 4 days, and larvae burrow into seeds to feed on emerging cotyledons and plant roots. After about 21 days, mature larvae pupate in the soil and remain there for approximately 7 to 14 days. A complete generation takes about 3 to 4 weeks, and about two to three generations occur yearly.

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 survive. 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.* 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 (http://www.agbio-inc.com/seedcorn-and-onion-maggot.html).
    - ChemTica page (https://www.chemtica.com/site/?p=2927) on seedcorn maggot.
- *Plant during fly-free periods determined by monitoring with traps..*
- *Don't overwater.* Seedcorn maggots like moisture.
- *Use row covers.* Row covers placed over transplants at planting time 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 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 seedcorn maggot larval populations. Predaceous ground beetles eat seedcorn 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 also occurs.

Corn Leaf Aphid *(Rhopalosiphum maidis)*

DESCRIPTION

Adult: Oval, wingless, and 2 mm long, adults have a pale bluish-green body with black antennae, legs, and cornicles (pair of tubes on posterior back). The winged form is similar in size to the wingless adult but has fragile transparent wings held roof-like over the body.

Egg: There are no eggs as females give birth to live young.

Nymph: Nymphs are 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

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 4 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. Infested tassels become covered in a sticky substance excreted by the feeding aphids, known as honeydew, possibly interfering with pollination and causing poor kernel fill. Infested plants may take on a black or sooty appearance due to a fungus that feeds and thrives on the honeydew. Heavily infested tassels may wilt and turn brown. All three aphid species mentioned (CLA, greenbug, and bird cherry-oat) transmit maize dwarf mosaic virus to corn from nearby sources.

MANAGEMENT

Cultural:

- *Plant early.* CLA tends 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 3 weeks before). Choose five locations within a field and check at least 10 plants at each location. Use a hand lens to carefully examine the ear, leaves, and stalk of plants. Carefully pull the whorl of leaves away from the stalk and unroll them, examining leaves for aphids. Estimate the number of aphids per plant, excluding any that appear off-colored since these aphids may be diseased or parasitized.
- *Use reflective mulches.* Metallic and red mulches can reduce early-season aphid populations.
- *Control weeds.* Good weed control can eliminate or reduce alternate virus and food sources for aphids.

Chemical:

Aphid infestations typically can be controlled by biological and environmental factors, but if 50% or more of the plants checked have more than 100 aphids per plant, the tassels are coated in honeydew, and plants are under drought stress, chemical treatment may be necessary.

Biological:

Natural enemies of aphids include predators such as lacewings, lady beetles, and syrphid or hover flies. The parasitic wasp *Lysiphlebus testaceipes* specializes in attacking aphids. It lays an egg inside the aphid where its larva feeds on internal tissues, killing the aphid. The newly developed adult wasp cuts a hole in the aphid back and emerges. The dead brown body of the aphid is called an "aphid mummy."

Note: Predators and parasites usually don't reduce aphid populations quickly enough to prevent virus infection.

USU EXTENSION FACT SHEET REFERENCES

- Aphid Natural Enemies and Biological Control
- Aphid Pests on Vegetables

Western Corn Rootworm
(Diabrotica virgifera virgifera)

There are two species of corn rootworm in Utah: the western and northern corn rootworms. The western corn rootworm (WRC), however, typically causes damage at an economic level requiring control measures.

DESCRIPTION

Adult: A small beetle, it is about 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.
Egg: Eggs are white, football-shaped, and less than 0.8 mm long.

Larva: Colorless when hatched, larvae turn white as they feed and develop. Mature larvae are creamy color, 13 mm long, with a brown head capsule.
Pupa: Translucent white, puape are similar in appearance to the adult stage.

LIFE HISTORY

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 midsummer. 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 known as "goosenecking." Yield losses may occur because pollination is often compromised and the misshapen plants are difficult to harvest. Damaged corn roots are also more susceptible to root and stalk diseases. Adults feed on corn leaves, silks, and pollen, which can result in poorly filled ears. Adult feeding, however, typically doesn't result in enough damage to cause economic losses.

MANAGEMENT

Cultural:

- *Monitor with sticky traps.* Knowing the adult population size will help to determine whether treatment is needed the following season. Using yellow sticky card traps can help determine initial and peak adult emergence during silking and pollen shed. Adults are attracted to the bright yellow color of the cards and get stuck on the adhesive substance on the surface. Use one sticky card for every 5 acres of corn. Consider treatment the following year in continuous-corn if adults exceed 35 per trap per week.

- *Rotate corn crops.* WCR has one generation per year. Rotating corn every 3 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 allowing plants to develop stronger roots systems.
- *Select varieties that produce vigorous roots systems and are well adapted to the area*. These varieties will be more tolerant of moderate amounts of root feeding.

Chemical:

The number of adults present during the previous growing season is the best guide for selecting the fields to be treated.

- Soil Treatments
  - Use granular insecticides at planting or cultivation. Insecticides can be applied in-furrow, banded over the row, or incorporated into the soil.
  - Liquid insecticides can also be applied at planting or cultivation by spraying at the base of the plant.
- Seed Treatments
  - Corn seeds treated with an insecticide can help reduce light to moderate WCR populations, but may not be effective under heavy pressure.

Biological:

There are few known natural predators of the WCR. 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.

USU EXTENSION FACT SHEET REFERENCES

- Western Corn Rootworm

European Earwig *(Forficula auricularia)*

DESCRIPTION

Adult: Adults have an elongated brown body with a red-brown head, 12.7 to 15.9 mm long. Adult earwigs can be easily identified by a prominent pair of "pinchers" (cerci) on the rear of the body. The cerci are used for defense, catching insects, and for the males to grasp females during mating. Male cerci are strongly curved, while those of the female are straighter but curve slightly toward the tip.

Egg: Eggs are elliptical, pearly white, and 1 mm 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 and similar in appearance to adults, but smaller.

LIFE HISTORY

Adults overwinter in the soil as brooding pairs or aboveground 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.

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 trapsto use include:
    - Corrugated cardboard rolled and tied to stakes along borders or dispersed throughout the field.
    - Rolled or crumpled moistened newspaper.
    - Grooved wood placed together.
    - Tuna cans, yogurt, or sour cream containers (punch holes in lids). Bait containers with smelly oils such as fish or clam oil, bacon grease, and wheat bran or wheat germ and then bury the bottom of containers in the ground.
- *Check traps twice per week.* Transfer live earwigs into a plastic container with soapy water for disposal. If using bait, replenish as needed.
- *Reduce or remove nesting and hiding places.* Earwigs seek refuge in dark areas during the day. Weeds, plant debris, and volunteer corn plants should be kept clear from fields, especially in the spring.

Chemical:

Insecticides should be applied in the late evening just before earwigs come out to feed. Target sites where earwigs congregate (sites where females brood their young) and on plants when injury appears.

Biological:

Earwigs emit a foul-smelling chemical that is distasteful to many predators; however, natural predators such as toads, song birds, chickens, ducks, and turkeys will eat earwigs. A parasitic tachinid fly will also attack the European earwig.

USU EXTENSION FACT SHEET REFERENCES

- European Earwig

Corn Earworm *(Helicoverpa zea)*

DESCRIPTION

Adult: Adults are a tannish-brown moth with a 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. The male moths have green eyes.
Egg: Very small, one-half the size of a pinhead, eggs are creamy white and dome-shaped with ridges, darkening in color as they near hatching.
Larva: Caterpillars are brown-headed with green, brown, or black bodies. Alternating dark and light stripes run lengthwise on the body. Larva length ranges from 1.5 mm up to 38.1 mm when fully grown.
Pupa: Cylindrical and brown, eggs are about 25 mm long.

LIFE HISTORY

Corn earworms (CEW) overwinters 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 occur in southern Utah. The first flight begins in mid-June to early July in northern Utah, and is typically small. The second and third flights are much larger and occur during August and September, respectively. Moths are active on warm, overcast evenings.

CEW moths typically lay eggs singly on fresh, green corn silks. Each female moth can lay up to 1,000 eggs, and will lay eggs on weeds and selected vegetables when corn silk is unavailable. Eggs hatch in 2 to 10 days, depending upon the temperature. The newly hatched larvae crawl down the corn silk and into the ear tip, where they chew into developing kernels, but larvae will also chew on silks and leaves. CEW larvae are cannibalistic 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 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.

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 clothespins.* Place a clothespin 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 in Table 11.1 for deciding when to take treatment action.

Chemical:

Good control depends on applying insecticides before larvae enter the ears. Start spraying within 2 days of the beginning of silking, or as indicated by trap counts. About half of the eggs are laid within 2 days of silk emergence, and the remainder are laid within the next 9 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 11.1. *Reapplication Intervals for Corn Earworm Treatment While Silks Are Actively Growing*

No. moths trapped per night	Insecticide reapplication intervals (days)
Less than 0.2	None
0.2 to 0.6	5
0.7 to 6.5	3
More than 6.5	2

Biological:

Many predators and parasites attack CEW eggs, including several species of *Trichogramma*, an egg parasitoid wasp. These wasps lay their eggs inside the earworms' eggs (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 release of this parasite into corn fields to control corn earworm has 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.

USU EXTENSION FACT SHEET REFERENCES

- *Corn Earworms*

Sap Beetles

Four-Spotted Sap Beetle *(Glischrochilus quadrisignatus)*
Dusky Sap Beetle *(Carpophilus lugubris)*
Corn Sap Beetle *(C. dimidiatus)*

DESCRIPTION

Adult: The **picnic beetle** is 8 mm long and black with four prominent orange or yellow spots on the wing covers. The **dusky sap beetle** is 4 mm long, with dull black, short wings that don't fully cover the abdomen, and club-shaped antennae. The **corn sap beetle** is similar in appearance to the dusky sap beetle, about

Sweet Corn

3 mm long, ranging from red-tinged black to brown-yellow.
Egg: Slender and white, about 0.8 mm long and 0.23 mm wide.
Larva: About 6 mm long, wormlike, with three pairs of short legs near their heads, larvae have white- to cream-colored bodies and brown heads and posteriors.
Pupa: White, turning cream-colored and later tan before adult emergence, pupae are about 4.4 mm in length and 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 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 corn pests 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.
- *Choose fields located strategically.* Locate fields away from favored breeding sites, such as vegetable and fruit dumps. Sweet corn that matures after surrounding field corn has dropped pollen tends to have lower sap beetle infestation.
- *Select resistant varieties.* Corn with tight, long husks provides better protection from corn earworm damage and is less 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:

Controlling 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, use products with a short preharvest interval.

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.

USU EXTENSION FACT SHEET REFERENCES

- *Sap Beetles*

Cutworms

Western Bean Cutworm *(Striacosta albicosta)*

DESCRIPTION

Adult: Adults are brown-bodied moths, about 19 mm long with a wingspan of 38 mm and marked with creamy white stripes on the leading edge of the forewings. Adjacent to the stripes, toward 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.
Egg: Eggs are dome-shaped and pinhead-sized, white with a thin, red ring around the top when newly hatched. Eggs change color with age from white to brown, and then finally turn a dark purple just before hatching
Larva: Larvae are 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 38 mm long with three short dark stripes on the first segment behind the head.
Pupa: Pupae are dark brown and oval shape.

LIFE HISTORY

The western bean cutworm is a late-season pest of corn. Adult moths emerge midsummer and mate shortly afterwards. Females lay eggs in July and August on various non-cultivated and cultivated host plants, including sweet corn. Females are attracted to fields with corn that is in late whorl or tasseling stage. They lay eggs in masses primarily on the upper surface of leaves. Egg masses contain an average of 50 eggs but can range from 5 to 200 eggs per mass. Eggs mature in about a week. Newly hatched larvae feed on their egg shells before moving to other protected feeding sites. Larvae feed on corn plants for about 30 days. When feeding and development is complete, fully mature larvae drop to the ground and burrow 3 to 9 inches beneath the soil. Once in the soil, larvae construct earthen overwintering chambers with their salivary gland secretions. These larvae remain in a dormant state throughout the winter. As temperatures rise the following spring and early summer, larvae pupate and complete development into adults.

Western bean cutworms have a single generation each year.

DAMAGE

Larvae feed on leaf tissue, fallen anthers/pollen, and silks on their way to the ear where most of the feeding is concentrated. Larvae enter the ear through the tip or by chewing through the husk and feeding directly on developing kernels. Damaged kernels are more prone to molds and mycotoxin infection. Injury from larval feeding can result in lower quality and reduced yield. Larvae from a single egg mass can invade nearby plants within a 6- to 10-ft circle, causing patchy infestations throughout the field. Several larvae may also feed on a single ear of corn, especially during high infestations.

Pale Western Cutworm *(Agrotis orthogonia)*

DESCRIPTION

Adult: Adults are mottled gray with yellowish and brownish spots on the forewing and a wingspan of 32 mm.
Egg: Spherical and about 1.6 mm in diameter, eggs appear white when first deposited, and then turn yellow-gray.
Larva: Young larvae are yellow-brown to slate gray with three pairs of greenish-gray stripes along the back and sides. Heads are amber with black markings that resemble an 'H' on young larvae and a 'V' on mature larvae. Mature larvae are 30-40 mm long.
Pupa: Pupae are yellowish initially, then dark brown, and about 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 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 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.
- *Scout fields.* Examine the upper leaf surface on the upper third of the plant for egg masses and 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 1 to 2 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 western bean cutworms 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). Consider treating pale western cutworm when larvae average two 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. Several predators have been observed feeding on pale western cutworm larvae, such as the leaf-footed bug, assassin bug, ambush bug, and ground beetles.

USU EXTENSION FACT SHEET REFERENCES

- Cutworms in Vegetable Production

Armyworms

Fall Armyworm *(Spodoptera frugiperda)*

DESCRIPTION

Adult: Mottled ash-gray with white or light gray spots near the tips of the forewings, adults' hind wings are iridescent silver-white with a narrow dark brown edge. The wingspans are about 38 mm.
Egg: Eggs are dome-shaped, light gray, and laid in clusters. Eggs become dark just before hatching.
Larva: Larvae are 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 orange-brown and have a distinct light-colored inverted "Y" on the face. Mature larvae may be up to 38.1 mm long.
Pupa: About 13 mm long, pupae are reddish brown, then darken as they mature.

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 4 to 5 days of life but can continue for up to 3 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. 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*. Include blacklight and pheromone traps to detect presence of moths.
- *Scout plants.* When moths are detected, look for armyworm eggs and larvae.
  - Search 20 plants in five locations or 10 plants in 10 locations.
  - Continue to check plants until silks begin to dry.
- *Plant early and plant early-maturing varieties.* Late-planted corn is more susceptible to larval feeding injury because more plants are in the seedling stage when larval feeding occurs.
- *Use transgenic varieties.* These hybrids can offer partial resistance to armyworm injury.

Chemical:

Insecticides should be applied before larvae burrow deep into the whorl or ear and are protected. Consider chemical control options when egg masses are present on 5% of the plants or when 25% of the plants show damage and live larvae are still present. Apply insecticides early or late in the day, since fall armyworm larvae are most active at these times.

Biological:

Numerous species of parasitoids and generalist predators affect fall armyworms. The most common species that parasitize fall armyworm include braconid wasps and tachinid flies. Predators include various ground beetles, spined soldier bug, the insidious flower bug, and vertebrates such as birds, skunks, and rodents. During favorable seasons, natural enemies can suppress fall armyworm populations; however, in cold, wet springs, their effectiveness is limited and fall armyworm population explosions may occur.

Spider Mites

Two-Spotted Spider Mite *(Tetranychus urticae)*
Banks Grass Mite *(Oligonychus pratensis)*

DESCRIPTION

Adult: The **two-spotted spider mite** (TSM) is eight-legged and variable in color, including pale yellow, green, orange and brown. Females are 0.4 mm long and males are 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 **banks grass mite** (BGM) is similar in appearance, but has two blackish-green pigmented areas that run along its sides and extend the full length of the body.

Egg: Eggs are very small, spherical, shiny, and straw-colored.

Larva: Six-legged and colorless, larvae resembles the body form of the nymph and adult. They are slightly larger than the egg.

Nymph: Nymphs are eight-legged and 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 midsummer 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 1 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. 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, partly 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 4 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. Applying 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.

USU EXTENSION FACT SHEET REFERENCES

- *Spider Mites in Corn*

Refer to Tables 11.3 and 11.5 for more information on commercial and small-scale insecticides for sweet corn production.

Disease Management

Corn Smut *(Ustilago maydis)*

CASUAL AGENT

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. 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 °F to 95 °F and moisture is present, the fungus produces a second type of spore blown by wind or splashed by water. Once the spores land on young corn plants, they germinate and produce hyphae that enter the plant tissue through stomates or through wounds from de-tasseling, hail, or insect feeding. The fungus causes the plant cells at the infection site to multiply, forming a gall. Over time, the fungus invades the galls and dark powder-like spores are produced that are then blown to infect other corn plants or to overwinter in the soil. Any part of the plant can be infected at any growth stage. Infections in the ear are most common and occur when the spores land on the silk and grow down into the ear.

MANAGEMENT

- *Use resistant varieties.* The best option is using 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'.
- *Maintain recommended fertility levels.* Plants grown under high nitrogen levels or with high rates of manure are more susceptible to the disease.
- *Employ deep plowing.* Deeply plowing corn stalks moves infected tissue into deeper soils, reducing disease incidence.
- *Avoid plant injury and insect damage.* Fewer injuries reduce the number of entrance points for the fungus, thus reducing disease incidence.

USU EXTENSION FACT SHEET REFERENCES

- Corn Smut

High Plains Virus

CASUAL AGENT

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. WCMs reproduce rapidly as temperatures reach 75 °F to 85 °F and stop at temperatures near freezing. Under ideal conditions, the WCM can complete a single generation in 8 to 10 days. Although heavy mite populations can cause the leaf margins to role or curl inward, most plant injury results from viruses that the WCM vectors.

SYMPTOMS

Symptoms vary depending on variety and time of infection. Initial symptoms are stunting and a mosaic pattern on the leaves. As symptoms progress, yellow stripes up to an inch wide are seen on infected plants' leaves and in some cases, purple streaks are observed. 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, Utah (extension.usu.edu/pests/uppdl/index).

MANAGEMENT

There is little that can be done to control the disease. Prevention is the best strategy.

- *Remove weeds.* Mites and the virus can survive in volunteer wheat and grass weeds until corn or wheat are planted.
- *Plant seed early in the season.* Mites migrate to corn as wheat dries down midsummer.

Bacterial Stalk Rot *(Erwinia carotovora)*

CASUAL AGENT

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. When using overhead irrigation, 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.

DISEASE CYCLE

E. carotovora survive in old stalks aboveground. 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 °F to 95 °F and high relative humidity increase the disease.

MANAGEMENT

Good cultural control practices in areas where the disease has occurred are best.

- *Plow plant debris like stalks deep into the ground.*
- *Avoid using surface water for irrigation (flooding or overhead).*

Sweet Corn Pesticide Tables for Commercial and Small-Scale Use

Table 11.2. *Herbicides* *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah*

		Application relative to crop			Application relative to weeds		Weeds controlled		
Brand name (REI/PHI)	**Active ingredient**	**Before planting or crop emergence**	**Postemergence to defined crop stage**	**Postemergence, shielded**	**Preemergence**	**Postemergence**	**Annual grass**	**Small-seeded broadleaves**	**Broadleaves**
2, 4-D amine (48hr/-)	2, 4-D		X	X		X		X	X
Surpass/Cadence (12hr/-)	acetochlor	X			X		X	X	X
Aim (12hr/-)	carfentrazone		X	X		X		X	X
alachlor products (12hr/-)	alachlor	X			X		X	X	X
atrazine (12hr/-)	atrazine	X	X		X	X		X	X
Stinger (12hr/30d)	clorpyralid		X			X		X	X
Outlook, others (12hr/-)	dimethenamid-P	X	X		X		X	X	
Define (12hr/-)	flufencaet	X			X		X		
Starane (12hr/31d)	fluroxypyr		X	X		X		X	X
Option (12hr/45d)	foramsulfuron		X	X					
RoundUp and others (12hr/-)	glyphosate	X		X		X	X	X	X
Sandea and others (12hr/30d)	halosulfuron-methyl		X		X	X		X	X
Callisto (12hr/45d)	mesotrione	X	X		X	X		X	X
Accent (Q) (12hr/-)	nicosulfuron		X	X		X			
Gramoxone Max (12hr/24hr)	paraquat		X	X		X	X	X	X
Prowl products (12hr/-)	pendimehtalin	X	X		X		X	X	
Princep/ Simazine/others (12hr/45d)	simazine	X			X		X	X	X
Dual (II) Magnum (12hr/-)	s-metachlor	X	X	X	X		X	X	
Laudis (12hr/-)	tembotrione		X			X		X	X
Impact (12hr/45d)	topramazone		X			X		X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 11.3. *Insecticides* *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Seedcorn maggot	Spider mite
carbaryl	Carbaryl 4L, Drexel Carbaryl 4L, Sevin XLR Plus	1A	10-14		X	X			
	Sevin 5 Bait					X			
	Carbaryl Cutworm Bait, Drexel Carbaryl 5% Bait					X			
	Sevin 4F				X				
methomyl	Corrida 29 SL, Corrida 90 WSP, DuPont Lannate LV, Lannate SP, Lanveer LV, Nudrin SP	1A	10-14	X	X	X			
	Nudrin LV			X		X			
malathion	Drexel Malathion 5EC, Fyfanon 57% EC, Fyfanon Malathion, Malathion 57%	1B	5-7	X	X				
	Fyfanon ULV AG							X	
terbufos 60-day PHI (at planting)	Counter 20G Lock 'n Load, Counter 20G SmartBox, Counter 20G SmartCartridge	1B				X		X	
alpha-cypermethrin	Fastac CS, Fastac EC	3A	10-14	X	X	X			
beta-cyfluthrin	Baythroid XL, Sultrus	3A	10-14		X	X		X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

° = Organic

Table 11.3., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Seedcorn maggot	Spider mite
bifenthrin	Batallion 2 EC, Batallion LFC, Bifender FC, Bifenture EC, Bifenture EC, Capture LFR, Discipline 2EC, Ethos XB, Fanfare 2EC, Fanfare ES, GCS Bifenthrin 2EC, GCS Bifenthrin LFC, Lancer FC, Omni Brand Bifenthrin 2EC, Suro LFC, Tepera Plus	3A	2-3 wks	X	X	X		X	X
	Bifenture LFC, Fanfare EC			X	X	X		X	
	Bifenture LFC, Capture 3rive 3D, Manticor LFR, Temitry LFR			X		X		X	
	Ethos 3D			X				X	
	StartUp Bifen					X		X	
	Sniper LFR			X	X			X	X
	Surrender G						X		
	Steed			X	X	X			
	Xpedient Plus					X			
cyfluthrin	Aztec 2.1G, Aztec 4.67% Granular, Aztec HC	3A	10-14			X		X	
	Tombstone, Tombstone Helios				X	X		X	
deltamethrin	Delta Gold 100	3A	14	X	X	X			
esfenvalerate	Asana XL, S-FenvaloStar	3A	10-14	X	X	X			
gamma-cyhalothrin	Declare	3A	10-14	X	X	X		X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

O = Organic

Table 11.3., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Seedcorn maggot	Spider mite
lambda-cyhalothrin	Crusader 2ME, Drexel L-C Insecticide, Grizzly Too, Kendo, Kendo 22.8 CS, Labamba, Lambda Select, Lambda T, Lambda T-2, Lambda T-2, Lambda-Cy AG, Lambda-Cy EC, Lambda-Cy EC A, LambdaStar, LambdaStar 1 CS, LambdaStar Plus, Lamcap II, Lunge, Nufarm Lambda-Cyhalothrin 1 EC, Omni Brand Lambda 1 EC, Paradigm VC, Province II, Ravage, Ravage II, Roundhouse 1 EC, Serpent 1 EC, Silencer, Tigris Lambda, Warrior II with Zeon Technology	3A	10-14	X	X	X		X	X
	Willowood Lambda-Cy 1EC					X			X
permethrin	Arctic 3.2 EC, Perm-UP 3.2 EC, Permethrin	3A	14		X	X			
	PermaStar AG				X				
	Pounce 1.5 G				X	X		X	
	Pounce 25 WP								
pyrethrins°	Pyrenone Crop Spray	3A	5-7	X	X	X	X		X
	PyGanic Crop Protection EC 1.4 II, PyGanic Crop Protection EC 5.0 II, Tersus			X	X		X		
	EverGreen Crop Protection EC 60-6			X	X		X		
tefluthrin	Force 10 G HL SmartBox, Force 10G HL Smart Cartridge, Force 3G, Force 3G Smart Box, Force 6.5G, Force Evo, Precept	3A				X		X	
zeta-cypermethrin	Cortes Maxx, Mustang, Mustang Maxx	3A	10-14	X		X			

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

° = Organic

Table 11.3., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Product name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Seedcorn maggot	Spider mite
acetamiprid	Afflict 30SG, Anarchy 30SG, Anarchy 70WP, Assail 30SC, Assail 30SG, Assail 70 WP, Assail 70 WP, Intruder Max 70WP, Omni Brand Acetamiprid 30 SG, Omni Brand Acetamiprid 70 WP, Savoy EC, Verso 30SG, Verso 70WP	4A	10-14	X					
imidacloprid	Attendant 480 FS, Attendant 600 FS, Axcess Seed Treatment, Dyna-Shield Imidacloprid 5, Gaucho 600 Flowable, Nitro Shield IV, Senator 600 FS	4A	10-14	X				X	
thiamethoxam	Cruiser 5FS, Legend 5L ST	4A	14	X		X			
sulfoxaflor	Transform WG	4C	10-14	X					
flupyradifurone	Sivanto 200 SL, Sivanto HL, Sivanto prime	4D	10-14	X					
spinetoram	Radiant SC	5	10-14		X	X			
spinosad[O]	Entrust, Entrust SC, Success, Blackhawk	5	7-10		X	X			
	Seduce Insect Bait						X		
	Conserve SC				X	X			
abamectin	Agri-Mek SC, Enterik 0.7 SC	6	14-21						X
hexythiazox	Hexamite, Onager, Onager Optek, Proneva EC	10A	N/A						X
etoxazole	Zara SC	10B							X
Bacillus thuringiensis ssp. kurstaki[O]	Bioprotec Plus, BT Now, DiPel ES, Leprotec	11A	5-7		X	X			
	Crymax				X				
propargite	Victimite	12C							X
methoxyfenozide	Acora, Engame, GCS Methoxy 2F, Inspirato 2 F, Intrepid 2F, Invertid 2F, Troubadour 2F Insecticide, Vexer, Zylo	18	10-14			X			
indoxacarb	Avaunt eVo	22A	14		X	X			
	Avaunt, Comber				X				

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Table 11.3., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA).*

Primary active ingredient	Product name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Seedcorn maggot	Spider mite
spiromesifen	Oberon 2 SC, Oberon 4 SC	23	7-14						X
chlorantraniliprole	Besiege, Elevest	28		X		X			X
	Coragen, Shenzi 400SC, Vantacor				X	X			
cyantraniliprole	Fortenza	28	10-14			X		X	
GS-omega/kappa-Hxtx-Hv1a[O]	Spear-LEP	32	5-7		X	X			
Beauveria bassiana strain ANT-03[O]	BioCeres WP	UN	5-7	X					
Beauveria bassiana Strain GHA[O]	BotaniGard 22WP, BotaniGard ES, BotaniGard Optima ES, BoteGHA ES, BoteGHA Optima ES, Mycotrol ESO, Mycotrol Optima ESO, Mycotrol WPO	UN	5-7	X					X
Chromobacterium subtsugae[O]	Grandevo	UN	5-7	X		X		X	
	Grandevo WDG			X		X			
cinnamaldehyde[O]	Seican	UN	3						X
cinnamon oil	Cinnerate	UN	3						X
geraniol[O]	Brandt Ecotec Plus	UN	3						X
heat-killed *Burkholderia* spp, strain A396[O]	Venerate XC	UN	7-10	X	X	X			
iron phosphate	Bug-N-Sluggo	UN	2-4 wks			X	X		
mineral oil[O]	440 Superior Spray Oil, BioCover MLT, BioCover SS, BioCover UL, PureSpray Green, SuffOil-X, TriTek	UN	3		X				X
	Glacial Spray Fluid, Ultra-Pure Oil			X	X				
neem oil[O]	Trilogy	UN	3						X
paraffinic oil[O]	JMS Stylet-Oil	UN	3		X				X
potassium salts of fatty acids[O]	Des-X, Kopa Insecticidal Soap	UN	5-7	X					X
sodium tetraborohydrate decahydrate	Prev-Am, Prev-Am Ultra	UN	10-14		X				

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Table 11.4. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA).*

Primary active ingredient	Product	MoA	Residual days	Bacterial stalk rot	Corn smut
copper hydroxide	DuPont Kocide 2000	M1	7	X	
extract of *Reynoutria sachalinensis*[O]	Regalia(R) Biofungicide	BM1	7-10		X
tea tree oil[O]	Timorex Act	BM1	3		X
Bacillus amyloliquefaciens F727[O]	STARGUS	BM2	5-7		X
Bacillus pumilus strain QST 2808[O]	Ballad Plus, Sonata	BM2	5-7		X
Bacillus subtilis strain QST 713[O]	Serenade ASO	BM2	5-7		X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[O] = Organic

Sweet Corn

Table 11.5. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Sap beetle	Seedcorn maggot	Spider mite	Corn rootworm
bifenthrin	Ferti-lome Broad Spectrum Insecticide, Ferti-lome Broad Spectrum Insecticide RTS	3A	2-3 wks	X	X	X	X	X		X	
	Hi-Yield Vegetable & Ornamental Insect Control Granules, Bonide Eight Flower & Vegetable Soil Insect Granule			X	X	X	X	X			
cyfluthrin	BioAdvanced Tomato & Vegetable Insect Killer RTU, BioAdvanced Tomato & Vegetable Killer RTS	3A	10-14	X	X	X	X	X			X
deltamethrin	Hi-Yield Multi-Use Dust	3A	14	X	X	X	X	X			
lambda-cyhalothrin	GardenTech Insect Killer Lawn Granules	3A	10-14	X	X	X	X	X			X
	Bonide Eight Garden & Home RTU, Spectracide Triaziscide Insect Killer for Lawn & Landscapes RTU			X	X	X	X	X		X	X
permethrin	Bonide Eight Vegetable, Fruit, & Flower Concentrate, Bonide Eight Yard & Garden RTS, Bonide Insect Control Garden Dust, Hi-Yield Garden & Farm Insect Control	3A	14	X	X	X	X	X			
pyrethrins[o]	Monterey Bug Buster	3A	5-7	X	X	X	X	X	X	X	X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

[o] = Organic

Table 11.5., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Sap beetle	Seedcorn maggot	Spider mite	Corn rootworm
zeta-cypermethrin	GardenTech Sevin Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X	X	X			X
bifenthrin + zeta-cypermethrin	GardenTech Insect Killer Lawn Granules	3A	2-3 wks	X	X	X	X	X		X	
pyrethrins° + canola oil°	Epsoma Organic Insect Control	3A/UN	5-7	X	X	X					
pyrethrins° + neem oil	Ferti-lome Triple Action, Ferti-lome Triple Action Plus RTU	3A/UN	5-7	X	X	X	X	X		X	
malathion	Bonide Malathion Concentrate	3B	5-7	X				X			X
	Spectracide Malathion Insect Spray Concentrate			X				X		X	
spinosad°	Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Captain Jack's Deadbug Brew Dust, Bonide Colorado Potato Beetle Beater, Monterey Garden Insect Spray, Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS	5	7-10		X	X	X	X			
Bacillus thuringiensis°	Monterey B.T., Monterey B.T. RTU	11	5-7		X	X					
Bacillus thuringiensis var. Kurstaki°	Natural Guard Caterpillar Killer Spray with BT RTU	11	5-7		X	X					

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

° = Organic

Table 11.5., continued. *Insecticides* *Registered for* ***SMALL-SCALE*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Sap beetle	Seedcorn maggot	Spider mite	Corn rootworm
sulfur° + pyrethrins°	BioAdvanced & Vegetable 3-in-1 Solution Concentrate, BioAdvanced & Vegetable 3-in-1 Solution RTU, Natria Insect, Disease, and Mite Control RTU, Natria Insect, Disease, and Mite Control RTS	UN/3A	10-14	X	X	X	X	X	X	X	
	Ortho Insect, Mite, & Disease 3-in-1 RTU			X	X	X	X	X	X	X	X
canola oil°	Natural Guard Horticultural Oil Concentrate, Natural Guard Horticultural Oil Concentrate RTS	UN	3	X	eggs					X	
neem oil°	BioAdvanced Organics Neem Oil RTU, Epsoma Organic Neem Oil 3n1, Monterey Neem Oil RTU, Monterey 70% Neem Oil, Natria Neem Oil Concentrate, Natria Neem Oil RTU, Natural Guard Neem Concentrate, Natural Guard Neem RTU	UN	3	X	eggs					X	
	Safer Brand Neem Oil Concentrate	UN		X						X	
cotton seed oil° + clove oil° + garlic oil°	Bonide Mite X RTU	UN	3	X	eggs					X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

° = Organic

Table 11.5., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Sap beetle	Seedcorn maggot	Spider mite	Corn rootworm
potassium salts of fatty acids°	Bonide Insecticidal Soap RTU, BioAdvanced Organics Insecticidal Soap RTU, Epsoma Organic Insect Soap, Monterey Insecticidal Soap RTU, Natria Insecticidal Soap RTU	UN	5-7	X			X			X	
	Natural Guard Insecticidal Soap			X			X	X		X	
potassium salts of fatty acids° + seaweed extract°	Safer Brand Insect Killing Soap RTU Spray	UN/5				X	X				
iron phosphate + spinosad°	Bonide Captain Jack's Bug & Slug Killer, Monterey Sluggo Plus	UN/5	2-4 wks			X	X				
	Natural Guard Bug, Slug, & Snail Bait					X	X	X			
potassium salts of fatty acids° + spinosad°	Bonide Insecticidal Super Soap RTU, BioAdvanced Organic Tomato, Vegetable, & Fruit RTU	UN/5	5-7	X		X	X	X		X	
	Monterey Garden Insect Spray RTU, Natural Guard Spinosad Soap Concentrate, Natural Guard Spinosad Soap RTS, Natural Guard Spinosad Soap RTU			X	X	X	X	X		X	
potassium salts of fatty acids° + sulfur°	Safer Brand Insect Killing Soap Concentrate	UN	5-7	X		X	X	X		X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

° = Organic

Table 11.5., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Corn earworm	Armyworm/ cutworm	Earwig	Sap beetle	Seedcorn maggot	Spider mite	Corn rootworm
mineral oil[o]	Safer Brand Horticultural & Dormant Spray Oil Concentrate	UN	3	X	X					X	
silicon dioxide	Bonide Diatomaceous Earth	UN	7-14	X	X	X	X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for small acreage and home use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was reference in 2023 from various major personal-use pesticide suppliers.

[o] = Organic

Sweet Corn

Table 11.6. ***Bactericides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Sweet Corn*** *in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Bacterial stalk rot
copper octonate	Bonide Captain Jack's Liquid Copper Fungicide Concentrate, Bonide Captain Jack's Liquid Copper Fungicide RTS, Natural Guard Copper Soap Fungicide Concentrate	M1		X

Sweet Corn

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for personal use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from various major home-use pesticide suppliers.

o = Organic


Irrigated field corn in Box Elder County.


Commercial sweet corn production in Utah County.

Symptoms of nitrogen deficiency in sweet corn.

Symptoms of phosphorus deficiency in sweet corn.

Symptoms of potassium deficiency in sweet corn.

Harvest occurs when silks are dried and brown.

Poor pollination leads to irregular kernel development.

Sweet corn field being mechanically harvested.

Seed corn maggot *(Delia platura)* feeding on corn seed.

Corn Leaf Aphid *(Rhopalosiphum maidis)*

Corn leaf aphid colony on sweet corn stalk.

Western Corn Rootworm Adult *(Diabrotica virgifera virgifera)*

Western Corn Rootworm Larva

Western corn rootworm feeding damage on roots.

European Earwig *(Forficula auricularia)*

European earwig feeding damage on sweet corn.

Corn Earworm Moth *(Helicoverpa zea)*

Corn Earworm Larva

Corn Earworm Egg *(Helicoverpa zea)*

Four-Spotted Sap Beetle *(Glischrochilus quadrisignatus)*

Dusky Sap Beetle *(Carpophilus lugubris)*

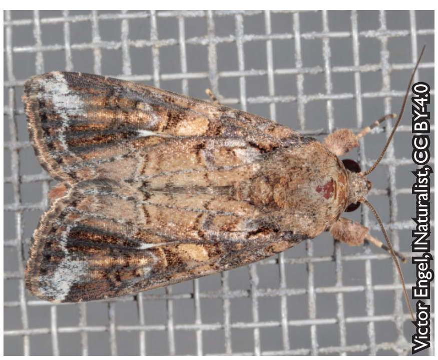
Corn Sap Beetle *(Carpophilus dimidiatus)*


Sap beetle feeding damage on corn ear.


Sap beetles feeding on corn ear.

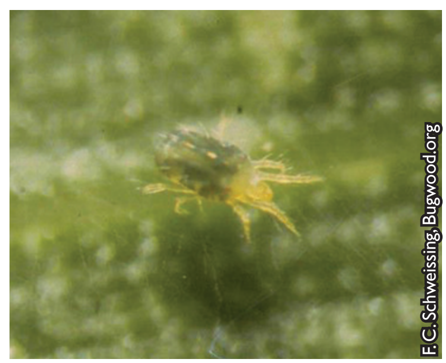
Western Bean Cutworm Moth *(Striacosta albicosta)*

Western Bean Cutworm



Fall Armyworm Moth *(Spodoptera frugiperda)*

Fall Armyworm



Banks Grass Mite *(Oligonychus pratensis)*

Corn foliage with spider mite feeding damage.


Corn smut *(Ustilago maydis)* on corn ear.


Corn smut *(Ustilago maydis)* on corn tassle.

High plains virus symptoms in sweet corn.

Bacterial Stalk Rot
(Erwinia carotovora)

CHAPTER 12: SOLANACEOUS CROP PRODUCTION

Varietal Selection

Since adequate testing of all the varieties in all the conditions present in Utah is impossible, the following information is meant as a guideline for identifying varieties that will grow well on your farm.

Eggplant and **pepper** fruits are frequently categorized by shape, size, color, and flavor. 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 disease name abbreviations listed with the variety name on seed packets. Verticillium (V) and Fusarium (F) wilts, 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.

Selecting **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 over 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 comparing 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 grow under local conditions are shown in Table 12.1.

Table 12.1. ***Variety Suggestions*** *- Eggplant, Pepper, and Tomato*

EGGPLANT	
Standard	*Cappi, Epic, Megal, Millionaire, Nadia, White Star*
Heirloom	*Black Beauty, Long Purple, Rosa Bianca*
PEPPER	
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*
TOMATO	
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 five to seven 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 °F to 65°F for eggplant and pepper, and 50 °F to 60 °F for tomato), starting one week before transplanting. This prepares the plant for fluctuating light and temperature conditions before 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 salt buildup. 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 3 years to reduce the buildup of soilborne 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

Before planting, test the soil to determine nutrient needs and deficiencies. If overfertilized, yield, earliness, or fruit quality may suffer. Incorporate composted organic matter before planting to sustain soil fertility. Initially applying 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.

Eggplant and Pepper

Nitrogen (N) – Incorporate 50-75 pounds/acre nitrogen prior to planting and an additional 150-200 pounds/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 pounds/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 pounds/acre potassium prior to planting depending on the soil analysis if extractable potassium is less than 150 ppm.

Tomato

Nitrogen (N) – Incorporate 50-75 pounds/acre nitrogen prior to planting and another 50-75 pounds/N when first fruits are 1 inch in diameter. Use the smaller amount if manure or compost has been applied to the soil.

Phosphorous (P) – Incorporate 50–150 pounds/acre phosphorous prior to planting depending on soil analysis. Use 150 pounds/acre if phosphorous is low (<15 ppm) and 50 pounds/acre if phosphorous is high (>25 ppm).

Potassium (K) – Incorporate 60–180 pounds/acre potassium prior to planting depending on the soil analysis. Use 180 pounds/acre if potassium is low (<130 ppm) and 60 pounds/acre if potassium is high (>250 ppm).

Planting

Planting dates for eggplants, peppers, and tomatoes in Utah vary depending on local climate conditions and range from early April in southern Utah to mid-May in northern Utah. Planting after frost danger passed. Information on local freeze dates can be accessed through the Utah Climate Center (climate.usu.edu).

Eggplants, peppers, and tomatoes grow best when daytime temperatures are 75 °F to 85 °F and when night temperatures stay above 60 °F 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 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. Plan roadways 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. Research shows total fruit weight is 26% higher on plants set to cover the cotyledons than on plants set to cover just the top of the root ball.

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 solanaceous plant production. 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. Monitor soil water status 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% 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 12.2). Reference the Soil Moisture Monitoring: Low-Cost Tools and Methods fact sheet (https://attra.ncat.org/publication/soil-moisture-monitoring-low-cost-tools-and-methods/) from Appropriate Technology Transfer for Rural Areas (ATTRA) Sustainable Agriculture.

USU EXTENSION FACT SHEET REFERENCES

- *Vegetable Irrigation: Sweet Pepper and Tomato*

Table 12.2. *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

Using black plastic ground mulch is recommended to control weeds in the row and conserve water. Plastic mulch may also raise soil temperatures in spring to promote an earlier harvest. In order for black plastic to raise the soil temperature, there must be good contact with the soil beneath. New plastic films called IRT (infrared-transmitting) provide more soil warming with similar weed control but are more expensive. Red plastic mulch does not raise soil temperature as much as black plastic but has been reported to improve yield specifically for tomato up to 20% compared to black plastic. However, results are inconsistent between field studies, possibly due to variations in plastic quality. Cover crop mulches and other organic mulches can also be beneficial. For more information on mulches, reference the University of California, Davis, fact sheet Mulches in California Vegetable Crop Production (https://anrcatalog.ucanr.edu/pdf/8129.pdf).

Row covers provide a windbreak that helps protect plants from frost and can enhance yield and earliness. Spunbonded row covers (such as Reemay) made of lightweight polyester or polypropylene can rest directly atop plants, but edges should be secured. Plastic row covers trap more heat during the day than spunbonded 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. Spunbonded 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.

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

Before applying the first string, remove suckers (secondary shoots). 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 1 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 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. Eggplant 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 overmature 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. Bell peppers are hand-harvested by cutting from the plant, leaving a one-inch stem on the fruit, or carefully twisting the fruit to break the stem. Peppers may be harvested at the immature (green) stage or after the mature color develops. Pepper harvest starts about 30 days after flowering (mature green), and it takes an additional 10 to 20 days before fruits are fully colored.

Tomato - An acre of tomato plants yields an average of 200 cwt/acre (1 cwt is equivalent to 100 pounds); however, using plasticulture techniques, such as plastic mulch and row covers has been reported to increase yields up to 600 cwt/acre. 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

Eggplant - Store eggplant between 45 °F 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.

Pepper - Postharvest 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 °F 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. Prepackaging peppers in plastic films helps retain moisture and can prolong the storage life up to a week longer than non-packaged peppers.

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 2 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 °F to 70 °F with 90% to 95% relative humidity. For slower ripening (in transit), keep temperatures at 57 °F to 61 °F.

For further detail on proper storage, handling, and ripening techniques, reference the publications and resources from the University of California Postharvest Center (postharvest.ucdavis.edu).

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. Using 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.

Herbicide and pesticide labels often change, so make sure to always consult the label to determine if the crop is listed on the label, what precautions are required, and what rates and application methods are allowed. It is critical to read the label before applying. Comparing the costs of different brands that may have the same active ingredient and percent of active ingredient is also a good idea.

Considerations for Herbicide Use

- Carefully read and follow all label directions and precautions.
- Use herbicides only on crops for which they are approved and recommended on the label.
- Use the recommended amount of product and apply it as stated. (Too much material may damage the crop and make it unsafe for consumption.)
- Apply herbicides only at times specified on the label and observe the recommended intervals of the time of planting and the time between treatments.
- Follow re-entry intervals (REI) and preharvest 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 beyond 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:

- **Preplant incorporated:** incorporated into the soil prior to seeding or transplanting the crop.
- **Preemergence:** applied to the soil after planting but before the crop or weeds emerge.
- **Post-transplant:** applied to the soil after the crop is transplanted, either before weeds have emerged or after clean cultivation.
- **Postemergence:** applied to weeds after both the weeds and the crop have emerged.
- **Directed postemergence:** applied as a directed or shielded spray postemergence on small weeds in rows of taller crops or in row middles. When using a postemergence herbicide, the entire weed must be covered for maximum control.

Refer to Tables 12.3, 12.4, and 12.5 for more information on using herbicides for eggplant, pepper, and tomato production.

Insect and Mite Pest Management

Aphids

Green Peach Aphid *(Myzus persicae)*
Melon Aphid *(Aphis gossypii)*
Potato Aphid *(Macrosiphum euphorbiae)*

DESCRIPTION

Reference page 76 for green peach, melon, and potato aphid descriptions.

APHID DAMAGE

Aphid feeding may cause yellow spots, water stress, and reduced plant growth rate. If aphid feeding is prolonged, or heavy infestations occur, reduced yield may result. One major concerns with aphids is their ability to transmit plant viruses (see this chapter's "Disease Management"section for information on virus diseases for eggplant, pepper, and tomato).

USU EXTENSION FACT SHEET REFERENCES

- *Aphid Natural Enemies and Biological Control*
- *Aphid Pests on Vegetables*
- *High Tunnel Pest Management - Aphids*

Armyworms

DESCRIPTION AND LIFE HISTORY

Reference page 111 for descriptions and life history of various armyworm species.

Cutworms

DESCRIPTION AND LIFE HISTORY

Reference page 111 for descriptions and life history of various cutworm species.

ARMYWORM AND CUTWORM DAMAGE

MANAGEMENT

Reference page 111 for management of various armyworm and cutworm species.

USU EXTENSION FACT SHEET REFERENCES

- *Cutworms in Vegetable Production*
- *High Tunnel Pest Management - Caterpillars*

Beet Leafhopper *(Circulifer tenellus)*

DESCRIPTION

Adult: Adults are wedge-shaped with a pale green, gray, or tan body and about 3 mm long.
Egg: Eggs are tiny and white.
Nymph: Similar in appearance to the adult but smaller, and wings are not fully developed.

LIFE HISTORY

Beet leafhopper overwinters as mated females on weed hosts and in uncultivated areas in the southern U.S. They migrate or are blown north in early summer. Adults move into cultivated fields when weeds begin to dry up, where they feed and reproduce on suitable host plants. Development from egg hatch to adult can take about 2-3 months. Multiple generations occur each year.

DAMAGE

Adults and nymphs use their piercing-sucking mouthparts to remove plant tissue from leaves and stems of host plants. When leaf hopper infestations are severe, feeding can result in shriveled and burned leaves, referred to as 'hopper burn'. The most severe damage to tomato and pepper crops; however, occurs when the beet leafhopper transmits curly top virus. 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 it does not pass the virus on to its progeny in utero.

MANAGEMENT

Management decisions should be focused on preventing leafhoppers from feeding and spreading the curly top virus.

Cultural:

- *Destroy and remove plant debris.* Weeds or volunteer plants from previous crops can act as overwintering hosts for leafhoppers and the virus. Keep field borders and interiors clear of weeds; this will reduce food sources for incoming infected leafhoppers in the spring and summer.
- *Plant virus-resistant varieties.* Trials in St. George, Utah, showed that the following resistant-labeled varieties performed well: 'Rowpac', 'Roza', 'Salad Master', and 'Colombian'.
- *Plant higher-than-normal density.* This will help to lower the probability that every plant in the field will be infected.
- *Use floating row covers or Reemay fabric.* Reemay is a white mesh, breathable fabric to cover plants and reduce feeding by beet leafhopper and other insects.

Biological:

Few natural enemies of the beet leafhopper have been identified. Research has shown a fly parasitoid (Pipunculidae) attacks beet leafhoppers, but the potential for population reduction is unknown.

Chemical:

The beet leafhopper's wide host range, ability to migrate long distances, and rapid virus transmission when feeding make management with insecticides difficult. Insecticides may prevent some within-field spread, but most applications should be directed toward other hosts, such as weeds, in order to prevent leafhopper spread into the desired crop. However, this method may be costly and have less than ideal results, making cultural control the primary approach to management.

Stink Bugs

DESCRIPTION

Adult: Shield-shaped, 13 to 16 mm long, brown or green adults have with an inverted triangle on the upper back.
Egg: Barrel-shaped, and white when first laid, eggs then darken as they mature. Eggs are laid in clusters of 10-30 on the undersides of leaves.
Nymph: Nymphs resemble adults but are smaller and more rounded with brightly patterned black, red, white, and green bodies.

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 are usually undesirable for the fresh market because the flavors may not be well developed.

MANAGEMENT

Stink bugs are difficult to control because they are strong fliers and readily migrate in and out of vegetable fields and gardens, dispersing by the time plant symptoms appear. In tomatoes, management should begin when fruits are 1 inch in diameter.

Cultural:

- *Monitor for the presence of stink bugs.* Shake foliage over a tray or onto the ground. Count fallen nymphs and adults. Treatment thresholds will vary with plant types and intended use, but generally one-third to one-half of a stink bug per tray shake will result in about 5% damaged fruit.
- *Handpick stink bugs from plants.* In small gardens, handpick adults, nymphs, and eggs from plants. Stink bugs can be squashed or drowned in a bucket of soapy water.

- *Eliminate weedy areas along field borders and within fields and gardens.* Remove weeds, especially along field borders and in the spring and late summer to avoid attracting of stink bugs to vegetable crops.

Chemical:

Small numbers of stink bugs can cause serious damage to fruits and 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.

USU EXTENSION FACT SHEET REFERENCES

- *Brown Marmorated Stink Bug*
- *Brown Marmorated Stink Bug Management for Fruits and Vegetables in Utah*
- *Brown Marmorated Stink Bug - Parasitoids*
- *Brown Marmorated Stink Bug - Predatory Samurai Wasp in Utah*
- *Common Stink Bugs of Utah*

Hornworms

Tomato Hornworm *(Manduca quinquemaculata)*
Tobacco Hornworm *(M. sexta)*

DESCRIPTION

Adults: Grayish-brown with wingspan of 10 to 13 cm. The abdomen sides have five orange-yellow spots. Forewings are longer than hind wings; hin wings have two narrow, dark, zigzag, diagonal lines running from the center.

Egg: Spherical oval-shapes, 1.6 mm in diameter, eggs vary in color from light green turning to white as they mature.

Larva: Cylindrical with five pairs of prolegs and three pairs of thoracic legs, larvae are about 90 mm in length with green bodies with eight white "v"-shaped marks along each side. A black, pointed structure or "horn", is located on the terminal abdominal segment.

Pupa: Pupa are dark brown, elongate-oval with pointed posterior; 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 resembling the handle of a pitcher.

LIFE HISTORY

Adults of tomato hornworm, also known as the five-spotted hawk moth, begin to emerge in late spring to early summer. Adult moths use their long, coiled, tube-like mouthparts to imbibe nectar from flowers. They can be seen hovering above flowers of dusk-blooming plants, resembling hummingbirds in flight. Females deposit eggs individually on the undersides of host plant leaves. Heavy egg deposition is common late in the summer and early fall. Hornworm larvae emerge from eggs after 2-8 days, depending on temperature, and begin feeding. Larvae prefer tomato and tobacco, but will feed on eggplant, pepper, potato, and some species of *Solanum* weeds. Larvae feed for 3 to 4 weeks and then burrow 3-4 inches (8-10 cm) deep into the soil to pupate. In the summer, adult moths will emerge after about 3 weeks and begin the cycle again. Tomato hornworms spend the winter as pupae in the soil. There are one to two generations per year in Utah.

DAMAGE

Hornworm larvae use their chewing mouthparts to feed primarily on leaves but will also eat blossoms, stems, and fruits. Larvae feed initially in the upper part of plants and create dark green or black droppings. As larvae mature, they consume large amounts of plant tissue and can defoliate plants and scar fruits, especially when populations are high.

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 the field after harvest.* Normal tillage practices move pupae to the soil surface, where they freeze during the winter, resulting in up to 90% mortality.

- *Rotate crops.* In sites with high overwintering populations, rotate to crops that are not attacked by hornworms (i.e., non-solanaceous plants).

Biological:

Natural enemies include several species of *Trichogramma* wasp parasitoids and parasitic brachonid wasps. Brachonid wasps oviposit eggs into hornworms, and when the eggs hatch, larvae begin feeding inside. When brachonid larvae are mature, they pupate on the back of the hornworms. Hornworms with pupal cases appear to have white projections on their backs. The wasp *Trichogramma pretiosum* will attack hornworm eggs and is available from commercial insectaries.

Chemical:

Hornworm populations often do not exceed economic thresholds due to predation from natural enemies. Treat for hornworms only if they cause extensive defoliation or feed on fruit. Target young larvae and eggs, as they are easier to kill. Apply insecticides to the foliage for larval suppression.

USU EXTENSION FACT SHEET REFERENCES

- Tomato Hornworm and Tobacco Hornworm

Thrips

Onion Thrips *(Thrips tabaci)*
Western Flower Thrips *(Frankliniella occidentalis)*

Reference page 172 for descriptions and life history of onion and western flower thrips.

DAMAGE ON SOLANACEOUS CROPS

Western flower thrips and onion thrips are the two most common vectors of tomato spotted wilt virus (TSWV) in solanaceous crops. See the TSWV in the "Disease Management" 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, 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.

THRIPS MANAGEMENT

Reference page 172 for management of thrips species.

USU EXTENSION FACT SHEET REFERENCES

- *High Tunnel Pest Management - Thrips*
- *Onion Thrips*
- *Western Flower Thrips*

Tomato Fruitworm *(Helicoverpa zea)*

DESCRIPTION

Reference page 261 for a description of the tomato fruitworm.

DAMAGE

Tomato fruitworm (TFW), also known as the corn earworm, 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. When fruit is present, the tomato fruitworm will often attack fruit without any leaf feeding. 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 disease invasion. Unlike corn, where one larva is found per ear, a single larva can enter several fruits during feeding and development.

MANAGEMENT

Cultural:

- *Monitor with traps.* Place pheromone traps on field perimeters. Traps can be used to indicate relative adult densities and peak activity.
- *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 four to five 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 toward 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.

USU EXTENSION FACT SHEET REFERENCES

- *Corn Earworm*
- *High Tunnel Pest Management - Caterpillars*

Tomato Russet Mite *(Aculops lycopersici)*

DESCRIPTION

Adult: Bodies of adults are cigar-shaped, yellowish-tan or pink, microscopic, and 0.3 mm long.
Egg: Colorless to white, roughly hemispherical and extremely small, eggs require a 100-power or greater magnification to be seen.
Nymph: 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 various 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. Damaged leaves may turn yellow, curl, wither, and fall from plants. Mite feeding on fruits can cause longitudinal cracks and bronze coloration.

MANAGEMENT

Cultural:

- *Use clean transplants.* Inspect transplants carefully to be sure they are free of russet mites.
- *Avoid planting during hot, dry periods.* Stressed seedlings are more vulnerable to attack by the mites.
- *Avoid transplanting seedlings near infested crops or weeds.*
- *Promptly remove or destroy infested plant debris.*
- *Sanitize equipment.* Make sure any tools or equipment used on infested plants are properly cleaned before being used on healthy plants.

Chemical:

Once russet mites are present on plants, insecticide treatment is the primary control option. Apply the insecticide to the undersides of leaves where most mites are located.

Biological:

There are several predatory mites that feed on tomato russet mites; however, there is often a lag time between increase in populations of tomato russet and predatory mites.

Refer to Tables 12.6 and 12.8 for more information on

Solanaceous Crops

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.

Alfalfa Mosaic Virus

CASUAL AGENT

Alfalfa mosaic virus is a single-stranded RNA virus transmitted by several aphid species through feeding.

SYMPTOMS

Infected plants display white-yellow blotches in a mosaic pattern on the foliage. Pepper fruits may have white discoloration that occurs in ring spots. Younger plants become stunted and may produce none to small, deformed fruit. Tomatoes with preexisting fruits often exhibit necrotic spots or blotches. Some plants may be asymptomatic.

DISEASE CYCLE

AMV spreads by aphids feeding on plant tissues with their piercing-sucking mouthparts. The virus is only transferable a short time after its acquisition, but aphids can re-acquire the virus anytime they feed on infected plants.

MANAGEMENT

Chemical control is ineffective, as viral spread occurs too quickly through aphid populations. If possible, avoid planting susceptible crops near alfalfa fields.

Bacterial Canker

(Clavibacter michiganensis subsp. *michiganensis)*

CASUAL AGENT

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. 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. 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 , such as the Utah Plant Pest Diagnostic Lab, for identification (extension.usu.edu/pests/uppdl/index).

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 2 years, and on weeds and volunteer tomatoes. Handling infected plants and then touching healthy plants can spread the bacteria, as does splashing water. The most likely means of spread is during clipping of transplants. One infected out of 10,000 transplants can result in a severe disease outbreak. Some infected seedlings show symptoms and die, but others will remain asymptomatic.

MANAGEMENT

- *Use disease-free seed.*
- *Use clean equipment.* Equipment such as trays, pots, benches, and pruning tools should be cleaned and disinfected after each use. Disinfect tools with a 70% ethanol solution.
- *Avoid overwatering.* Time irrigation so that leaves are dry in the evening.
- *Rotate with nonhost crops for 3 to 4 years.*
- *Remove solanaceous weeds.*
- *Deep plow soil to bury plant debris.*
- *Use copper products on tomato transplants in greenhouses.* Copper-based products have been shown to be effective in greenhouse transplant production for processing tomato, but were ineffective in the field after transplanting.

Bacterial Speck
(Pseudomonas syringae pv. *tomato)*

CASUAL AGENT

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, irregularly shaped brown, necrotic lesions, often surrounded by a yellow halo. On small fruit (about 1 mm in size), round, black, superficial skin lesions develop.

DISEASE CYCLE

The bacteria can be seedborne and 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, using contaminated tools, and 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 2 years to nonhost crops.*

Blossom-End Rot

Blossom-end rot of tomato is caused by calcium deficiency. Blossom-end rot also occurs in peppers, eggplant, and cucurbits.

SYMPTOMS

Brown, enlarged spots develop usually at the blossom end of the tomato or fruit but can sometimes also develop in other areas or internally (without showing external symptoms). Over time, the lesions turn dark and leathery, and may be colonized by mold.

MANAGEMENT

Utah soils generally have plenty of calcium, and calcium additions are not recommended.

Control blossom-end rot by using cultural practices that allow for proper uptake of calcium by the plant.

- *Test soil*. Before planting to determine if an adequate concentration of calcium is available.
- *Use infrequent, deep irrigation.* Keep the soil uniformly moist and avoid water stress of fluctuating soil moisture.
- *Consider using drip irrigation.* This allows for more direct and uniform watering.
- *Do not allow plants to be water stressed at night.*
- *Maintain even soil moisture by using organic or plastic mulch.* Grass clippings/straw/etc. (2-3 inches thick) can be placed around the plant's base to keep the soil cooler and reduce water loss.
- *Avoid overfertilizing.* Do not use ammonium-based nitrogen fertilizers.
- *Avoid injuring roots.* Do not hoe or cultivate near plants. Pull weeds next to plants or use a plastic mulch.
- *Do not overwater, especially in heavy clay soils.*
- *Use foliar sprays*. Anhydrous calcium chloride can reduce symptoms during the growing season but are generally not recommended in Utah.

Black Mold *(Alternaria alternata)*

CASUAL AGENT

Black mold is a late-season and postharvest disease of tomatoes caused by the fungus *Alternaria alternata*.

SYMPTOMS

Brown to black lesions appear on the epidermal tissue of ripe fruit. In warm, humid weather, the fungus sporulates to form a black, velvet-like layer on the surface of the existing lesions.

DISEASE CYCLE

Black mold can appear in the field late in the season after rain or dew. Fungal spores require 3 to 5 hours of moisture to germinate.

MANAGEMENT

- Avoid overhead irrigation later in the season to keep tomato fruits dry.
- Harvest tomato fruit as soon as they ripen.

Beet Curly Top Virus

CASUAL AGENT

Curly top disease of tomato and pepper is caused by beet curly top virus, of the curtovirus group. In recent years, due to molecular identification, it was discovered that there is not just one beet curly top virus, but several viruses with different characteristics causing similar symptoms on tomatoes and peppers. The disease can be devastating on tomatoes and peppers. Other hosts include: beets, chard, spinach, beans, and cucurbits.

SYMPTOMS

Tomato and pepper plants infected with curly top are stunted and have upwards curled, yellow leaves. The veins on the underside of tomato leaves are purple. Infected plants may not produce fruit, or fruit that develops will ripen prematurely. While older plants are less susceptible to the virus, plants that are infected at an early stage may die.

DISEASE CYCLE

The virus is transmitted by the beet leafhopper (*Cicurlifer tennellus*). 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

Managing curly top disease is challenging in part because there are no resistant tomato or pepper varieties available. The following suggestions may help reduce disease incidence.

- *Delay planting by 1 or 2 weeks.* Planting after leafhopper migration has moved through can reduce disease incidence significantly, depending on the area.
- *Manage weeds.* Treating weeds with insecticides can help manage the leafhopper populations on the plants, however, this method is ineffective on 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.

USU EXTENSION FACT SHEET REFERENCES

- *Curly Top of Tomato*

Early Blight *(Alternaria solani)*

CASUAL AGENT

Early blight disease affects tomato and eggplant but not pepper. It is caused by the fungus *Alternaria solani.* Potatoes are also susceptible to early blight.

SYMPTOMS

Lesions can develop on leaves, fruit, and stems. The first foliar symptoms are brown necrotic spots on older leaves 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. When there are numerous or large lesions, the entire leaf may become yellow and fall off, exposing fruit underneath to potential sunscald. Severe infections result in reduced yield and lower-quality of fruit. Seedlings can develop stem infections. Infected seedlings planted in the field either die as stem lesions enlarge, or the plants may be stunted and unproductive. Fruit may also be infected.

Lesions on green or ripe fruit develop near the calyx end and become leathery over time.

DISEASE CYCLE

Optimum conditions for infection occur during warm (78 °F to 84 °F), wet periods of rain, overhead irrigation, or heavy dew. The fungus survives in plant debris in the soil (main source for inoculum) and on seed. After landing on tomato plants, spores only require two hours to germinate and infect the plant. Lesions become evident two to three days later. Spores develop on lesions and are dispersed by wind.

MANAGEMENT

- *Use resistant varieties.* 'Mountain Supreme', 'Mountain Fresh', 'Plum Dandy', 'Mountain Magic', and 'Defiant PhR' have resistance to the disease.
- *Only use pathogen-free seed.*
- *Use crop rotation.* Rotate soil out of all solanaceous crops for at least 2 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.* Employ good soil fertility regimes.
- *Use fungicides.* See Tables 12.7 and 12.9 on fungicides of effective products for controlling of early blight.

Fusarium Root Rot *(Fusarium solani)*

CASUAL AGENT

Fusarium root rot, caused by the fungus *Fusarium solani*, infects the roots of peppers, eggplants, tomatoes, and cucurbits. *F. solani* has what are called "formae speciales," (f. sp.) meaning that these types are very host-specific. For example, *F. solani* f.sp. *eumartii* infects pepper, tomato, eggplant, and potato but does not infect cucurbits. We currently have not identified the forma speciales that occur in Utah.

SYMPTOMS

Infected roots will have reddish-brown lesions along the cortex of the main lateral roots. Vascular discoloration also occurs a few inches above and below these lesions. Foliar symptoms include interveinal chlorosis and necrosis, typically on a single branch. As the disease advances in the roots, the leaves of the entire plant will eventually turn brown and collapse.

DISEASE CYCLE

F. solani can survive in the soil for 2-3 years without a host. The pathogen infects plants through root wounds and is most severe in temperatures ranging from 77 °F to 86 °F.

MANAGEMENT

There are currently no plant varieties fully resistant to Fusarium root rot.

- *Crop rotation*. Rotate to non-host crops for at least 2 years to reduce inoculum buildup in the soil.
- *Practice sanitation*. Prevent the spread of pathogens between the field by thoroughly cleaning mechanical equipment and other tools.
- *Sterilize the soil.* Soil fumigation or solarization treatment may be effective in fields where crop rotation is not an option.

Late Blight *(Phytophthora infestans)*

CASUAL AGENT

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*, infamous for causing the potato famine in Ireland in the 1840s.

SYMPTOMS

All aboveground 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. Eventually, the leaves dry up and die. Severely infected plants can die. On the underside of leaves, white mold becomes visible on the lesions. Infected green fruit has brown or olive-colored lesions and often develops 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 °F and 72 °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 3 days of infection, and plants can collapse so rapidly that they may appear to have been damaged by frost. *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'.
- *Use fungicides.* Tables 12.7 and 12.9 lists effective fungicide products for controlling early blight.

Leaf Mold *(Passalora fulva)*

CASUAL AGENT

Leaf mold is caused by the fungus *Passalora fulva* and exclusively infects tomatoes. It is primarily a disease of plants grown in protected cultivation.

SYMPTOMS

The oldest leaves are infected first. Pale green-yellow spots (1/4 inch) form on the upper side of the foliage and eventually turn completely yellow. As the leaf dies, a velvety mold appears on the underside of the leaf, opposite the spots. Infected blossoms will turn black and fall off. Fruit infections, which include sunken, dry, and leathery skin, have not been observed in Utah.

DISEASE CYCLE

P. fulva overwinters on previously infected plant debris in the soil. Spores form in spring, are spread by wind, water, and tools, and can also be introduced by infected seed. *P. fulva* is most prevalent in relative humidity greater than 85%, and occurs in broad temperature ranges (50 °F to 90 °F).

MANAGEMENT

- *Remove all crop residue at the end of the season.*
- *Use drip irrigation and avoid overhead irrigation.*
- *Allow proper airflow.* Implement proper plant spacing, and stake and prune plants.

Liberibacter
(Candidatus Liberibacter solacearum*)*

CASUAL AGENT

The bacterium, *Candidatus* Liberibacter solanacearum (Lso) is primarily known for causing zebra chip on potato, but can also infect pepper, tomato, eggplant, and carrot. Lso was first identified in Utah in 2014 on potato and pepper. In Utah, it is transmitted by the southwest-native insect, potato psyllid (*Bactericera cockerelli*). The potato psyllid is a small phloem-feeding insect. Adults resemble black winged aphids, while nymphs are flattened, cream-colored with red eyes, and usually feed on the undersides of leaves.

SYMPTOMS

The symptoms vary, depending on plant age and time of infection. Leaves of plants getting infected early in the season often show vein greening. The leaf veins are darker green than normal. It is combined with interveinal chlorosis. New leaves are also stunted and cupped. Some infected plants produce more flowers than normal, but they are often aborted. In addition, the new growth can be stunted and have shortened internodes. Usually no fruit develops after infection. If fruit does develop, it is often deformed. Fruit that develops before infection appears to have normal development but is often pale and of low quality.

DISEASE CYCLE

Potato psyllids acquire Lso by feeding on an infected plant. The bacterium can also be passed on from adult females to progeny. Depending on the number of potato psyllids feeding on an individual plant, infection can occur within 1 to 6 hours.

MANAGEMENT

It is important to start scouting for potato psyllids using yellow sticky cards early in the season. In addition, inspect the underside of leaves for psyllid nymphs. Once a plant is infected with Lso, there is no cure for it. It should be removed to reduce the amount of inoculum present in the field.

- *Choose planting sites carefully.* Avoid planting peppers in an area where potato psyllids have been a problem in the past.
- *Apply insecticides.* Effective active ingredients include imidacloprid at planting, spinosad, and spiromesifen.

USU EXTENSION FACT SHEET REFERENCES

- Candidatus Liberbacter of Pepper

Powdery Mildew
(Leveillula taurica and *Erysiphe lycopercici)*

CASUAL AGENT

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**. 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** 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 for fast, mass dispersal.

Infection occurs in early summer, either from spores released from fruiting structures in plant debris or by spores blown from warmer areas in the south. Spores can be carried by wind currents for hundreds of miles. In contrast to many fungi, powdery mildews do not grow well in rain or free water. For infection, powdery mildews only need high humidity or dew for a few hours. After a spore lands on a suitable plant surface, it germinates, and the germ tube penetrates the tissue and starts growing either on the plant surface (*E. lycopersici*) or within the plant tissue (*L. taurica*). It takes about a week after infection before the first spores are produced and dispersed. Once spores are produced in a field, powdery mildew spreads quickly from plant to plant by wind and on clothes of workers.

MANAGEMENT

Powdery mildew must be controlled early when the first lesion is seen. Once the fungus grows over the leaf tissue or entire leaves are yellow, it is too late to control the disease.

- *Remove infected plant debris from fields before planting a new crop.*
- *Use fungicides.* Apply fungicides throughout the growing season after the first symptoms have developed, according to label directions.

USU EXTENSION FACT SHEET REFERENCES

- *Powdery Mildews on Vegetables*

Root-Knot Nematodes *(Meloidogyne spp.)*

CASUAL AGENT

Root-knot nematodes are microscopic roundworms. Juveniles and male nematodes are wormlike 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. 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 2 to 3 years.*
- *Remove all weeds.* They can host root-knot nematodes.
- *Rototill fallow areas once every 3 to 4 weeks during the hot, dry summer months.* Rototilling 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.

Tobacco Etch Virus (TEV)

CASUAL AGENT

Tobacco etch virus is an aphid-transmitted potyvirus found on pepper plants in Utah.

SYMPTOMS

The virus causes foliage to become severely mottled in coloration and wrinkled. Plants infected early in the season will become stunted and not produce harvestable fruit.

DISEASE CYCLE

Multiple aphid species can transmit the virus from other solanaceous crop and weed hosts. Aphids only need to feed on a TEV-infected plant for a few seconds to pick up the virus. The virus is not transmissible by seed.

MANAGEMENT

- *Remove nearby weeds.* Weed species such as thistle, lambsquarter, sickle pod, jimson weed, black nightshade and others can serve as an alternate host. If possible, allow at least 30 yards between susceptible crops and weeds.
- *Monitor early.* Monitor for infected plants early in the season and remove them.
- *Use insecticides.* Apply insecticide treatments when needed.

Tobacco Mosaic Virus (TMV)
Tomato Mosaic Virus (ToMV)

CASUAL AGENT

Tobacco mosaic virus (TMV) and tomato mosaic virus (ToMV) are two very closely related viruses with similar symptoms. Antibody-based molecular testing is necessary for accurate identification. TMV and ToMV are two of only a few plant viruses that are not transmitted by insects. In contrast to many other plant viruses, TMV and ToMV can survive for up to 50 years in plant debris and for weeks to months on trellises or wooden stakes.

SYMPTOMS

Infected **eggplants** have small leaves with mosaic patterns.

On **pepper**, leaves will grow in the shape of an oak leaf (jalapeño peppers) 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, or the parenchyma layer of cells inside the fruit will turn brown. 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 (extension.usu.edu/pests./uppdl/index).

DISEASE CYCLE

TMV is transmitted by artificial grafting and by contaminated seed. The virus can be spread on pruning tools or by bare hands, such as during sucker pruning or staking. The virus can also be spread by growers' hands that handled tobacco cigarettes or chew that is infected with TMV. If seedlings are planted in pots or beds where previously infected plants grew, they can become infected.

A common mode of TMV infection in greenhouses is through contaminated seed. Once the virus has entered the plant, through wounds as small as torn plant hairs, it spreads though the entire plant, including roots.

MANAGEMENT

TMV and ToMV 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 1 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, this will minimize infection.
- *Use resistant varieties.*
    - TMV-resistant **eggplant** varieties including 'Epic', 'Dusky' and 'Imperial'.
    - TMV- or ToMV-resistant **pepper** varieties include 'Telestar', 'Crusader' and 'Paladin'.
    - There are many TMV- and ToMV-resistant **tomato** varieties. Most heirloom varieties are susceptible to both viruses. Correctly identifying the virus is necessary if using resistant varieties. Some varieties are only resistant to one of the two viruses. Breakdown in resistance of some tomato varieties to the viruses has occurred.

Tomato Spotted Wilt Virus (TSWV)

CASUAL AGENT

Tomato spotted wilt virus (TSWV) is a tospovirus 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 2 years. The virus has over 1,000 known hosts; among them are many weeds that do not show symptoms. Thrips have to acquire the virus as larvae to be able to transmit it to a healthy plant.

Once thrips larvae have acquired the virus, they will transmit it for the rest of their lives.

SYMPTOMS

Symptoms of TSWV vary between plant species and within a species depending on the strain of the virus, time of infection, and plant variety.

TSWV-infected **eggplants** will die back from tips of new shoots, and the fruit will have orange and yellow rings.

Leaf symptoms on **peppers** consist of chlorotic ring spot patterns. Fruit can display blotchiness ranging from green to red or display ring spots similar to tomatoes.

On **tomatoes**, symptoms on leaves consist of brown (necrotic), irregular-shaped spots. Initially, the spots are very small and can be overlooked on young transplants. On green, immature fruit, brown ring spots occur that can also be seen on ripe tomatoes. On some tomato varieties, such as 'Roma' types, the ripe fruits develop blotches of variable colors from yellow to orange and red. 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*.
- *Remove and destroy all infected plants.*
- *Purchase healthy transplants***.** If transplants have suspect brown spots on the leaves, even if it is only one spot, plants should not be used.
- *Use resistant varieties:* (The varieties listed below are not common in Utah suppliers but can be purchased

over the internet.)

- Resistant tomato varieties include 'Jimbo', 'Southern Star', 'Amelia', 'Crista', 'Red Defender', 'Primo Red', and 'Talledaga'.
- Resistant pepper varieties include 'Stileto', 'Heritage', 'Plato' and 'Magico'.
- 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.

USU EXTENSION FACT SHEET REFERENCES

- *Tomato Spotted Wilt Virus of Tomato and Pepper*

Fusarium Wilt
(Fusarium oxysporum f. sp. *lycopersici)*
Verticillium Wilt
(Verticillium dahliae and *V. albo-atrum)*

CASUAL AGENTS

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 solanaceous crops will not infect cucurbit crops and vice versa.

SYMPTOMS

Initial infected plant symptoms include wilting during the hot part of the day, with recovery in the evening. Eventually, the wilt is permanent. Discolored vascular tissue can be seen by cutting through the main stem. 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 partly caused by the fungal growth clogging the phloem and xylem and the plant trying to stop the fungus movement by blocking the colonized vascular tissue.

Fusarium infections are favoured by high soil temperatures (90 °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 °F to 74 °F) and in soils with a high pH, which are very common in Utah. It produces an overwintering structure (survival structure) called a microsclerotium, which is a hard black ball of fungal tissue that can survive for a decade or more in the soil, waiting for a suitable host to be planted.

MANAGEMENT

Both diseases are very difficult to control due to the production of the long-term survival structures in the soil.

- *Use resistant varieties* when available. Resistant tomato varieties are available for *Verticillium* race 1 but not race 2, and for *Fusarium oxysporum* races 1, 2, and 3.
- *Plant on raised beds for better water drainage.*

USU EXTENSION FACT SHEET REFERENCES

- *Fusarium and Verticillium Wilts of Vegetables*

Refer to Tables 12.7 and 12.9 for more information on using fungicides and bactericides for solanaceous crop production.

Solanaceous Crop Pesticides for Commercial and Small-Scale Use

Table 12.3. *Herbicides* Registered for *COMMERCIAL* Use on *Tomato* in Utah

		Application relative to crop				Application for weeds		Weed groups controlled			
Brand name (REI/PHI)	Active ingredient	Before transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded 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 (12hr/30d)	halosulfuron	X		X	X		X		X	X	Helps control nutsedge
Select products (12hr/20d)	clethodim	X	X	X	X		X		X	X	
Spartan (12hr/-)	sulfentrazone	X				X			X	X	Helps controls nutsedge
Treflan products (12hr/-)	trifluralin	X		X		X		X	X	X	
Tricor (12hr/7d)	metribuzin			X	X	X			X	X	Not for direct-seeded
Organic Products											
Corn gluten meal	corn meal	X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus oil	X	X	X			X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 12.4. *Herbicides* *Registered for* ***COMMERCIAL*** *Use on* ***Peppers*** *in Utah*

Brand name (REI/PHI)	Active ingredient	Application relative to crop				Application for weeds		Weed groups controlled			Comments
		Before transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
Aim (12hr/-)	carfentrazone	X	X	X		X			X	X	Use on transplants only
Command (12hr/-)	clomazone	X	X	X		X		X			All peppers but not banana types
Devrinol (12hr/30-60d)	napropamide	X				X		X	X		
Gramaxone Inteon (12hr/30d)	paraquat	X	X	X	X		X	X	X	X	Restricted use product
Poast (12hr/7-20d)	sethoxydim				X		X	X	X		
Prefar 4E (12hr/-)	bensulide	X				X		X			
Prowl H2O (12hr/70d)	pendimethalin	X	X	X	X	X		X	X		
RoundUp and others (12hr/14d)	glyphosate	X	X	X			X	X	X	X	
Sandea (12hr/30d)	halosulfuron	X		X	X		X		X	X	Helps control nutsedge
Select products (12hr/20d)	clethodim	X	X	X	X		X		X	X	
Treflan products (12hr/-)	trifluralin	X		X		X		X	X	X	
Organic Products											
Corn gluten meal	corn meal	X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/clove oil	X	X	X			X	X	X	X	
Worry Free	citrus Oil	X	X	X			X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 12.5. *Herbicides* *Registered for* *COMMERCIAL* *Use on* *Eggplants* *in Utah*

Brand name (REI/PHI)	Active ingredient	Application relative to crop				Application for weeds		Weed groups controlled			Comments
		Before transplanting	Preemergence	Post transplanting directed, shielded	Postemergence	Preemergence	Postemergence	Annual grass	Small-seeded broadleaves	Broadleaves	
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 (12hr/30d)	halosulfuron	X		X	X		X		X	X	Helps control nutsedge
Select products (12hr/20d)	clethodim	X	X	X	X		X		X	X	
Treflan products (12hr/-)	trifluralin	X		X		X		X	X	X	
Organic Products											
Corn gluten meal	corn meal	X	X			X			X	X	
Summerset Alldown	acetic/citric acid	X	X	X			X	X	X	X	
Weed Zap	cinnamon/ clove oil	X	X	X			X	X	X	X	
Worry Free	citrus Oil	X	X	X			X	X	X	X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive but provides examples of products that are registered for use in Utah. Always review the product label for the specific crop you are treating around, targeted weeds, application instructions, and safety information.

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

Table 12.6. *Insecticides* *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
carbaryl	Carbaryl 4L, Drexel Carbaryl 4L, Sevin 4F, Sevin SL Carbaryl,Sevin XLR Plus	1A	10-14		X	X	X	X			X		X	
	Carbaryl Cutworm Bait, Drexel Carbaryl 5% Bait, Sevin 5 Bait				X						X		X	
methomyl	Corrida 29 SL Insecticide, Corrida 90 WSP, Lannate SP, Lanveer LV, Nudrin LV	1A	10-14	X	X			X						
	DuPont Lannate LV Insecticide, Nudrin SP			X	X									
malathion	Drexel Malathion 5EC, Fyfanon 57% EC, Fyfanon Malathion, Malathion 8 Aquamul Malathion 5, Malathion 57%,	1B	5-7	X	X							X		
alpha-cypermethrin	Fastac CS, Fastac EC	3A	10-14	X	X	X	X	X	X		X		X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

[o] = Organic

Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
bifenthrin	Avenger Max, Batallion 10 WSP, Steed, Suro LFC, Tundra EC	3A	2-3 wks	X	X	X	X	X	X	X	X	X	X	
	Batallion 2 EC, Batallion LFC, Bi-Dash 2E, Bifender FC, Bifenthrin 2EC, Bifenture EC, Bifenture LFC, Brigade 2EC, Brigade WSB, Capture LFR, Discipline 2EC, Fanfare 2EC, Fanfare EC, Fanfare ES, GCS Bifenthrin 2EC, GCS Bifenthrin LFC, Lancer FC, Omni Brand Bifenthrin 2EC, Reveal, Skyraider, Sniper, Sniper Helios, Sniper LFR			X	X	X	X		X	X	X	X	X	
	Bifenture LFC			X	X					X		X		
	Swagger, Tempest, Tepera Plus			X	X	X	X		X	X	X		X	
cyfluthrin	Tombstone	3A	10-14	X	X	X	X	X	X	X	X			
	Tombstone Helios			X	X	X	X	X			X			
deltamethrin	Delta Gold 100	3A	14	X	X	X	X	X	X	X	X			
esfenvalerate	Asana XL	3A	10-14	X	X		X	X	X				X	
	S-FenvaloStar			X	X		X		X				X	
fenpropathrin	Danitol 2.4 EC Spray	3A	10-14	X	X		X	X	X			X		
gamma-cyhalothrin	Declare	3A	10-14	X	X	X	X	X	X		X	X	X	

Solanaceous Crops

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O = Organic

Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
lambda-cyhalothrin	Crusader 2ME, Drexel L-C Insecticide, Endigo ZCX, Grizzly Too, Kendo, Kendo 22.8 CS, Kilter, Labamba, Lambda Select, Lambda T, Lambda T-2, Lambda-Cy Ag, Lambda-Cy EC, LambdaStar, LambdaStar 1 CS, LambdaStar Plus, Lamcap II, Lunge, Nufarm Lambda-Cyhalothrin 1 EC, Omni Brand Lambda 1 EC, Paradigm VC, Province II, Ravage, RAVAGE 2.0, Ravage II, Roundhouse 1 EC, Serpent 1 EC, Silencer, Tigris Lambda, Warrior II with Zeon Technology, Willowood Lambda-Cy 1EC	3A	10-14	X	X	X	X	X	X		X	X	X	
permethrin	Arctic 3.2 EC, Perm-UP 3.2 EC, PermaStar AG, Permethrin, Pounce 25 WP	3A	14		X			X						
pyrethrins[O]	EverGreen Crop Protection EC 60-6, PyGanic Crop Protection EC 1.4 II, PyGanic Crop Protection EC 5.0 II, Tersus	3A	5-7	X	X	X	X	X	X	X	X		X	X
	Pyrethrum TR, Pyrus TR			X		X		X			X	X		
zeta-cypermethrin	Cortes Maxx	3A	10-14	X	X	X	X	X	X	X	X		X	
	Hero, Hero EW, Mustang, Mustang Maxx			X	X	X	X	X	X	X	X		X	
	Gladiator			X	X	X	X	X	X	X	X	X	X	

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Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
beta-cyfluthrin	Baythroid XL, Sultrus	3A	10-14	X	X	X	X	X	X	X	X			
acetamiprid	Afflict 30SG, Assail 30SC, Assail 30SG, Assail 70 WP, Intruder Max 70WP, Assail 30SG, Intruder Max 70WP	4A	10-14	X		X					X			
	Anarchy 30SG Insecticide, Anarchy 70WP, Omni Brand Acetamiprid 30 SG, Omni Brand Acetamiprid 70 WP, Savoy EC, Verso 30SG, Verso 70WP			X							X			
	TriStar 8.5 SL			X	X	X					X			
dinotefuran	Certador, Safari 20 SG, Scorpion 35SL, Venom	4A	14	X		X	X				X			
imidacloprid	Acronyx 4 F, Admire Pro, Advise Four, Alias 2F, Alias 4F, Dominion Fruit Tree & Vegetable, Imidashot DF, Lada 2F, Macho 2.0 FL, Macho 4.0, Malice 2F, Mallet 75 WSP, Marathon 1% Granular, Marathon II, Midash 2SC, Mineiro 2 F Flex, Montana 2F, Montana 4F, Nuprid 2SC, Nuprid 4.6F Pro, Nuprid 4F Max, Omni Imidacloprid 4F, Prey 1.6, Provoke, Sherpa, Viloprid FC 1.7, Widow, Willowood Imidacloprid 4SC, Wrangler	4A	10-14	X		X					X			
thiamethoxam	Actara, Flagship 25WG, Platinum 75 SG	4A	14	X		X					X			

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

O = Organic

Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
sulfoxaflor	Transform WG	4C	10-14	X							X	X		
flupyradifurone	Altus, Sivanto 200 SL, Sivanto HL, Sivanto prime	4D	10-14	X		X					X			
spinetoram	Radiant SC	5	10-14		X			X			X			
spinosad[O]	Entrust, Entrust SC, SpinTor 2SC, Success	5	7-10		X			X			X			
	Seduce Insect Bait													X
abamectin	Abacus V, Abacus V6, Abamex, AbbA Ultra, Agri-Mek SC, AVERLAND FC, Enterik 0.7 SC, Epi-Mek 0.15 EC, Timectin 0.15 EC Ag, Willowood Abamectin 0.15LV, Willowood Abamectin 0.7SC, Enterik 0.15 LV, Reaper 0.15 EC, Reaper Advance, Reaper ClearForm	6	14-21							X	X	X		
	Minecto Pro			X	X			X		X	X	X		
emamectin benzoate	Proclaim	6	7-14		X			X			X			
pyriproxyfen	Senstar, Sever 0.86EC, SEVER 35 WSB	7C	14	X										
afidopyropen	Sefina, Inscalis, Ventigra	9D	7	X										
hexythiazox	Hexamite, Hexamite 1AQ Select, Hexcel 50 DF, Hexy 1E, Hexygon IQ, Hexygon Miticide, Onager, Onager Optek, PRONEVA EC, Ruger 1 EC	10A	N/A									X		
etoxazole	Eschaton 5 WDG, TetraSan 5 WDG	10B										X		

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[O] = Organic

Solanaceous Crops

Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
*Bacillus thuringiensis*ᴼ	Biobit HP, XenTari	11A	5-7		X			X	X					
	Bioprotec Plus, BT Now, Crymax, Deliver, DiPel DF, DiPel Pro DF, Javelin WG, Leprotec				X			X	X					
Bacillus thuringiensis subsp. kurstaki, strain ABTS-351ᴼ	Leap ES	11A	5-7		X			X	X	X				
pymetrozine	Achiever, Endeavor, Fulfill, Seville	12	7-10	X										
buprofezin	Talus 70DF	16		X		X								
methoxyfenozide	Acora, Engame, GCS Methoxy 2F, Inspirato 2 F, Intrepid 2F, Invertid 2F, Troubadour 2F, Vexer, Zylo	18	10-14		X			X	X					
acequinocyl	Kanemite 15 SC, Shuttle O	20B								X		X		
bifenazate	Acramite 50WS, Acramite-4SC	20D	14							X	X	X		
	Actuate SC, Banter WDG, Bifenamite 2SC, Bizate 4SC, Bizate 50 WDG, Bizate 50 WSP, Enervate 4 SC, Enervate 50 WDG, Enervate 50 WSB, Engulf GHN, Floramite SC, Vanish WSB, Vigilant 4SC, Vigilant 4SC									X		X		
fenazaquin	Magister SC	21A								X		X		
tolfenpyrad	Hachi-Hachi SC	21A	14	X							X			
	Torac			X	X	X		X			X			
indoxacarb	Avaunt, Avaunt eVo, Comber	22A	14		X			X	X					
spiromesifen	Oberon 2 SC	23	7-14							X		X		
spirotetramat	Kontos, Movento	23	14	X		X					X			

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are registered for commercial use in Utah. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from the TELUS Agronomy Label Database.

ᴼ = Organic

Solanaceous Crops

Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
cyflumetofen	Nealta, Sultan	25A								X		X		
chlorantraniliprole	Coragen, Durivo	28			X	X		X			X			
	Shenzi 400SC							X			X			
cyantraniliprole	Verimark, Exirel	28	10-14	X	X			X			X			
cyclaniliprole	Harvanta 50SL	28	14-17	X	X		X	X			X			
flonicamid	Beleaf 50 SG	29	14	X							X			
GS-omega/kappa-hxtx-hv1a[O]	Spear-LEP	32	5-7		X			X	X	X	X			
	Spear-T Liquid Concentrate			X								X		
azadirachtin[O]	Atrevia 1.2% SL, Atrevia 3.0% SL, AzaGuard, Aza-Direct, AzaSol, Azatin O, Molt-X, Neemix 4.5, Ornazin 3% EC	UN	7-10	X		X	X				X			
canola oil[O]	Captiva Prime	UN	3			X					X			
	Pycana			X	X	X	X	X	X	X	X	X	X	X
cinnamon[O]	Aramite	UN	3	X						X		X		
iron phosphate	Bug-N-Sluggo	UN	2-4 wks											X
sulfur[O]	Acoidal, Cosavet DF Edge, Crusade DF, Drexel Sulfur 80 WDG, Microthiol Disperss, Sulfur Dry Flowable, Thiolux	UN	7-10							X		X		
Chromobacterium[O]	Grandevo	UN	5-7	X	X			X			X			
	Grandevo WDG			X	X		X	X			X			
heat-killed *Burkholderia* spp, strain A396[O]	Venerate CG	UN	7-10	X	X	X	X	X			X	X		
	Venerate XC			X	X		X	X			X			
cinnamon oil[O]	Cinnerate	UN	3	X					X		X	X		
neem oil[O]	Rango, Trilogy	UN	3	X							X	X		
	EcoWorks EC			X						X	X	X		

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[O] = Organic

Table 12.6., continued. ***Insecticides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Products	MoA	Residual days	Aphid	Armyworm/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitworm	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
corn oil^{O}	PureCrop1	UN	3	X							X	X		
garlic oil^{O}	Captiva	UN	3	X		X				X	X	X		
geraniol^{O}	Brandt Ecotec Plus	UN	3	X		X					X			
	Wrath			X		X	X				X			X
Beauveria bassiana^{O}	BioCeres WP	UN	5-7	X							X			
	BotaniGard 22WP, BotaniGard ES, BoteGHA ES, Mycotrol ESO			X	X	X	X			X	X	X	X	
	BotaniGard Optima ES			X	X							X	X	
	BoteGHA Optima ES, Mycotrol Optima ESO, Mycotrol WPO			X	X	X	X				X	X	X	
Isaria fumosorosea strain FE 9901^{O}	Nofly WP	UN	5-7	X		X					X	X	X	
	Preferal			X							X	X		
Metarhizium anisopliae Strain F52^{O}	Lalguard M52 OD	UN	7	X							X			
	Met 52 EC										X			
kaolin^{O}	Surround WP	UN	5-7			X					X		X	
mineral oil^{O}	BioCover MLT, BioCover SS, BioCover UL, Omni Supreme Spray, PureSpray Green, SuffOil-X, TriTek	UN	3	X						X	X	X		
	Glacial Spray Fluid, Ultra-Pure Oil			X		X					X			
paraffinic oil^{O}	JMS Stylet-Oil	UN	3			X								
potassium salts of fatty acids^{O}	Des-X, Kopa Insecticidal Soap, M-Pede	UN	5-7	X		X					X	X		
potassium silicate	Carbon Defense, Sil-Matrix LC	UN	7	X										
sodium tetraborohydrate decahydrate	Prev-AM, Prev-AM Ultra	UN	10-14	X	X	X								

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^{O} = Organic

Solanaceous Crops

Table 12.7. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Early blight	Late blight	Powdery mildew
flutriafol	Rhyme	3				X		X
mefentrifluconazole	Provysol	3				X		
	Veltyma					X	X	X
myclobutanil	Rally 40W	3	14					X
tebuconazole	Orius 3.6F	3	7-14					X
	Felcura 3.6 F, Omni Tebuconazole 3.6F, Toledo 3.6F, VIBE, Tebu-Crop 3.6F, Tebuconazole 3.6 Select, Tebuzol 3.6F, Willowood Teb 3.6SC					X		X
tetraconazole	Affiance, Mettle 125 ME	3				X		X
triflumizole	Terraguard SC, Terraguard SC, Trionic 4SC	3	14					X
boscalid	Bonafide, Endura	7	7-14			X		
	Pageant, Intrinsic, Pompa					X		X
fluopyram	Velum Prime	7	5			X		X
fluxapyroxad	Tesaris	7				X		X
penthiopyrad	Fontelis	7				X		X
pydiflumetofen	Postiva	7				X		X
cyprodinil	Inspire Super, Xuvance, Xuvia	9	7-10			X		X
pyrimethanil	Scala SC	9				X		
azoxystrobin	A-Zox 25SC, Acadia ESQ, Acadia LFC, Aframe, Atticus Acadia 2 SC, Azoxy 50WDG Select, AzoxyStar, Azoxyzone, Azterknot, Azteroid FC 3.3, Drexel Azoxystrobin SC, GCS Azoxy 2SC, Heritage, Heritage SC, Mazolin, Mazolin 50WDG, Mika SC, Mural, Quadris, Satori, Tetraban Fungicide, Tigris Azoxy 2 SC, Topguard EQ, Trevo, Trevo DCZ, Trevo Elite, Tycoon	11	10-14			X		X
	Cadera					X	X	X
	Dexter Max				X	X		
fenamidone	Reason 500 SC	11	5-7			X	X	
fluoxastrobin	Aftershock, Evito 480 SC, Tepera, Tepera Plus HD	11				X	X	

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Table 12.7., continued. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Early blight	Late blight	Powdery mildew
pyraclostrobin	Cabrio EG, Innliven Elite	11	7-10			X	X	
	Empire					X		
	Innliven TRZ, Priaxor, Xemium					X	X	X
trifloxystrobin	Flint Extra, Flint, Gem 500 SC	11				X	X	X
fludioxonil	Alterity 62.5 WG, Emblem, Miravis Prime, Spirato GHN, Switch 62.5 WG	12	7-10			X		X
cyazofamid	Ranman 400SC Fungicide, RenaZ SC, Zilker SC	21	14				X	
tolfenpyrad	Hachi-Hachi SC, Torac	21A	14					X
zoxamide	Gavel 75DF	22			X	X	X	
streptomycin sulfate	Agri-Mycin 50	25	3-4		X			
	FireWall 50 WP			X	X			
cymoxanil	Tanos	27	5-7	X	X	X	X	
propamocarb hydrochloride	Previcur Flex	28	7-14			X	X	
mono- and dipotassium salts of phosphorous acid[O]	OxiPhos	33	1-3 wks		X			X
dimethomorph	Forum	40	7-10				X	
mandipropamid	Micora, Orondis Ultra (Premix), Revus	40	7-10				X	
fluopicolide	Presidio	43	7-14				X	
oxathiapiprolin	Orondis Opti A	49					X	
metrafenone	Vivando	50						X
pyriofenone	PROLIVO 300SC	50						X
Banda de Lupinus albus doce (BLAD)[O]	ProBlad Verde	BM1					X	X
	Fracture							X
canola oil[O]	Pycana	BM1	3					X
neem oil[O]	EcoWorks EC, Rango, Trilogy	BM1	3					X
corn oil[O]	PureCrop1	BM1	3					X
extract of *Swinglea glutinosa*[O]	EcoSwing	BM1	5-7					X
soybean oil[O]	Bionatrol-M	BM1	3					X

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[O] = Organic

Table 12.7., continued. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Early blight	Late blight	Powdery mildew
Bacillus amyloliquefaciens strain D747[O]	Double Nickel 55, Double Nickel LC, Serife, Triathlon BA	BM2	5-7		X	X	X	X
	Stargus					X	X	X
Bacillus mycoides isolate J[O]	LifeGard LC, LifeGard WG	BM2	7		X	X	X	
Bacillus pumilis strain QST 2808[O]	Sonata	BM2	7			X	X	X
Bacillus subtilis strain IAB/BS03[O]	Aviv, Milagrum Plus, Taegro 2	BM2	5-7		X	X	X	X
Bacillus subtilis strain QST 713[O]	Cease, Rhapsody, Serenade MAX	BM2	5-7		X	X	X	X
	Serenade ASO			X	X	X	X	X
	Serenade Opti WP				X	X	X	
bacteriophage[O]	AgriPhage-CMM	BM2		X	X			
Clonostachys rosea Strain J1446[O]	Lalstop G46 WG	BM2	5-7					X
Streptomyces lydicus WYEC 108[O]	Actinovate AG	BM2	5-7		X	X	X	
Streptomyces sp. Strain K61[O]	Mycostop, PreFence	BM2	5-7			X		
copper hydroxide	Champ Dry Prill, Champ Formula 2 Flowable, Champ WG, ChampION++, Kocide 2000, Kocide 3000, Kalmor, Kocide 50DF, Kocide HCu, Nu-Cop 30 HB, Nu-Cop 50 DF, Nu-Cop HB, Previsto	M1	7		X	X	X	
	Mankocide				X	X	X	
copper octanoate	Camelot O, Cueva, Grotto	M1	10		X	X	X	
copper oxychloride	Badge X2	M1	7	X	X	X	X	
	Badge SC			X	X	X	X	
	C-O-C-S WDG					X	X	
copper sulfate	Basic Copper 53, Cuprofix Ultra 40 Disperss, Cuproxat FL	M1	7		X	X	X	
copper sulfate pentahydrate	CS 2005, ET-F	M1	7		X	X	X	
	MasterCop				X	X	X	X

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Table 12.7., continued. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Early blight	Late blight	Powdery mildew
mancozeb	Dexter Max, Dithane F-45 Rainshield, Dithane M45, Fortuna 75 WDG, Manzate Max, Manzate Max, Manzate Pro-Stick, Penncozeb 75DF, Protect DF, Roper DF, Roper DF Rainshield, Penncozeb 80WP	M3	7-10		X	X	X	
chlorothalonil	Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Catamaran, Drexel Chlorothalonil 720, Echo 720, Echo Zn, Eluvium, Equus 720 SST, Initiate Zn, Omni Chlorothalonil 720 SC, Orondis Opti B, Praiz, Rialto 720 F, Zing!, Bravo ZN, Echo 90 DF, Initiate 720, Oranil 6L, Orondis Opti (Premix), Praiz NG	M5	7-14			X	X	
hydrogen peroxide	OxiDate 2.0, ZeroTol 2.0	NC	7				X	X
mineral oil[O]	PureSpray Green, Ultra-Pure Oil, SuffOil-X, TriTek	NC	3					X
peroxyacetic acid	Jet-Ag, Jet-Ag 5%	NC	7					X
	OxiDate 5.0, Rendition				X	X	X	X
polyoxin D zinc salt[O]	Affirm WDG, Ph-D	19	5-7			X		X
	OSO 5%SC					X	X	X
potassium bicarbonate[O]	Carb-O-Nator	NC	5-7			X		X
	Kaligreen, MilStop, MilStop SP							X
potassium salts of fatty acids[O]	Des-X, Kopa Insecticidal Soap, M-Pede	UN	5-7					X
potassium silicate[O]	Sil-Matrix LC	NC	7					X
sodium carbonate peroxyhydrate	TerraCyte Pro	NC						X
sodium tetraborohydrate decahydrate	Prev-AM Prev-AM Ultra	NC	10-14				X	X
ziram	Ziram Granuflo, Ziram 76DF, Ziram XCEL	NC				X		
extract of *Reynoutria sachalinensis* [O]	Regalia CG, Regalia	P5	7-10		X	X	X	X

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Solanaceous Crops

Table 12.7., continued. ***Fungicides and Bactericides*** *Registered for* ***COMMERCIAL*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Primary active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Early blight	Late blight	Powdery mildew
mono- and dipotassium salts of phosphorous acid[O]	Fungi-Phite, Reliant, Sparra, Fosphite, Rampart	P7	1-3 wks					X
	K-Phite 7LP						X	X
chitosan	WarHammer	UN	2-8 wks					X
cyflufenamid[O]	Fastback, Torino	UN	7-10					X
sulfur[O]	Acoidal, Crusade DF, Sulfomex, That Flowable Sulfur, Thiolux, Cosavet DF Edge, Microthiol Disperss Micronized Wettable Sulfur, Sulfur Dry Flowable	UN	7-10					X
paraffinic oil[O]	JMS Stylet-Oil	UNM	3					X

Solanaceous Crops

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Table 12.8. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworms/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitwrom	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
bifenthrin	GardenTech Sevin Insect Killer Dust, Ferti-lome Broad Spectrum Insecticide RTS	3A	2-3 wks	X	X	X	X	X	X	X	X	X	X	X
	Ferti-lome Broad Spectrum Insecticide			X	X	X				X	X	X	X	X
	Hi-Yield Vegetable & Ornamental Insect Control Granules			X	X	X	X	X		X	X	X	X	X
	Bonide Eight Flower & Vegetable Soil Insect Granules			X	X	X	X	X	X		X		X	X
zeta-cypermethrin	GardenTech Sevin Insect Killer Concentrate, GardenTech Sevin Insect Killer RTS	3A	10-14	X	X	X	X	X	X		X		X	X
lambda-cyhalothrin	GardenTech Sevin Insect Killer RTU, Spectracide Triazicide Insect Killer for Lawns & Landscapes RTU	3A	10-14	X	X	X	X	X	X		X		X	X
bifenthrin + zeta-cypermethrin	GardenTech Insect Killer Lawn Granules	3A	2-3 wks	X	X	X	X	X	X	X	X	X	X	X
permethrin	Hi-Yield Garden & Farn Insect Control, Bonide Insect Control Garden Dust, Bonide Eight Vegetable, Fruit, & Flower Concentrate, Bonide Eight Yard & Garden RTS	3A	14	X	X	X	X	X	X		X		X	X
	Hi-Yield Garden, Pet, & Livestock Dust				X	X	X	X	X		X		X	X
deltamethrin	Ortho Insect Killer Flower & Vegetable Garden Dust	3A	14	X	X	X	X	X	X		X		X	X
pyrethrins°	Monterey Bug Buster-O	3A	5-7	X	X	X	X	X	X		X		X	X
	Bonide Pyrethrin Garden Spray Concentrate			X	X	X	X	X	X	X	X	X	X	X
cyfluthrin	BioAdvanced Tomato & Vegetable Insect Killer RTU	3A	10-14	X	X	X	X	X	X		X		X	X
	BioAdvanced Tomato & Vegetable Insect Killer RTS			X	X	X	X	X	X		X			X
pyrethrins° + potassium salts of fatty acids°	Safer Brand Insecticidal Soap + Pyrethrin Concentrate	3A/UN	5-7	X	X	X	X		X		X	X		X

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° = Organic

Solanaceous Crops

Table 12.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworms/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitwrom	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
pyrethrins[o] + neem oil[o]	Ferti-lome Triple Action Plus RTU, Fertilome Triple Action	3A/ UN	5-7	X	X	X	X	X	X	X	X	X	X	X
pyrethrins[o] + canola oil[o]	Espoma Organic Insect Control	3A/ UN	5-7	X	X	X	X	X	X	X	X	X	X	X
malathion	Hi-Yield 55% Malathion Spray, Bonide Malathion Concentrate	3B	5-7	X								X		
	Ortho MAX Malathion Insect Spray Concentrate			X		X					X			
	Spectracide Malathion Insect Spray Concentrate			X							X	X		
imiclacloprid	Monterey Fruit Tree & Vegetable Systemic Soil Drench, BioAdvanced Fruit, Citrus, & Vegetable Insect Control Concentrate	4A	N/A	X		X					X			
spinosad[o]	Natural Guard Spinosad Concentrate, Natural Guard Spinosad RTS, Monterey Garden Insect Spray, Bonide Captain Jack's Deadbug Brew Concentrate, Bonide Captain Jack's Deadbug Brew Dust, Bonide Colorado Potato Beetle Beater	5	7-10	X				X	X		X			
Bacillus thuringiensis var. Kurstaki[o]	Safer Brand Caterpillar Killer Spray With Bt, Safer Brand Caterpillar Killer II Concentrate, Natural Guard Caterpillar Killer Spray with Bt RTU, Ferti-lome Dipel Dust Biological Insecticide	11	5-7		X			X	X					
Bacillus thuringiensis[o]	Monterey B.T., Monterey B.T. RTU, Bonide Captain Jack's Bt, Bonide Thuricide (Bt) Concentrate	11	5-7		X			X	X					
sulfur[o]	GardenTech Sevin Sulfur Dust	11A	7-10		X			X	X					

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Table 12.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworms/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitwrom	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
sulfur[o] + pyrethrins[o]	Ortho Insect, Mite, Disease 3-in-1 RTU, Natria Insect, Disease, and Mite Control RTS, Natria Insect, Disease, and Mite Control RTU, BioAdvanced Fruit & Vegetable 3-in-1 Solution RTU, BioAdvanced Fruit & Vegetable 3-in-1 Solution Concentrate	UN/ 3A	10-14	X	X	X	X	X	X	X	X	X		X
canola oil[o]	Natural Guard Horicultural Oil Concentrate, Natural Guard Horticultural Oil RTS	UN	3	X						X		X		
cotton seed oil[o] + clove oil[o] + garlic oil[o]	Bonide Mite X RTU	UN	3	X						X		X		
neem oil[o]	Natural Guard Neem Concentrate, Natural Guard Neem RTU, Monterery 70% Neem Oil, Natria Neem Oil Concentrate, Natria Neem Oil RTU, BioAdvanced Organics Neem Oil RTU, Espoma Organic Neem Oil 3-in-1	UN	3	X						X	X	X		
	Monterey Neem Oil RTU			X						X		X		
potassium salts of fatty acids[o]	Natural Guard Insecticidal Soap,	UN	5-7	X		X				X	X	X		X
	Monterey Insecticidal Soap RTU			X						X	X	X		
	Bonide Insecticidal Soap RTU			X						X	X	X		X
	Natria Insecticidal Soap RTU			X						X	X	X	X	X
	BioAdvanced Organics Insecticidal Soap RTU			X						X	X	X		X
potassium salts of fatty acids[o] + seaweed extract[o]	Safer Brand Insect Killing Soap RTU Spray	UN	5-7	X						X	X	X		
potassium salts of fatty acids[o] + neem oil[o]	Safer Brand RTU End ALL Insect Killer	UN	5-7	X						X	X	X		X
iron phosphate + spinosad[o]	Natural Guard Bug, Slug, and Snail Bait, Monterey Sluggo Plus, Bonide Captain Jack's Bug & Slug Killer	UN/5	2-4 wks		X									X

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[o] = Organic

Solanaceous Crops

Table 12.8., continued. ***Insecticides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Aphid	Armyworms/cutworm	Beet leafhopper	Stink bug	Hornworm	Tomato fruitwrom	Tomato russet mite	Thrips	Spider mite	Grasshopper	Earwig
potassium salts of fatty acids° + spinosad°	Natural Guard Spinosad Soap RTU, Natural Guard Spinosad Soap Concentrate, Natural Guard Spinosad Soap RTS, Bonide Insecticidal Super Soap RTU	UN/5	5-7	X	X	X		X	X	X	X	X		X
	BioAdvanced Organic Tomato Vegetable, & Fruit RTU, Monterey Garden Insect Spray RTU			X	X	X		X	X		X	X		X
potassium salts of fatty acids° + sulfur°	Safer Brand 3-in-1 Concentrate, Safer Brand 3-in-1 RTU Garden Spray	UN	7-10	X						X	X	X		X
	Safer Brand Tomato & Vegetable 3-in-1 Garden Spray			X		X		X	X		X	X		X
mineral oil°	Safer brand Horticultural & Dormant Spray Oil Concentrate	UN	3	X							X	X		
silicon dioxide	Natural Guard Diatomaceous Earth Crawling Insect Control	UN	7-14										X	X
	Bonide Diatomaceous Earth			X	X	X	X	X	X	X	X	X	X	X

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° = Organic

Solanaceous Crops

Table 12.9. ***Fungicides and Bactericides*** *Registered for* ***SMALL-SCALE*** *Use on* ***Solanaceous Crops*** *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Black mold + fruit rot	Early blight	Late blight	Leaf mold	Powdery mildew
copper octanoate	Bonide Captain Jack's Liquid Copper Fungicide Concentrate, Bonide Captain Jack's Liquid Copper Fungicide RTS, Bonide Captain Jack's Liquid Copper Fungicide RTU, Epsoma Organic Copper Soap RTU, Monterey Liquid Copper Fungicide RTU, Natural Guard Copper Soap Fungicide Concentrate, Natural Guard Copper Soap Fungicide RTU	M1	10	X	X		X	X	X	
copper sulfate	Bonide Copper Fungicide Spray/ Dust	M1	7	X	X		X	X		
sulfur°	Bonide PLant Fungicide Dust, GardenTech Sevin Sulfur Dust 2-in-1 Disease & Insect Control, Safer Garden Fungicide Concentrate, Safer Garden Fungicide RTU	M2	7-10							X
sulfur + pyrethrins°	Natria Insect, Disease, & Mite Control RTS, Natria Insect, Disease, & Mite Control RTS	M2/ 3A	10-14							X
mancozeb	Bonide Mancozeb Flowable w/ Zinc Concentrate	M3	7-10		X		X		X	
chlorothalonil	Bonide Fung-onil Concentrate, Bonide Fung-onil RTU	M5	7-14			X	X	X	X	
	Ferti-lome Broad Spectrum Landscape & Garden Fungicide, Ferti-lome Broad Spectrum Landscape & Garden Fungicide RTU, GardenTech Daconil Fungicide Concentrate, GardenTech Daconil Fungicide RTU, Hi-Yield Vegetable, Flower, Fruit, and Ornamental Fungicide					X	X		X	

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for personal use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from various major home-use pesticide suppliers.

° = Organic

Table 12.9, continued. *Fungicides and Bactericides* Registered for *SMALL-SCALE* Use on *Solanaceous Crops* *(Tomatoes, Peppers, Eggplants, etc.) in Utah, Organized by Mode of Action (MoA)*

Active ingredient	Brand name	MoA	Residual days	Bacterial canker	Bacterial speck	Black mold + fruit rot	Early blight	Late blight	Leaf mold	Powdery mildew
myclobutanil	Ferti-lome F-Stop Lawn & Garden Fungicide Concentrate, Ferti-lome F-Stop Lawn & Garden Fungicide RTS	3	14			X	X			X
propiconazole	Bonide INFUSE Disease Control Concentrate	3	14			X				X
pyrethrins[O]	Ferti-lome Triple Action O, Ferti-Lome Triple Action RTS, Ferti-lome Triple Action Plus RTU	3A	5-7							X
Bacillus amyloliquefaciens strain D747[O]	Bonide Revitalize Bio Fungicide Concentrate, Bonide Revitalize Bio Fungicide RTU	MBCA	5-7		X	X			X	X
neem oil[O]	BioAdvanced Organics Neem Oil RTU, Epsoma Organic Neem Oil 3n1, Monterey Neem Oil RTU, Natria Neem Oil Concentrate, Natria Neem Oil RTU, Natural Guard Neem Concentrate O, Natural Guard Neem RTU, Safer Neem Oil Concentrate, Safer Neem Oil RTU	UN	3							X
mineral oil[O]	Monterey Horticultural Oil O, Monterey Horticultural Oil O, Safer Horticultural + Dormant Spray Oil Concentrate	UN	3							X
mono- and dipotassium salts of phosphorous acid[O]	Monterey Garden Phos Concentrate	UN	1-3 wks							X
potassium salts of fatty acids[O] + sulfur[O]	Safer Tomato & Vegetable 3-in-1 RTU O	UN/ M2	7-10							X

Note: All products listed in this table are registered trademarks. The list is not all-inclusive, but provides examples of products that are available for personal use. Always review the product label for the specific crop you are treating, targeted pests, safety information, and preharvest intervals. All product information was sourced in 2023 from various major home-use pesticide suppliers.

[O] = Organic


Small-scale tomato production in Grand County.


Commercial pepper production in Weber County.

Symptoms of nitrogen deficiency in tomatoes.

Symptoms of nitrogen deficiency in peppers.

Symptoms of nitrogen deficiency in eggplants.


Blossom end rot in tomatoes.


Shade cloth used in commercial tomato production.


Sunscald damage on pepper.

Winged aphids on tomato plant.

Yellow-striped armyworm *(Spodoptera ornithogalli)* feeding on tomato fruit.

Army cutworm *(Euxoa auxiliaris)* feeding on tomato stem.

Beet Leafhopper *(Circulifer tenellus)*

Stink bug (*Thyanta* sp.) feeding on tomato fruit.

Stink bug nymph feeding on tomato fruit.

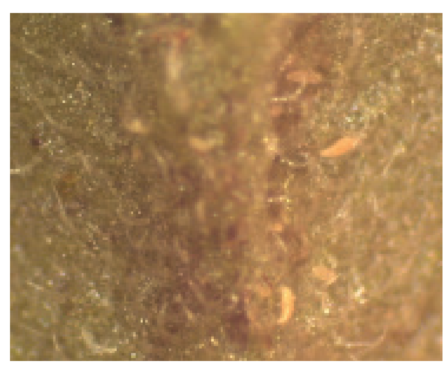
Tomato Hornworm *(Manduca quinquemaculata)*

Tobacco Hornworm *(Manduca sexta)*

Thrips on tomato foliage.

Thrips flecking damage on tomato.

Tomato Fruitworm *(Helicoverpa zea)*



Tomato Russet Mite *(Aculops lycopersici)*

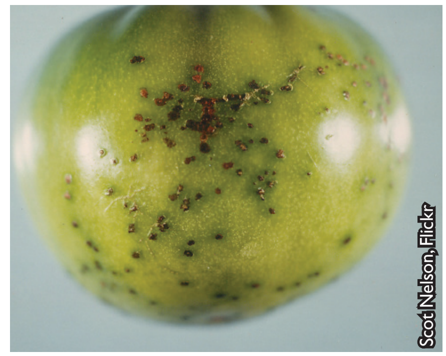

Tomato russet mite damage.


Pepper infected with alfalfa mosaic virus.

Bacterial Canker *(Clavibacter michiganensis* ssp. *michiganensis)*

Bacterial canker symptoms on tomato stem.

Bacterial Speck *(Pseudomonas syringae* pv. *tomato)*



Bacterial Speck

Black Mold *(Alternaria alternata)*


Tomato infested with beet curly top virus.


Early blight *(Alternaria solani)* symptoms on tomato foliage.


Fusarium Root Rot *(Fusarium solani)*

Leaf mold *(Passalora fulva)* on tomato foliage.


Liberibacter symptoms (*Candidatus* Liberibacter solacearum) in pepper.

Powdery mildew *(Leveillula taurica)* on tomato foliage.

Nematode damage on tomato roots.

Tomato infected with tobacco etch virus.

Tomato fruit symptoms of tomato mosaic virus.

Tomato foliar symptoms of tomato mosaic virus.

Pepper fruit symptoms of tomato spotted wilt virus.

Tomato foliar symptoms of tomato spotted wilt virus.

Vascular discoloration from verticillium wilt.

Foliar symptoms in tomato from verticillium wilt.

CHAPTER 13: 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 (EPA) 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 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. Private applicators are persons who uses (or supervises the use of) restricted use pesticides on agricultural lands owned or rented by themselves or their employer. Private applicators may not apply restricted use pesticides on another person's property if they are to receive monetary compensation. Commercial applicators are defined as persons who use or supervise the use of any pesticides for monetary compensation. Both categories require an applicator's license; however, the testing and recertification differ between the two.

Applicants can pick up study materials at the Utah Department of Agriculture and Food (UDAF) in Salt Lake City or any UDAF District Field Office. Make an appointment to take the exam, and allow 2 hours.

- Private applicators' exams (general and agriculture) are open-book, and the fee is $20. Upon passing, the license will last 3 years. To recertify, applicants can retake the exams or obtain 9 total CEU units.
- Commercial applicators' exams cost $65, and the license lasts three years. Business owners must also obtain a Commercial Pesticide Business license or get a Non-Commercial license if this does not apply. The applicant must achieve 70% to pass. To recertify, applicants can retake 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
ag.utah.gov/farmers/plants-industry/pesticides

Pesticide Recordkeeping

Federal laws require that private and commercial applicators maintain pesticide records for all applications of restricted use products for at least 2 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 of making the application, and must include:

1. Name and address of property owner.
2. Location of treatment site (if different than contact information), crop treated, and area size.
3. Target pest.
4. Exact application date.
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 federal standards require worker notification of all pesticide applications, we recommend keeping comparable records of all pesticide applications. This will enable you to complete a pesticide list at harvest time. 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 nontarget 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 UDAF received approval from the EPA for its Groundwater and Pesticide State Management Plan. The plan outlines strategies to protect groundwater from pesticide contamination and response to detecting a pesticide or pesticides in groundwater.

If pesticide detection in groundwater is confirmed, Pesticides 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 UDAF.

The UDAF will work with the landowner to prevent further groundwater contamination. A number of different farming practices, called best management practices (BMPs), and simple devices can significantly reduce the possibility of pesticides entering the groundwater system. BMPs will be required by the EPA as a condition of future pesticide use.

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. Keep the storage facility 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 with original labels and closed tightly. 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 products. 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 according to their labeled instructions. The UDAF occasionally holds pesticide disposal drop-offs with no questions asked.

Pesticide Use

Using 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 product effectiveness. However, selection must be done with care, considering all the factors that may affect spray performance. Using 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 the amount and type of adjuvant needed will vary with the water's hardness and pH. 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. Using 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 1,000 square feet) 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 13.1 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 or 1,000 square feet), 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 are 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 mililiters. Instead, use a graduated medicine spoon. When measuring out small amounts, you will need to use a syringe, which is 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.

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.

Table 13.1. *Conversion Values for Preparing 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 lb (1,814.3 grams)	90.7 g or 3.19 oz	54.4 g or 1.92 oz	18.1 g or 0.63 oz
	2 lb (907.2 g)	45.4 g or 1.659 oz	27.2 g or 0.95 oz	9.1 g or 0.32 oz
	1 lb (453.6 g)	22.7 g or 0.79 oz	13.6 g or 0.48 oz	4.5 g or 0.16 oz
	8 oz (226.8 g)	11.3 g or 0.39 oz	6.8 g or 0.24 oz	2.3 g or 0.08 oz
	4 oz (113.4 g)	5.7 g or 0.2 oz	3.4 g or 0.11 oz	1.1 g or 0.04 oz
	2 oz (66.7 g)	2.8 g or 0.06 oz	1.7 g or 0.05 oz	0.6 g or 0.02 oz
Liquids: Liquid or emulsifiable concentrates, & liquid flowables	1 gal (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.

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 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. Consider the following example label and product information explanations.

Product Information

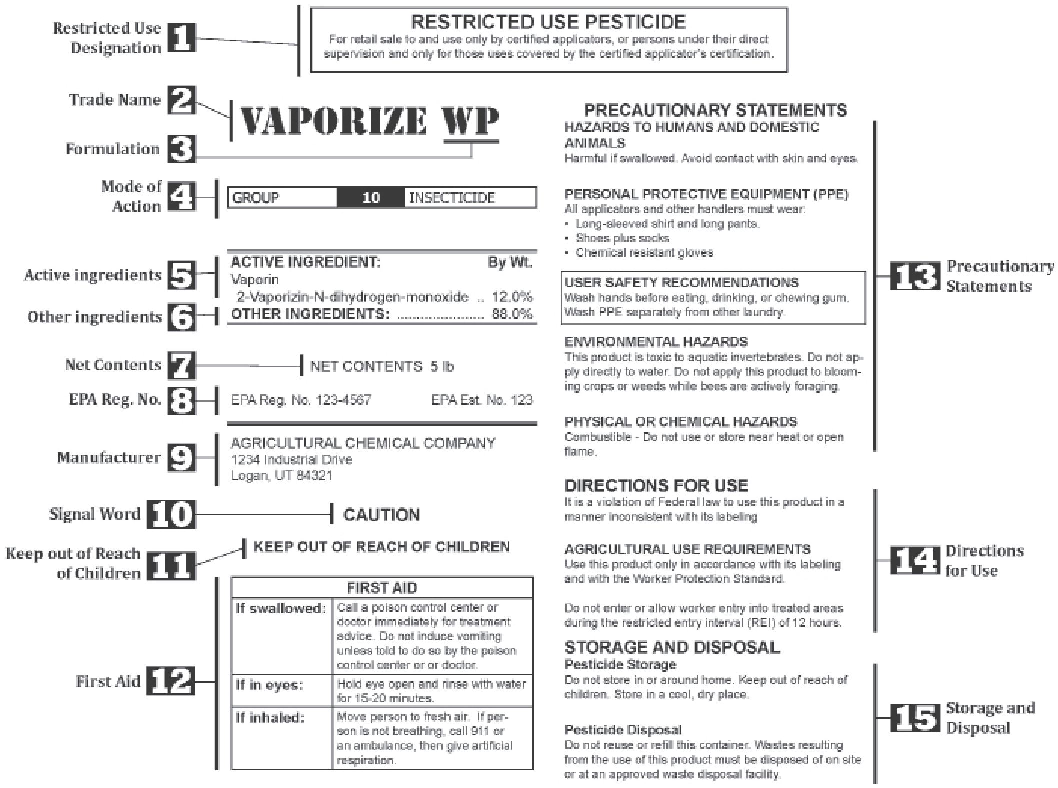
1 ***Product Classification:*** When a pesticide is classified as restricted, the label will state "restricted use pesticide" at the top of the front panel. Below this heading may be a reason for the restriction. To purchase and apply restricted use pesticides, you must be certified and licensed through the UDAF.

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):** This is an oil-based liquid solution plus an emulsifier that, when mixed with water, forms a milky solution. It requires moderate agitation, and is easily handled and applied.

FRONT PANEL



- **Flowable (or liquid) (F or L):** The active ingredient has been imbedded in an inert solid and ground to a fine powder. It requires moderate agitation, and is easy to handle and apply.
- **Solution (S):** The active ingredient mixes readily with liquid and does not separate.
- **Wettable powder (WP):** This dust-like formulation does not dissolve in water and must be constantly agitated to remain in suspension.
- **Soluble powder (SP):** This powder formulation readily forms a suspension in water; it is a rare formulation because few pesticide active ingredients are soluble in water.
- **Water dispersible granules (or dry flowables) (WDG or DF):** These small granules, when mixed with water, disperse to fine particles. It requires constant agitation.
- **Water soluble packets (WSP):** A wettable or soluble powder that has been premeasured 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.

Chapter 13: Pesticide Information

Safety and Environmental Information

10 ***Signal Word:*** Each pesticide label has a "signal word."

- **Danger - Poison:** Accompanied by a red skull and crossbones, this 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:** This is corrosive and can cause irreversible eye damage or skin injury.
- **Warning:** This is moderately toxic and can cause moderate eye or skin irritation. Wash thoroughly with soap and water after handling.
- **Caution:** While mildly toxic, it 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 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:** These suggestions include information on proper washing after handling the pesticide.
- **Environmental hazards:** This part explains the nature of potential hazards and the precautions needed to prevent injury or damage to nontarget organisms or the environment, especially preventing groundwater contamination.
- **Physical or chemical hazards:** This part explains hazards for fire or other dangers.

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:

- Crops to which the product can be applied.
- Pests the product targets.
- Amount to use.
- Method of application.
- Preharvest 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.

Pesticides

CROP USE DIRECTIONS

Registered Site(s) 1

Registered Pest(s) 2

3 Rate of Application

CROP USE DIRECTIONS

Crop	Pest	Rate Per Acre Per Application
Fruiting Vegetables Eggplant Ground cherry Pepino Peppers (bell, chili, cooking, pimento, and sweet) Tomatillo Tomato	Aphids Colorado Potato Beetle Flea beetles Leafhoppers	2.0 - 3.0 oz/A
	Whiteflies Pepper Weevil Stink Bugs	3.0 – 5.5 oz/A

Maximum Application Rates 4

Application Methods 5

6 Preharvest Interval(s) (PHI)

7 Protection Interval (PI)

Use Restrictions:

- **Maximum Actara Allowed per Growing Season:** Do not exceed a total of 11.0 oz/Acre (0.172 lb ai/A) of Actara or 0.172 lb ai of thiamethoxam containing products per acre per growing season.
- **Application Timing:** Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels. Apply the higher rate within the listed rate range for heavy infestations.
- **Preharvest Interval (PHI):** 0 day
- **Minimum Interval Between Applications:** 5 days
- **Water Volume:** Use sufficient water volume to ensure thorough coverage of foliage. Do not use less than 10 GPA for ground applications or 5 GPA for aerial applications. Allow spray to dry prior to harvest.

Refer to Pollinator Precautions section.
Refer to Resistance Management section.

8 Other Use Restrictions

Basic Elements of Crop Use Directions

Be aware that old/stored products may have old labels and that previously accepted uses and language may no longer be recommended. Agency guidance such as PR Notices may have been updated or clarified. The entire label should be reviewed very carefully before using any product. Organization of information on any given label will vary.

Keep labels on bottles and be aware that registered site(s) and pest(s) may change from year-to-year (a label only applies to the product it is attached to). Directions for use will vary between the different sites and pests listed on the same label. Be sure to thoroughly read and understand the requirements and restrictions for the specific site and pest you are targeting.

1 ***Registered Site(s):*** This indicates the site(s) where the product can be used. Sites may be limited to structures, crops, ornamentals, or any combination of the three.

2 ***Registered Pest(s):*** This indicates the pest(s) that the product can be used to control. The word pest(s) refers to insects, mites, and diseases.

3 ***Rate of Application:*** This displays how much pesticide can be used and the rate of application.

4 ***Maximum Application Rates:*** This shows the maximum amount of product allowed per treatment and per year.

5 ***Application Methods:*** This indicates the application methods required or preferred. These methods may be scattered throughout the Directions for Use section. Product labels should be read thoroughly to acquire all necessary information.

6 ***Pre-harvest Interval(s) (PHI):*** PHI is the number of days required after the last application before the treated plants can be harvested..

7 ***Protection Interval(s) (PI):*** PI shows how often the pesticide should or can be applied.

8 ***Other Use Restrictions:*** Other Use Restrictions: The Directions for Use section contains information on whether there are any restrictions on use for factors such as weather, time of day, season of the year, contamination of sensitive areas, exposure of nontarget species, etc. Here again, thoroughly reading and understanding of the label is important.

See the Pollinator Precautions and Resistant Management sections on the next page.

Other Use Restrictions 8

Pollinator Precautions

- Actara is highly toxic to bees exposed to direct treatment on blooming crops/plants or weeds.
- For **apples**, do not apply Actara after pre-bloom (early pink growth stage) or before post bloom (petal fall growth stage).
- For **citrus**, do not apply during pre-bloom or during bloom when bees are actively foraging.
- For **pears**, do not apply Actara after pre-bloom (green cluster stage) or before post bloom (petal fall growth stage).
- For **stone fruit**, do not apply Actara between the pre-bloom (swollen bud) and post bloom (petal fall) growth stages.
- Do not apply Actara or allow it to drift to blooming crops/plants or weeds if bees are **foraging in/ or adjacent to the treatment area.** This is especially critical if there are adjacent orchards that are blooming. (Refer to **Spray Drift Precautions** for additional information).
- **After an Actara application, wait at least 5 days before placing beehives in the treated field.**
- If bees are foraging in the ground cover and it contains any blooming plants or weeds, always remove flowers before making an application. This may be accomplished by mowing, disking, mulching, flailing, or applying a labeled herbicide.
- Consult with your local cooperative extension service or state agency responsible for regulating pesticide use for additional pollinator safety practices.

USE INFORMATION

Resistance Management

Some insect pests are known to develop resistance to products after repeated use. Because resistance development cannot be predicted, the use of this product should conform to sound resistance management strategies established for the crop and use area. Syngenta encourages responsible product stewardship to ensure effective long-term control of the insects on this label.

Actara contains a Group 4A insecticide (thiamethoxam, belonging to the neonicotinoid class of chemistry). Insect biotypes with acquired or inherent resistance to Group 4A insecticides may eventually dominate the insect population if Group 4A insecticides are used repeatedly as the predominant method of control for targeted species. This may result in partial or total loss of control of those species by Actara or other Group 4A insecticides.

If resistance to this product develops in your area, this product, or other products with a similar mode of action, may not provide adequate control. If poor performance cannot be attributed to improper application or extreme weather conditions, a resistant strain of insect may be present. If you experience difficulty with control and resistance is a reasonable cause, immediately consult your local company representative or agricultural advisor for the best alternative method of control for your area.

In order to maintain susceptibility to this class of chemistry:

- Avoid using Group 4A insecticide exclusively for season long control of insect species with more than one generation per crop season.
- For insect species with successive or overlapping generations, apply Actara or other Group 4A insecticides using a “treatment window” approach. A treatment window is a period of time as defined by the stage of crop development and/or the biology of the pests of concern. Within the treatment window, depending on the length of residual activity, there may either be single or consecutive applications (seed treatment, soil, foliar, unless otherwise stated) of the Group 4A insecticides. Do not exceed the maximum Actara allowed per growing season.
- Following a treatment window of Group 4A insecticides, rotate to a treatment window of effective products with a different mode of action before making additional applications of Group 4A insecticide.
- A treatment window rotation, along with other IPM practices for the crop and use area, is considered an effective strategy for preventing or delaying a pest’s ability to develop resistance to these classes of chemistry.
- If resistance is suspected, do not reapply Actara or other Group 4A insecticides.

Other Insect Resistance Management (IRM) practices include:

- Incorporating IPM techniques into your insect control program.
- Monitoring treated insect populations for loss of field efficacy.
- Using tank-mixtures or premixes with insecticides from a different target site of action group as long as the involved products are all registered for the same crop outlet and effective rates are applied.

For additional information on Insect Resistance Management:

- Contact your local extension specialist, certified crop advisor and/or product manufacturer for additional insect resistance management recommendations.
- Visit the Insecticide Resistance Action Committee (IRAC) on the web at http://www.irac-online.org/